CRANFIELD UNIVERSITY

NORMAN G. ROTH



PERFORMANCE MEASUREMENT TO IMPROVE KNOWLEDGE REUSE AND INVENTION IN NEW PRODUCT DEVELOPMENT

SCHOOL OF
INDUSTRIAL AND MANUFACTURING SCIENCE

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Supervisor: Professor Stephen Evans

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Abstract

The aim of this research is to identify novel functions and design principles for performance measurement which assist the user in better managing knowledge reuse and invention in New Product Development (NPD) environments.

Within this research performance management is defined as the methods, processes, structures and behavioural patterns an organisation uses to improve the performance of its knowledge asset invention and reuse activities. Performance management may be used during the strategic and operative planning, implementation and communication stages of knowledge asset invention and reuse. Performance measurement is defined as the process that gathers and records the effectiveness and efficiency of the implementation and planning stages.

There is a rich body of performance measurement, knowledge management and NPD literature. However there is a lack of understanding of how performance can be managed and measured in the NPD context explicitly focusing on knowledge reuse and invention. Performance measurement of knowledge is emerging as a possible mechanism to support improvement in highly complex NPD environments.

Based on an extensive literature review, a definition of performance management and measurement has been elaborated as well as a taxonomy of purposes for performance measurement which is the base-line for this research. The purposes have been used to derive a set of requirements for performance measurement from a knowledge reuse and invention perspective. The requirements in turn have led to the detailed formulation of those functions needed to support effective performance measurement targeted to the specific context of knowledge reuse and invention.

Performance measurement theory resulting in novel performance measurement functions has been developed, implemented and tested in four businesses (ranging from 45 to 7000 employees). The research is of a problem-oriented nature starting from a real-world problem, relying mainly on phenomenological and qualitative data analysis principles due to the "messy" nature of the problem. The analysis is based on direct interaction with more than 30 users of the functions (being the Performance Measurement Infrastructure, the framework, the catalogue, the software, and the build and implementation method).

The major contributions to knowledge of this research can be summarised as follows:

- Provision of comprehensive design principles for a *performance measurement framework* targeted to knowledge reuse and invention in NPD.
- Delivery of a well-structured r*euse and invention measurement catalogue* embedding a set of specific *reuse and invention focused measures.*
- Using the knowledge asset structuring concept from Knowledge Management and *integrating with* performance measurement principles. This is embodied in a novel *Performance Measurement Infrastructure* which applies measures directly to knowledge asset reuse and invention in NPD.
- *Design principles* for an enabling information technology solution for the above modules.
- A build and implementation methodology which embodies knowledge on *how to build and implement* reuse and invention oriented performance measurement functions.

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List of contents

ABSTRACT ..... **I**
LIST OF CONTENTS ..... **II**
ACKNOWLEDGEMENTS ..... **IV**
AUTHOR PROFILE ..... **V**
PUBLICATIONS ..... **VI**
LIST OF FIGURES ..... **VIII**
LIST OF TABLES ..... **X**
ABBREVIATIONS AND FORMULA ..... **XI**
1 INTRODUCTION **1**
1.1 Research focus 1
1.2 Problem statement 3
1.3 Research objectives and research outcome 4
1.4 Research question 5
2 RESEARCH APPROACH, TOOLS APPLIED AND THE RESEARCH PROCESS DESIGN 6
2.1 The research approach 6
2.2 The research tools applied and the research process 11
2.3 Thesis Navigator 22
2.4 Conclusion 24
3 LITERATURE REVIEW **25**
3.1 New product development 25
3.2 Knowledge management (KM) 30
3.3 Performance measurement in new product development 39
3.4 State of the art frameworks in Performance Management and Measurement 47
3.5 Conclusion 64
4 A DEFINITION AND TAXONOMY OF PURPOSES FOR PERFORMANCE MANAGEMENT AND MEASUREMENT TO IMPROVE KNOWLEDGE REUSE AND INVENTION IN NPD **65**
4.1 Introduction 65
4.2 A proposed definition of performance management and measurement 66
4.3 Expanding the proposed definition: A definition of performance management and measurement from a knowledge reuse and invention perspective 69
4.4 Purposes of performance measurement 71
4.5 Conclusion 76
5 REQUIREMENTS ANALYSIS **77**
5.1 Introduction 77
5.2 A taxonomy of PMS requirement clusters from a reuse and invention perspective for NPD 78
5.3 Assessment of some of the leading PMS approaches against the taxonomy of requirement clusters 89
5.4 Functional specification for reuse and invention oriented PMS functions for NPD 91
5.5 QFD assessment of user needs against the functional specification 93
5.6 Conclusion and problem validation 98
6 DESIGN PRINCIPLES FOR REUSE AND INVENTION ORIENTED PMS FUNCTIONS 99
6.1 Introduction 99
6.2 The PMS framework 100

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6.3 Reuse and invention measurement catalogue ... 121
6.4 Performance measurement infrastructure (PMI) ... 127
6.5 The software realisation ... 133
6.6 Summary, conclusion and review of the functional specification ... 139
7 DESIGN PRINCIPLES FOR THE PMS BUILD AND IMPLEMENTATION FUNCTION ... 141
7.1 Overview on the PMS build and implementation function ... 141
7.2 Awareness ... 145
7.3 Building the PMI ... 145
7.4 Building the PMS framework ... 150
7.5 Piloting ... 155
7.6 Rolling out ... 155
7.7 Continuous improvement and refinement – the management and use of the PMS functions ... 155
7.8 Conclusion and review of the critical success factors and functional specification ... 155
8 THEORY TESTING WITHIN CASE STUDIES ... 157
8.1 Introduction ... 157
8.2 Case study 1: The Gear Manufacturer (GM) ... 158
8.3 Case study 2: The Financial Service Provider (FS) ... 166
8.4 Case study 3: The Automotive Supplier (AS) ... 172
8.5 Case study 4: The High Tech Company (HT) ... 177
8.6 Summary and conclusion ... 184
9 DISCUSSION, REFLECTIONS AND CROSS-CASE LEARNING ... 186
9.1 Introduction ... 186
9.2 Reuse and Invention performance management and measurement in NPD - some thoughts on general lessons learned ... 186
9.3 The PMS framework ... 189
9.4 The Performance Measurement Infrastructure (PMI) and the measurement catalogue ... 192
9.5 The enabling software technology ... 196
9.6 The build and implementation function ... 196
9.7 A word on the use of the PMS ... 198
9.8 Have the provided functions met the novel demanded purposes? ... 199
9.9 The Research focus, approach, tools and research process design ... 200
9.10 Conclusions ... 201
10 CONCLUSIONS ... 203
10.1 Research conclusions ... 203
10.2 Contribution to knowledge ... 205
10.3 Recommendations for further research ... 206
10.4 The last word ... 208
REFERENCES ... 209
GLOSSARY ... 223
APPENDIX A: OTHER MEASUREMENT APPROACHES AT A GLANCE ... I
APPENDIX B: THE MEASUREMENT CATALOGUE MEASURES ... XII
APPENDIX C: THE SEMI STRUCTURED INTERVIEW QUESTIONNAIRE ... XXIX
APPENDIX D: EXPERT INTERVIEW QUESTIONNAIRE ... XXXI
APPENDIX E: THE SURVEY QUESTIONNAIRE ... XXXII
APPENDIX F: THESIS NAVIGATOR FOLD-OUT PAGE ... XXXIV

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I dedicate this thesis to my wife Viviana Barbara and my son David Leonard Roth.

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Author Profile



Norman studied Industrial Engineering at the Technical University of Karlsruhe, Germany where he graduated as Dipl.-Wirt.-Ing. in 1998 (equivalent to a M.Sc.). During his studies he spent 8 months at Robert Bosch Ltd. in South Carolina, USA and 6 months at Brüstlein S.A., Rixheim, France working in product development environments improving product development performance. After his studies he worked for four months as process improvement consultant at Robert Bosch Ltd. before he joined the University of Stuttgart at the end of 1998 and subsequently the Fraunhofer Institute for Industrial Engineering beginning of 2000. Since then he has been working on various industrial consulting and research projects in the product development, knowledge management and performance management domain.

In 1999 he wrote as overall project manager, together with Cranfield University and six other partners a research proposal which aimed at providing a performance management and measurement solution for NPD from a knowledge perspective - the cornerstone for the present Ph.D. work. It was Prof. Stephen Evans who motivated him to start a research assignment at Cranfield University, School of Industrial and Manufacturing Science.

Norman is a strategic advisor to the European Commission, DG Information Societies in knowledge management and measurement issues. He has served several times as consulting expert and peer-reviewer for the Commission. He is a member of the "Verband Deutscher Ingenieure (VDI)", the "Performance Measurement Association (PMA)" and the "European Knowledge Management Forum (EKMF)". Recently he has served for the renowned "Deutsche Forschungsgemeinschaft (DFG)" as evaluator on product development issues. He is author of more than 20 journal articles, conference papers and book chapters.

In his spare time he likes mountain-biking, martial arts, snowboarding, meeting with friends – and simply spending time with his wife Viviana and little son David Leonard.

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Publications

From this research:

Bullinger, H.-J.; Warschat, J.; Roth, N.; Wagner, F.; Haußß, I. (2000). Vom Informations- zum Wissensmanagement. In: *Innovationsforum Berlin 2000 - Proceedings*, Berlin.

Dvir, R.; Evans, S.; Pasher, E.; Prieto, J.; Roth, N. (2000). New-Use , Innovation & The Delicate Balance Between Them. In: *Productivity & Quality Management Frontiers 9 Conference Proceedings*, edited by E. Dar-El; A. Notea; A. Hari. July 2000, Israel MCB University Press, Bradford, 115-120.

Dvir, R.; Pasher, E.; Evans, S.; Roth, N.; Prieto, J. (2000). How to manage the Balance between New-Use and Innovation in R&D Processes. In: *3rd European Project Management Institute (PMI) Conference Proceedings*, edited by Israel Project Management Institute. July 2000, ORTRA, Tel Aviv, CD ROM without page numbers.

Frielingsdorf, H.; Roth, N.; Frech, J.; Wagner, F. (1999). Erweiterung der EDM/PDM-Funktionalität zur Unterstützung der frühen Phasen der Produktentwicklung. In: *VDI Berichte 1497 Beschleunigung der Produktentwicklung durch EDM/PDM- und Feature-Technologie*, edited by the Verband Deutscher Ingenieure (VDI). October 1999, München, 18-27.

Prieto, J.; Roth, N.; Pilarek, D. (2001). A Methodology for Building and Implementing a Performance Management System from a Knowledge Reuse and Invention-oriented Perspective in New Product Development. In: Proceedings of the 7th International Conference on Concurrent Enterprising: 'Engineering the Knowledge Economy through Co-operation', edited by K.-D. Thoben; F. Weber; K. S. Pawar, Centre for Concurrent Enterprising University of Nottingham, Nottingham, June 2001, 195-203.

Roth, N.; Prieto J. (2000). Ein integriertes Wissensmanagement Konzept für die Produktentwicklung. *CADCAM Report*, 5, 100-110.

Roth, N.; Prieto J.; Pilarek, D.; Evans, S. (2001): An integrated Performance Management System from a reuse and invention perspective for knowledge intensive development processes. *Knowledge Management*, 3, 21-27

Roth, N.; Prieto, J. (2001). NIMCube: Managing performance from a reuse and invention perspective. *Newsletter of the Performance Management Association*, Cranfield, 1(3), 3.

Roth, N.; Prieto, J. (2001). The NIMCube project. *The European R&D Insider: A newsletter on new methods of work & e-commerce*, 3, 6-7.

Roth, N.; Prieto, J.; Dvir R. (2000). New-use and Innovation Measurement and Management Methodology for R&D (NIMCube). In: *Proceedings of 6th International Conference on Concurrent Enterprising: 'Enhancing Business Competitiveness through Sharing Experiences Between Research & Industry', Centre for Concurrent Enterprising University of Nottingham, Nottingham*, edited by F. Weber and K. Pawar. June 2000, Centre for Concurrent Enterprising University of Nottingham, Nottingham, 151-161.

Roth, N.; Prieto, J.; Dvir, R.; Evans, S. (2000). An integrated framework for New-Use and Innovation Management and Measurement. In: *Performance Measurement 2000 – Performance Measurement, Past, Present and Future*, edited by A.D. Neely. July 2000, Centre for Business Performance Cranfield University, Cranfield, 491-498.

Roth, N.; Prieto, J.; Evans, S.; Lettice, F.; Young, K.; Dvir, R.; Tsanev, M.; Penev, I.; Schulte, T. (2001). An integrated Performance Management System from a reuse and invention perspective for new product development. In: *E-work and E-commerce: Novel solutions and practices for a global networked economy*, edited by B. Stanford-Smith and E. Chiozza, October 2001, IOS press, Amsterdam, 86-92.[1]

Roth, N.; Prieto, J.; Pilarek D. (2001). Ein integriertes Performance Management System aus einer wissensorientierten Perspektive für die Neuproduktentwicklung. *IO Management*, 3, 34-40.

Roth, N.; Prieto, J.; Wagner, F.; Röhrborn, D. (2000): Knowledge Management und wissensbasierte Rechnerintegration. *CADWORLD*, 3, 104-105.

[1] This paper has been awarded as being among the best three papers presented at the e-business and e-work 2001 conference in Venice. Altogether more than 190 papers from all European Union countries have been presented.

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Warschat, J.; Wagner, F.; Roth N.; Prieto J. (2000). Ein integriertes Konzept für die evolutionär-iterative Produktentwicklung. In: *Forschungs- und Entwicklungsmanagement 2000plus. Konzepte und Herausforderungen für die Zukunft*, edited by H.D. Bürgel. Springer, Berlin, 115-129.

Others:

Bullinger, H.-J., Frielingsdorf, H.; Roth, N.; Wagner, F.; Zeichen, G.; Fürst, K.; Brandstätter, T. (1999). *Marktstudie: Engineering Data Management Systeme: EDM als strategischer Erfolgsfaktor im innovativen Unternehmen*, 2. Auflage, IRB Verlag, Stuttgart.

Kemp, J.; Roth, N.; Prieto, J.; Meier, C.; Affolter, I.; Brouyère, L.; Hartmann, M.; Städtler, P. (2001). IMS Project SYMPHONY: on the management of knowledge-based, adaptive organisations in the knowledge-driven economy. In: *E-work and E-commerce: Novel solutions and practices for a global networked economy*, edited by B. Stanford-Smith and E. Chiozza. October 2001, IOS press, Amsterdam, 748-754.

Meier, C.; Jehle, P.; Affolter, I.; Brouyère, L.; Merino, E.; Sciboz, L.; Roth, N.; Prieto, J.; Kemp,J. (2000): A dynamic management methodology with modular and integrated methods and tools for knowledge-based adapted SMEs IMS project SYMPHONY. In: *E.business: Key issues, Applications and technologies*, edited by B. Stanford-Smith and P.T. Kidd. October 2000, IOS press, Amsterdam, 680-686.

Roth, N.; Frielingsdorf, H.; Bröcker, A. (1999). Innovative methods in product development - A systems engineering based quantifying approach. In: *2nd International Symposium on Concurrent Multidisciplinary Engineering (CME) proceedings*, edited by S. Rill. September 1999, Bremen.

Roth, N.; Kemp, J.: Albiez, A.; Wagner, F. (2001). A Professional Rapid Concept Development Methodology. In: *Proceedings of the 7th International Conference on Concurrent Enterprising: 'Engineering the Knowledge Economy through Co-operation'*; Centre for Concurrent Engineering University of Nottingham, edited by F. Weber, K. Pawar and K.D. Thoben. June 2001, Nottingham, 277-281.

Vankan, J.; Roth, N.; Bröcker, A.; Carver, E. (2000). Concurrent Engineering and Human Factors in the European project ENHANCE – Enhanced Aeronautical Concurrent Engineering. In: *Proceedings of 6th International Conference on Concurrent Enterprising: 'Enhancing Business Competitiveness through Sharing Experiences Between Research & Industry', Centre for Concurrent Enterprising University of Nottingham, Nottingham*, edited by F. Weber and K. Pawar. June 2000, Toulouse, 309-317.

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Roth, N.; Prieto, J.; Evans, S.; Lettice, F. (2002). Performance Measurement from a knowledge reuse and invention perspective. *International Journal of Business Performance Management.*

Roth, N.; Prieto, J.; Evans, S.; Lettice, F. (2002). Performance Measurement to improve knowledge reuse and invention in NPD. *The third international conference on theory and practice in performance measurement*, July 2002, Boston.

Roth, N.; Evans, S.; Lettice, F. (2002). New-use and Innovation Management and Measurement Methodology for R&D (NIMCube) – Testing the hypothesis. *The eighth international conference on concurrent enterprising (ICE 2002),* June 2002, Rome.

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List of figures

Figure 1: A taxonomy of researcher roles (Gill and Johnson, 1997) 8
Figure 2: Overview on the chosen research approach 11
Figure 3: Overview on the multiple case study set up (Yin, 1984) and its linkage to the structure of the thesis. 12
Figure 4: Overview on the different types of case studies (Yin, 1984) 13
Figure 5: Overview on the research process design (based on Phillips and Pugh, 2000) 20
Figure 6: Thesis Navigator 23
Figure 7: Theoretical organisation of IC (Roos et al., 1997) 30
Figure 8: KM as an information handling tool (Mårtensson, 2000) 31
Figure 9: The knowledge value chain (Weggeman, 1999) 33
Figure 10 : The Innovation success factors (Pinchot and Pellmann, 1999) 36
Figure 11: Innovation leading to competitiveness (Nonaka and Takeuchi, 1995) 36
Figure 12: Balanced Scorecard framework (Kaplan and Norton, 1996b) 48
Figure 13: Using the Balanced Scorecard as a strategic management system (Kaplan and Norton, 1996b) 50
Figure 14: IC Value Scheme (based on Skandia, 1999) 52
Figure 15: Skandia Navigator (Skandia, 1999) 52
Figure 16: SkandiaLink's Business Navigator (Skandia, 1994) 53
Figure 17: Overview on Skandia's strategic planning process (Skandia 1994) 53
Figure 18: Performance Pyramid (based on Lynch and Cross, 1995) 55
Figure 19: Overview on some exemplary BOS measures (Lynch and Cross, 1995) 55
Figure 20: Performance Prism – the five facets (Neely and Adams, 2000a) 57
Figure 21: Stakeholders' wants and needs vs. organisation's wants and needs (Neely and Adams, 2000a) 58
Figure 22: The Performance Prism – categorisation of facets (Neely and Adams, 2000b) 59
Figure 23: Software reuse diamond (Lim, 1998) 60
Figure 24: The framework for reuse metrics (Lim, 1998) 61
Figure 25: Six-stage reuse measurement process (based on Berns, 1994) 63
Figure 26: Conception of Performance Management (Klingebiel, 1999, translated from German and simplified) 67
Figure 27: Measurement system impact on control (Kerssens-van Drongelen and Cook, 1997) 68
Figure 28: Preliminary taxonomy of performance measurement purposes in the performance control model (Kerssens-van Drongelen, 1999) 74
Figure 29: Relationships between performance measurement requirements (see also Table 13) and the requirement clusters of the taxonomy 81
Figure 30: Graphical overview on the relationships between the PMS requirements taxonomy and taxonomy of purposes 82
Figure 31: Relationships between the reuse and invention oriented requirements (see also Table 13) and the taxonomy of requirement clusters 87
Figure 32: Assessment table for some of the leading PMS 90
Figure 33: Overview on the reuse and invention oriented PMS functions (based on Kennerley and Neely, 2000) 100
Figure 34: Overview on the measurement perspectives and subjects of the PMS framework 101
Figure 35: Generic innovation process in a broader sense (based on Brockhoff, 1993) 109
Figure 36: Measurement facet means-end relations 111
Figure 37: Navigation axes 112
Figure 38: Navigation of the measurement facets along the navigation axes (example) 112
Figure 39 Innovation cube architecture 114
Figure 40: Innovation house architecture (based on Edvinsson and Malone, 1997) 115
Figure 41: Innovation pipeline architecture 115
Figure 42: Strategic plan (example, based on case study 2) 117
Figure 43: Link of the PMS methodical framework (represented in this case through the cube metaphor) and strategic management systems (2 alternative scenarios) 117
Figure 44: The PMS focus area in the strategic plan (example, based on case study 2) 118
Figure 45: Asset structure model within the PMI (Prenninger et al., 1999; Roth et al., 2000) 128
Figure 46: Relationship between the NPD process, the PMI and the performance framework 132

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Figure 47: Overview on the Software Architecture (NIMCube, 2000b) 134
Figure 48: Overview on the login screen of the software solution (NIMCube, 2001c) 135
Figure 49: User Screen of the performance management framework from a reuse and invention perspective (NIMCube, 2001c) 136
Figure 50: Screenshot of a measurement catalogue screen (NIMCube, 2001c) 137
Figure 51: Visualisation of the measurement results for the measure invention maturity within the navigation dimension "organisation level" (NIMCube, 2001c) 137
Figure 52: Overview on the data model of the performance measurement infrastructure (NIMCube, 2001c) 138
Figure 53: Overview on the asset type "SW module" with describing attributes (NIMCube, 2001c) 138
Figure 54: User Screen of the performance measurement infrastructure based on Inxight™ technology (NIMCube, 2001c) 139
Figure 55: Critical success factors in change management (based on Doppler and Lauterburg 1999) 141
Figure 56: Overview on the PMS build and implementation function 144
Figure 57: Process model (example, done with the ARIS Toolset™) 147
Figure 58: Assignment of knowledge assets the NPD process (example, based on case study 1; Prenninger et al., 1999; Roth et al., 2001) 148
Figure 59: Asset recording sheet (example based on case study 1; Prenninger et al., 1999; Roth et al , 2001) 148
Figure 60: Reuse and invention asset catalogue (example based on case study 1; Prenninger et al., 1999; Roth et al., 2001) 149
Figure 61: Navigation axes for verifying the reuse and invention asset catalogue 149
Figure 62: Knowledge asset model (based on case study 1) 150
Figure 63: Overview on the impact of reuse and invention performance measurement on the overall NPD performance at the GM (n=8) 162
Figure 64: Importance of the six measurement facets at the GM (n=8) 163
Figure 65: Importance of the subjects within the performance facet "operating context" (n=8) 164
Figure 66: Overview on the measurement framework for corporate NPD of the FS 168
Figure 67: Importance of the six measurement facets at the AS (n=10) 174
Figure 68: Overview on the impact of reuse and invention performance measurement on the overall NPD performance at the AS (n=10) 175
Figure 69: Overview on the estimated reuse and invention level at the AS (n=10) 175
Figure 70: Overview on the estimated reuse and invention level at the HT (n=8) 179
Figure 71: Impact of reuse and invention performance measurement on NPD outcome measures at the HT n=8 180
Figure 72: Need to develop specific reuse and invention measures for the organisation at the HT (n=8) 180
Figure 73: Relevance of the six measurement facets at the HT (n=8) 181
Figure 74: Subjects of the operating context dimension and their importance at the HT (n=8) 182
Figure 75: Invisible Balance Sheet (based on Sveiby, 1997) I
Figure 76: Intangible Assets Monitor (based on Sveiby, 1997) II
Figure 77: Reference model of knowledge-oriented enterprising (based on North, 1998) II
Figure 78: Intellectual capital navigator (based on Stewart, 1998) V

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List of Tables

Table 1: Overview on the positivist and the phenomenological paradigm (Easterby-Smith et al., 1991) 7
Table 2: Overview on the case studies and the applied research tools 14
Table 3: List of the interviewed experts 16
Table 4: Objective and characteristics of Process Monitoring Systems (Krahn, 1998) 41
Table 5: Requirements for a performance management model 48
Table 6: Characteristics and requirements of performance measurement frameworks 57
Table 7: Requirements for and principles of the framework for reuse metrics 61
Table 8: Overview on the process flow of the chapter 4. 66
Table 9: Expert statements regarding the reuse and invention measurement topic 73
Table 10: Preliminary taxonomy of performance measurement purposes (based on Kerssens-van Drongelen, 1999) 74
Table 11: Extended taxonomy of performance measurement purposes from a reuse and invention perspective for new product development 75
Table 12: Overview on the process flow of the chapter 5 78
Table 13: Overview on major requirements of performance measurement 80
Table 14: Taxonomy of requirement clusters for a PMS from a reuse and invention perspective 88
Table 15: Overview on the QFD done at the GM 94
Table 16: Overview on the QFD done at the FS 95
Table 17: Overview on the QFD done at the AS 96
Table 18: Overview on the QFD done at the HT 97
Table 19: Preliminary PMS measurement list (example, based on case study 2, see also section 8.3) 119
Table 20: Preliminary PMS measurement list mapped against facets and NPD navigation axes (example, based on case study 2, see also section 8.3) 119
Table 21: Completed PMS measurement list mapped against facets and NPD navigation axes (example, based on case study 2, see also section 8.3) 120
Table 22: Measurement recording sheet (template) (based on Neely, 1998) 124
Table 23: Overview on the structure of a reuse and invention asset (real-life example; based on case study 1 (section 8.2), Prenninger et al., 1999 and Roth et al., 2000) 128
Table 24: Overview on the asset related operational measures 131
Table 25: Overview on the asset related management measures 132
Table 26: Overview on the basic functionalities of the Software 135
Table 27: Overview on resource allocation and research tool application 158

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Abbreviations and Formula

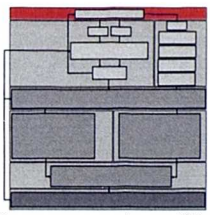
A	Asset type A
AA(A_i)	Asset age
AAR(A, T2, T1))	Asset Addition Rate
ADR(A, T2, T1))	Asset Delete Rate
A_i	Asset i
AP_i	Approved Asset i
ARR(A, T2, T1))	Asset Renewal Rate
ARR(A_i)	Asset reuse rate
AS	Automotive Supplier (case study 2 company)
ATP	Advanced Technology Planning
BOS	Business Operating System
CE	Concurrent Engineering
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CARDS	Central Archive for Reusable Defense Software
CMM	Capability Maturity Model
CRD(A_i)	Creation date
CSE	Concurrent Simultaneous Engineering
CSV	Comma Separated Value
CUD(A_i)	Current date
DMU	Digital Mock-up
EDM	Engineering Data Management
EVA	Economic Value Added Analysis
e.g.	For example
FS	Financial Service Provider (case study 3 company)
GM	Gear Manufacturer (case study 4 company)
HRM	Human Resource Management
HT	High Tech Company (case study 4 company)
i.e.	This means
IC	Intellectual Capital
IT	Information Technology
JVM	Java Virtual Machine
JDK	Java Development Kit
JSP	Java Server Pages
KM	Knowledge Management
MA(A)	Mean Asset Age
MAAR (A, AP)	Mean Asset approval rate
MARR(A)	Mean asset reuse rate
MRD(A_i)	Measurement date
N(A)	Asset number
N(AP)	Approved asset number
Nadd(A)	Added Asset j per period (T2,T1)
Ndel(A)	Deleted Asset k per period (T1,T0)
NIMCube	New-use and innovation Management and Measurement Methodology for R&D
NPD	New Product Development
PDM	Product Data Management
PM	Performance Management/Measurement
PMA	Performance Measurement Association
PMI	Performance Management Infrastructure
PMS	Performance Measurement System
QFD	Quality Function Deployment
RA(A_i)	Reuse action
RAS	Reuse Approval Status
RAS(A_i)	Reuse Approval Status
SWOT	Strength, Weakness, Opportunity, Threat
STARS	Software Technology for Adaptable, Reliable Systems
TQM	Total Quality Management
SQL	Standard Query Language
UI	User Interface
UML	Unified Modelling Language
VR	Virtual Reality
XML	Extended Mark-up Language

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1 Introduction

"...those who look only to the past or the present are certain to miss the future"

John F. Kennedy, former US President



The intent of this chapter is to give an overview on the research focus, the research problem, the research objectives and the research question. The research focuses on the themes of product development, of knowledge management, and of performance management and measurement as well as their interactions. The research problem is that today there are no explicit functions which support sufficiently performance measurement from a knowledge reuse and invention perspective for New Product Development (NPD).
The main objective of this research is therefore to equip the community with novel performance measurement functions and design principles which enhance knowledge reuse and invention in NPD. The research objective leads into the formulation of the research question at the outset of this research "What does a performance measurement system have to provide in order to support explicitly the management of knowledge reuse and invention in new product development environments?".

1.1 Research focus

According to Pahl and Beitz (1996) the early phases of product development determine largely the future success of a product. They state that it is extremely difficult, if not impossible to correct fundamental shortcomings caused in those phases in the subsequent phases, like detail development or manufacturing. Wheelwright and Clark (1992) state that the enhancement of the early product development phases is a key success factor for a further reduction of the time-to-market of a product. Martin (1996) points out that up to 75% of product costs are fixed by the time the design is drawn. Platz (1996) points out that 70-80% of the product quality is determined through product development. It is a main principle of product development approaches like Concurrent Engineering (CE) (Prasad, 1996) or Simultaneous Engineering (SE) (Bullinger and Warschat, 1996) to place high importance on early development activities and to create time to study a larger range of alternatives, giving remedy to the problem of adopting the first reasonable idea (NIMCube, 2000a).

In literature, there exist many approaches which describe frameworks for the early phases of a product development project (Wheelwright and Clark, 1992; Blanchard and Fabrycky, 1997; Clark and Fujimoto, 1991; Ulrich and Eppinger, 1995; Prasad, 1996). However, the main emphasis has been put on the definition of organisational, procedural and technological infrastructures. In order to assure sustainable growth and efficiency of organisations, it becomes increasingly important to consider company-specific and product-specific knowledge as a key success factor (Probst et al., 1997; Bullinger et al., 1997; Nonaka and Takeuchi, 1995). In this context again the early phases of product development have to be emphasised as they are characterised by an enormous knowledge intensity (Kerssens-van Drongelen, 1999). In these phases fuzzy, often unstructured information and the experience of people play a crucial role, (Warschat et al., 2000a). A recently conducted survey by Bullinger et al. (1997) reveals that the production factor knowledge represents more than 50% of the value creation of a product and that through efficient and controlled reuse the productivity of companies could be increased by more than 30%.

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Thus the performance of the early phases of product development has to be also managed and improved from a knowledge point of view (Edvinsson, 2000). Especially the measurement of product development related knowledge is of crucial importance: A survey conducted on behalf of PricewaterhouseCoopers (Colemann and Eccles, 1997) asked 107 information analysts in which areas of the company they were seriously deficient in terms of the information they released. The result of this survey shows that three out of the four highest ranked areas in terms of importance were directly or indirectly related to New Product Development.

A recent survey of VDI Nachrichten (2001) reveals that more than 75% of the product development engineers being asked do not have an infrastructure for the very early phases of product development available which supports them in reusing their knowledge. This fact causes them major efficiency deficiencies. Lim (1998) states that reuse of knowledge especially in knowledge intensive environments is important. Christensen (1997) puts forward that invention and innovation are key drivers for business success and therefore of special relevance.

Under the big pressure to shorten down the time-to-market nobody can afford nowadays to reinvent the wheel (Dvir and Evans, 1998). However the desire to increase efficiency through a better reuse of knowledge to enhance productivity could imply a decrease of invention and creativity capability. Therefore it is crucial to consider especially the balance between reuse of existing knowledge and creation of new knowledge, meaning being inventive and efficient. The necessity to reuse existing knowledge to solve problems and to create new knowledge where appropriate requires holistic and controlled reuse and invention management based on measurement (Edvinsson, 2000).

Edvinsson (2000) states that in order to manage the balance between reuse and invention a measurement system is required which helps to determine in which direction to go. According to him measurement is essential for management of knowledge and Intellectual Capital. Today's measurement systems do not cover sufficiently this aspect of NPD management. Therefore today's performance measurement functions for product development have to be enriched or completed by a reuse and invention, meaning a knowledge-oriented function.

Measuring product development performance is already complex (Clark and Fujimoto, 1991; Busby and Williamson, 2000), therefore the difficulty is high to measure in addition from a knowledge-oriented perspective but the cost of opportunity linked to better management of reuse and invention justifies the extra effort (Edvinsson, 2000).

According to Lingle and Schiemann (1996) performance measurement is a fundamental part of the management process. If companies do management based on measurement, they perform better. Edvinsson and Malone (1997) and Edvinsson (1997) state that any kind of measurement can only work if the measurement system is embedded in an adequate performance environment.

Christensen (1997) and Hamel (2000) state that there are different types of innovation: The radical innovation, which has a direct impact on the company's mission and vision and the incremental innovation which can be characterised as being continuous and less stressful for the company. Both types of innovation can be applied in a narrow product related sense or in a broader business concept related sense. For the context of this research the focus is on managing and measuring incremental innovation in a narrow, product-related sense.

Summarising it can be stated that the focus of this research is performance measurement from a knowledge reuse and invention perspective, in new product development environments. This means that the performance management and measurement of the resource "knowledge" in new product development contexts is the focal point of this research.

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1.2 Problem statement

For many years performance frameworks have been used by companies to improve their performance. It goes back to the beginning of the 20th century when DuPont started to use a pyramid of financial ratios, which linked a wide range of financial ratios to return on investment. (Kennerley and Neely, 2000)

Recognising the need for additional non-financial measures, companies started to implement sets of non-financial measures (Kaplan and Norton, 1996a). Keegan et al. (1989) proposed a performance matrix based on balanced measures, Lynch and Cross (1995) were the first who considered internal and external performance measures and Fitzgerald et al. (1991) realised the concept of causality. Following, the CARDS approach developed a concept of linking measures and metrics through cause-and-effect relationships (HGO Tech, 1994). Finally Kaplan and Norton (1996a) proposed their famous Balanced Scorecard, providing a multi-dimensional corporate measurement system. North et al. (1998) began to think about measurement from a knowledge oriented perspective, whereas Kerssens-van Drongelen (1999) put special emphasis on R&D. A quite new measurement model which has to be mentioned finally is the Performance Prism by Kennerley and Neely (2000) as it adopts a stakeholder centric view of performance measurement.

However in spite of this amazing evolution several major weaknesses can be identified regarding today's implemented performance management and measurement functions:

- Most of the present performance management and measurement frameworks provide generic functions for company-wide measurement. Very few of them focus on the early knowledge intensive phases of new product development. (Kerssens-van Drongelen, 1999, Kaplan and Norton, 1996a). The reason for this weakness of today's PMS frameworks and their implementations might be that those early phases are a very challenging phase for performance management implementations due to the high system dynamics and complexity (Kerssens van Drongelen, 1999 and Johnson, 2000) and the fact that current frameworks lack specific required design principles meeting the specific requirements coming from this phase of the value chain (Klingebiel, 1999).
- Insufficient alignment between strategic performance measurement and operative process related measurement especially from a knowledge reuse and invention perspective. Although some recent performance measurement frameworks (Pritchard, 1990; Lynch and Cross, 1995; Kennerley and Neely, 2000) provide a set-up which enables break-downs from strategic down to operative levels, most of the PMS do not support measurement on day-to-day process-level *and* strategic level enabled through a set of specific measures for the different levels, NPD process phases and disciplines (Säubert and Bürgel, 1998 and Kaplan and Norton, 1996a). The reason for that might be that on the one hand most of the available systems have been designed as strategic performance management frameworks and are therefore not required to support operational improvement. The other more process-oriented performance systems, like process monitoring and control systems (GE's 6 Sigma System is a famous example) on the other hand are not designed to support strategic performance management systems[2]. Only recently people get increasingly aware that the focus of PMS on pure strategic aspects *or* pure operative process-oriented measurement misses a great opportunity in terms of overall improvement support[2].

[2] These statements have been made during the expert interviews (section 2.2.2) by Scott Hawkins from Skandia. He has been actively involved in the development of the Skandia Navigator, one of the most well-known performance management frameworks.

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- Few frameworks consider measurement opportunities from a knowledge oriented perspective (Marr et al., 2001 and Smith, 2001). This means that the meaning of the terms efficiency, effectiveness and invention have to be extended to knowledge management thinking. Efficiency should thus not only refer to the traditional, often final product oriented performance measures; also efficient reuse of knowledge and the creation of new knowledge through invention should be measured. Efficiency (reuse of existing knowledge) and the ability to create new knowledge (being inventive) is one of the key problems in today's industrial environments (Sveiby, 2000); (Ward, 2000); (Amidon, 2000); (Evans, 2000). The reason for this situation might be that although KM (especially reuse and invention) and performance management/measurement are well-established topics, the recognition of the enormous potential through bringing these domains together is quite a recent finding (Dvir et al., 2000).
- It is widely accepted that organisational performance needs to be viewed from several perspectives, like stakeholder contributions, capabilities, processes or stakeholder expectations (Kennerley and Neely, 2000). However, so far there is no performance management and measurement framework implemented which explicitly takes the reuse and invention perspective into account. Though some of the approaches integrate non-financial variables, the concrete relation to the evaluation of knowledge related assets is mostly missing due to the fact that the knowledge reuse and invention problem is so far a neglected issue in performance management thinking (Edvinsson, 2000).
- Currently there is no process-oriented, knowledge asset related infrastructure available which supports reuse and invention performance management and measurement within a day-to-day working environment due to the fact that most of the PMS are exclusively used as strategic management tools (Pasher, 2000).

The problem identified at the outset of the research was therefore:

"Currently there is no sufficient set of performance measurement functions available which improves knowledge reuse and invention to enhance NPD performance"

1.3 Research objectives and research outcome

The following research objectives have been set:

- To understand and learn from existing theories and approaches in the new product development, knowledge management, performance management and measurement domains to create a solid base-line for theory development.
- To deliver a sound definition of performance management and measurement as well as a taxonomy of performance measurement purposes to improve knowledge reuse and invention in new product development.
- To develop novel performance measurement functions based on a concrete need for action identified in literature and real-life companies.
- To test and validate the developed functions in real-life environments.

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To meet those objectives, the following results, being the research outcomes, are expected:

- A sound overview and understanding of relevant literature and experts' opinions in the subjects of new product development, knowledge management, performance management and measurement.
- A definition for performance management and measurement to improve reuse and invention in new product development and a taxonomy of PMS purposes as well as referring requirement clusters.
- Novel, pragmatic and validated performance measurement functions and design principles which meet the identified functional PMS requirements.

The results will serve as tangible yardsticks which help to verify that the research objectives have been met.

1.4 Research question

In order to assure goal-oriented research in this thesis, a research question has been developed. This question will be used to verify whether the research objectives have been met. The question is:

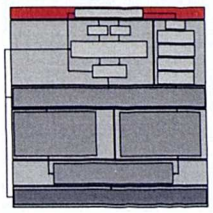
"What does a performance measurement system have to provide in order to support explicitly the management of knowledge reuse and invention in new product development environments?".

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2 Research approach, tools applied and the research process design

"Basic research is what I am doing when I do not know what I am doing."

Wernher von Braun, Scientist



This chapter describes the research approach chosen for this research, discusses its appropriateness and describes its strengths and weaknesses. The approach relies on phenomenological principles incorporating also some positivistic principles. The research in this project is driven by a real-world problem, therefore problem-oriented research seems to be the right choice as research type. Being for most of the time participant-as-observer, the majority of data collected is of a qualitative nature.
Throughout the whole research process a broad selection of research tools will be used at different stages of the research process following triangulation principles. The main research tools which will be applied in this thesis are case studies, semi structured interviews, surveys, knowledge cafés, expert interviews, focus groups and Quality Function Deployments (QFDs). Four case study companies have been involved from the beginning of this research. They represent the testing environments for the theory provided in this research and the starting point for generalisations of the findings. The linear-analytic, longitudinal case studies are of explanatory nature, holistic and follow a multiple case design. At the end of this chapter the author proposes a graphical navigator which helps navigating through this thesis.

2.1 The research approach

People undertake research in order to find things out in a systematic way, thereby increasing their level of knowledge (Jankowicz, 2000). Thus research should be based on the development of logical cause and effect relationships, robust and meaningful results rather than on ad-hoc driven, unstable assumptions and beliefs (Jankowicz, 2000). The research tools are the means the author applies during the research process in order to ensure sound and coherent research and finally bring the research approach to life. It is crucial to understand that the research approach chosen in a project and the tools applied are heavily dependent on the chosen type of research (Yin, 1994). In the following sections the author will explain the various strategic research decisions he took which determine his research approach.

2.1.1 Phenomenology vs. Positivism

There are two major basic approaches on how to conduct research: the positivist approach which favours quantitative methods and the phenomenological approach which favours qualitative methods (Table 1 and Easterby-Smith et al., 1991). Research activities which have no influence on the subject being studied are positivist in nature, like an experiment in a laboratory with clearly defined system borders, fully controlled variables and a high level of repeatability. As the context of this research is real-life industrial scenarios, with many internal and external parameters which cannot, due to the complexity of the industrial environments, be fully controlled with additionally active involvement of the researcher the phenomenological approach has been favoured.

On the other hand the author intends to provide novel performance measurement functions, which are also based on quantifiable needs and requirements, considering causalities followed by quantitative as well as qualitative testing in operational real-life en-

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vironments. This thinking suggests the application of the positivist paradigm (based on Easterby-Smith et al. 1991).

Summarising it can be stated that due to the active involvement of the researcher (section 2.1.3) in this project which takes place in a real-life environment and due to the pursuit of determining clear requirements, clearly defined specifications, extensive testing and operationalisation of the concepts a **phenomenological** approach incorporating also some positivist principles is suggested.

	Positivist paradigm	Phenomenological Paradigm
Basic Beliefs	❑ World is external and objective. ❑ Observer is independent. ❑ Science is value free.	❑ The world is socially constructed and subjective. ❑ Observer is part of what is observed. ❑ Science is driven by human interests.
Researcher should	❑ Focus on facts. ❑ Look for causality and fundamental laws. ❑ Reduce phenomena to simplest elements. ❑ Formulate hypotheses and test them.	❑ Focus on meaning. ❑ Try to understand what is happening. ❑ Look at the totality of each situation. ❑ Develop ideas through induction from data.
Preferred methods include	❑ Operationalising concepts so that they can be measured. ❑ Taking large samples.	❑ Use multiple methods to establish different views of phenomena. ❑ Small samples investigated in depth over time.

Table 1: Overview on the positivist and the phenomenological paradigm (Easterby-Smith et al., 1991)

2.1.2 Exploratory, testing-out and problem solving (action) research

Research has traditionally been classified into two types: pure and applied research (Phillips and Pugh, 2000). According to them this distinction is too rigid to characterise what happens in most disciplines where real-world research generates its own theories and does not just apply pure theories. Therefore Phillips and Pugh (2000) suggest a distinction of three basic types of research.

❑ Exploratory Research

This research suggests the tackling of new problems and topics about which little is known so far. Often the formulation of the research problem cannot be defined concretely due to the novelty of the subject. The main objective is to create new knowledge hoping that something useful will come out (Phillips and Pugh, 2000). This type of research attempts thus to expand the limits of knowledge rather than directly involving the researcher in a particular, pragmatic problem (Zikmund, 1991). The target audience of this type of research is often the academic community (Robson, 1993).

❑ Testing-out research

In this type of research activity the limits of previous generalisations are explored (Phillips and Pugh, 2000). The main purpose of this research activity is therefore to improve previous generalisations through which most of the research disciplines evolve.

❑ Problem solving research

The starting point for this type of research is a concrete real-world problem which the author intends to (at least partly) solve (Phillips and Pugh, 2000). This approach suggests a clear and sound problem definition followed by a comprehensive requirements definition to ensure that the to be developed tool or methodology

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solves the initial problem identified by the researchers. This type of research should lead to change in a real-world environment (Phillips and Pugh, 2000). It is assumed in this context that if somebody wants to understand something well he should try changing it and study how a phenomena develops over time. This problem-solving approach is similar to variants of action research (Robson, 1993). Action research is defined as "participant observation with active intervention" (Gummerson, 1991). According to van der Zwaan (1992) action research is the same as longitudinal case study research (section 2.2.1). Robson (1993) states that action research is appropriate where the process of changing circumstances itself is important for the understanding of the overall system and if there are interactions between the researcher and the subject of research. Understanding of causes and effects and promoting change within a system are central elements of action research (Robson, 1993; Lewin, 1946). Lewin (1946) suggests a circle of planning, acting, observing and reflecting as the action research process. Thus action research aims to solve a problem for a client and contributes to the chosen field of academic research (Robson, 1993).

In his role being the participant-as-observer (section 2.1.3) the author was intensively involved in the problem solution process within the case studies. So the research design's objective is clearly to lead to change of the then current situation in the user companies. The research in this project is clearly driven by operative needs of real-life industrial companies and by a need detected through intensive literature analysis to develop new functions for performance measurement. Thus, with this research work the author wants to offer comprehensive performance measurement functions which meet concrete and operative problems and pushes on the same time the boundary of knowledge in this domain. The author will test the developed theory in business contexts (chapter 8) through a series of explanatory case studies (section 2.2.1) to observe the behaviour of the system over time caused by the implementation of the theory proposed in this thesis. The nature of this present research is therefore of a **problem-solving** nature.

2.1.3 The role of the author being the researcher

The type of role the author took had a big impact on the research strategy and tools applied. Gill and Johnson (1997) suggest a taxonomy of roles a researcher can take within research.

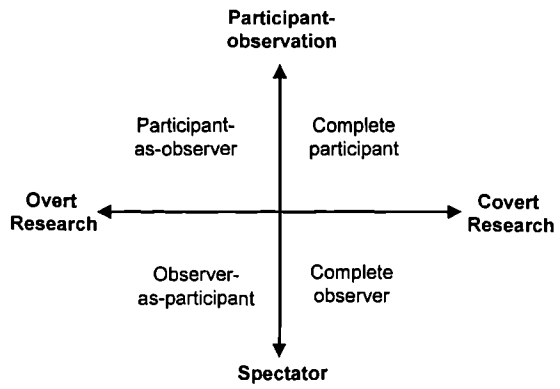


Figure 1: A taxonomy of researcher roles (Gill and Johnson, 1997)

The observer being a spectator tries to avoid any involvement in the subject of research whereas the participant-observation role induces full participation of the observer into the subject of research. If the subject of research knows about, or are aware of the presence of the researcher, then the subject may behave differently. Gill and Johnson (1997) consider this overt research whereas covert research suggests that the observer is concealed from the subject studied but does have an impact on it.

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This research project took place within the context of the European project <<IST-1999-11926 NIMCube (New-use and Innovation Management and Measurement Methodology for R&D)>>. The author was actively involved in the development of the solutions from the beginning of the project. The four case studies referred to in this thesis represent the industrial users in this project. Thus the author was over a period of almost two years often on-site at these four companies, applying many different research tools (see also section 2.2) and doing extensive testing in business environments. Therefore the **participant-as-observer** role is assumed for this research. The author is aware of the fact that his presence in the research process might have potentially biased the research outcomes and findings and therefore shares this concern with several authors (Steier, 1991; Gill and Johnson, 1997). In order to overcome this threat of the research design different research tools have been used with the same stakeholders, to find a balanced mix of personal involvement and delegation of tasks to the stakeholders of the research and to obtain a deep understanding of the author's impact on the subject being studied (see also section 2.2.8). The advantage of the participant-as-observer role is the good validity of results as the phenomena were studied in real-life contexts.

2.1.4 Quantitative vs. qualitative data

Traditionally, phenomenology would suggest qualitative methods and tools for data collection and validation (Easterby and Smith, 1991). Indeed during the data collection and validation phase the author largely relied on qualitative research. The application of quantitative methods and tools in real-world context is challenging as real-life problems are often of "a messy nature" (Phillips and Pugh, 2000) and therefore it is difficult to fully control the variables in order to ensure robust high-quality quantitative data. Qualitative research allows a much richer and deeper understanding of complex real-life scenarios as opposing to quantitative data analysis. Qualitative understanding does not require simplifications which might heavily influence the quality of the data. However, as the potential of quantitative methods is enormous regarding generalisability and replicability to other settings and circumstances (Robson, 1993) the author also employed quantitative methods and tools in the data collection, development and validation phase. It is crucial to note that the motivation for quantitative data collection and analysis was not to create strongly statistically validated and verified data. Instead the author applied quantitative methods in order to rank user needs and for validating solutions through the voice of the customer by applying, for example, survey techniques.

Summarising it can be stated that the main emphasis during this research was on the application of **qualitative data** collection and validation methods and tools, however the author also felt a need to employ methods and tools which support quantitative data gathering and analysis.

2.1.5 A note on triangulation

According to Jick (1979) triangulation is the application of different research tools to the same stakeholders which can significantly improve the quality of the data, solutions and findings of the research work. Yin (1994) states that triangulation, being the rationale for using multiple sources of evidence, significantly contributes to the quality of the research output. Patton (1987) suggests four types of triangulation. In the following sections the author will outline how he addressed the four different types of triangulation:

- Triangulation of data sources (data triangulation)

  Throughout all phases of the research several sources of data have been used. During the more descriptive phase of the research (chapters 3 and 4) literature as well as expert interviews have been used to capture the domain knowledge. The

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literature review relied on on-site library research, internet research and personal contacts. The activities took place in three different countries namely UK, Germany and USA. The requirements analysis phase (chapter 5) relies on state of the art literature (gathered also in a wide-spanning way like in the literature analysis phase), input from the potential user companies ("the voice of the customer") as well as expert interviews. The testing and validation phase (chapters 8 and 9) uses 4 holistic case studies to ensure more compelling data (Herriott and Firestone, 1983). Each case study itself uses a variety of data sources, like documentation (for example process guidelines, manuals and work procedures), interview protocols, project deliverables and workshop protocols.

- Triangulation among different evaluators (investigator triangulation)

  As the research presented in this thesis took place in the context of an EC funded research a multi-disciplinary team worked very closely together. The project consortium consisted of people coming from academia being experts in measurement, knowledge management, concurrent engineering and product development. Therefore the present research has been enriched over a period of more than two years by stimuli from various other investigators. The writing up phase of this research is characterised through a rich and continuous review process: Apart from the supervisor, various experts[3] coming from different fields of expertise reviewed continuously this thesis in a great level of detail.

- Triangulation of perspectives on the same data set (theory triangulation)

  This type of triangulation is for the context of this research aligned to type 2. Industrial users have been involved in this research work so academic at least two different perspectives on data sets have been ensured: the research perspective and the pragmatic user perspective. In fact the representation of those two communities proved to be very beneficial for the research outcome resulting in a sound balance between providing novel PMS functions which represent a contribution to knowledge and pragmatic, user-oriented solutions.

- Triangulation of methods (methodological triangulation)

  In all phases of the research great variety of research tools have been applied. The early phases of the research applied expert interviews, and quality function deployments. The nature of the four case studies in this phase of the research was more of a descriptive nature. The explanatory testing and validation phase largely relies on the four case studies which employed most of the commonly known research tools and methods (surveys, semi-structured focused interviews, workshops, knowledge cafés).

Summarising it can be stated that triangulation was a major principle for the research design.

[3] The experts were (see also section 2.2.2.2):

- Ron Dvir, Innovation Ecology, expert in KM and QM
- Dr. Fiona Lettice, Cranfield University, expert in NPD and PM
- Scott Hawkins from Skandia, expert in IC, KM and PM
- Juan Prieto from Fraunhofer IAO, expert in KM and NPD
- Atai Ziv, ECI Telecom Ltd., expert in R&D Management
- Dr. Mike Kennerley, Cranfield University, expert in Business Performance Measurement

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2.1.6 Summary on the chosen research approach

The figure below summarises the different decisions made regarding the selection of the research approach.

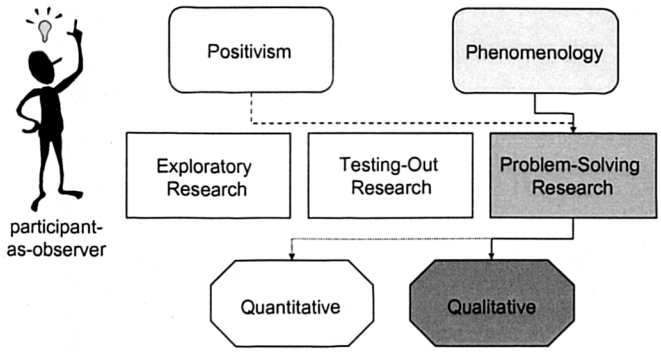


Figure 2: Overview on the chosen research approach

The research is phenomenological in nature, shows a problem oriented set-up and relies predominantly on qualitative data analysis.

2.2 The research tools applied and the research process

In order to ensure good data quality the author applied a variety of research tools which will be outlined in the following sections. The tools have been applied in different phases of the research process (Figure 5, page 20).

2.2.1 Holistic, longitudinal, multiple case studies

2.2.1.1 Background

Yin (1984) provides probably the most cited source regarding case study research. According to him a case study is an empirical enquiry that

- investigates a contemporary phenomenon within its real-life context especially when
- the boundaries between the phenomenon and context are not clearly evident.

The overall research question asks *"What does a performance measurement system have to provide in order to support explicitly the management of knowledge reuse and invention in new product development environments?"*. An objective of this problem-oriented research is to validate the research output (the answer to the "what") in business contexts (section 1.3). A question for the testing and validation phase of this research could therefore be "How does the provided theory (the "what") behave in business contexts and how does it meet the requirements and functional specification set at the beginning of the research?". As the theory which the author provides could be considered a contemporary phenomenon and as the investigation takes place in real-life environments and as the boundaries between phenomenon and context are unclear (or at least not entirely definable) case studies might be an appropriate research tool to answer this question (Yin, 1984).

According to Yin (1984) case studies can be of descriptive, exploratory and explanatory nature. As case studies were used in the context of this thesis mainly for validating and testing the outcome of the research the explanatory type of case study is proposed, although especially in the early phases of the research the case studies also show some descriptive and exploratory elements. Further on Yin (1984) distinguishes between two basic types of case studies: The *embedded* case study refers to different units of research whereas the *holistic* case study focuses on one clearly defined scenario. The case studies presented in this thesis consist of different individuals (being also a research unit) which operate in a clearly defined environment. The fact

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that several research units are involved may suggest an embedded design at first however due to the clearly defined pilot boundaries, all the case studies presented in the context of this research are suggested to be of holistic nature.

Yin (1984) states that single case studies are justifiable where the case represents a critical test of existing theory, where the case is a rare or unique event, where the case serves a revelatory purpose or where the case is used as an exploratory device. Yin (1984) points out that single case studies offer the vulnerability that the case may turn out to be different than originally assumed. In multiple case studies several single cases are executed in different systems and afterwards synthesised and generalised considering cross-case aspects.

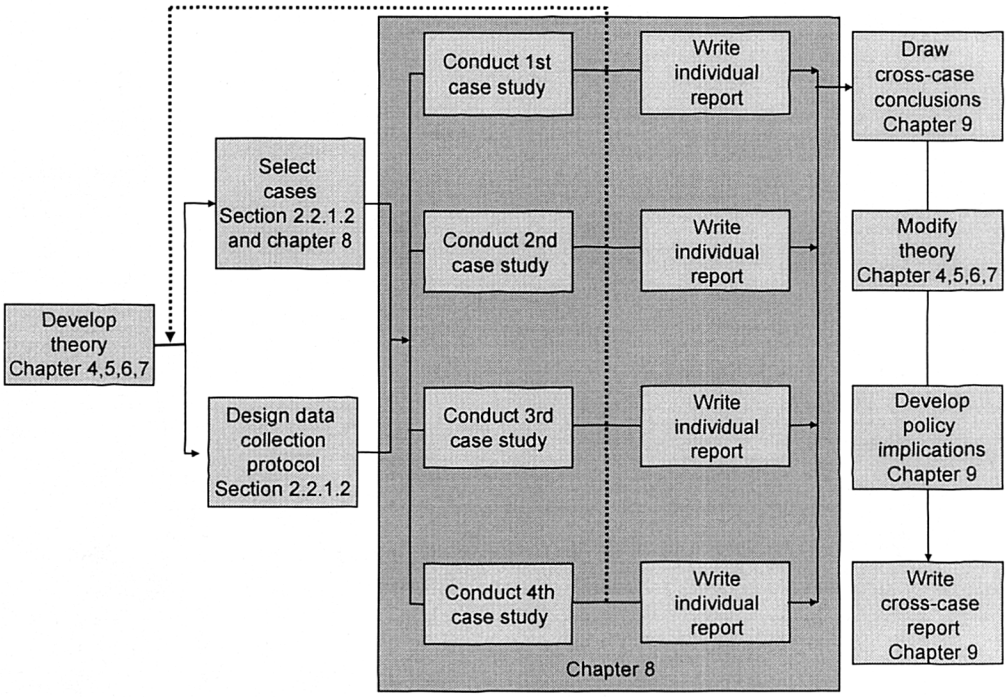


Figure 3: Overview on the multiple case study set up (Yin, 1984) and its linkage to the structure of the thesis.

There is some evidence in literature (Yin, 1984, van der Zwaan, 1992) that the risk of misinterpretation might be smaller when several case studies are executed within a multiple case study set-up. Herriott and Firestone (1983) consider multiple case studies to be more robust due to the different data sources. As indicated in Figure 3 the multiple case study concept has been picked up within this research. Figure 3 also gives an indication of where the necessary multiple case study activities can be refound within the structure of this thesis. Looking at this figure it can be seen that the author was less interested in telling the story of how the theory evolved. Instead he presents the completed theory in chapters 4,5,6,7 discussing within chapters 8 and 9 the findings and observations which led to the completed theory. The cross-case report is more implicit and is achieved by discussing conclusions drawn from the four case studies.

Figure 4 summarises the different types of case studies (Yin, 1984) showing that type 3 (multiple-case design; holistic nature) is the most appropriate type for this thesis.

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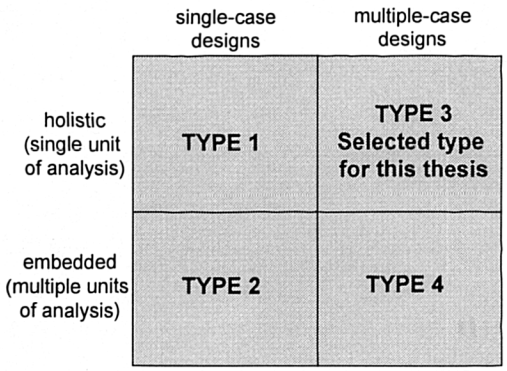


Figure 4: Overview on the different types of case studies (Yin, 1984)

Kerssens-van Drongelen (1999) states that a case study which is studied over a certain period of time is of a longitudinal nature. According to van der Zwaan (1992) action research (section 2.1.2) is by nature a longitudinal case study.

2.2.1.2 The detailed design of the 4 case studies

Reflecting on the thoughts given in the previous section it can be stated that all four case studies in this research show the following characteristics:

- Each of the case studies is of a holistic nature, due to the very defined system borders for the pilot case and limited complexity of the pilot system (The pilots took place in a clearly defined organisational environment, with a limited number of people involved).
- All the case studies were studied over a longer period of time, at the beginning of the research more from a descriptive / exploratory perspective and during the testing and validation phase from an explanatory perspective. Therefore all the case studies are longitudinal case studies.
- The four case studies are part of a multi-case study design, as the four case studies on their own provide valid and documented insights which are presented in chapter 8, but also the cross-case aspects and generalisations which are presented in chapter 9, are relevant for the discussion of the research subject.
- The case studies realise the triangulation paradigm as described in section 2.1.5 of this thesis.

The 4 case studies were studied in the context of the EU co-sponsored research project <<IST-1999-11926 NIMCube>>. This project enabled the author to study four industrial user companies over a period of more than two years. The motivation for the selection of these four companies was to achieve a broad coverage of the NPD subject to support generalisations at the end of the research: The four companies represent different sizes (from 45 to 7000 employees), different industries (gear manufacturing, high precision punching and bending parts for automotive industry, high technology semiconductor industry and the emerging service domain) and different cultures. The long period enabled the author to get a very deep understanding of the companies and develop a very open and friendly relationship with the stakeholders in the company. The companies were involved in this project from the beginning which allowed the author to study them within different phases of the research. The following table gives an overview of the case studies and the applied research tools.

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		Case Study 1 Gear Manufacturer (GM)	Case Study 2 Financial Service Company (FS)	Case Study 3 Automotive Supplier (AS)	Case Study 4 High Tech Company (HT)
Size of the company (Employees)		150	7000	45	6000
Size of the unit where the case study activities took place (Employees)		20	18	7	50
Type of market (Business to Consumer, Business to Business)		Business to Business	Business to Business	Business to Business	Business to Business
Applied research tools (Yes, No)	**QFD**	Y, a QFD was conducted within a workshop where 8 senior engineers and engineers from development and production participated.	Y, a QFD was conducted within a workshop where 3 product managers, two people from legal department, one person from accounting and the head of HR participated.	Y, a QFD was conducted within a workshop where 4 senior engineers, a member of the IT department as well as the CEO participated.	Y, a QFD was conducted within a workshop where 6 senior engineers participated.
	Survey	Y, the survey was discussed with a champion from the company and he supported 7 other employees in understanding the survey and filling it out. The survey was conducted two times one time before implementation of the solution, one time after having implemented the solution.	N, as the user company declined due to resource constraints.	Y, the survey was discussed with a champion from the company and he supported 10 other employees in understanding the survey and filling it out.	Y, the survey was discussed with a champion from the company and he supported 7 other employees in understanding the survey and filling it out.
	Semi-structured focused interviews	Y, the semi-structured interviews were conducted with three key people from the PMS project team.	Y, the semi-structured interviews were conducted with three key people from the local project team and one person from the corporate knowledge and innovation team.	Y, the semi-structured interviews were conducted with three key people from the project team and the CEO.	Y, the semi-structured interviews were conducted with two key people from the PMS project team.
	Focus Groups	Y, 9 on-site focus groups were conducted during the data collection, requirements engineering, development, implementation and testing phase.	Y, 5 on-site focus groups were conducted during the data collection, requirements engineering, development, implementation and testing phase.	Y, 3 on-site focus groups were conducted during the data collection, requirements engineering, development, implementation and testing phase.	Y, 3 on-site focus groups were conducted during the data collection, requirements engineering, development, implementation and testing phase.
	Knowledge Cafés	Y, 1 knowledge café was conducted with participants from R&D and IT department during the validation phase.	Y, 1 knowledge café was conducted during the validation phase with people from the Knowledge Exchange department.	Y, 1 knowledge café was conducted with participants from development, quality and production department during the validation phase.	N, as the user company declined due to resource constraints.

Table 2: Overview on the case studies and the applied research tools

At all the four case studies most of the other research tools described in the following sections have been applied to meet the triangulation principle as demanded by Yin (1984) and Jick (1979) and to finally achieve good, robust and reliable data which represent a solid basis for subsequent cross-case considerations.

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2.2.2 Open-ended, semi-structured expert interviews[4] and open-ended, semi-structured, focused interviews

2.2.2.1 Background

According to Yin (1984) and Robson (1993) interviews are a very important tool for case study information retrieval. The most common form of interviews are of an open-ended nature where open questions will be asked to the interviewee. These kind of questions allow him to state the facts of a matter and also his opinion. In fact the interviewee might even impact the direction of interview by proposing his own insights into certain occurrences (Yin, 1984).

Goffin (1994) suggests in his repertory grid interview approach to improve the quality of the interview outcome (interview constructs) through a prioritisation of the given answers by the interviewee using a 1-9 scale. The semi-structured interviews may conclude with a joint session where the results of all interviewees are elaborated (on a voluntary basis). Robson (1993) stresses that a semi-structured interview should not take longer than 1,5 hours. The interviewer should try to influence positively the interview process through (Robson, 1993)[5]

- listening more than speaking,
- putting questions in a straightforward, clear and non-threatening way,
- eliminating cues which might have led interviewees to respond in a particular way,
- enjoying it through creating a friendly and open atmosphere.

In order not to be distracted through taking notes a research assistant may take notes or the interview should be recorded on tape.

2.2.2.2 The design of the expert interviews

The objective of these interviews was to discuss the reuse and invention management and measurement topic with some of the leading experts in the field. As the author was interested in a broad discussion about the research subject he choose the open-ended semi-structured interview type. The interviews were conducted in a very open style allowing the interviewee extensive reflections on his very specific expertise.

A good balance of experts from industry as well as academia has been selected. The expert interviews were conducted mainly during the data collection phase and influenced the way the author defined purposes, requirements, specifications and functions for performance measurement from a reuse and invention perspective which is presented in this thesis. The following experts were interviewed either within on-site meetings or via telephone conferences of roughly one to one and a half hour duration:

Name of the expert	Background and Expertise
Arian Ward	❑ President, CEO and founder of Work Frontiers™ International and Pool of wonder former Chief Knowledge Manager of Hughes Aircraft and Communications.
Debra Amidon	❑ The founder president and chief strategist of ENTOVATION International Ltd., a global research and strategy consulting network of innovation experts.
Gordon Petrash	❑ Partner with Pricewaterhouse Coopers (PwC).
Hubert Saint-Onge	❑ Senior Vice President, Strategic Capabilities at Clarica.
Dr. Karl-Erik Sveiby	❑ The principle of his own consulting company – Sveiby Knowledge Management. Recognised leader in the KM and IC movement.
Prof. Leif Edvinsson	❑ One of the world's leading experts on Intellectual Capital (IC). Former vice president and the worlds first corporate director of Intellectual Capital at Skandia, Sweden.

4 This part of the research was supported by Dr. Edna Pasher and Irit Sacher from Pasher Consultants, Israel and Calé Detherridge Walis from Cranfield University, UK.

5 The author tried to meet these recommendations in all the interviews he conducted.

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Prof. Andrew Neely	❑ Professor of Operations Strategy and Performance, Cranfield University, author of the book "Measuring Business Performance", published by the Economist.
Scott Hawkins	❑ Expert in Knowledge Management from Skandia, has been involved in the development of the Skandia Navigator.
Dr. Edna Pasher	❑ Expert in Knowledge and Innovation Management, founder and CEO of Pasher Management Consultants, an Israeli Strategy Consultant.
Atai Ziv	❑ Expert in strategic performance management at ECI Telecom.

Table 3: List of the interviewed experts

An overview of some of questions posed to the experts can be found in Appendix D.

2.2.2.3 The design of the focused interviews

As the pilot scenarios had a clearly defined scope and as the author had quite a good idea of the expected outcome of the interviews, he decided to choose the focused type of the open ended semi-structured interviews as suggested by Yin (1984). They were conducted at all the case studies to validate and verify the theory developed in this research. The list of questions can be found in Appendix C of this thesis.

The interviews which took between one and one and a half hours were conducted on an individual basis with at least three key people from each of the case studies involved in the project. The session started with broad open questions with regard to the PMS design, build and implementation.

The strengths, weaknesses, opportunities, threats (SWOT) tool was applied at this stage and proved to be very beneficial as it supported the gathering of key enablers and inhibitors in a very efficient way. The interviewee was given the opportunity to prioritise his answers as suggested by Goffin (1994). For example if several weaknesses of the system have been stated, the interviewees were asked to prioritise them according to their importance. More detailed issues were then discussed, like "Did the system meet your needs as defined at the beginning of this research?" or "Did the system provide the promised functions in a satisfying way?".

The interviews ended with open questions, like "What are your lessons learned from this project?" or "What additional needs and requirements did you elaborate during the PMS project?". The whole interview session closed with a joint session the next day, where the results of the individual interviews were presented and discussed. Those interviews gave a deep insight of the users' views on the solution.

The author decided not to put the detailed documentation of the interviews in this research document, instead he preferred to refer to the various interviews where appropriate. Beyond, he has been able to develop friendships with some of the experts mentioned above and has therefore been able to discuss the research subject in more than 40 side discussions, which certainly increased his learning on the subject.

2.2.3 (Panel) survey

2.2.3.1 Background

A survey is a research tool which is passive and seeks to describe and/or analyse, even in some cases to explore, some aspect of the world out there as it is (Robson, 1993). A survey can be of descriptive, explanatory or exploratory nature (Yin, 1984). According to Yin (1984) and Robson (1993), surveys are a very powerful instrument to get at a specific point in time a snapshot of the investigated system. Surveys provide a means to answer the what, who, where, how many, how much research questions (van der Zwaan, 1992). Surveys provide a comparatively simple and straightforward approach to the study of attitudes, values, beliefs and motives (Robson, 1993). Surveys have the disadvantage that they represent highly subjective opinions and the fact that the respondents will not necessarily report their beliefs and attitudes. Surveys work best with standardised, short and easily understandable questions (Yin, 1984).

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The simple one time conducted survey might be expanded to a more comprehensive panel (longitudinal) survey (Robson, 1993). This survey type has the advantage that it includes a temporal sequence in the data obtained, which might enable the analyser to detect changes in the system over time and to interpret relationships (Robson, 1993). However van der Zwaan (1992), Yin (1984) and Robson (1993) stress that the analysis of detailed correlations and causes/effects are best done within an experiment.

Following the phenomenological approach, the author was more interested in the relationships and overall impact of the theory on the system than in investigating the impact of a specified set of variables. In any case, this would not have been possible due to the real-life "messy" nature of the research environment.

2.2.3.2 The design of the (panel) survey

The survey was conducted at case study companies three and four as a single survey and within case study 1 as two times panel survey (section 2.2.3). The survey can be found in Appendix E of this thesis. The survey questionnaire was developed together with subject experts and had been tested in several industrial companies in terms of comprehensiveness, understanding of the questions and time slot needed for completion before it has been applied at the case study companies.

The survey was discussed with a champion within each of the companies. This champion organised the explanation (being aware that he should not influence the respondents) and distribution to most of the employees which were involved in the build and implementation process of the developed theory. For all the three surveys between 8 and 10 people filled out the survey questionnaire. In the panel case the survey was distributed the first time during the data collection phase (4th month of the research) in order to ensure integration of user needs regarding the development of the solution and to justify the approach the author decided to apply. The second time the survey questionnaire was distributed during the testing phase of the solution to the same employees (18th month of the research, together with the other surveys). They were offered to cross-check their answers with the answers they had given within the first stage. The remaining gap regarding the answers represented a good starting point for interpretation of the application scenario's impact to the company (section 8.2.2). In the single case the survey was distributed during the piloting phase.

The author is aware that the sample size is not big enough to draw statistically valid conclusions, however the findings from these small sample sizes might give some indication regarding the behaviour of the developed theory in business.

2.2.4 Focus groups

2.2.4.1 Background

Zikmund (1991) describes focus groups being a facilitated session set up to elaborate on a specific topic with a group of participants with comments recorded for later analysis. According to him focus groups are often applied in an exploratory context as they provide a powerful tool for identifying potential factors within the subject of research. The outcome is dependant on the role of the moderator (Zikmund, 1991). He can either take the role of a facilitator trying not to impact the outcome of the focus group or play an active role being a full member of the focus group. Dominant participants and people who are not willing to contribute are a potential risk of this research tool.

2.2.4.2 The design of the focus groups

Focus Groups were conducted to allow the key "stakeholders[6]" to elaborate on a very specific topic within this research. Focus Groups were conducted within all four case

6 Main stakeholders in this context are the four case study companies and the European Commission, DG Information Societies.

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studies, with 6-8 participants often coming from different disciplines or companies. The focus groups were enriched through application of brainstorming techniques, metaplan techniques, process analysis tools, like ARIS™ process analysis tool or learning maps which proved to be beneficial with regard to the quality of the data gathered.

This research tool was applied during all the phases of the research process, which means during the data collection, theory building and validation phase, however mostly during the theory building phase. The focus groups were often a one to two day event. They were thoroughly prepared beforehand: An agenda was agreed among all participants, tasks were delegated as preparation for the workshop and often an appropriate ecology was chosen – which proved to have a bigger positive impact than the author originally assumed.

2.2.5 Knowledge Café[7]

2.2.5.1 Background

The knowledge café is a modification of a focus group and provides a specific set-up which supports a focused, in-depth discussion of a specific question in a very participative and collaborative style. The knowledge café starts with a presentation of a subject, which is followed by posting a question to the 5-8 (this is the ideal size but often the number of participants might be higher) participants. Afterwards 3 to 4 people gather together in a café house style around a table and start discussing the subject with one facilitator. One of the participants may take notes which he presents at the very end within a joint session to the other group(s).

2.2.5.2 The design of the knowledge cafés

The knowledge cafés were conducted at all four case study companies as well as during one fair (KM Europe 2000 in Brussels, Belgium in November 2000) and two conferences (ICE 2000 conference in Toulouse, France in July 2000; ICE 2001 conference in Bremen, Germany in June 2001). The research topic was presented to the audience, followed by 4 questions from a SWOT (Strength, Weakness, Opportunity, Threat) analysis:

- What are the strengths of the new performance measurement functions?
- What are the weaknesses of the new performance measurement functions?
- What are the opportunities to improve the new performance measurement functions?
- What are the threats of the new performance measurement functions?

The design of all the cafés followed the general recommendations provided in the previous section. The number of participants at each of the cafés was between 20 and 50 which resulted in a higher number of individual café tables led by facilitators.

2.2.6 Quality Function Deployment (QFD)

2.2.6.1 Background

QFD is a tool which is very often applied in professional product development. It is a very structured tool to map customer needs versus functions for solutions and competitors' solutions including market potentials of the solutions (Pfeifer, 1996). The main objective of this tool is therefore to translate the "voice of the customer" into a list of weighted functions which the product later has to meet. The QFD can be conducted as a group process with 6-8 people led by a facilitator who is not contextually involved in

[7] This part of the research was supported by Scott Hawkins from Skandia, Ron Dvir from Innovation Ecology, Juan Prieto from Fraunhofer IAO and Dr. Edna Pasher from Pasher Management Consultants.

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the process (Pfeifer, 1996). An industrial QFD process is very complex starting with elaboration of customer requirements, followed by a definition of functions, elaboration of target measures for the functions leading into a cross-check of interrelationships ending with a rating of the overall product (Hering et al., 1993). Thoroughly conducted QFDs result in very high quality data. The effort to conduct a QFD can be considerable.

2.2.6.2 The design of the QFDs

The objective of this thesis is to provide novel performance measurement functions from a reuse and invention perspective for practical industrial use in real-life contexts. Listening to the "voice of the customer" was therefore one of the guiding principles throughout the whole research work.

The specific set-up of the QFD design in this research represents a strong simplification of the original QFD set-up. However, the author thinks that for the specific purpose of this research this set-up is appropriate as the simplifications mainly refer on the one hand to assessments of competitor products; a referring assessment however is provided in section 5.3. On the other hand in QFDs often quantitative measures for describing the characteristics of the functions are defined, however due to the phenomenological approach the author relies more on qualitative data for functional characteristics.

The QFDs were conducted during the requirements analysis phase in order to cross-check that the true and real needs of the case study companies are met through the *measurement design principles* the author intended to provide. It is important to understand that the needs and requirements have been elaborated by 4 to 8 users while the PMS design principles have been delivered by the author. During the QFD sessions the author acted as participant as observer. The mapping of the needs and requirement versus the PMS functions has been done by the users (see also section 5.5) to ensure good data quality representing the voice of the customer.

The author is aware that this activity might show a certain redundancy with activities which took place during the data collection phase, like focus groups or the survey. However, this redundancy proved to be beneficial for the quality of the data and therefore of the solutions developed during this research. The case studies did not impact the overall specification as the QFDs were done once the specification had been drawn.

2.2.7 Overview on the research process design

The research process is designed according to the research process design for problem solving research as suggested by Phillips and Pugh (2000) and Ulrich (1981). This means that the journey starts from a particular problem existing in the "real-world" bringing together all the intellectual resources that can be brought to bear on its solution (Phillips and Pugh, 2000 and Ulrich, 1981). The solution development is followed by an extensive validation phase within a "real-world" environment. Following at this juncture also the testing out research principles, the author recaptures the limits of previously made generalisations in the subject and tries to push the boundaries of knowledge in this domain through providing some lessons learned based on the research findings.

The development of the performance measurement functions in this project bases on the experience of the author in the performance management and knowledge management environment and reflects an iterative learning process in the context of an EU funded research project, industrial consulting projects, extensive literature research, expert interviews and case studies. The set-up of the research process described in Figure 5 takes into account all the decisions made regarding the overall research approach (Figure 2, page 11). It is important to understand that the research process de-

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scribed in the figure below was not gone through in a purely sequential manner, instead the research is characterised through a highly iterative set-up.

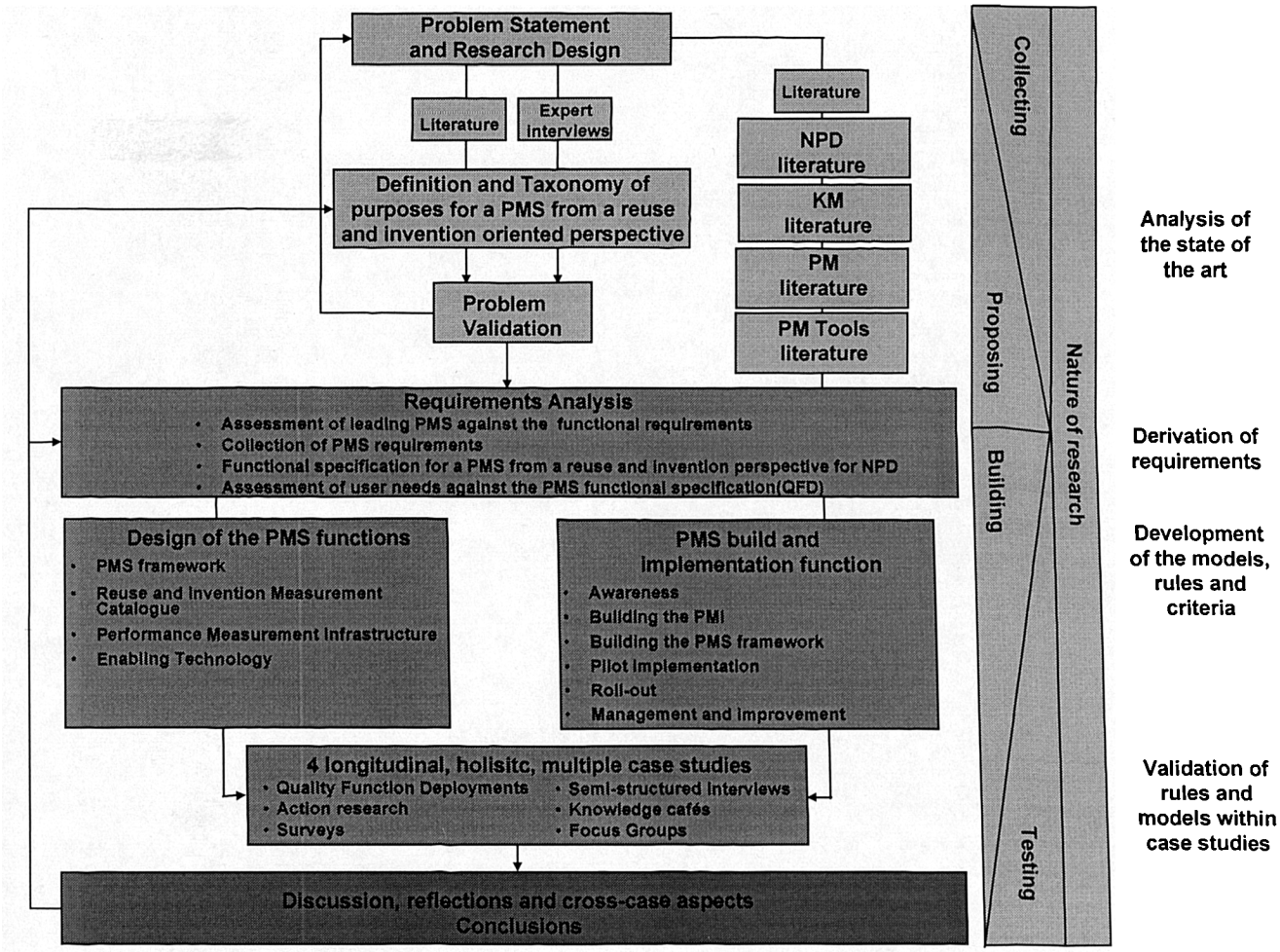


Figure 5: Overview on the research process design (based on Phillips and Pugh, 2000)

The research process outlined above can be categorised into two major sub-phases:

Collecting and proposing

The starting point of the research is a problem presented in section 1.2 identified in the real world. In a first step relevant literature is reviewed combined with expert interviews. The theoretical baseline could then be proposed (chapter 3 and chapter 4). This proved to be necessary as the overriding subjects of this thesis, namely performance management and measurement and knowledge management are often understood differently, therefore the author provides some specific definitions and purposes for the very context of this thesis which are relevant to the further understanding of the research.

Theory building and testing

This phase starts with a definition of requirements for the proposed solution (chapter 5). The requirements are mapped against leading existing approaches to identify the gap and need for action. The gap analysis leads into a functional specification for the solution. The functions are mapped within simplified Quality Function Deployments (QFDs) against the needs of the case study companies to set a focus for the development of the theory. The requirements analysis concludes with a review of the research problem. The detailed theory building (chapter 6 and 7) is based on the outcome of the functional specification and the prioritisation of the PMS functions given through the QFDs. The testing and validation process is based on case study research

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principles as suggested by Yin (1994): Four case studies will serve as testing environment for the developed theory (chapter 8) which will lead into a more general discussion of the subject looking also at cross case-aspects (chapter 9).

2.2.8 Assessment of the chosen research approach

Limitations and threats

For the context of this research the author has identified the following potential limitations:

1. The focus on only 4 case studies might make generalisations difficult.
2. Basically in this research the author tries to bring together the Knowledge Management and the Performance Management domain, the danger in this broad research set-up might be a loss of focus.
3. Being participant-as-observer the author might have influenced the research process and caused severe bias on the research outcomes.
4. The interviewees might have feared to tell the truth.
5. Ph.D. research should be based on an open system of thoughts, the problem-solving nature of this research might cause the danger that the research set-up is too narrow minded and purely problem driven in this research.
6. A predominantly qualitative data analysis approach was selected for the research.

Counterbalances

For the above mentioned potential threats the following counterbalances are suggested:

1. As the focus of this project is on qualitative data analysis, it is a prerequisite to get a deep understanding of the subject of research to ensure rich, high-quality data. The time restrictions of this research did not allow a greater number of in-depth testing scenarios. Other research tools (section 2.2) were applied in the case studies to ensure good data quality.
2. Although performance management, measurement and knowledge management are widely referenced this research shows a clear focus (new product development processes, reuse and invention perspective, performance management, process-orientation). Later the reader will see (section 5.2.2) that several functions and design principles for a performance measurement system from a reuse and invention perspective for new product development have been identified. In order to provide a holistic solution the author would have to address all of those functions in the same level of detail. However due to resource restrictions the author will mainly address those aspects in *great* detail he considers novel.
3. Although the author has been actively involved in the design process, he tried to overcome the limitations which are due to the nature of this researcher role (Robson, 1993) through application of a broad variety of research tools (triangulation, 2.1.5) in different stages of the research process.
4. Over a period of almost two years the author has been working together with the people in the case study companies and was able to create an ecology which is characterised through trust and openness.
5. Although this research work clearly pursues the problem-solving approach the author has been able to develop a deep understanding of the subject. The data collection chapter offers an in-depth discussion of the subject and provides therefore a very solid fundament for the development of the novel performance management functions.

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6. As this research tries to solve (at least partly) a real-world problem the system complexity is high. According to Miles & Huberman (1985) qualitative data have the big advantage of being rich and holistic, with a strong potential for revealing complexity. The qualitative approach suggests working with small samples that tend to be purposive rather than random. Thus, through use of qualitative data analysis the author can focus on events taking place in their original context and therefore obtain a better understanding of the subject of research. Beyond the decision qualitative vs. quantitative data was not of binary nature: The focus is certainly on the qualitative data side, however through for example surveys and QFDs it has been tried in addition to incorporate quantitative data in the research design.

2.3 Thesis Navigator

The thesis is structured into 7 main chapters (Figure 6, next page).

Chapter 3 reviews literature with regard to the domains new product development, knowledge management and performance management and measurement. Several performance management and measurement tools are discussed in great detail. The author delivers an overview on the most important models and approaches in the domains knowledge (reuse and invention) management, performance management and measurement and new product development.

As performance management and measurement is a wide-spread and intensively discussed topic in research and practice in chapter 4 a definition of performance management and measurement from a knowledge reuse and invention point of view is proposed. Beyond a referring taxonomy of purposes is presented. The research problem stated at the beginning of this research is revisited. The chapter shows that the research problem stated at the beginning of this research is valid and worth to be approached.

In chapter 5, the author conducts, based on rational decomposition principles, a requirements analysis for the development of the novel performance measurement functions. Requirements from literature for PMS functions from a reuse and invention perspective are identified. The existing performance management tools are mapped against the previously defined requirement clusters. The identified gap leads to the formulation of a functional specification. Finally using Quality Function Deployments (QFDs) conducted at the four case study companies the importance of the functions is elaborated based on the very specific user needs. Thus this chapter provides a clear and solid base-line for the detailed design of the PMS functions.

Based on the functional specification, design principles for performance measurement functions are presented in detail in chapter 6. The author starts with the presentation of the six measurement facet concept with a referring navigation function being the core of the reuse and invention oriented PMS framework, followed by the presentation of a specific measurement catalogue. The Performance Measurement Infrastructure (PMI) which is elaborated afterwards represents the process oriented base-line for the performance management system. The NPD process is translated in a new perspective, described through reuse and invention assets, attributes and relations. This new view allows a very consistent alignment from the measurement model to the knowledge perspective. Finally the author will present the pre-commercial software realisation which has been realised relying on the concepts presented in this research work. This detailed theory development chapter delivers a considerable contribution to PMS design theory.

In chapter 7, a build and implementation methodology for the performance measurement design principles elaborated in chapter 6 is presented. The impact of those functions on the system where it is implemented is manifold. So it is crucial to provide a sound implementation guide-line which ensures a thorough and coherent change in

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organisations applying the PMS functions. The chapter describes the proposed process to bring the performance measurement functions elaborated in the previous chapters to life.

The case studies, being the testing environments for the PMS functions, are presented in chapter 8. The author will show how the developed functions have been implemented in 4 companies and discuss the findings. The requirements and implementation scenarios are described in great detail. The chapter delivers a deep understanding on how the PMS functions behave in different NPD environments.

In chapter 9 a general discussion and reflection on the research topic is presented considering also cross-case learning from the four case studies. The author presents major lessons learned and lines of thought based on experience made in the context of this research. Indication for theory improvement is also given.

In the final chapter 10 the author concludes through re-comparing the actual research outcome with the objectives and research question set at the beginning of the research, explaining the contribution to knowledge and outlining potentials for further research. The chapter shows that the research objectives have been met and that a solution for the problem has been delivered. The chapter shows as well that the research subject is very rich, therefore various recommendations for future research are given.

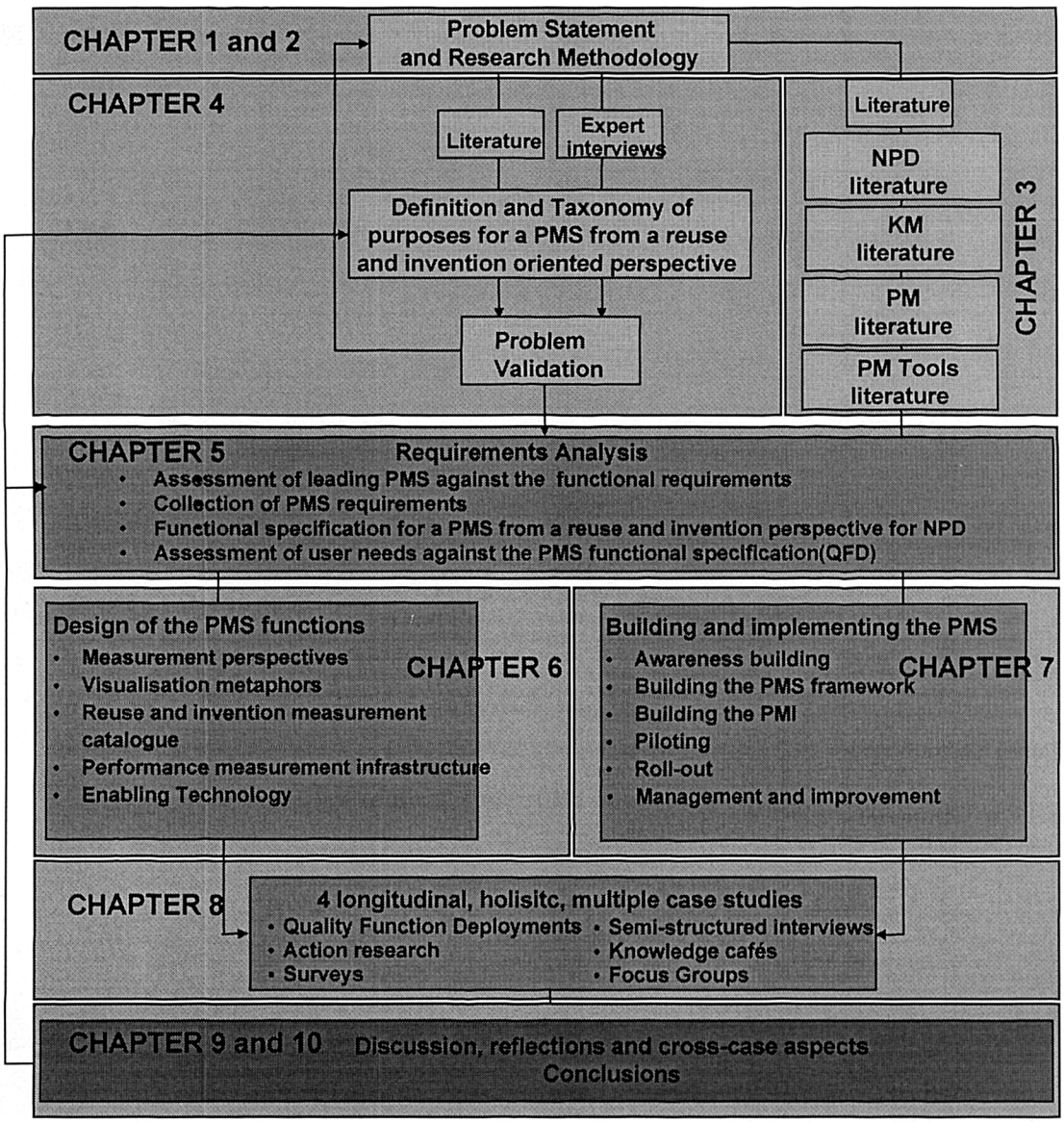


Figure 6: Thesis Navigator

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2.4 Conclusion

The chapter has presented the selected research approach of this research. Due to the fact that the research is driven by a real-world problem a phenomenological, problem-oriented set-up has been proposed. The various research tools which will be applied in real-life contexts will ensure a solid and sound verification and validation of the developed theory.

The research design will on the one hand ensure a solid theory development due to the comprehensive literature analysis and expert interview activities. The developed theory represents the major contribution to knowledge in this thesis. On the other hand a high level of applicability of the developed theory in real-life contexts is ensured due to the pragmatic, user-oriented perspective of the overall research set-up.

Summarising it can be stated that the proposed research approach, process and tools are comprehensive, rich and appropriate to address the research problem set at the outset of this research.

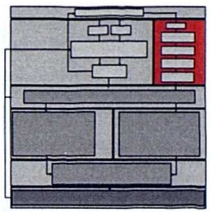
The Thesis Navigator should be used as navigation instrument helping the reader of this document to navigate through the comprehensive document. For the reader's convenience there can be found in Appendix F the Thesis Navigator from the figure above as fold-out page.

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3 Literature Review

"The man who does not read good books has no advantage over man who can't read."

Mark Twain, Author



This chapter gives an insight on the literature in the domains new product development, knowledge management including reuse and invention management and performance management and measurement. Trends, theories and principles in the different domains are discussed to create a solid base-line for the further theory development. Specifically some of the leading performance management and measurement approaches, like the Balanced Scorecard, the Skandia Navigator, the Performance Pyramid or the Performance Prism are discussed in greater detail.

3.1 New product development

The purpose of the next three sub-sections is to give an insight in the new product development environment, its performance relevant drivers and its specific characteristics which are important knowledge for the later design work. The new product development section is clustered into the dimensions process, organisation/people and technology as used by, for example Matheson and Matheson, 1998.

3.1.1 NPD Processes

Bürgel et al. (1997) put new product development in the global context of R&D. According to them R&D starts with strategic early warning activities, followed by strategy development and NPD programme planning which leads into a concrete NPD project (assuming that the project organisation is the dominant organisational principle in today's NPD environments). The NPD process therefore starts according to him when a NPD project has been initiated. Ulrich and Eppinger (1995) define the new product development process as "the sequence of steps or activities that an enterprise employs to conceive, design and commercialise a new product".

Concepts like Total Quality Management, Lean Production and Business Process Reengineering have their focus on processes in common (Al-Ani, 1996). The advantages of this process focus are for example; easiness to control processes, possibility to monitor progress and an early possibility to take corrective measures when the plan is not kept (Thaller, 1998). Another advantage is provided by Wheelwright and Clark (1992): they state that most development processes are complex because they involve a multitude of decisions, different interests and numerous objectives. A disciplined process is one of the ways to cope with this complexity. According to Berndes et al. (1996), NPD organisations have to stop thinking in a functional and departmental oriented way. Instead they should try to think in a process oriented way, establishing a view on the entire process, to achieve integration. Therefore any performance solution for product development should reflect on the process orientation paradigm (Klingebiel, 1999). Fan et al. (2000) confirm the importance of process orientation in the context of performance measurement as well.

Process orientation leads to the integration of departments (Berndes et al., 1996). These processes are mostly organised around procedures which influence the effectiveness and efficiency of the organisation (Berndes et al., 1996). Other important issues to ensure a good process are the use of phases and clear and understandable criteria to move from one phase to another. Wheelwright and Clark, (1992) state that "Excessive rules, bureaucratic procedures and guidelines can, of course, stifle

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creativity, drain excitement, and bog down the project in a morass of red tape". Therefore it is important to be aware of the dangers of implementing too rigorous procedures and rules. A good balance needs to be found between a process structure which supports creativity on the one hand and effectiveness and efficiency on the other. One may conclude that for a PMS solution in product development very similar criteria should be met.

New product development increasingly has to face the challenge of globalisation in a way that products are developed over different physical locations (Boutellier et al., 1998). At the same time products are becoming more and more complex. The knowledge intensity of NPD is therefore dramatically increasing (Kerssens-van Drongelen, 1999). Ulrich and Eppinger (1995) state that today's global competition is about to test a company's ability to be dynamic, customer-oriented, innovative whilst remaining efficient. According to them these many, regularly conflicting goals put demands upon an organisation across all its disciplines, processes and members which are therefore crucial performance dimensions. They share the view that these are not only marketing problems, nor design or manufacturing problems, but new product development (NPD) problems, which comprise all these diverse functions. The outcome of NPD today, the final product, has usually both tangible and intangible components (Merle, 1994).

Clark and Fujimoto (1991) provide a simple, industrial-oriented model of a product development process consisting of four major sequential phases, which are concept generation, product planning, product engineering and process engineering. However, they are aware that in reality the NPD process is complex with a high degree of parallelism. Also, according to Syan (1994), a traditional Western company would develop, produce and market a new product according to a strict sequential process. This sequential process starts with marketing identifying a need for new products. They develop a list of requirements which leads to the satisfaction of the customers needs and which beats the product of the competitors. This list of requirements is handed to design and engineering. Design and engineering then start with developing the technical requirements to meet this list of market requirements. The efforts made by design and engineering result in documentation of the final design of the product. This document can for instance consist of drawings and bills of materials. This document is handed over to manufacturing and testing. These departments start working only when they have received the final approved documentation of the product design. This process is also known as 'over the wall engineering' (Syan 1994, Ehrlenspiel 1995). Every function in sequential engineering stays between its walls and performs the work to its own satisfaction, without considering the requirements of other departments (Fleming and Koppelman, 1998). Organisations started realising that they faced problems caused by flaws in this way of engineering and designing new products (Syan, 1994), like insufficient attention to specifications which leads to an excessive amount of modifications or late changes in the products which are more costly the later they occur.

One of the most promising approaches to overcome some of the problems identified above is the Concurrent Engineering (CE) methodology (Bullinger and Warschat 1996, Prasad 1996, Weber 1999, Deasley and Lettice, 1997) being a "systematic approach to the integrated concurrent design of products and their related processes" (Prasad 1996). CE consists of the three guiding principles parallelisation, standardisation and integration (Bullinger and Warschat, 1996). Prasad (1996) considers the level of concurrency a major performance measure for NPD which has a direct positive impact on the overall lead time.

Graaf (1996) has developed a model which reflects on the ideas of collaborative engineering. The ideas of Graaf acknowledge the main focus of concurrent engineering, namely that the design and development of a product is a multidisciplinary effort and that the product and production process are designed and developed concurrently. He identifies seven critical success factors for collaborative engineering performance

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measurement which are process focus, project management, information technology structure, customer focus, strategy, teams, supplier integration, top down approach and product testing and evaluation.

Eisenhardt and Tabrizi (1995) stress that increased effort in the early phases of product development through a higher number of concept development cycles and increased testing leads to an overall reduction of lead time and development costs. According to them good performance in those phases result in good overall product development performance.

Applying systematic design principles, Pahl and Beitz (1996) provide a standard framework for new product development processes starting from task clarification and overall system specification leading into solution development of subsystems, integration and testing of the overall system. Kerssens-van Drongelen (1999) used this structured approach to provide a development guideline for PMS in companies.

A good NPD strategy derived from the mission of an organisation can create a clear focus for the employees in an organisation (Berndes et al., 1996). The business strategy needs to be translated into a strategy for every development project. This strategy should lead to one common objective, which can motivate the employees and can break down functional barriers, necessary to achieve integration (Berndes et al., 1996). The link between the individual development processes and the overall business strategy is quite extensively explained by Wheelwright and Clark (1992). In their opinion the project leader and the project members must have a common and clear understanding of the strategic direction of the organisation. "Behind the foundation of a successful development project must be a process that identifies and integrates the strategies and the functions, and links them to the overall direction of the business (Wheelwright and Clark, 1992)." Edvinsson (2000) points therefore out that a PMS explicitly has to support performance management at a project level providing also aggregation functionalities to align the project's performance to the overall NPD system performance.

3.1.2 NPD Organisations

The majority of NPD organisations of today are characterised by a matrix structure (Boutellier et al., 1998): The line functions (like mechanical engineering, purchase, sales) deliver resources to (interdisciplinary) project teams which are responsible for the overall execution of the development of the referring product. Clark and Fujimoto (1991) provide several types of project organisations discussing the role and power of the project manager (light-weight vs. heavy weight project manager) in different contexts. Klingebiel (1999) stresses that the structure of the project organisation should be reflected in the design of a performance management system.

Boutellier et al. (1998) provide a framework for product development organisations in complex, distributed and dynamic environments. Depending on the four parameters type of project work, type of innovation, type of resource binding and knowledge mode, he suggests four alternative organisational design concepts reaching from a centralised venture team to a decentralised self-co-ordinated project team. The Fractal Company approach by Warnecke (1995) relies on the principles of self-regulation, self-co-ordination, and self-administration. A fractal is defined as the basic element of a "Fractal company" which constitutes a partial system of an enterprise offering thereby opportunities for entrepreneurship to all employees (Warnecke, 1995). In their smart organisations concept Filos and Banahan (2000) point out that above all in the new economy NPD organisations increasingly have to be considered as living systems based on the principles of complexity theory (Kauffman, 1996). According to them the classic hierarchical command and control structures should be replaced by interlinked cross-functional knowledge and competence networks. The nodes and connections are the basic ingredients for the networks, and by adding intelligence and self responsibility to the nodes enables the network to reach a high level of overall smartness (Filos and

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Banahan, 2000). Kaplan and Norton (1996a) stress that a sound PMS should enable the coherent integration in different organisational structures.

Concepts like knowledge management and Total Quality Management both stress the importance of teamwork. One reason to work in project teams is to be able to innovate and to be able to adapt to changing conditions (Berndes et al., 1996). Both innovation and adaptation are important to survive in the fast changing market place (Berndes et al., 1996). Wheelwright and Clark (1992) state that mismatches between departments are one of the biggest problems in product development. These mismatches occur because departments demand that a product should live up to certain expectations they have of a product. These expectations might prove to be unrealistic or even impossible. To solve these problems organisation and process integration is necessary (Wheelwright and Clark, 1992). With regard to reuse performance Pasher (2000) stresses that the "walls" between different entities is one of the biggest inhibitors.

According to Pawar (1994) team performance is a key driver for overall product development performance. Berndes et al. (1996) are of the same opinion: "Advantages of teamwork can be seen in the shortest possible closed loops, which is leading to a higher degree of process parallelisation, of integration of knowledge among the people involved, and of motivation and performance". Pawar (1994) adds that companies should develop performance criteria to choose the right team members. These criteria should be based on for example age, qualifications, experience and character. Driva (1997) stresses that team and process/product performance are the two major product development performance dimensions.

Prasad (1996) points out that it was not too long ago that companies were quite reluctant to establish relationships with their suppliers. This mainly changed due to the increased competitiveness which lead to a sharp decline in profit margins and in an increase in product complexity. Through these changes it became almost impossible for one organisation to design, build and assemble an entire product. This point is also acknowledged by Moerman et al. (1993). They discuss that automotive producers at the end of the supply chain will limit their activities to their 'core-activities'. These core activities are for instance assembly, marketing and research. This leads to a bigger need to co-operate with their suppliers, who will have to increase their share of the total development activities. Johnson (2000) and Jukes (2000) elaborate intensively on the importance of supplier performance for overall product development performance. Bidault et al. (1998) discuss that quite a lot of research took place to understand the performance gaps between Western and Japanese manufacturers. One of the reasons that the Japanese firms outperformed their Western counterparts was found in their close supplier relationship. Japanese firms are trying to blur their organisational boundaries to create competitive advantage by close supplier relationships (Cooper and Yoshikawa, 1994). This close supplier relationship is one of the cornerstones of concepts such as lean management and just-in-time (JIT) management (Bidault et al., 1998; Moerman, 1998).

A lot of authors stress the importance of good knowledge of the customer and of the market. Wheelwright and Clark (1992) state that two of the biggest problems in product development are: "the moving target", caused by a change in the market place and "lack of product distinctiveness", caused by poor market research and poor tracking of shifts in the marketplace when the product development process has already started. Many authors agree that the customer is a key stakeholder and therefore NPD performance management should cover the fulfilment of customer expectations (Kaplan and Norton, 1996a). Customer focus is not only important though to meet the customers' needs and expectations. It can also be important for the development process itself, namely by achieving an unifying force which again is necessary to achieve *integration* between the departments (Wheelwright and Clark, 1992).

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Cooper and Kleinschmidt (1986 and 1995) have published two articles in which they stress the importance of good and proficient market research for a successful development process. They also identify the critical role of the marketing function to shape the concept and design of the product. Finally Cooper (1990) states that: "The provocative finding is that those firms that did proportionally more market-related activities reaped the benefits," and "Twice as much market research (measured in both man-days and dollars spent) was conducted in successful products as in failures".

3.1.3 NPD Enabling technologies

Today's NPD increasingly relies on extensive employment of enabling information technologies, like for example CAD/CAM (Spur and Krause, 1997), Digital Mock-up (DMU, Spur and Krause, 1997), Virtual Reality (VR, Landauer et al., 1997), GroupWare Systems (Bullinger et al., 1999) and Engineering Data Management Systems (Bullinger et al., 1999). All major performance management frameworks elaborate on the importance of IT infrastructures (for example Kaplan and Norton, 1996a; Edvinsson and Malone, 1997).

Terwiesch et al. (1998) have identified that intensive communication is one of the key drivers of the performance in product development. When this communication is supported by information technology the performance of the product development process will improve because of two reasons: The first reason is that information technology lowers the cost made to implement design changes and the second reason is that it plays an important role in anticipating and eliminating project risk and uncertainty.

Examples of major information technologies in product development are given by Chelsom (1994), namely Computer Aided Design (CAD), simulation tools and rapid prototyping. Increasingly knowledge management systems and knowledge based engineering tools emerge also in NPD contexts (Schulte, 1999).

Above all in complex NPD environments like aeronautics and automotive, virtual product development without physical prototyping has become reality (Spur and Krause, 1997). Thus, the aeronautical and automotive environment are leading branches with regard to IT application in product development (Kablouti, 2000). Big aircraft, like recently the Boeing 777 are nowadays developed, assembled and tested completely virtually, without any physical prototypes (Kablouti, 2000). According to him this fact puts enormous requirements on the software infrastructure and integration of different types of native data. Currently, the European project ENHance (Enhanced Aeronautical Concurrent Engineering, Enhance, 2001) is developing one of the most sophisticated IT environments for product development. All major native data applications, like Digital Mock-up (DMU), stress simulation programmes, CAD systems, CAM systems, logistic systems, workflow engines, virtual data navigation systems, security applications and management information systems are being integrated within one leading IT backbone Product Data Management (PDM) System. Currently the project becomes aware that knowledge management principles and referring IT solutions must be built on top so that users can handle this vast amount of available information (Kablouti, 2000).

3.1.4 Conclusion

This section 3.1 gave an overview on the new product development environment of today. The author gave an overview on potential performance drivers in NPD which may be important for the later solution development. Summarising the following list highlights those aspects which make NPD a very special phase in the product value chain (Prasad, 1996; Ulrich and Eppinger, 1995; Enhance, 2001; Evans, 2000):

- Very high system complexity.
- Dynamic, unstable processes and process focus.
- High knowledge intensity.

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- Very decentralised structure of development teams.
- Project structure is still the leading organisational structure.
- High level of IT application.
- High level of interdisciplinarity.

3.2 Knowledge management (KM)

The following subsections provide an overview on the KM topic. After bringing KM into the context of Intellectual Capital (IC), the issue of knowledge management as a management tool is discussed. Various perspectives on KM which are relevant for this research are described subsequently, putting special emphasis on the knowledge reuse and invention perspective. The author considers this section important in order to provide a structured and common overview on the very comprehensive KM topic and to bring the knowledge reuse and invention theme into the context of KM. Also this section will help to create a base-line and stimulus for later theory development.

3.2.1 The context of knowledge management

There is broad agreement on knowledge being a vital prerequisite for productivity, flexibility and competitiveness in both the private sector and public sector, as the world moves into an information society and economy (Drucker, 1993; Mårtensson, 2000; Menon et al., 1998). The knowledge-based theory of the firm claims that knowledge is the only resource to provide sustainable competitive advantage (Roberts, 1998). According to Hamel et al. (1998), the advent of KM comes along with an increasing recognition of knowledge as the true strategic asset; which means that it is rare, valuable, imperfectly imitable and non-substitutable (Michalisn et al., 1997). This trend and awareness however stands in sharp contrast with the absence of a commonly accepted and applied understanding of KM (Menon et al. 1998).

KM is understood as the management of Intellectual Capital (IC) controlled by a company (Guthrie, 2000). IC is thereby used as an umbrella term and further defined as the applied knowledge in organisations, technology, relationships and skills, providing a competitive advantage (Edvinsson and Malone, 1997). Drawing on this framework, Roos et al. (1997) trace the concept of IC back to strategy and to measurement (Figure 7). Whilst measurement typically focuses on information systems and non-financial performance data, strategy deals with creation, use of knowledge and how it is leveraged into value (Roos et al., 1997).

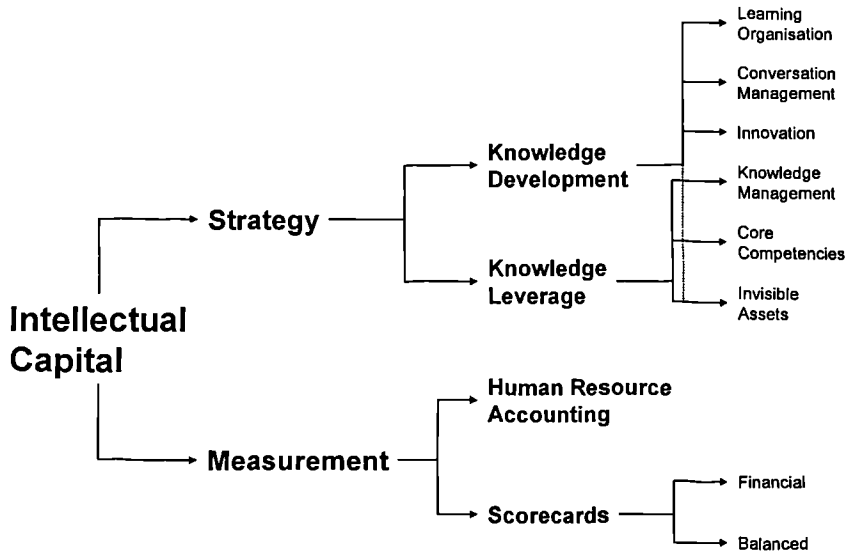


Figure 7: Theoretical organisation of IC (Roos et al., 1997)

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The consideration of intangible assets or resources as a distinctive competence to build economic wealth is suggested to drive organisations to concentrate on "..processes flowing through these structural arrangements, through which individuals engage in knowledge creation, storage, and deployment." (Roberts, 1998 and Grant, 1991).

Even though the nature of knowledge has been subject to discussion for several hundred years (so-called epistemology), the search for a formal definition of knowledge and consequently for KM continues (Emery, 1997). Thus, the objective of the next sections is not to provide another collection of connotations and definitions, but to aid the understanding of structure and organisation of leading KM activities and concepts. In doing so, the author will draw on the basic works of Mårtensson (2000), Menon et al. (1998) and Binney (2001). Amidon (2000) has provided a very simple, but clear definition of knowledge "being information with a meaning". This very pragmatic definition is proposed to be a base-line for the term "knowledge" in the next chapters.

3.2.2 Knowledge management as a management tool

KM is frequently considered a management approach for matters of information handling (DiMattia and Oder, 1997). It would then in particular apply to the creation, (re-)use and exploitation of knowledge in a working context. Most literature agrees on a process of distinctive, but closely related stages or KM activities (Figure 8).

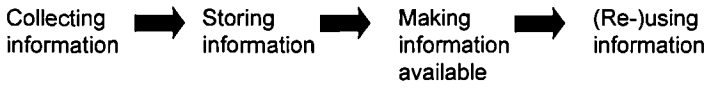


Figure 8: KM as an information handling tool (Mårtensson, 2000)

The process is suggested to start with the acquisition of information or data. The invariably linked second step should then be logical documentation, codification, transformation and organisation of this information in some organisational storage system. The systematic record of knowledge is more often found in almost every recent KM definition (Weggeman, 1999; Probst et al., 1997; Yeh at al., 2000; Cole-Gomolski, 1997a and 1998; Hibbard, 1997; Blake, 2000; Symoens, 1998; Laberis, 1998). In a third stage the stored information is supposed to be made accessible by technological means to as many members of an organisation as considered feasible and possible (LaPlante, 1997). Ostro (1997) speaks of distributing the right content to the right users at the right time. Eventually, the knowledge is likely to be (re-)used through talking and socialising in digital or analogue form (Laberis, 1998).

Within the strategic concept of KM, knowledge is recognised as an organisation's most valuable asset (Roberts, 1998). This regularly under-used resource is then put at the heart of the organisation's purpose (Ash, 1998). Amongst others, Gopal and Gagnon (1995), as well as Manville and Foote (1996) maintain that effective KM always starts with a sound corporate strategy. Companies should assign diverse objectives and rationales to creating and implementing a KM strategy. Ostro (1997) mentions performance improvement, whilst Maglitta (1995) refers to increased productivity and competitive strength. More effective information handling is thought to enable organisations to optimise decision-making (Pasher, 2000). The capture and exploitation of best practices is suggested by Cole-Gomolski (1998), reduction of R&D costs and delays coming along with growing innovativeness is associated to KM by Maglitta (1995) and Hibbard (1997). From her review on publications on strategic KM, (Mårtensson, 2000) identifies a set of critical success factors to capitalise on KM efforts:

- The "so what?" question: KM must be linked to the original purpose of the organisation. It must be evident how these means will affect peoples' work (Klaila, 2000).
- Top-management support: the executive level is required to foster and encourage knowledge sharing and serve as a role model. Gopal and Gagnon (1996) have ob-

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served that those organisations, where top-management assumed the responsibility of a full-time position dedicated to KM, achieved greatest success.

- Communication: Ash (1998) recognises that a large proportion of companies failed in implementing and realising a KM strategy due to a lack of sound and comprehensive communication.
- Creativity: According to Kao (1997), KM cannot only build on the strategic framework given. The organisation moreover has to provide a fusion between KM and its basic skills of creativity.
- Culture and people: at the heart of the knowledge-based firm Pasher (2000) assumes corporate culture and committed employees. Even though this issue seems among the most difficult to resolve, it is likely to produce the greatest benefits.
- Sharing: A 1997 APQC study (Alter, 1997) shows that well-established processes and systems for distributing knowledge generally benefit firms. Ostro (1997) requires employees to realise that their particular knowledge is of value and use to others in the company.
- Incentives: in the same turn, it is found crucial to reward people for contributing to organisational knowledge and for (re-)using these assets. They should thereby clearly understand the individual and collective benefit of KM (Cole-Gomolski, 1997b).
- Time: the greatest enemy to knowledge contribution is believed to be the time required for input, maintenance and retrieval (Mayo, 1998). Thus, organisations must allow for opportunities and time to learn, to create and to (re-)use.
- Evaluation: more often managers fail to give evidence to investments in and outcomes of KM. It is therefore vital to install formal and informal means of evaluating, monitoring and controlling KM efforts and performance.

In a nutshell, the successful implementation of a KM strategy zeros in on two essential features: the creation of knowledge (for example through learning and invention) and the leverage of knowledge (for example (re-)use, commercialisation, distribution) (Roos et al., 1997; Mårtensson, 2000).

3.2.3 Relevant perspectives on knowledge management

A glance at the entire spectrum of perspectives on KM reveal that almost every author has a particular view on the subject. Menon et al. (1998) therefore find it difficult to define distinctive schools without any overlap. They nevertheless offer some loose and rough categories to organise the various approaches and to provide a satisfying picture of the domain. The following sections describe the identified approaches and some selected publications related to them.

3.2.3.1 The operational knowledge management perspective

Menon et al. (1998) assign tools, methods and practices for implementing and analysing processes of KM to this area.

A typical mechanism is the knowledge market, introduced by Davenport and Prusak (1998). These authors suggest approaches to codifying and distributing knowledge, based on information technologies. They deem time, money, management focus and technology eventually the essentials of effective knowledge management.

Another approach is presented by Weggeman (1999). He refers KM to the organisation and control of operational processes within the knowledge value chain (Figure 9).

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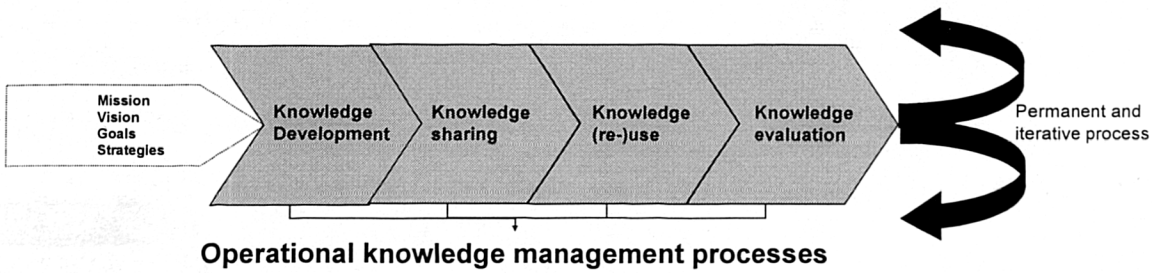


Figure 9: The knowledge value chain (Weggeman, 1999)

The picture of a value chain is chosen to underscore the increasing value of knowledge as it moves through the distinct processes. At the operational level, it is composed of the following interrelated stages:

- Development of knowledge (identification and acquisition).
- Sharing knowledge.
- (Re-)use of knowledge.
- Evaluation of knowledge.

These stages are supposed to form an iterative and cyclical process. Weggeman (1999) adds a strategic level to his approach, which answers for the strategy-driven control and structure of the value chain and the operational processes within. A third, tactical level is installed to facilitate and support the knowledge value chain, through infrastructure, technology, management, culture, etc. Further well-known models of operational KM are for instance, the knowledge market concept of North (1999) and the KM cycle approach of Probst et al. (1997).

The process-oriented view on knowledge management outlined in this sub-section is considered to be important as this perspective makes the wide knowledge management topic more tangible and supports thus the development of operational solutions in process-driven environments like new product development.

3.2.3.2 The strategic knowledge management perspective

Concepts of strategic KM share the broad perspective on knowledge being important for sustainable competitive advantage. They find expression in knowledge-based theory of the firm and the awareness of knowledge as the fourth production factor. Manville and Foote (1996) propose five principles vital to execution of strategic KM:

- Strategic KM must begin with corporate strategy; i.e. the fundamental purpose of the company needs to be defined in advance.
- Any KM strategy must link to some traditional, financial measures to give evidence to its positive impact on performance.
- The realisation of a KM strategy is not merely managing knowledge, but rather nurturing people with skills, expertise and insight.
- The strategic leverage of knowledge builds on networks of people. Tools and technologies serve as enablers only.
- In avoidance of overload KM should pursue an organisational "pull" and be linked to genuine business tasks.

Amidon (1997) states that knowledge is deemed to reshape the entire organisation and the ways business is done. Within the knowledge-based theory of the firm Grant (1997) states that:

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- Organisational capability builds on team-based integration of individuals' specialist knowledge.
- The key to competitive advantage is achieving internal replication of knowledge, whilst avoiding external replication.
- In recognition of tacit knowledge, hierarchies become increasingly inefficient. It is hence critical to create team-based subsystems and design qualified interfaces.
- Informed decisions can only be made where the knowledge is located.
- Strategic alliances between organisations enable taking advantage of internal and external knowledge assets.

Last but not least, Whitehill (1997) maintains that advantage from strategic KM evolves from share of knowledge at higher organisational levels and then working downwards. Strategic KM has the holistic view of managing intangibles in common. It does however not conflict with operational KM, but rather gives direction and shapes the collective context for these processes and activities.

It is considered to be important to understand that KM activities have to be aligned with the company's overall (NPD) strategy and operations to ensure an overall consistent and coherent KM framework.

3.2.3.3 The knowledge reuse perspective on knowledge management[8]

According to Edvinsson (2000) the (re)use of knowledge is the key activity in the KM value chain and therefore of special interest and importance. The reuse of (knowledge) assets is according to Lim (1998) a significant contributor to a company's productivity enhancement and business success. Lim (1998) provides a holistic management framework for reuse of software designs – an important knowledge asset in the software development environment. His approach is outlined in detail in section 3.4.5.

Clausing (1998) provides with his reusability matrix a tool which helps in the planning and control of reusability in product development. This tool can be considered a performance management system supporting the product development process through provision of various metrics (among them different types of reuse) to different stakeholders in order to enhance the balance between the reuse of knowledge and innovation and to optimise the prevention of rework.

Wolf (2000) provides a best practice reuse system defining a reuse process, supporting organisation and an enabling IT infrastructure. She assumes knowledge gained in projects a critical reusable asset. Once a project is completed she suggests adding a so called knowledge certification process managed by several people (project managers, specialists) lead by the reuse champion. The outcome of this process is a number of certified reusable knowledge assets.

The Next Generation Manufacturing Systems project (NGMS, 1997) suggests a concept which aligns the KM process with the manufacturing process in order to enhance reuse of knowledge. According to them, first the processes have to be stable and aligned before enabling IT can be implemented. The project distinguishes between reusable embodied knowledge and reusable explicit knowledge.

McClure (2000) provides a complete reusability process consisting of reuse-based planning, domain analysis, business area analysis, reuse-based design, reuse based construction and finally a final reuse review. He applies thereby the reuse tools com-

8 The author is aware that the terms reuse and invention can also be seen in a non-knowledge related context, however due to the fact that the author and other authors (for example Weggeman, 1999; Probst et al., 1997; Edvinsson, 2000) assume reuse and invention being key phases of the knowledge value chain, the discussion of these terms is done within the knowledge management chapter.

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monality analysis, domain analysis, redundancy checking, reuse planning, reuse library and reuse workshops. According to McClure (2000) the main inhibitors for reuse are:

- Cost of reuse is too high.
- It is too time consuming to reuse.
- Current tools and methods do not provide methodical support.
- Not invented here syndrome.
- Management is not convinced of the benefits.

The Virginia Centre of Excellence for Software Reuse (1993) provides a reference model for software reuse identifying an input-output oriented activity based process model and a role concept for SW reuse:

The Activities:

- Initiate Reuse Program.
- Understand Context.
- Analyse Risks and Select Strategy .
- Plan Improvements.
- Implement Improvements.
- Review and Update Reuse Program.

The Roles:

- Sponsor - an individual/group who authorises and reinforces the reuse program.
- Reuse Champion - an individual/group, usually respected for technical or personal leadership, who advocates and supports the reuse program.
- Reuse Agent - an individual/group who plans and implements the reuse program.
- User - an individual/group who uses the adopted reuse technologies.

The reuse section has shown that reuse of knowledge is one of the most important KM activities. The reuse of knowledge has to be seen in the context of other KM related activities like knowledge acquisition, storage and sharing of knowledge. The reuse of knowledge must therefore have a clear procedural dimension as well as an organisational, infrastructural and managerial, measurement related dimension.

3.2.3.4 The knowledge creation (invention) and innovation perspective on knowledge management

Edvinsson (2000) defines invention as a main constituent element for creation of knowledge. Hahner (2000) brings reuse and invention in the context of innovation through stating that innovation requires an (existing) theoretical conception plus a technical invention which is commercially exploited. Similarly Dvir et al. (2000) define innovation equalling reuse plus invention (creation of new knowledge) multiplied by the exploitation factor. Also Hahner (2000), Brockhoff (1993) agree that innovation requires invention, translation and commercialisation.

Amidon and Mahdjoubi (2000) base their atlas on knowledge innovation on the three guiding principles

- mapping for organising commonalties,
- scaling to provide measurement and relational information and
- compassing for direction.

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According to them the "mapping" considers all the resources - human, financial and technical - to be integrated as a continuous learning system. The "scaling measurements" consider the intellectual capital of an enterprise - often described as the difference between book value and market value. The "compass" finally provides a coherent, common vision within which internal and external variables are leveraged to optimal value including the flexibility to capitalise upon unexpected market changes. Amidon (1997) has identified 18 drivers for calibrating the knowledge innovation strategy of a company: Collaborative Processes, Performance Measures, Education and Development, Distributed Learning Network, Intelligence Market Positioning, Knowledge Products and Services, Collaborative Market Penetration, Market Image Campaign, Leadership Competencies and Communications Technology.

Pinchot and Pellman (1999) have identified 18 success factors for implementing cost effective innovation in companies. They are outlined in the figure below:

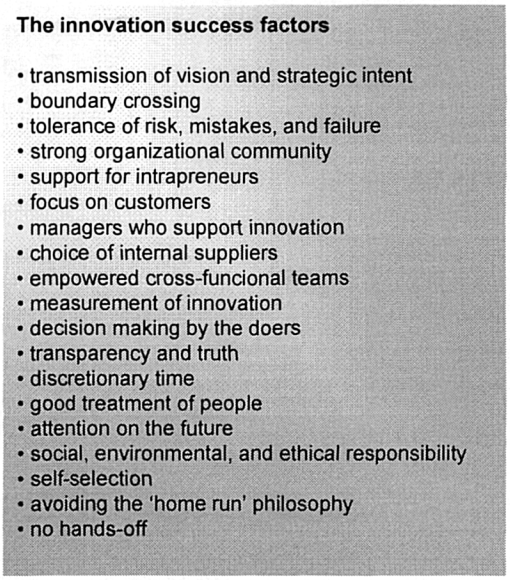


Figure 10 : The Innovation success factors (Pinchot and Pellmann, 1999)

According to Nonaka and Takeuchi (1995) the innovation perspective concentrates on the very process of knowledge creation and its contribution to organisations' innovativeness and business success through exploiting the knowledge created (Figure 11).

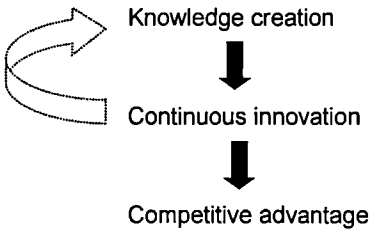


Figure 11: Innovation leading to competitiveness (Nonaka and Takeuchi, 1995)

The authors conclude from their study of successful Japanese companies that knowledge creation is a continuous and complex process that spans the entire organisation and eventually crosses its boundaries. Initially, knowledge is seen as something personal, evolving from subjective views and insights. This knowledge is leveraged into organisational capability and competitive advantage through socialisation, combination, internalisation and explication. Recognising this personal character of knowledge is suggested to come along with new ways of learning, communication and interaction between individuals.

Nonaka and Takeuchi (1995) propose diverse means of transforming knowledge, such as metaphors, analogy, ambiguity and redundancy. Their findings are underscored by

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Leonard-Barton (1995) who states that individuals and organisations finally compete on their ability to create knowledge. She then refers to the tacit parts of organisational knowledge as core or strategic capabilities. These require permanent identification and rejuvenation, as they form the primary drivers of growth. The role of the manager in this context is the stimulation of creative abrasion by maintaining the different skills among employees. Obviously, strategic KM and the innovation perspective share the value placed on knowledge as a critical strategic asset. The innovation perspective however focuses exclusively on the processes of creation and transformation of this asset.

It is important to understand that both reuse and invention are important drivers for innovation. There is evidence in literature that innovation requires in addition a comprehensive exploitation aspect. This point of view is certainly only one out of various viewpoints on the innovation topic, however for the context of this research this simple but clear understanding of reuse, invention and innovation is proposed.

3.2.3.5 The technology focus perspective on knowledge management

Since development in information technologies has rocketed, KM has more often been equated to the installation of sophisticated databases, data warehouses and management information systems. "Knowledge management in the West has risen hand-in-hand with technologies such as GroupWare, whiteboarding and videoconferencing..." (Guth, 1996). Nevertheless these technologies fail to transform implicit knowledge into explicit knowledge effectively (Menon et al., 1998).

Therefore, focus gradually shifts back to a rather human-centred and personal understanding of innovative practices and knowledge management (Sveiby, 2000). Information technology is assumed to be a supportive tool, subordinate to people. Practitioners and academics perceive the potential benefit of technological solutions in:

- Connecting people to people and information to people.
- Lowering the barriers of time and geography in order to further co-operation, co-ordination and communication.
- Enabling larger and more dynamic personal networks.
- Facilitating human contribution to innovation.
- Organising knowledge assets for valuation and reuse.

These benefits are likely to be realised, when information technologies are applied against considerations, such as:

- Keeping technological systems simple and intelligible.
- Involving users in design and implementation.
- Emphasising quality relative to quantity.
- Actualising and updating any content over short periods of time.
- Familiarising users with technology through personal assistance.

The ongoing debate over information technologies in KM concentrates on: "How much skill and creativity embodied in a modern workforce can be rendered into some digital form, catalogued, and shared via knowledge management?" (Gardner, 1998).

It can be summarised that enabling technologies supporting KM processes like knowledge storage, sharing, reuse and invention are considered to be important enablers in business contexts.

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3.2.3.6 The accounting and measurement perspective on knowledge management

Those advocating IC and its impact on organisations' value provide the accounting and measurement perspective on KM. These authors take an enterprise governance view on the management of intangible assets.

Stewart (1997) agrees that key assets are of an intangible nature and that knowledge content required for any work is ever increasing. Thus, management is deemed to answer for investment in employees, structures and relationships and to develop means for evaluating these investments.

The broad range of methods ranges from simple market-to-book ratio and Tobin's Q, over the Balanced Scorecard of Kaplan and Norton (1996a), the Intangible Assets Monitor of Sveiby (1997), or the Skandia Navigator (Skandia, 1996). The model of this Swedish insurance company led to the development of IC management. The so-called IC value scheme (Skandia, 1999) distinguishes the following elements (see also section 3.4.2, page 51 for more details):

- Human capital describes the competencies, skills, experiences and abilities of the individuals in an organisation. It increases through education, training and social interactions. In a free society the enterprise can not own, but only rent its human capital from the people it employs.
- Structural capital consists of the externalised and codified results of intellectual activities. It is incorporated in documents, machines and knowledge bases.
- Customer capital is made up of the relationships an organisation builds with its customers, as well as the customers' knowledge articulated through interests, problems, needs and wishes.
- Organisational capital reflects the working environment, the equipment and facilities; i.e. the physical infrastructure of the enterprise.
- Process capital is embedded in value creating processes, management systems, procedures and organisational structures.
- Innovation capital is the tacit and explicit knowledge, which enables people to act and innovate. It is made up of intellectual property, such as patents, trade marks, etc. This finally leaves intangible assets as the balancing value.

The function of KM in this concept is that of planning, implementing and operating those activities required for effective utilisation of an organisation's IC (Wiig, 1997).

North et al., (1998) have composed a rather technical and financially-focused approach to intellectual capital measurement, the "knowledge balance sheet". Laying a claim to attain a precise measurement of knowledge, is assumed to "...flutter about objectivity, where there is only estimation possible."(Roehl and Romhardt, 1997). Building on this recognition, North et al. (1998) summarise current dysfunctionalities in knowledge management and measurement which are for example the neglect of most important (intangible) assets, concentration on misleading indicators and lack of focus. Setting the current measurement frameworks like the Balanced Scorecard (Kaplan and Norton, 1996a) or the Intangible Assets Monitor (Sveiby, 1997) against these shortcomings, they conclude that none addresses those disfunctionalities satisfactorily. They hence propose a system of knowledge indicators, which allows the deduction of a complete finance and knowledge balance sheet. This system is outlined in greater detail in Appendix A2 of this thesis. The benchmarking based EFQM approach (Bading and Frech, 1999) currently extends its measurement dimensions with a knowledge dimension. Within this dimension mainly people's ability to identify, store and share knowledge are assessed.

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Recently Marr et al. (2001) have added to the Performance Prism concept (which is described in detail in section 3.4.4, page 56) a knowledge measurement dimension. The identified knowledge assets in a company which are clustered into stakeholder resources and structural resources are equipped with specific knowledge asset related indicators which allow for an assessment of the various knowledge areas. They recommend a balanced set of knowledge indicators for each of the knowledge assets.

Several institutions like the Global Knowledge Economics Council (GKEC, 2001) or the University of Regensburg (Maier, 2001) are offering extensive lists of indicators which can be used for knowledge measurement. Most of the indicators refer thereby knowledge related activities like store, learning, knowledge diffusion, knowledge sharing or creation.

There is considerable evidence in literature (see also sections 1.1, 5.2.3 and chapter 6.2) that management of knowledge based on measurement results in better business performance. Most of the current knowledge measurement approaches share a rather financial balance oriented viewpoint on the subject which might be partly problematic as the direct measurement of the value of knowledge is always driven through the context where the knowledge is applied and therefore highly subjective.

3.2.4 Conclusion

In the sections above, an overview on the most influential theories, concepts and perspectives within the discipline of KM has been provided. The overview draws on the categorisation of Menon et al. (1998). However, one should keep in mind that the distinction of operational and strategic KM, of a reuse, invention, innovation and accounting perspective, of a technology focus and the principles of the learning organisation are somewhat subjective and arbitrary. Thus, Menon et al. (1998) agree that there is tremendous overlap between those perspectives. Due to the richness of KM literature, it was not possible to give an overview on all concepts and theories which are currently available. However for the specific context of this thesis (reuse, invention, process-orientation, NPD, performance perspective) the author has outlined the most relevant ones.

3.3 Performance measurement in new product development

The next two sections provide an overview on current thoughts, concepts and functions around the performance measurement topic. Thereby the author distinguishes between the design aspect of a PMS, referring to the basic working principles and features of and important drivers for PMS functions and the implementation aspect which elaborates on the issue of how PMS designs can be brought to life in real-life environments.

3.3.1 Performance measurement design concepts, principles and characteristics

Measurement, being an essential part of management in the context of product development, is considered vital to document the value of development efforts, to evaluate research programs and to allocate resources diligently (Hauser and Zettelmeyer, 1997). Against this background, academic research, as well as industrial practice have been active in the study and construction of adequate R&D (NPD) metrics and metric systems respectively.

Griffin and Page (1996) for instance have reviewed 61 research studies and 77 articles on the issue prior to 1993 alone. In the course of this analysis, they identified over 75 distinct measures of R&D performance. However, the largest problems arise from the multi-dimensionality of product development (Hart et al., 1998) and the concentration

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on micro-level metrics; i.e. the isolated project level. Overall program performance and contribution to business success are hardly captured (Loch et al., 1996).

In the early 1980s Cooper has pointed to the problem of suitable concepts for strategic thinking in new product development (NPD). Griffin and Page (1996) describe the Product Development and Management Association (PDMA) Success Measurement Project. This research is motivated by the recognised deficiencies of currently available R&D measures (Montoya-Weiss and Calantone, 1994). The work of this PDMA project addresses three identified and independent dimensions of product development success; i.e. consumer-based results, financial outcome and process-based performance. The authors see a compelling need to distinguish measurement on individual project levels from measurement on the overall development program level.

Loch et al. (1996) present a measurement concept that builds up on the earlier works of Griffin and Page (1996). They take their concept a step further and extend it to capture the impact of project success on business success. They claim to close "..a gap between industry characteristics and discrete innovation projects" (Adler, 1989), by distinguishing different levels of performance in product development. Three performance dimensions form the foundation of this measurement concept:

- Business performance: a firm's success on the target markets.
- Development output performance: the contribution of R&D to business objectives and success.
- Development process performance: the internal drivers and factors of development output.

These three dimensions link to a causal chain of enabling processes, contributing output and overall success (or failure). They concentrate their composition on development output and development processes, i.e. on the operational management of product development (Loch et al., 1996).

The International Centre for Research on the Management of Technology (ICRMOT) at MIT Sloan School of Management is funding an ongoing scientific study called R,D&E[9] measurement. Hauser and Zettelmeyer (1997) summarise the findings of the study, which appeared in several MIT working papers (Hauser and Zettelmeyer, 1995; Hauser, 1996; Hauser, 1997). The scientific guide to R,D&E metric selection is based on a fine distinction of R,D&E activities. The authors recognise that R,D&E is a multifaceted process, which is made up of diverse activities. The authors adopt a common classification applied to technology management (Krause and Liu, 1993 and Tipping et al., 1995) and distinguish as follows:

- Tier 1: basic research, which explores generic science and technology. These explorations regularly have a longer perspective and entail some risk and uncertainty.
- Tier 2: activities, which select and further develop programs in line with the core technological competencies of an organisation.
- Tier 3: specific projects, directed at concrete customer needs. They are within current capabilities and attempt short-termed problem-solving.

Organisations, as well as individual scientists and engineers often have a mix of these stages in their portfolio. In the course of their initial research the authors found that "..many of the mistakes occurred when technology managers attempted to apply the same metrics throughout the process." (Hauser and Zettelmeyer, 1997). They therefore assume that an integration of the diverse activities and metric selection according to

9 R,D&E: research, development and engineering; most authors do not make this distinction, but include engineering efforts in their concept of R&D from the inception (comment by the author).

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this variation is a key success factor in R,D&E measurement. The tier concept is likely to provide the framework for this selection.

Another well-known performance measurement approach is the closed loop approach described by Dorf and Bishop (1995). In their concept the process is controlled through monitoring process input, output and process feed-back. The inputs to the process are the performance targets that the process should achieve, while the output are the actual as-is values compared to the input. The essential element of the closed-loop system is feedback (Maskell, 1989). Its effect on an individual's behaviour has been recognised as essential for learning and for motivation in performance-oriented organisations (Ilgen et al., 1979). The feedback element provides information which controls the future functioning of a process (Nalder, 1980) through for example reports, scores and annual appraisals.

Process Monitoring Tools, like those described by Krahn (1998) focus on the genuine NPD process; i.e. they are oriented towards current operations. At the very core of such a system would be a set of process indicators. Further on Krahn (1998) suggests a reference model for a systematic definition of indicators and the entrenchment of a Process Monitoring System (Table 4). This system evolves from concepts of process management, comprising design, controlling and development of business processes. By directing attention to aspects of controlling, Krahn (1998) defines Process Monitoring as follows: "Process Monitoring is the in-depth and continuous observation of ... processes."

Objective	Capture and measurement of process quality
Characteristics	❑ Attainment of holistic and integrative view of business processes ❑ Diligent process handling ❑ Support of goal-oriented process improvement ❑ Determination of changes in process quality ❑ Comparability of process quality ❑ Performance-oriented incentive scheme

Table 4: Objective and characteristics of Process Monitoring Systems (Krahn, 1998)

Lingle and Schiemann (1996) suggest four mechanisms that contribute to the success of measurement-managed organisations: Agreement on strategy, clarity of communication, focus and alignment efforts and organisational culture. Driva (1997) developed an implementation framework and a tool in the form of a workbook to use performance measures to improve decision-making during the product development process.

Kerssens-van Drongelen (1999) provides a comprehensive set of taxonomies and functions for performance measurement (she calls it performance control) in product development environments (see also section 4.1). She uses a systematic design approach to provide a comprehensive performance management implementation path. She also provides an extensive collection of performance measures suitable for product development environments.

Johnson (2000) identified 22 characteristics for a PMS in product development environments. Out of those 22 he considers 5 - process focus, acceptance, timeliness, objectivity and transparency - for deeper investigation.

Wagner and Hauss (2000) suggest a measurement system to evaluate the value of R&D knowledge. They rely on the Skandia Navigator concept (section 3.4.2) and enrich it with additional innovation capability oriented measures for R&D environments. Krause (2000) developed a tool-kit called Management Knowledge Engineering which supports the design and maintenance of performance indicators in engineering environments. The tool-kit consists of a balanced scorecard based PMS, a process for the implementation of an adaptive management system, an indicator catalogue as well as an enabling information technology.

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Chennel et al. (2000) provide a framework for the development and implementation of an efficient and effective measurement system in an enterprise. The approach relies on the three principles

- alignment, which demands the alignment of personal efforts to the strategic direction of the enterprise,
- process thinking, which requires that the measurement system should be linked appropriately with the system and process monitoring,
- and practicability which suggests that for any level of the enterprise there is a consistent process for identifying the sorts of measurements that need to be collected.

Säubert and Bürgel (1998) present in their work a performance management solution for product development environments which relies on the Balanced Scorecard (BSC) principles (Kaplan and Norton, 1996a). They align the BSC with the specific NPD processes and provide a knowledge orientation through mapping the BSC in addition to the different phases of the knowledge management value chain. He refers thereby to works of Probst et al. (1997) (see also section 3.2.3, page 32).

Martins (2000) suggests a framework on how to acquire, collate, sort, analyse, integrate and disseminate measurement data. The PMS process relies on three major phases which are developing the business objectives, translating these objectives into measures and implementation of the measures. The process is of facilitated, non-expert nature.

Bititci et al. (2000) provide an overview on the Integrated Performance Measurement Systems (IPMS) Reference Model which was originally developed by the University of Strathycle. The approach is based on Beer's Viable Systems Model (Beer, 1985) four levels: Business, Business Unit, Business Process and Activities. Each of those levels relies on the four elements: stakeholders' requirements, external monitor, objectives and performance measures. The IPMS approach also provides an assessment model which assesses companies' PMS against the above mentioned reference structure of the IPMS model.

Grimaldi (2000) proposes a new set of indicators for measuring the performance of R&D collaboration efforts. Sarkis and Bonnici (2000) suggest a four step process for developing a strategic, activity-based development framework for performance measurement. The four phases of the process are introduction, charting of activity-based process flows, linking of activities with other departments and identification of key performance measures.

Neely (1998) reflects on the issue of the number of measures that should be collected in maximum in order not to create too much confusion to the recipient. He states that generally companies apply far too many measures. In some cases more than 100 measures were collected in one single company. A company should envision to employ few but meaningful measures.

Jukes (2000) identifies from literature 10 key factors - existence of a change champion, improvement of communications, improving customer focus, cross-functionality, overlapping processes, developing a vision of success, building the required infrastructure, incremental changes, product strategy and learning through doing- which should be controlled for enhancing product development performance.

Matheson and Matheson (1998) align the quality of performance measurement in R&D heavily with the quality of decision making. They suggest a three tier architecture for decision making, which are technology strategy, portfolio strategy and project strategy. Their underlying "smart organisation" concept is based on the elements decision quality, best practices, principles, processes and beyond R&D which aligns the R&D entity to the broader context of the organisation.

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Sedecon (1999) suggest fifteen managerial recommendations into strategic performance measurement: start with strategy, think about measurement purposes, align measurement system development with strategy development, enable learning, the system should create a common language, shift of power caused by measurement can result in politics, combining measurement information requires cautiousness, preserve the understanding of the relationships between indicators and the dynamics of the numbers, include all stakeholders in the strategic measurement system, set target levels, combine measurement with rewarding only when measurement works in practice, facilitate forecasting, measurement functionality testing, prepare for the "Valley of death" once the system has to be rolled out, concentrate on the essential.

Gibbert et al. (2000) present within the Siemens case book an indicator framework which measures the performance of the organisational knowledge networking and knowledge transfer in development environments. The framework refers to the knowledge management processes identification, distribution, use and preservation and KM initiatives, like yellow pages.

Rigas and Fan (2000) suggest a knowledge rich performance indicator model which provides organisations with the ability to perform look forward planning within an improvement context. Through elaboration of filtering constraints they want to identify the most relevant factors which impact the indicator's level of performance within an organisation. They provide a process which provides a guideline of how the influencing factors for a specific indicator can be analysed, the constraints can be assessed and corrective actions can be identified.

Norton (1999) provides with his strategy map concept three basic assumptions for designing a performance management system:

- Strategy is a hypothesis which makes certain assumptions about outcomes that can be achieved.
- Strategy can be described as a set of cause and effect relationships, which can be made explicit and testable.
- Strategy requires the definition of activities that are the drivers of desired outcomes.

According to him these three assumptions are key for a PMS implementation strategy. He suggests the use of statistical correlation analysis as a new means to test the hypotheses, meaning the different strategies.

Cooper and Kleinschmidt (2000) conducted a large survey at 55 Australian companies, with 110 products being launched. They identified 13 drivers for NPD performance which are product advantage, NPD process quality of execution (up-front or pre-development activities, marketing tasks, technical tasks), project organisation, marketing synergies, top management support, perceived risk, firm's power over the technology development, customer influence, market conditions and technological conditions. From these 13 blocks of variables, 54 measures were identified. By means of statistical analysis, out of the whole set of measures three main performance factors emerged: Financial performance, Efficiency and Window of opportunity indicating whether the referring NPD project opened new opportunities for the business.

Zairi (1993), Kaydos (1991) and Sink (1985) have aligned the PMS subject to operational improvement activities such as TQM and productivity improvement. Feurer and Chaharbaghi (1995) stress that a PMS has to suit employment on different hierarchical structures and business process views which cut across the functional hierarchies.

Kennerley (2000) provides a PMS model and cause and effect relationships which align strategic PMS thinking with the manufacturing function. With his work he provides a concrete process improvement tool for enhancing manufacturing performance.

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Voss (1992) suggests to measure product development performance in terms of innovation and design performance. According to him on the one hand the outcome of the innovation process should be measured based on the determinants and results matrix by Fitzgerald et al. (1991) and on the other hand the performance of the innovation process should be measured by identifying the determinants of success and failure.

Oliver et al. (1996) point out that a list of metrics alone provides little insight into the intangible issues of product development, however it might be very valuable in terms of comparing different projects against each other. Brookes and Backhouse (1998) suggest three basic mechanisms for effective performance measurement in NPD: mechanisms should be aimed at the whole process level, mechanisms should be balanced in terms of resources, lead-time and quality and mechanisms should facilitate performance comparisons across projects. Hultnik and Robben (1996) propose that new product development success reflects on the dimensions technical success, financial success and commercial success.

Caffyn (1997) outlines the key differences between performance management in new product development and manufacturing: Product development is less tangible and more volatile and unstructured than manufacturing therefore measurement is more difficult. Beyond, product development has longer time scales and the outcome can be earliest quantified, in many cases, a long time after the product has been introduced to the market.

IDS Scheer (2000) provide a process oriented performance management solution also suitable for engineering environments. They base their measurement system on a complete process model describing the process, involved organisations and involved tools and methods. The system provides for the three levels: top management, middle management and operational level for various views on performance relevant information. The performance management solution is fully IT enabled and bases on the ARIS™ process modelling tool-suite. The measurement system allows for a support of the BSC principles but also allows definition of specific dimensions for clustering the performance data.

The Data Envelopment Analysis as suggested by Dyson et al. (2001) is a linear programming based technique for measuring the relative performance of organisational entities where the presence of multiple inputs and outputs makes comparisons difficult. The approach supports the determination of relative efficiencies and target setting for inefficient organisational entities.

It can be seen that the body of PMS literature also in the context of new product development is very rich. Key words and terms in this context are

- strategy alignment,
- process orientation,
- infrastructures for managing performance data,
- cause and effect relationships,
- PMS as an operational improvement tool,
- and indicators being a central element of performance measurement frameworks.

However, looking at the above section it can be seen that the body of literature which elaborates on the relationship between performance management and measurement, new product development *and* knowledge management (which has been presented in the last section) is rather rare so far.

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3.3.2 Performance measurement build and implementation concepts, procedures and guidelines

Sink and Turtle (1989) outline an eight step process for designing, building and implementing a PMS:

- Analyse organisational systems.
- Identify strategies developed for performance improvement of the target system.
- Identify performance drivers.
- Identify required data.
- Conversion of data into the needed information.
- Finalise and document PMS development plan.
- Develop and maintain a visibility system for the PMS.
- Constant and continuous improvement of the PMS.

Clark and Zirner (1993) base their PMS design, build and implementation on the level of maturity in performance management. They employ a 34 step linear process which can be customised to a company's specific needs. According to them user involvement is key for a successful PMS implementation. In addition, they provide a three step process for implementing a PMS: Prepare for implementation, implementation at the organisational target subsystem and implementation throughout the organisation.

Kaydos (1991) stresses that the implementation of a PMS is like untying the "Gordian Knot". He suggests the use of a high level implementation plan, which is flexible enough to cope with modifications due to new insights.

Lobo et al. (2000) use the Axiometric Design principles to build and implement a Balanced Scorecard. This approach allows for a coherent alignment between the desired objectives and the means to achieve them. The approach suggests the derivation of requirements for the PMS build and implementation based on customer -internal and external- needs. The requirements are systematically translated into design parameters.

Bititci et al. (2000) provide a performance management implementation process which had been developed from the University of Cambridge and is called Performance Measurement Design Process (Neely et al. 1996). The approach is based on the concepts of the Balanced Scorecard (Kaplan and Norton, 1996a) and "Order Winners and Order Qualifiers" (Hill, 1989).

Dimanescu and Dwenger (1996) suggest three types of measures for NPD performance: Static measures which are gathered after an event has occurred, motivational measures which achieve a 50 % improvement over uniform time periods and dynamic measures with real-time data feed-back. They point out that the two pitfalls that people learn over time how to beat the system and that even the best measures lead parts of the organisation to overwhelm another must be taken seriously into account if the PMS wants to be successful in real-life environments. Most of the leading PMS approaches like for example the Balanced Scorecard (Kaplan and Norton, 1996a) or the Skandia Navigator (Skandia, 1999) provide a process for building and implementing the different measurement functions. The further elaboration on this specific issue will be captured in section 3.4, page 47 where some of the major PMS approaches are outlined in greater detail.

Beaumont (1996) suggests a comprehensive measurement cycle which bases on the steps clarification of business goals and objectives, establishment of priorities, translation into metrics, creation and communication of the measurements plan, setting

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of improvement goals, collection of measurements data, reporting of measurements data, analysis of measurements information, identification and conduction of improvement actions, review and improvement of measurement program.

Fan et al. (2000) suggest, based on the plan-do-check-act cycle an implementation and operation methodology for performance measurement and management. They stress the importance of the design oriented phase for the future use of the PMS. A sound top down design process aligns the company's mission and vision to the operational business processes. Indicators of different levels of aggregation support strategic as well as operational performance measurement.

Schiuma (2001) suggests an assessment tool called Expatriate Value Monitor (EVM) which provides management with a structured approach and guidance on how to assess the value of the company. It adopts a methodology which is based on the principles of well-known performance management systems like the Balanced Scorecard (section 3.4.1) or the Skandia Navigator (section 3.4.2).

Neely[10] sees 4 major phases for a measurement system: design, implementation, use and ongoing management. For each of the phases he sees the following critical success factors:

- Design: "The designer has to be careful to detail the 'purpose' of all the measures to be used."
- Implementation: "You must involve the people who are going to use it (give them 'ownership'). Ask the question 'How do we access the data (may need to find new/individual methods of capturing data).'
- Use: "Ask questions like: How do I manage it? How do I analyse the data obtained? You should use measurement data like a detective would to construct a case."
- Ongoing Management: "The measurement system is usually designed for now and it might be alright for today. But things may change. What often happens then is that people add new measures but don't delete obsolete ones - this means that information 'piles up' and the management becomes very complex. I know of one firm where they actually found that they had two different measures for the same thing - and they were 30, 000 pounds out from each other!"

It can be seen that people increasingly get aware that one of the real challenges in the context of performance measurement is the build and implementation of PMS design principles in business contexts. An emerging community has a process-oriented view on building performance measurement systems thereby increasingly principles known from industrial development projects. The following list highlights some of the most important issues for building and implementing a PMS:

- User involvement and acceptance.
- Top management support.
- Holistic solutions.
- Simple but comprehensive solutions.
- Clear and transparent build and implementation guidelines.
- Sound, human focused change management.

3.3.3 Conclusion

The above two sections demonstrate that the build and implementation of performance management and measurement systems is considered to be as important as the

[10] The present documentation bases on the expert interview with Prof. Andy Neely (see section 2.2.2.2).

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underlying design principles and functions of the PMS itself. Measures are an invaluable means to bring the measurement system to life. Therefore big emphasis should be put on the definition of the right measures for the right business. The body of subject literature is rich, however, as in the knowledge management domain there exists very little consensus on PMS terminology, standard PMS functions and PMS measures which could serve as a base-line for and support the further development and refinement of existing principles and functions.

3.4 State of the art frameworks in Performance Management and Measurement[11]

Within the following sections, the author will present a review of some of the current frameworks for performance management. Four alternatives, on the top of the scientific community's agenda today are discussed in detail: the Balanced Scorecard of Kaplan and Norton (1996a), the concept of Skandia Intelligent Enterprising (Skandia, 1994), the Performance Pyramid (Lynch and Cross, 1995) and the Performance Prism, as developed at Cranfield University in co-operation with Accenture (Kennerley and Neely, 2000). In compliance with the original focus on reuse and invention of knowledge, a very comprehensive approach by Lim (1998) dedicated to reuse measurement finalise this review. Even though not representing a holistic management model, the last approach is discussed to shed some additional light on the subject of reuse and invention measurement. The consideration of just five models within this study, results from an assumption that most competing concepts add little, if any, value to research and practise as they are likely to build on the existing ones presented in this thesis (Hilb, 1997 and Brown, 1996).

For further reading and study however, the author has added several performance management and measurement models to Appendix A, including some based on benchmarking. In section 5.3 some of the leading PMS approaches are assessed against the taxonomy of requirement clusters developed within this thesis. It is deemed fruitful to elaborate on the following approaches in greater detail as they not only support understanding of the PMS subject, but also set the base line for further development of theory.

3.4.1 The Balanced Scorecard

55% of large U.S. companies and 45% of the major European companies has recently been found applying, or experimenting with the Balanced Scorecard (Rigby, 1999). Not surprisingly, this concept introduced to the corporate world by Kaplan and Norton (1992) is more often considered synonymous with performance management (Klingebiel, 1999). Their original idea is further developed and exploited by consulting firms, software vendors and researchers across the globe (Weber and Schäffer, 1999b and Horváth and Kaufmann, 1998).

3.4.1.1 The rationale behind[12]

Organisations face an obligation of building their long-term competitive capabilities and an immediate demand for historical-cost financial reporting to their owners. It is the overriding objective of the Balanced Scorecard to integrate these two requirements.

The Balanced Scorecard builds on providing those fundamental measures of past performance, complemented with non-financial measures of future performance, to the interested parties within and around the organisation. Combining the two classes of measures should eventually lead to a consistent and transparent chain of causes and

11 In chapter 4 a clear definition of performance management and measurement will be given.

12 The following description of the Balanced Scorecard builds on the articles (Kaplan and Norton, 1992; Kaplan and Norton, 1993 and Kaplan and Norton, 1996b), the 1996 book (Kaplan and Norton, 1996a) and the 2001 book (Kaplan and Norton, 2001). Additional references are explicitly indicated.

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effects. External measures and critical internal drivers are in balance, with the quantifiable and objective measures being balanced with some subjective and judgmental indicators. Such a comprehensive composition should allow for an organisation not only to monitor their functional measures diagnostically, but also for focusing the strategically relevant key indicators.[13]

A basic idea behind the Balanced Scorecard is the translation of corporate vision, mission and strategy into operating targets, measures and initiatives. The typical measurement and management process should supply the organisation with strategic feedback and learning. Implementing these characteristics is assumed to resolve the inherent problems of conventional performance measurement. Table 5 gives an overview of the requirements Kaplan and Norton assume critical for performance management.

A performance management model has to...
❑ provide a balanced set of measures (internal vs. external; financial vs. non-financial; short-term vs. long-term; etc.).
❑ focus on strategic chain of cause-and-effects (performance drivers vs. lagging indicators).
❑ Communicate strategy through translation into operating targets, measures and initiatives.
❑ Concentrate on strategically relevant key measures.
❑ be applicable across disciplines and through hierarchies.
❑ Enhance strategic feedback and learning.

Table 5: Requirements for a performance management model

The following subsections describe how these purposes and requirements are realised in the framework of the Balanced Scorecard.

3.4.1.2 The perspectives of the Balanced Scorecard

Translation and implementation of strategy cascades across four different core perspectives of performance – the financial perspective, the customer perspective, the internal business process perspective and the learning and growth perspective[14] (Figure 12).

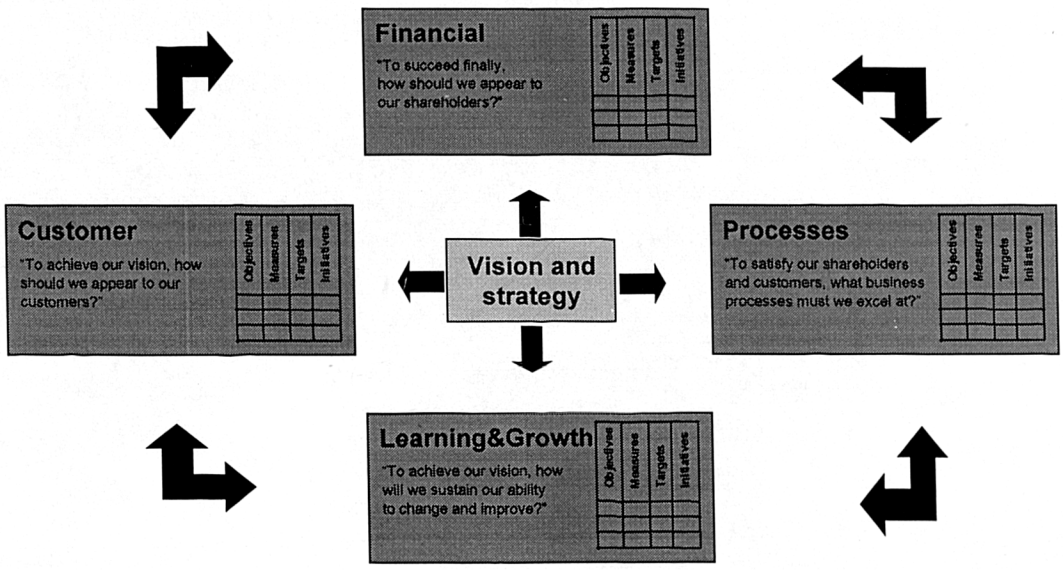


Figure 12: Balanced Scorecard framework (Kaplan and Norton, 1996b)

13 The debate over diagnostic and interactive measurement has recently been taken up by Weber and Schäffer (1999). Their conclusions however, stand in sharp contrast with those of Kaplan and Norton (1996a).

14 These four generic perspectives have been found valid across most industries. Kaplan and Norton nevertheless admit that organisations might want to add, delete or rename perspectives: "..the four perspectives should be considered a template, not a straight jacket." (Kaplan and Norton, 1996a)

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- The financial perspective describes whether and / or how the implementation and implementation of a strategy feed into financial returns. The financial measures thereby serve as points of focus for the remaining (three) perspectives. Thus, customer-, process- and learning-indicators will have to link to financials in means-end-relations. Kaplan and Norton propose some typical measures for this perspective, such as return-on-investment, profitability, revenue growth and productivity.
- The customer perspective attributes strategic objectives to customer and / or market segments. These segments are then addressed by operating targets, measures and initiatives. Derived from so-called customer value propositions (for example product attributes, relationship, image and reputation) some core measures are suggested: market share, customer acquisition, retention, satisfaction and profitability.
- Processes which are critical to customer objectives and commercial success are reflected within the internal business process perspective. Kaplan and Norton distinguish an innovation process, an operations process and a post sales process. The intention should above all be to identify needs for new processes in a timely manner. Processes are regularly measured in terms of time, cost and quality.
- The infrastructure and the human capital an organisation's strategy builds on, is mirrored within the final learning and growth perspective. Kaplan and Norton put, in contrast to conventional measurement, particular emphasis on this perspective.[15]

3.4.1.3 Relational structures in a Balanced Scorecard

It has been mentioned before that the concept of the Balanced Scorecard builds on stringent connections and dependencies between measures, targets and strategy. The deduction of cause-and-effect relations, the identification of performance drivers and the linkage to financials are the cornerstone of this idea.

- Hypothesised means-end relations pervade and connect all perspectives of the Balanced Scorecard.[16] These relationships eventually picture a sort of organisational value chain from input (learning), to transformation (processes), to output (customer), to outcome (financials).
- The leading performance drivers show the determinants of future results. They are inevitably related to outcome measures; this means that the historic, financially oriented view is combined with an outlook to the prospects.
- The linkage to financial results from the causality of all activities and measures focusing on financial returns – the satisfaction of shareholders' and investors' requirements.

The founders of the Balanced Scorecard nevertheless fail to provide a methodology for an analytically and verified construction of all those relations and interdependencies. Hence, many critics consider the true benefit being the discussion of and reflection on strategy in the course of trying to agree on certain logical connections (Weber and Schäffer, 1999b).

3.4.1.4 The Balanced Scorecard as a strategic management system

Beyond serving as a measurement tool, the Balanced Scorecard claims to be a strategic, long-term management system. The concept is assumed to relate strategy planning with its implementation and actualisation. Kaplan and Norton regularly observed problems such as visions and strategies which are hardly actionable and provide tacti-

15 According to Kaplan and Norton (1996a) these are the very assets and capabilities that are critical for success in today's and tomorrow's competitive environment.

16 "Like a flight simulator, the scorecard should incorporate the complex set of cause-and-effect relationships among the critical variables ....of the strategy (Kaplan and Norton, 1996a).

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cal feedback only. Applying the Balanced Scorecard as a strategic framework as shown in Figure 13 is suggested to remedy some of these frequent drawbacks.

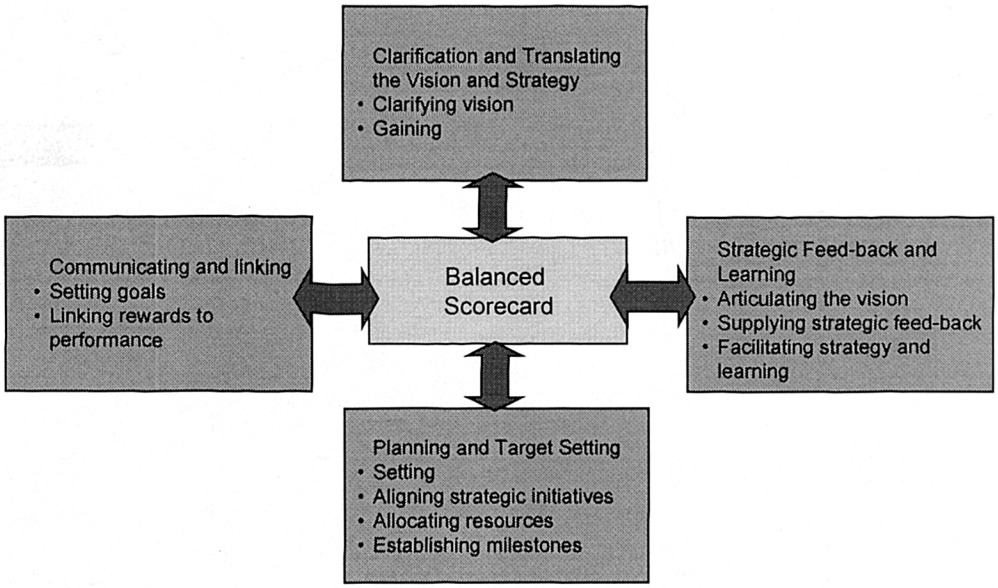


Figure 13: Using the Balanced Scorecard as a strategic management system (Kaplan and Norton, 1996b)

The construction of the Balanced Scorecard supports management in clarification of a corporate vision by agreeing on their high-level objectives. Cascading these objectives down through the four perspectives does accordingly allow for alignment and strategic focus of operations. Means of communication, rewarding goal setting and resource allocation drive this process of strategic pervasion. The operational levels are now able to give feedback on strategic issues, even the strategy itself. This kind of review furthers the art of double-loop learning (Horváth, 1997 and Weber and Schäffer, 1999b). In other words: the organisation is capable of permanently verifying viability and potentials of a chosen strategy. All this is assumed to solve a dilemma between strategy formulation and today's environmental dynamism (Horváth, 1997 and Weber and Schäffer, 1999b): "The Balanced Scorecard fills the void that exists in most management systems – the lack of a systematic process to implement and obtain feedback about strategy. Management processes built around the scorecard enable the organisation to become aligned and focused on implementing the long-term strategy." (Kaplan and Norton, 1996a)

3.4.1.5 Conclusion

The Balanced Scorecard as proposed by Kaplan and Norton represents a comprehensive, intelligible and very wide-spread framework for performance management and measurement. With its four performance dimensions, it addresses the long-standing demand for strategic management control going beyond the purely financial orientation[17]. The concept takes intangible resources explicitly into account within the Learning and Growth perspective and addresses their perceived impact on overall performance. It provides a comprehensive and qualified perspective on the diverse aspects of success, competitive abilities and strategy implementation. It is considered highly adaptable and scalable to organisational entities of different size, hierarchy or industry (Kaplan and Norton, 1996a). The Balanced Scorecard concept is rather simple, understandable and practical; in fact it might be this simplicity which made the Balanced Scorecard so successful. However, numerous authors have recently

[17] Non-financial measures have already been addressed by General Electric in 1951 or by the French Tableaux de Bord in the 1950s (Eccles and Noriah, 1992 and Schott, 1991). Unique and innovative however, is the combination within the four scorecard perspectives (Weber and Schäffer, 1998)

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identified shortcomings of the Balanced Scorecard and reported on some failed implementation projects (Weber and Schäffer, 1998; Weber and Schäffer, 1999a; Weber and Schäffer, 1999b; Matheis and Schalch, 1999; Kennerley and Neely, 2000 and North et al., 1998). Kennerley and Neely (2000) criticise the lack of additional dimensions, such as supplier performance, competition, community, etc.. North et al. (1998) point to insufficient functionalities for measuring intangible assets while Weber and Schäffer (1998) address the missing ability of the scorecard to support strategic learning. The author proposes that the great value of the Balanced Scorecard lies within the consistent communication of strategy throughout the organisation, the clear and simple alternative view management obtains of the business model and the approach of constructing significant interrelationships between performance drivers and measures. A shortcoming however seems to be the practical realisation in rather operational and knowledge-intensive environments, such as NPD. Beyond, so far there are no BSC implementations which truly reflect on the knowledge asset structures of companies.

3.4.2 The Skandia Way

3.4.2.1 Skandia Intelligent Enterprising

Many of the recent publications on intellectual capital (IC) refer to the model given by Swedish financial services group Skandia Insurance Company Ltd. (Christ, 1999; Menon et al., 1998 and Romhardt, 1998). The company pursues a very comprehensive approach to developing and maintaining its valuable intangible resources. This so-called IC Enterprising concept, complements financial accounting, provides means for shaping an innovative, encouraging and learning culture and above all, leverages business (Grafström, 1999). Skandia has documented its efforts and achievements in this area in frequent supplements to its annual financial report since 1994. At the core of the entire concept resides an unique derivative from the Balanced Scorecard (Kaplan and Norton, 1996a), the Skandia Navigator.

3.4.2.2 The rationale[18]

In general, an organisation's market value is considered to be made up of two complementary parts, financial capital and intellectual capital. Intellectual capital serves as an indication of an organisation's ability to (over-) achieve its financial targets; i.e. future value to stakeholders (Goldmann and Hoogenboom, 1997). The utilisation of those intellectual resources should then allow for realising vision and strategies.

In Skandia's first supplement in 1994 it already says: "Auditors, analysts and accounting people have long lacked instruments and generally accepted norms for accurately evaluating service companies and their 'intellectual capital'. At Skandia we have always maintained that our IC is at least as important as our financial capital in providing truly sustainable earnings."

Skandia has then taken this insight for developing a mental model and a management tool dedicated to intellectual capital, the IC Value Scheme and the already mentioned Skandia Navigator.

3.4.2.3 The IC Value Scheme

The IC Value Scheme (section 3.2), depicted in Figure 14, shows the two major building blocks of market value; i.e. financial capital and intellectual capital. Moreover, it indicates the diverse components forming an organisation's intellectual capital.

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18 The description of Skandia IC Enterprising is based on Edvinsson and Malone (1997); Skandia (1999); Grafström (1999) and Grafström and Edvinsson (1999). Other references are explicitly indicated.

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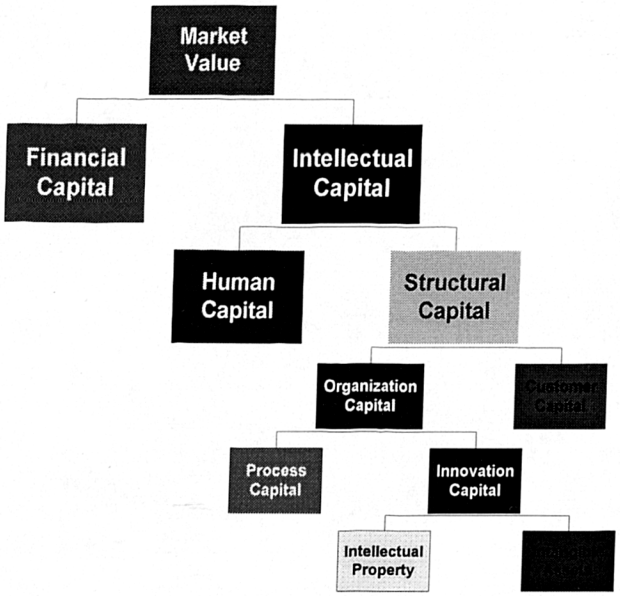


Figure 14: IC Value Scheme (based on Skandia, 1999)

This mental model makes the components of intellectual capital visible and comprehensible. It thus enables managers to take their decisions on a broader and knowledge-oriented base.

3.4.2.4 The Skandia Navigator

The Skandia Navigator builds on the principles of the Balanced Scorecard. The six focus areas or building blocks of an organisation's value over time interplay as a navigation and evaluation tool (Figure 15).

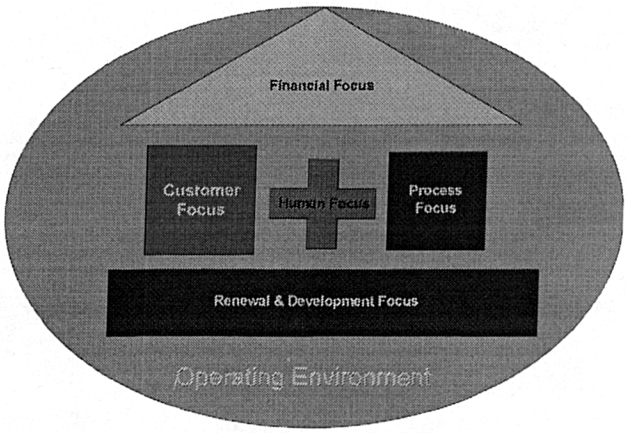


Figure 15: Skandia Navigator (Skandia, 1999)

Skandia describes these focus areas as follows[19]:

- The financial focus represents the company's historic achievements as documented in its annual reports.
- Within the customer focus, the company identifies performance relative to customers.
- The process focus allows for capture of effectiveness and efficiency in internal operations and supportive technologies.
- A view on capabilities, threats, changes and opportunities is given within renewal and development.

19 A more detailed description is given in section 3.2.3.6.

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- As an intriguing and bridging element the human focus links all focus areas.
- Last, but not least, the company investigates the social, political, cultural and economic context within which it competes, within the operating environment.

The addition of a dimension of time turns the Skandia Navigator into a more dynamic tool. The past is thereby assumed inherent to the financial focus, process focus, human focus and customer focus stand for the present and future is finally pictured within renewal and development. In analogy to the Balanced Scorecard, measures and indicators should culminate in the financial focus and add to monetary success (section 3.4.1).

In developing the navigator a range of measures for each of the focus has been suggested. These suggestions serve as guidelines and reference for Skandia's world-wide subsidiaries and units when implementing the Skandia Navigator (see example in Figure 16).

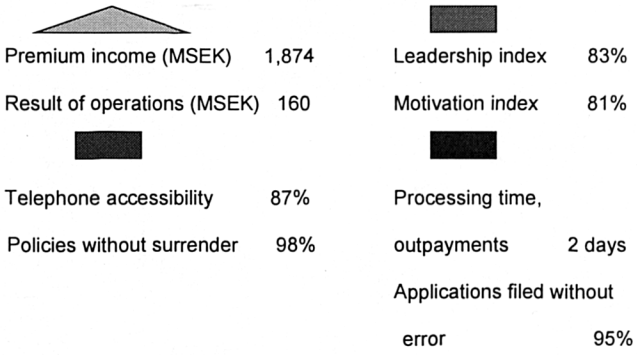


Figure 16: SkandiaLink's Business Navigator (Skandia, 1994)

A follow-up system, the FLINK index, ensures that market- and customer demands are met. FLINK index comprises those factors deemed most crucial to market success and profitability (Skandia, 1994):

- satisfied customers,
- satisfied salesperson,
- motivated and competent staff,
- and quality-assured and effective administration.

The Skandia approach provides a sound strategic planning process for identifying in a top-down driven process, the indicators for the six dimensions (see Figure 17).

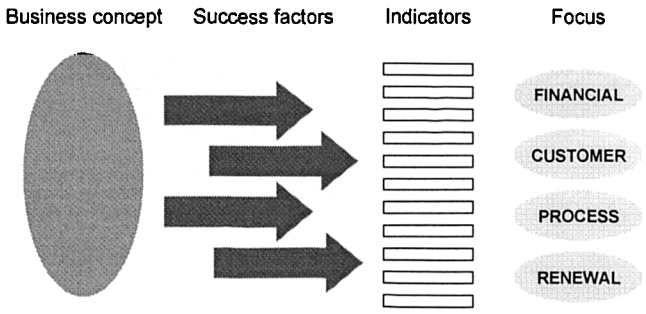


Figure 17: Overview on Skandia's strategic planning process (Skandia 1994)

Two new components have recently been introduced to the toolkit of IC Enterprising. One being a PC-based software solution called Dolphin. Dolphin allows for supplying the individual user with business information tailored to his or her very needs. The other novelty is a consolidation of various indicators to the IC-index. This index is pro-

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posed to reflect the development of intellectual capital over time. However, according to company information, the IC-index is not actually used so far.[20]

3.4.2.5 Conclusion

Skandia's approach realises a broad, innovative and well-accepted understanding of managing intellectual capital. It is shaped around the Skandia Navigator, a performance management and measurement framework, which integrates the financial aspects and non-financial aspects of business. It incorporates the various influential factors on and drivers of performance and eventually relates them to economic outcome measures. The relation to knowledge and intellectual capital is not necessarily intelligible (Christ, 1999). However, one should note that the entire approach is continuously further refined and still so far providing a unique perspective on managing intangible values and options.

3.4.3 The Performance Pyramid

The origins of this measurement approach go back to the end of the eighties when Lynch and Cross (1995) began to realise that there was a big need to define yardsticks to measure productivity performance. Both, Lynch and Cross have an industrial background, thus the overall objective of this approach was to help troubled industrial companies to perform better through a simple, operational, easy-to-apply performance measurement system. The underlying principles of this approach are based on the principles of strategic planning, total quality control, activity counting, just-in-time and workflow simplification (Lynch and Cross, 1995).

3.4.3.1 The rationale and system architecture[21]

According to Lynch and Cross the customer and the stockholder determine what is relevant to be measured. This external perspective determines how good the company's performance needs to be. Thus the two corporate dimensions of the Performance Pyramid are "Market" and "Financial". These two overriding dimensions referring to corporate level, are broken down in the dimensions "Customer satisfaction", "Flexibility" and "Productivity" on business operating systems level. In order to provide the more operative levels with measurement perspectives, the Pyramid has been equipped with another two levels: The departments and work centres level with its categories "Quality, Delivery, Cycle Time and Waste" as well as the operations for measuring the process-oriented day-to-day performance. This four-level set up ensures a coherent communication of the overall company's vision through all the different levels down to the operational level through a top-down process. At the top level, a vision for the business is articulated by corporate senior management, followed by the definition of strategies which take place on the second level. On the third level more operative objectives are defined while the fourth level converts those objectives into operational criteria (based on Lynch and Cross, 1995). Apart from the communication of strategies down to operations the Pyramid also provides a concept of how measures can be rolled up at various levels in the organisation. The selection of measurement perspectives like "Market" and "Customer Focus" indicate that this approach is driven by an external effectiveness-oriented focus, while the perspectives "Financial", "Productivity" and "Waste" pronounce the more efficiency-oriented internal focus (Figure 18).

20 This refers to a statement made by the interviewed expert Scott Hawkins from Skandia.

21 The following sections are based on Lynch and Cross (1995). Other references are indicated explicitly.

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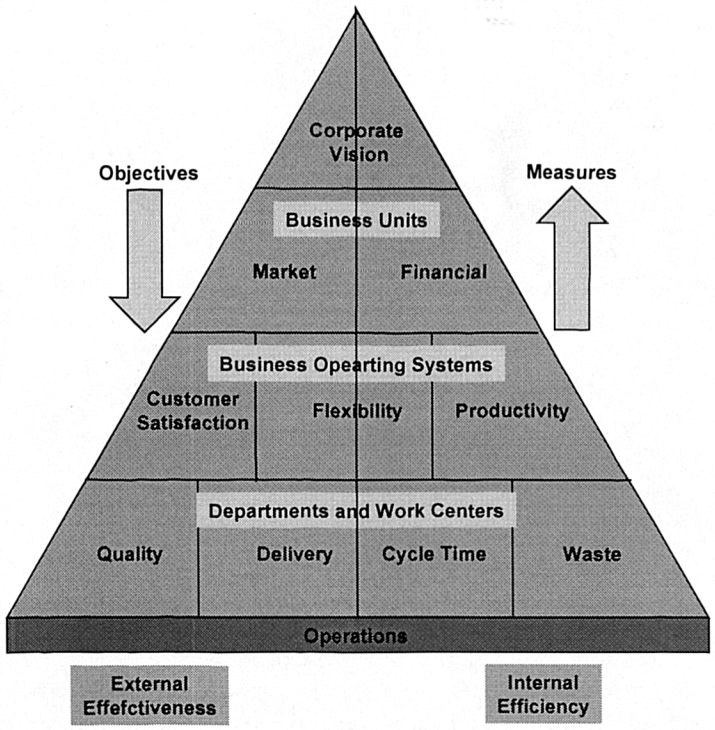


Figure 18: Performance Pyramid (based on Lynch and Cross, 1995)

3.4.3.2 The perspectives of the Performance Pyramid

Strategic business unit objectives

The approach suggests the definition of strategic business units as underlying organisational principles for large companies in case the units have distinct business concepts, their own competitors and if the company pursues decentralisation policies. The Pyramid is generally very output oriented seeking for external market measures and internal financial measures. The approach tries to provide a top-down process through the formulation of a corporate vision which is broken down into measures for the market and financial dimension.

The Business Operating System (BOS) level

The BOS represents the bridge between the top-level market and financial indicators and the day-to-day operational measures in the new paradigm. The BOS covers all the relevant internal functions, activities, policies, procedures and supporting systems which are necessary to implement a distinct business strategy in a company. Thus the BOS is the link between a specific department's performance and the overall strategy and performance of the business. This set-up allows the departmental measures to align to the entire operating system instead of focusing on increasing efficiency at department level. The three driving factors for the BOS are customer satisfaction, flexibility and productivity equipped with different weightings for different operating systems. The following figure gives an overview on some exemplary measures for each of those dimensions.

Customer Satisfaction:	Flexibility:	Productivity:
• Lapse rate	• Quoted lead times	• Total factor productivity
• Renewal rate	• On-time delivery for rush orders	• Cost of sales
• Retention rate	• Inventory turns	• Selling and general administrative expenses
• Revenue per customer	• Development speed	• Product margins
• Number of complaints	• Rapid design changes	• Expens ratios
• Customer ratings from surveys	• Numbers of products	• Asset turnover ratio
• Customer intent to repurchase		

Figure 19: Overview on some exemplary BOS measures (Lynch and Cross, 1995)

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Beyond those three dimensions the approach suggests "Global measures" which might be a combination and aggregation from the lower levels of the Performance Pyramid as well as specific workflow measures which are based on concrete, specific measures for day-to-day operations.

The operations

The measurement dimensions on operations level, namely quality, delivery, cycle time and waste serve the purpose to increase quality and delivery and to reduce cycle time on a product level. Also on the operations level, the understanding of the difference and interrelations between externally oriented measures (quality and delivery) and internally, process-oriented measures (cycle time and waste) is key for increasing efficiency and effectiveness of operations. So called yardsticks which are derived from the strategy and are broken down to operations level enable an early warning system for corrective action when performance falters. The yardstick thinking also supports the creation of cause and effect relationships on all levels.

3.4.3.3 Conclusion

The Performance Pyramid is an advanced performance measurement framework which provides a comprehensive structure for translating the corporate goals into actions through providing performance perspectives for different levels of organisations. It explicitly addresses operations stressing that the alignment of measures from top down is important. It provides a comprehensive set of measures which may serve as a starting point for build and implementation projects.

3.4.4 The Performance Prism

The framework which will be described in the following subsections results from research headed by Prof. Andy Neely of Cranfield University's Centre for Business Performance (CBP, 2000), in collaboration with Accenture.

3.4.4.1 The rationale[22]

Most of the current performance management frameworks, for example the Balanced Scorecard (Kaplan and Norton, 1996a), the EFQM model (Bading and Frech, 1999) or the EVA approach (Rappaport, 1998) add some value to industrial users. However, "...despite the claims of some of the proponents of these frameworks and methodologies, there is no 'holy grail' or best way to view business performance." (Neely and Adams, 2000a). Recently, CBP researchers published a review on many popular performance measurement frameworks. This enabled them to derive a set of common characteristics and requirements (Table 6). Nevertheless, none of the analysed approaches was found covering all critical requirements. The research group took these shortcomings as a starting point for developing a multi-faceted and flexible framework – the Performance Prism.

A performance management model has to...
❑ provide a balanced set of measures (internal vs. external; financial vs. non-financial; short-term vs. long-term; etc.).
❑ focus on strategic chain of cause-and-effects (results as a function of determinants).
❑ give a succinct overview of performance.
❑ must be easily understood by users and applied to their organisation.
❑ must reflect the different dimensions of performance[23].

22 The following description of the Performance Prism builds on the publications of Kennerley and Neely, 2000; Neely and Adams, 2000a; Neely and Adams, 2000b and CBP, 2000. Additional references are explicitly indicated.

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❑ be sufficiently comprehensive to map all possible measures of performance onto the framework.
❑ integrate across the organisational functions and through its hierarchy.

Table 6: Characteristics and requirements of performance measurement frameworks

The following subsections will render a brief description of how these assumptions are addressed in the Performance Prism.

3.4.4.2 The facets of the Performance Prism

As illustrated in Figure 20 an organisation's performance is likely to be described on five separate facets. Each of these addresses distinct aspects of performance and arranges them in a cause-and-effect relation.

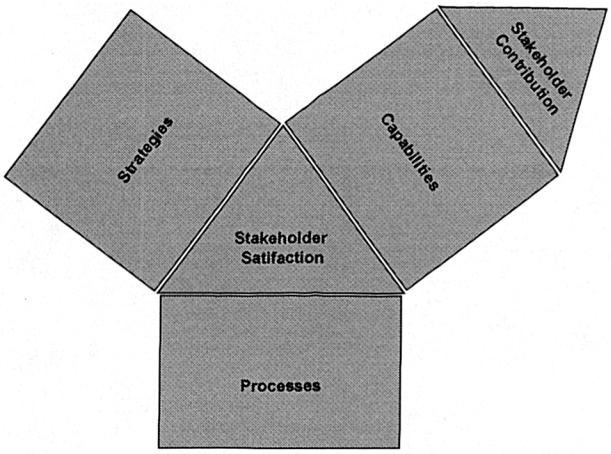


Figure 20: Performance Prism – the five facets (Neely and Adams, 2000a)

The architecture is built on the assumption that organisations striving for competitive abilities and long-run success dispose of a clear and sound business model and are aware of the critical drivers of performance. Such a business model would then be shaped around the five dimensions discussed below.

- ❑ Stakeholder satisfaction presents the dominant perspective. The CBP researchers therefore start building their framework on the wants and needs of stakeholders. This refers to a common misinterpretation of the idea of strategy. As a measurement system's purpose is basically the determination of a company's progress towards its goals, "strategy, however is not about destination. Instead it is about the route you choose – how to reach that destination." (Neely and Adams, 2000a). Above, companies' stakeholders gain in importance. Success increasingly depends on a growing range of stakeholders (RSA, 1995 and Crowe, 1999). In the 1980s and 1990s companies became more aware of additional interest groups. This process began with consideration of customers and employees, to legal entities and regulators, to non-governmental organisations (NGO).[24] In summary, permanent awareness of a wide lot of stakeholders is now crucial for the success of commercial enterprises. Consequently, performance management must adopt a stakeholder-centric view and drive managers to realise their stakeholders' specific requirements.
- ❑ These requirements can only be satisfied by implementation of sound strategies. Measuring strategy then serves four purposes: First to verify whether a planned strategy has been realised, second to communicate the strategy through the hierarchies and entities of the company, third, to encourage and incentivise strategy im-

23 "...however, there is no consensus over what the dimensions of performance are." (Kennerley and Neely, 2000).

24 The reader may recall the ban of genetically modified food from European markets.

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plementation and fourth, to trace whether the strategy was right, and if not, why not. At this point however, most performance management frameworks are considered to stop. The remaining three facets therefore address the key success factors of strategy realisation.

- Processes aid the fulfilment of strategic imperatives. Process measures trace whether practices are in place, they communicate the different priorities and drive improvement.
- To execute processes, certain individual and organisational capabilities need to be given; i.e. a diligent combination of infrastructure, of technology, of structures and of people.
- With stakeholder contributions one closes the loop. They present the counterpart to stakeholder satisfaction. Networked and complex organisations rely more on distinct contributions from their different stakeholders. This includes for example, loyalty of customers, commitment of employees, reliability of suppliers and co-operative regulators. These two aspects of stakeholder orientation are depicted in Figure 21.

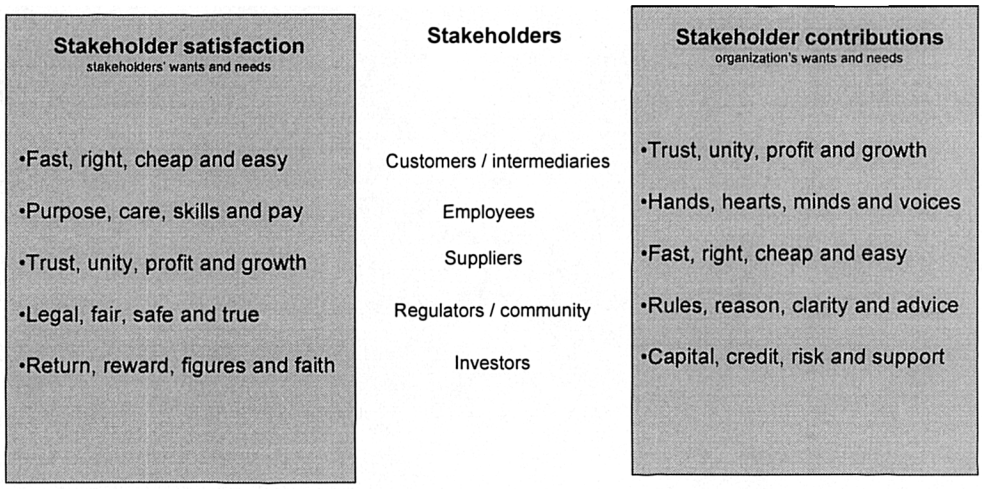


Figure 21: Stakeholders' wants and needs vs. organisation's wants and needs (Neely and Adams, 2000a)

These perspectives additionally combine to a chain of enablers and results, if set up diligently. The provision of the measurement catalogue as described in the subsection below, supports the transfer of the Performance Prism into practice.

3.4.4.3 The measurement catalogue

These five facets form the framework for applying distinct indicators and metrics to the various dimensions of performance. A set of measures[25] would have to address questions as follows:

- Who are the key stakeholders and what are their wants and needs?
- What strategies have to be put in place to satisfy the wants and needs of key stakeholders?
- What core processes are needed to execute these strategies?
- What capabilities are critical to operate and enhance these processes?
- What contributions are required from stakeholders to maintain and develop those capabilities?

[25] The reader will learn later that Neely et al. (1995) defined performance measurement, a set of metrics, used to quantify both, the effectiveness and the efficiency of action.

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In order to facilitate the generation and selection of measures answering these five themes, the Performance Prism provides a catalogue of over 200 indicators and metrics as a reference. In doing so, the five facets are subdivided into categories of finer granularity as shown in Figure 22.

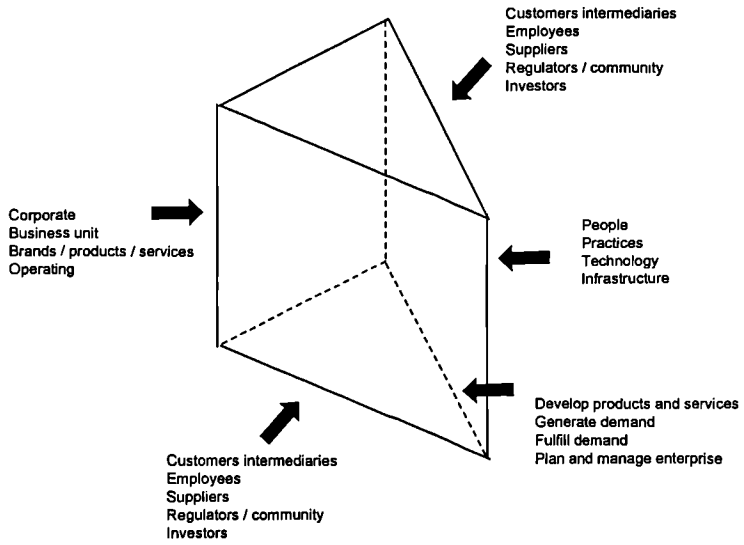


Figure 22: The Performance Prism – categorisation of facets (Neely and Adams, 2000b)

Suggested metrics are then associated to these categories, set into context and, if feasible, reciprocally interlinked.

The Performance Prism and the accompanying catalogue of measures aid organisations in obtaining a multi-dimensional view on business performance. Similar to the Balanced Scorecard, the Performance Prism is continuously being further developed and refined (see http://www.cranfield.ac.uk/som/cbp, accessed 10th August, 2000).

3.4.4.4 Conclusion

The Performance Prism addresses the current shortcomings and omissions of current performance measurement frameworks as identified by Neely, Kennerley and Adams (see subsection 3.4.4.1): The multi-dimensional composition of five facets is assumed to reflect on stakeholder satisfaction as being the major outcome measure through a set of determinants, namely strategies, processes, capabilities and stakeholder contributions. It thereby claims to establish a tight link between strategy, critical processes and required capabilities. The top-down deployment of strategy is supposed to be complemented with the resource-based capabilities on business and operating levels. Answering the five key questions (section 3.4.3.2) should ensure a succinct overview of organisational performance. With the provision of the measurement catalogue and the subdivision of the facets the Performance Prism is deemed to attain comprehensiveness and completeness. The categorisation of the facets and the generic nature of the architecture suggest that the model can be applied across functions, at diverse hierarchical levels in different operating environments. Recently the Prism has been enriched with a rather static knowledge asset view which is considered to be relevant for the theory development in this research.

3.4.5 A framework for reuse metrics

Systematic and industrial reuse of assets originates from early days of software development (Lim, 1998). Lim (1998) for example, reports a library of reusable subroutines, established at Cambridge University in 1949. This instance suggests that the software industry is most advanced in the discipline of reuse management and measurement. Software reuse is then considered ".. an inevitable consequence and sign of a maturing

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discipline and industry." (Lim, 1998) In fact, code, algorithms, routines, etc. seem to be perfectly made assets for reuse. In 1986, (Maginnis, 1986) estimated that approximately 75% of application code, 50% of system programs and nearly 70% of telecommunications software shared identical resources. These observations lead us to introducing a software reuse measurement framework composed by Lim (1998). The framework however does not claim to be a sound performance management approach. It rather provides ideas for systematic measurement.

3.4.5.1 The rationale[26]

Reuse is deemed most effective when practised consistently, systematically in an integrated fashion. Thus, it should be firmly entrenched within a broader management context as shown in Figure 23.

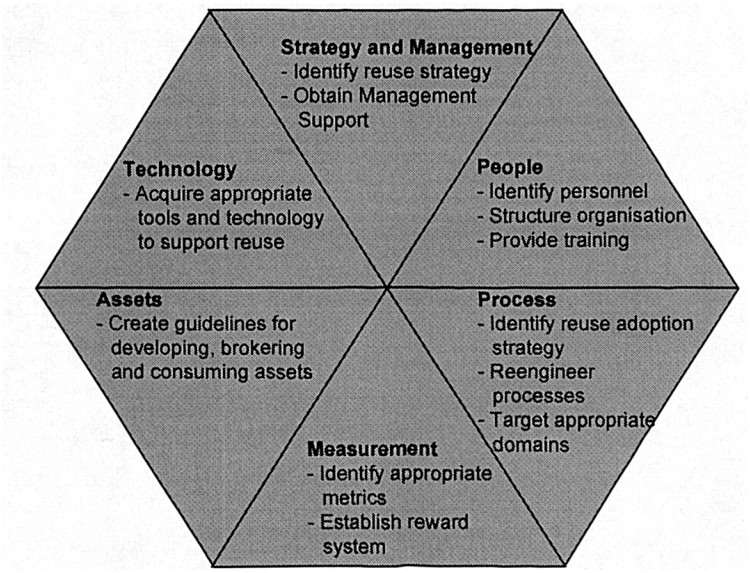


Figure 23: Software reuse diamond (Lim, 1998)

Obviously, measurement plays a vital role within this concept. This stems from organisations needing reliable information as to whether reuse targets have been achieved, which processes needed greater attention and which processes are already well developed. The rationale for reuse measurement are thought to be:

- Benchmarking and comparison.
- Incentives and recognition.
- Decision-making support.

Lim then proceeds with discussing several criteria for effective reuse measurement. Essentially, one finds, that metrics need to be closely tied to organisational goals and the parties affected in defining these goals. That requires providing different information for different entities within an organisation. Meyer (1994) therefore suggests concentrating interactive means of measurement on a very few key indicators. Additional metrics are then only applied to deepen understanding. Measures must build on a clear and unambiguous definition to avoid confusion and misinterpretation. As many others researchers do, Lim also advocates the requirement of cause-and-effect chains built along the selected measures and goals. Last, but not least, a corporation should share few high-level and core measures. A summary of these principles and requirements is given in Table 7.

26 The following description of software reuse measurement builds on the publication of Lim (1998). Additional references are explicitly indicated.

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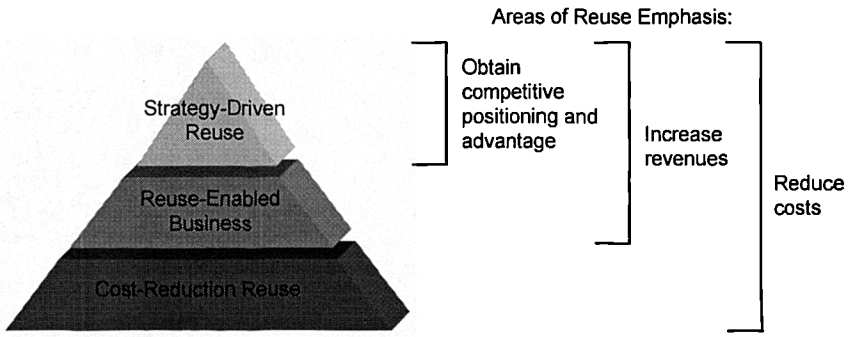
A framework for systematic measurement has to...
❑ further benchmarking, incentive systems and decision-making.
❑ establish a goal-oriented chain of cause-and-effects (results as a function of determinants).
❑ support the participative definition of goals.
❑ focus on key metrics for interactive monitoring.
❑ consider the different factors and aspects of performance.
❑ be sufficiently comprehensive to map all possible measures of performance onto the framework.
❑ supply information across the organisational functions and through its hierarchy.
❑ provide a set of aggregate measures on corporate level.

Table 7: Requirements for and principles of the framework for reuse metrics

Within the subsections below the author will illustrate how these requirements and principles are met within the framework for reuse metrics.

3.4.5.2 The framework

The overall architecture for measurement of software reuse, as suggested by Lim is illustrated in Figure 24.



Strategy-Driven Reuse:	"How can we obtain competitive positioning by entering markets and/or creating new products through reuse?"
Reuse-Enabled Business:	"How can we reduce the time-to-market for our products and what new products can we develop with our reusable assets?"
Cost-Reduction Reuse:	"How can we reduce the development and maintenance costs of our products through reuse?"

Figure 24: The framework for reuse metrics (Lim, 1998)

Lim draws on the works of numerous researchers and industrial practitioners in elaborating this framework. Therefore, his approach may be viewed a summary of state-of-the-art approaches to software reuse measurement. Metrics are organised in a classification of three namely economic metrics, primary metrics and driver metrics. Each of these classes is briefly discussed below.

Reuse economic metrics

Reuse economic metrics show the results of reuse efforts in terms of costs and benefits. They cover:

- ❑ Value metrics measuring monetary and / or non-monetary value[27] delivered to the customer by reusing assets.
- ❑ Return-on-investment metrics compare benefits of reuse relative to costs caused by reuse[28]. Calculation of these metrics applies net present value, internal rate of return, risk of capital, etc.

---

27 The terminology used in software development can be explained as follows (Lim, 1998):

- ❑ Asset: products or by-products of the software development process (e.g. code, design plans).
- ❑ Producers: software developer creating reusable assets.
- ❑ Consumer: software developer using reusable assets for creation of other software.

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- Cost prediction metrics are used for estimating productivity gains and cost savings after having implemented a reuse program.

The models for calculating these metrics, presented by Lim however, hardly apply to NPD in general, as they are very software specific.

Primary metrics

Primary or process metrics generally determine the above. Lim distinguishes:

- Quality metrics describing changes to assets' quality through reuse (e.g. defect density).
- Productivity metrics calculate changes to efficiency in creation and application of reusable assets (e.g. engineering days per non-reusable asset vs. engineering days per reusable asset).
- Time-to-market metrics gauge timesaving through starting a reuse program.

It also counts for primary metrics, that adaptation of examples given by Lim to non-software disciplines is rather limited.

Reuse driver metrics

Eventually, driver metrics are leading indicators of and contributors to primary metrics. In general, they apply to infrastructures and processes.

- Reuse library metrics ascertain effectiveness, efficiency and capacity of an asset repository (e.g. recall rate, precision, utilisation and volume)
- Reuse process metrics measure performance along a typical reuse process of production, brokerage and consumption (e.g. consumer satisfaction, cycle-times, submission rates, etc.)
- Reuse product metrics describe features and performance of the products incorporating reused assets (e.g. reuse levels, reuse percentage, etc.)
- Reuse asset metrics characterise the very reusable asset (e.g. qualification, variability, size, etc.)

Within this class it seems more or less feasible to apply the suggested metrics to NPD environments outside software development (if one is aware of the units of measure).

3.4.5.3 A process for reuse metrics selection

A flexible, yet systematic selection and implementation process allows an organisation to identify an appropriate set of metrics, addressing specific needs and goals. The process (Berns, 1994) consists of six stages building on each other as depicted below:

[28] Costs are incurred through additional efforts / expenses for preparing an asset for reusability.

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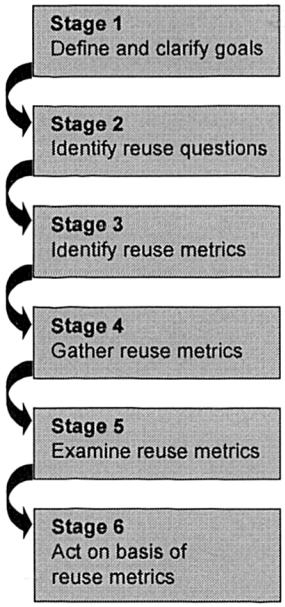


Figure 25: Six-stage reuse measurement process (based on Berns, 1994)

- Define and clarify goals: at high levels of an organisation's hierarchy, goals, needs and scope of the reuse activities are defined. These are then more often cascaded down the subordinate levels of the organisation.
- Identify reuse questions: management formulates questions addressing the previously stated goals. Thus a set of questions is associated to each of the goals.
- Identify reuse metrics: management drafts and streamlines a list of key metrics providing answers to the questions above. Metrics have to be specified in terms of unit of measure, ownership, data source, etc..
- Gather reuse metrics: measurement data is then collected and used for placing values on the metrics (e.g. by means of an audit, self-assessment or OLAP systems).
- Examine reuse metrics: the populated metrics are then investigated for trends, decision-making support, comparison, etc. Documentation of problem- and success areas comes along with this step. This would most likely help in setting priorities for any required corrective action.
- Act on the basis of reuse metrics: metrics strengthen management in supporting and taking corrective measures and initiatives.

This process is iterative; especially steps four through six are preferably integrated into daily business routines. Steps one through three are more strategic and refer to the classic goal-question-metric paradigm suggested by Park et al. (1996) and Basili and Rombach (1987). This approach is implicit to many performance management frameworks already discussed (like the Balanced Scorecard and the Performance Prism).[29]

3.4.5.4 Conclusion for the reuse framework

The model is proposed to be an integrative element of a holistic approach to systematic reuse. Its explicit focus on software reuse nevertheless allows only for limited adaptability to general NPD environments. Above, it partly neglects the invention[30] perspective of a typical development process. As noted at the outset, the framework is not supposed to form a comprehensive performance management model. However the

[29] Both, the Balanced Scorecard and the Performance Prism set out with key questions associated to the measurement perspectives (Kaplan and Norton (1996a) and Neely and Adams (2000a).

[30] Lim nevertheless shares some thoughts on commercial aspects in a chapter of his book (Lim, 1998).

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metrics selection process is considered to be very comprehensive and generic enough to be potentially suitable for NPD.

In summary, Lim has delivered a very transparent and structured reuse management framework. He recognises the importance of cause-and-effect relationships on different levels in the company and provides the potential implementer and user with a catalogue of validated reference measures. He also provides a sound management concept for reuse reaching from reuse strategy definition to operational guidelines for doing better reuse. In spite of the limitation to software development, the present approach is proposed to provide learning for the design of an enhanced performance measurement model, especially with regard to measuring and valuing knowledge reuse.

3.5 Conclusion

In the sections 3.1 to 3.3 the three cornerstones of this research new product development, knowledge management and performance management and measurement have been discussed. Relevant approaches, models and tools were analysed in order to create a sound knowledge base for the research. In sections 3.4.1 to 3.4.5, several frameworks in the field of performance management and measurement have been examined in greater detail to learn how relevant frameworks work. The review comprised four mature performance management models, namely the widespread Balanced Scorecard by Kaplan and Norton (1996a), the Skandia Intelligent Enterprising Concept (Skandia, 1997), the Performance Pyramid by Lynch and Cross (1995) and the recently introduced Performance Prism by Cranfield University's Center for Business Performance and Accenture (Kennerley and Neely, 2000). In addition, one approach developed in the context of software reuse measurement has been presented – the reuse framework as suggested by Lim (1998).

The author learned that for each of the domains NPD, KM (reuse and invention) and performance management (frameworks) a rich body of literature exists, however only limited literature can be found which refers explicitly to the intersection of those domains. The author was seeking to find answers to questions such as "What does it really mean to be reuse and invention oriented for a PMS?" or "What are the features of a PMS which explicitly refer to the NPD environment?" but he could not find answers which satisfied him entirely.

The presentation and description of the various performance management frameworks proved to be challenging due to the fact that it might be a subjective decision as to which theory or implementation still belongs to the core of the referring PMS theory and what does not. For example: "What is the Balanced Scorecard concept ?" Is it the design principles and implementation cases which are described in the famous book by Kaplan and Norton (1996a) or is it the whole theory which is documented in literature including software realisations, specific (potential) implementations and add-ons which have been developed over time by various bodies. The author tried to find a balance describing the core concepts and relevant surrounding implementation concepts.

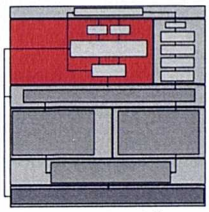
Summarising it can be stated that the author has been able to present the most relevant literature for the context of this research highlighting the most important aspects for each theme. The detailed discussions and conclusions with regard to the presented performance management and measurement frameworks provide a valuable base-line for further theory development. He gave further indication that the research question, set in the first chapter is important, worth to be addressed and not resolved so far.

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4 A definition and taxonomy of purposes for performance management and measurement to improve knowledge reuse and invention in NPD

"If you have built castles in the air your work need not to be lost, that is where they should be. Now put the foundation under them"

Henry David Thoreau, Author



This chapter establishes a definition and a taxonomy of purposes for performance measurement from a knowledge reuse and invention perspective in NPD. In a first step a general discussion of performance management and measurement is drawn. Reviewing current definitions of performance measurement and management, the author proposes his own definition for the context of this thesis and extends this definition to a definition of performance measurement from a knowledge reuse and invention perspective. Subsequently a taxonomy of performance measurement purposes is proposed which are, together with the literature review presented in the previous chapter, the basis for the proposition of requirements for performance measurement from a knowledge reuse and invention perspective for new product development.

4.1 Introduction

The previous chapter has provided a broad insight in the domains NPD, KM and performance management and measurement. It could be seen that there exists a very rich body of literature for all the domains.

Within this chapter the author will start to filter and structure the existing domain knowledge taking conscious decisions through delivering own definitions and purposes for performance management and measurement. This activity is important to put the further theory development in the overall domain context and to give insight into the many, often opposing meanings of the terms performance management and measurement including the various purposes assigned to them.

The author will deploy a rational, clear and straight decomposition process which is very well known from engineering product development (Pahl and Beitz, 1996). He will start by providing definitions which will lead into the formulation of purposes for performance measurement (from a knowledge reuse and invention perspective). This set-up will ensure coherent alignment of definitions and purposes for doing measurement.

The following Table 8 gives an overview of the research process within this chapter, the objectives of each phase, the major actions to be performed, the expected outcomes and the contribution to knowledge of each phase.

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Chapter 4 Process Flow	Objectives	Actions	Outcomes	Comments
Definition for performance management and measurement	Create a better understanding of the overall subject of this research.	Review of existing PM definitions. Proposal of own definition.	A sound definition for performance measurement and management (PM).	The definition delivers a better understanding of the terms performance management and measurement.
Definition for performance management and measurement from a knowledge reuse and invention perspective	Create a better understanding of the specific research focus (reuse and invention, NPD).	Review KM (reuse/invention) definitions. Proposal of a definition.	An expanded definition for PM from a reuse and invention perspective.	The synthesis of KM and PM resulting in one high level definition provide a valuable contribution to knowledge.
Taxonomy of purposes for performance measurement	Clarify the reasons for measuring (to be able to design good PMS functions).	Review existing purposes. Decomposition through proposing a taxonomy of measurement purposes.	A need for action to propose additional reuse and invention related purposes.	It has been shown that the existing purposes do not reflect sufficiently on the reuse and invention aspect.
Taxonomy of purposes for performance measurement from a knowledge reuse and invention perspective	To enhance PMS theory and understanding by establishing novel purposes for measuring.	Derivation of two novel PMS purposes. Proposal of an expanded taxonomy.	A sound taxonomy of purposes reflecting on reuse and invention issues to fill the gap.	The proposed reqs are analytically derived from literature and are novel in the context of performance measurement.

Table 8: Overview on the process flow of the chapter 4.

4.2 A proposed definition of performance management and measurement

Until the late 1980s financial-oriented control systems were very dominant in businesses world-wide. The intellectual roots of these accounting procedures can be traced back to events which occurred almost 100 years ago. The DuPont System of Financial Control, developed in 1919 by U.S. based DuPont de Nemours and Co. for instance arranged a set of financial measures resulting in return-on-investment (Christ, 1999). In 1951, General Electric planned a system of partly non-financial measures (Eccles and Noriah, 1992), whilst French companies started to work with the renowned Tableaux de Bord in 1959 (Weber and Schäffer, 1998). Throughout the 1980s and 1990s interest in performance management has increased considerably. However, the original performance management purpose of facilitating cost *and* process control on individual and corporate level have been deteriorated to one of mere cost orientation. It was for Johnson and Kaplan (1987) to elaborate on the obsolescence of such accounting. Driven by rapid changes in information technologies, reduced product life cycles, new organisational structures, increased awareness of intangible assets and stronger stakeholder-orientation Johnson and Kaplan (1987) laid the foundation to a new understanding of management control (Klingebiel, 1999): It was they who started first with relating costs directly to activities using extensively non-monetary measures (Johnson and Kaplan, 1987).

Looking at recent performance management and measurement theory, it can be noticed that the subject offers a rich body of literature (section 3.3). The objectives and intentions assigned to performance management and measurement are still diverse and heterogeneous. The borders between the terms definition, concept, connotation, purpose, requirement and function are fuzzy. Thus, neither literature nor practice provides a commonly agreed definition for performance management and measurement so far (Klingebiel, 1999).

Therefore, the author proposes to compare some of the frequently applied and recognised definitions in order to derive a conceptual framework for this thesis resulting in own definitions for performance management and measurement. The obvious confusion of definitions may result from the variety of purposes and intentions assigned to the performance management and measurement function. The following sections offer a review of currently available definitions and premises:

Lynch and Cross (1995) suggest three general basic premises about performance:

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- Operations are aligned to strategic goals by translating aggregate market and financial goals into operational terms for each business system which are translated into concrete measures.
- Financial and non-financial measure information has to be integrated and filtered.
- All business activities focus on the needs of the customer.

Kennerley and Neely (2000) state that a performance measurement system has three constituent parts:

- Individual measures that quantify the efficiency and effectiveness of actions.
- A set of measures that combine to assess the performance of an organisation as a whole.
- A supporting infrastructure that enables data to be acquired, collated, sorted, analysed, interpreted and disseminated.

Klingebiel (1999) identifies three prevailing perceptions of performance management:

- Performance management as a system to control corporate performance.
- Performance management as a system to direct (individual) people performance.
- Performance management as an integrated system controlling and directing corporate performance as well as (individual) people.

The United States Office of Personnel Management (OPM, 2001) defines performance management as a "systematic process by which an agency involves its employees, as individuals and members of a group, in improving organizational effectiveness in the accomplishment of agency mission and goals".

Further Klingebiel (1999) defines performance management as a comprehensive approach, building on the interaction of people, processes and organisational and technological systems. It therefore aims at the inclusive improvement of readiness and capacity to perform. Performance management thus consists of activities, like: strategic and operational goal setting, monitoring and development of performance against these objectives and application of appropriate steering measures.

Klingebiel (1999) adds that performance measurement can be described as being a means or sub-set of performance management. Figure 26 illustrates the conceptual performance management framework as proposed by Klingebiel (1999).

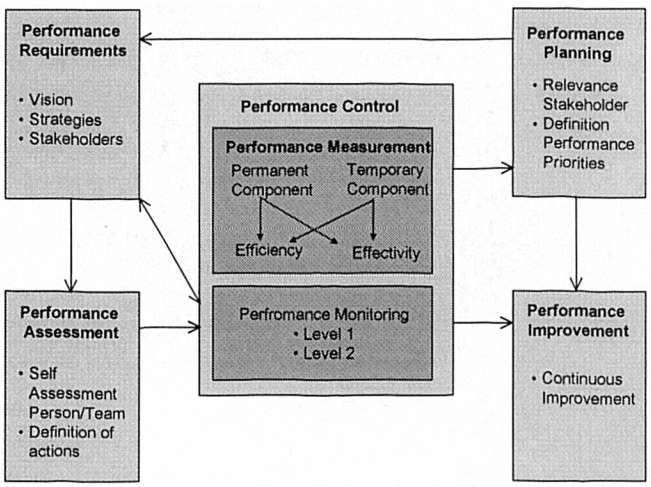


Figure 26: Conception of Performance Management (Klingebiel, 1999, translated from German and simplified)

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Kerssens-van Drongelen (1999) presents a performance measurement foundation concept basing on two distinct approaches to performance control. First a structural, cybernetic systems based approach, originating from disciplines such as management accounting, with measurement of quantitative information as the core element. Second, a behavioural, agency-theory based approach of formal and informal mechanisms of co-ordination and motivation with quantifiable measurement acting as an enabling tool. A synthesis of the two perspectives results in her process of performance control:

"...the acquisition and analysis of information and the interpretation of this information to determine what to do and how to do it, and the application of the chosen courses of action to influence people and processes so that the efforts and outputs are aligned with company objectives and plans." (Kerssens-van Drongelen, 1999)

Performance measurement, being considered a subset of performance control, can then be understood as: "...that part of the control process that has to do with the acquisition and analysis of information about the actual attainment of company objectives and plans, and about factors that may influence plan realisation." (Kerssens-van Drongelen, 1999). A performance measurement system, finally is defined as "...the mechanism supporting the measurement process, by which the required performance information is gathered, recorded and processed" (Kerssens-van Drongelen, 1999). Replacing the term "control" with "management"[31] makes the definition quite comparable with that of Klingebiel (1999). Figure 27 gives confirmation to this similarity.

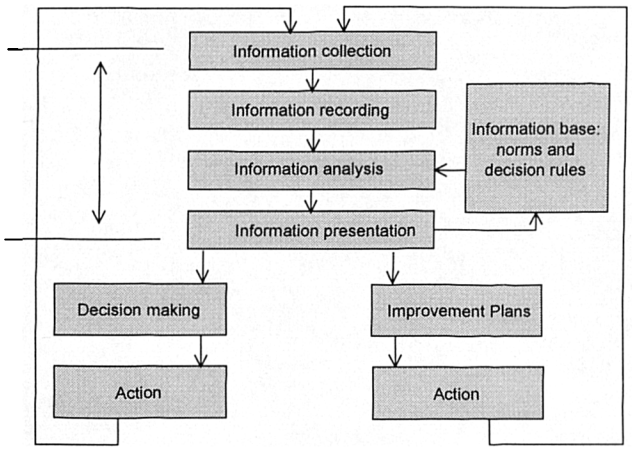


Figure 27: Measurement system impact on control (Kerssens-van Drongelen and Cook, 1997)

Neely et al. (1995) suggest a pragmatic definition, stating that performance measurement consists of "...a set of metrics used to quantify both efficiency and effectiveness of actions." Neely et al. (1996) state "performance measurement is the process of quantifying purposeful action where the process of quantification is measurement and purposeful action equates with performance". Neely (1998) states that acquisition, collation, sorting, analysis, interpretation and dissemination of data are at the core of performance measurement. Kennerley and Neely (2000) recently added: "consideration [in performance measurement] must be given, however, to the other stakeholder groups such as other investors, customers, employees and suppliers,....whether the organisation has the strategies in place to deliver stakeholder satisfaction".

The definitions above commonly describe measurement as the process of acquiring and processing information relevant to objectives. In that sense, information facilitates management through a better basis for decision making; this means that information is

[31] The author discussed this issue with van Drongelen via email in September 2001. She agrees that the terms "performance control" and "performance management" can be used interchangeably.

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used for managerial responsibilities and duties. Measurement can then be considered a supportive management tool or as Neely et al. (1996) puts it "...measurement is a means to an end, not an end in itself".

The previous sections show that it is necessary to propose a definition of performance management and measurement in order to ensure a common understanding of those terms. Against the overall objective of improving performance (for example in NPD), it is then assumed logical to adopt a comprehensive definition of performance management with measurement being a core function or component:

> Performance management is defined as the
>
> - methods,
> - processes,
> - structures
>
> and behavioural patterns an organisation uses to improve performance. Performance management may be used during
>
> - strategic and operative (tactical) planning,
> - execution (or implementation),
> - communication stages activity.
>
> As part of the communication activity, performance measurement is the process that gathers and records the effectiveness and efficiency of the execution (action) and planning stages.

Using the term performance management thus covers the mechanisms and practices of measurement, but adds the aspect of developing and improving the target system which can be the business, the organisation, the NPD system or the individual person through planning, acting and communicating. The author will also apply the term "model" serving as the superordinate concept for the methodologies, structures, systems and processes of performance management.

4.3 Expanding the proposed definition: A definition of performance management and measurement from a knowledge reuse and invention perspective

The impact of knowledge reuse and invention on NPD performance has been briefly discussed in section 1.1 and the basic principles of knowledge management with reuse and invention as core knowledge management processes have been described in section 3.2. The previous section of this chapter has delivered a definition for the terms performance management and measurement. This research studies the reuse and invention perspective within the performance management and measurement subject, making it necessary to elaborate the relationships between knowledge management and performance management and measurement, and then to synthesise those themes resulting in a referring definition. To attain this objective selected, representative definitions of knowledge management (KM) will be introduced:

Van der Spek and Spijkervet (1997) centre KM around four characteristic means:

- Formulation of a strategic policy for creation and use of knowledge.
- Implementation and execution of this policy.
- Improvement of the organisation with respect to optimal use and actualisation of knowledge.
- Monitoring, controlling and evaluation of performance of available knowledge.

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According to Weggeman (1999), KM

- deals with organising and controlling the operational processes in the knowledge value chain (section 3.2.3) and
- focuses on improving the performance of processes, organisations and systems from a perspective that knowledge is the critical production factor.

Wiig (1997) agrees that KM focuses on:

- Facilitating and managing creation, capture, transformation, use of knowledge and
- planning, implementing, operating and monitoring programs for effective intellectual capital management.

Setting these definitions against the author's view of performance measurement, its purposes and typical functions, a reciprocal relationship can be observed: performance measurement relies to a considerable amount on soundly processed information. This information is transformed into knowledge of and for the target system which means that knowledge management serves as an enabling tool for performance measurement and management. In addition to knowledge management being an enabling tool for performance management and measurement, it is often the knowledge or knowledge related activities themselves which are the most important subjects to be measured (Van der Spek and Spijkervet (1997)).

Neely (2001) agrees with this, stating that "Knowledge Management is increasingly a watchword for efficient business...". Knowledge management implies the evaluation, monitoring and improvement of strategies and operations relevant to an organisation's knowledge assets. Recently, Baird and Henderson (2001) and Smith (2001) stress the importance of knowledge asset thinking in the context of performance measurement. Earlier in this section it has been stated that the knowledge value chain according to Weggeman (1999) consists of different phases. Among these phases the (re)use and development (creation) of new knowledge are often considered the most important ones (for example Edvinsson (2000) and Weggeman (1999)).

In recognition of the importance of the KM subject in the performance management and measurement context, an extension of the above definition is suggested by explicitly emphasising the contribution of performance management and measurement to improve knowledge reuse and invention. In doing so, the author proposes herewith the term performance management (measurement) from a knowledge reuse and invention perspective:

> Within the context of the invention and reuse of knowledge assets, performance management is defined as
>
> - the methods,
> - processes,
> - structures
>
> and behavioural patterns an organisation uses to improve the performance of its knowledge asset invention and reuse activities. Performance management may be used during
>
> - strategic and operative (tactical) planning,
> - execution (or implementation),
> - communication stages of knowledge asset invention and reuse activity.
>
> As part of the communication of knowledge asset invention and reuse activity, performance measurement is the process that gathers and records the effectiveness and efficiency of the execution (action) and planning stages.

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The author will focus in the following discussions on more specific aspects of performance measurement as he envisions to provide functions which support primarily the measurement of performance. The knowledge intensity of NPD (section 1.1) suggests that this phase of the value chain is an appropriate context for further theory development activity. For the rest of the thesis the author will bear this knowledge reuse and invention orientation of performance measurement in mind when talking about performance measurement.

4.4 Purposes of performance measurement

In section 4.1, the author noted that performance measurement is executed to meet specific purposes[32]. It is considered to be crucial that the various rationales of measurement and knowledge management lead coherently into different requirements for the performance measurement model. This means that the consideration of end and objective with foresight is considered to be crucial for successful development of performance measurement requirements and functions. (Kerssens-van Drongelen, 1999; Sink and Tuttle, 1989 and Neely, 1998). Management literature, both of industrial and academic origin, offers a diverse and rich collection of purposes of performance measurement. The author will therefore investigate the available scientific and practical bibliographical resources and complement them with the suppositions derived from the expert interviews. This overview should then allow for formulation of a taxonomy of performance measurement purposes as a sound base-line for further theory development.

4.4.1 Purposes reported from academia

Sections 3.3.1 and 3.4 already offer several interrelated and commonly shared purposes. Performance measurement supports an organisation in formulating and setting strategic and operational targets (Klingebiel, 1999 and Kaplan and Norton, 1996a). It is then supposed to gather and process information, which allows for verification of performance against these targets (Kerssens-van Drongelen, 1999 and Kennerley and Neely, 2000). Eventually, performance measurement supports the selection and application of adequate mechanisms and measures supporting goal achievement (Kerssens-van Drongelen, 1999).

Lynch and Cross (1995) point out that the information a performance measurement system provides serves as a stimulus for process improvement. They also see performance management as an important means to communicate changing quality and delivery demands from the customers. Finally they consider a main objective of performance management "...to motivate behaviour leading to continuous improvement in customer satisfaction, flexibility, and productivity" (Lynch and Cross, 1995). Similarly, Pritchard (1990) has extensively reflected on performance management as being a motivational tool.

Park et al. (1996) stress the support of performance management to understand one's business, to evaluate the current position, to plan and to improve. Kaplan and Norton (1996a) consider performance management (in particular their Balanced Scorecard) as a means "...to articulate the strategy of the business, to communicate the strategy of the business and to help align individual, organisational, and cross-departmental initiatives to achieve a common goal." (Kaplan and Norton, 1996a).

In his extensive research on control systems, Simons (1994) assigns two main purposes to his so-called diagnostic and interactive management control systems which are target building and encouragement of strategic and organisational learning. Lim (1998) proposes three rationales for measurement namely benchmarking, incentives

[32] *In literature "purposes" overlaps with other frequently used terms such as "functions" or "reason", However, the author reserves the term "functions" for a different context in this thesis.*

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and decision-making. Bonsdorff and Andersin (1995) have assessed the respective literature up to 1995 and summarised various reasons such as, employee motivation, clarify individual contribution, communication of expectancies, provision of management information, gap identification and decision support. In 1985, Sink (1985) already noted "..the most important and perhaps the only valid reason for measuring performance of an organisation is to support and enhance improvement.". He states that further motives for measurement are control, prediction, estimation, decision-making and reactive problem solving. A broader classification, set up by Butler (1995) reflects on organisational and individual improvement, assistance in decision-making, visibility of results, improved understanding, -communication and –motivation, retention of control and absolute comparison as possible reasons for measuring.

Neely (1998) provides a quite comprehensive description of performance measurement purposes. According to him a performance measurement system serves the following purposes: Checking the position of the company, communicating the current position of the company, confirming priorities for action and finally compelling progress through actions which have been taken based on measurement results.

4.4.2 Purposes reported from operations and interviewed experts

Findings from cases reported in articles, theses, books

Skandia (Edvinsson, 2000) applies performance measurement to improve overall business performance through better decision quality based on measurement. 3M (Krogh et al., 1998) implemented a performance control system for evaluation of current R&D programs and for improved R&D program analysis, selection and execution. Eventually, Hewlett Packard (House and Price, 1991) established performance management to improve the decision-making quality and encourage collaboration across research units. General Electric (Robb, 1991) applies performance control for justification of its corporate research laboratory and for the detection of improvement opportunities. Borg-Warner (Collier, 1977) addressed the purpose of internal comparison, of determination of bonuses to research staff and of process improvement to performance management. The performance measures of GM Hughes Electronics (Chester, 1995) mainly enabled results-based compensation. Simons summarises a long term research with ten newly appointed managers and how they used performance control systems for the purpose of leveraging strategic renewal and development (Simons, 1994). Finally, Weber and Schäffer (1999b) illustrate several examples of how performance measurement concepts, mostly variations of the Balanced Scorecard, were applied in German enterprises to foster organisational learning and to support the clarification and communication of strategy. Similar examples are reported from Klingebiel (1999), who analyses eight large consulting firms applying performance management for corporate assessment and business development at their customers.

Findings from expert interviews[33]

The table below represents the key findings of the expert interviews which have been conducted in the context of this research (see also section 2.2.2). It should be noted that the presented statements are not limited to the context of purposes for performance measurement. Instead statements are presented which contribute in general to the understanding of performance management and measurement from a reuse and invention perspective and reuse and invention management in general. The experts interviewed have partly an academic and partly an industrial background. The set-up of the interview is documented in section 2.2.2.2. The questions posed to the interviewees can be found in Appendix F of this thesis.

[33] This part of the research was supported by Irit Sacher and Dr. Edna Pasher from Pasher Consultants, as well as Calé Detheridge Walis of Cranfield University.

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Name	Key statements
Arian Ward	"An important aspect [of PMS] is the need for measurements: **In order to manage reuse and innovation processes successfully, we need to measure**, but metrics should not be prescriptive. It is important to have a variety of metrics from a variety of industries, that managers could learn from them to improve things."
Debra Amidon	"Traditional [performance] management is multi-divisional and hierarchical, where business units are independent (SBU's) as opposed to the human knowledge form which focuses on strategic business networks and intangible assets."
Gordon Petrash	"I think that they [reuse and innovation] are very much intertwined with each other. Existing knowledge is a great catalyst for new knowledge developed. In manufacturing we have a term for it, it is called "product extension", like knowledge extension. **We always think of new knowledge having to create it from scratch but in fact 99.9% of innovation is incremental improvements over the past.**"
Hubert Saint-Onge	"Measurements are not possible right now, **the technology is not in place to do measurement of intangible assets and I can not assure that I can tell for every dollar invested in strategy, what is the impact of that dollar**. Nobody has figured it out yet. Some people claim that they have but they may have done some work on a very defined circumscribed peripheral project to the organisation but I do not believe in any of that, because I do not believe they have made a sustainable change."
Dr. Karl-Erik Sveiby	**"Why do we want to measure innovation? Surely, it must be with the purpose to improve it!** So measuring innovation must support the management of innovation. Measuring must never disturb the creative process and it must help and support the sources of innovation; the creative people, be they employees or customers. This is why network analysis and surveys can be useful, because they measure the sources of ideas and the "channels" for the flows, the relationships. We can for instance distinguish out of one thousand customers the ten customers that are providing ideas of new products or processes. Once we have that knowledge we can start managing the innovative process by managing the relationship with those ten clients to make the most of their creativity."
Prof. Leif Edvinsson	"The main challenge is to identify and define the conditions for "Innovation Genes": What are the essential characteristics that would enhance innovation, in other words, the parameters that would lead the organisation from the past – the old economy, towards the future – the new economy and the knowledge era. **The overriding purpose of measurement is thus to enhance innovation and guiding the change through taking the right decisions based on measurement results.**"
Prof. Andrew Neely	"You need to send signals that "we really care about new-use", in other words it must be supportive... **People can be very nervous about being measured, so you could force people to take existing knowledge and use it** (to keep up with the measurement system) when it may not fit. So *'new-use'* should be defined as the *appropriate* use of existing knowledge."
Scott Hawkins	"**The main purpose of performance management systems is the communication of the corporate strategy throughout the whole organisation**. Measures clearly have to be aligned to the company's mission and vision".
Dr. Edna Pasher	"You cannot measure the knowledge itself, but what you certainly can measure is the quality, the reuse level and the amount of reusable knowledge assets in an organisation. **An important purpose for measurement is to make people learn from their mistakes and successes made in the past**".
Atai Ziv	"Reuse and Invention performance management have to be carried out on all levels of the organisation. It needs a strategic as well as an operative component. The PMS framework has to be simple and clear relying on proven standards. The applied measures for reuse and invention have to be well balanced as the balance is largely controlled through the selected of measures. **PMS are a very important tool for communicating the company's strategy and for motivating people**".

Table 9: Expert statements regarding the reuse and invention measurement topic

Almost all experts agreed that the overriding purpose of doing performance measurement is to improve businesses and guide change in organisations.

4.4.3 A proposed taxonomy of purposes

Even though it can be observed that there is congruence between the purposes presumed by academics and those actually pursued and realised by practitioners and experts two limitations can be identified: On the one hand, there does not exist so far a complete and accepted set of performance measurement purposes. On the other hand, the propositions outlined so far lack a sound and well-structured basis as being the base-line for the proposition of functional PMS requirements meeting the purposes set at the outset. In order to outline a set of performance measurement purposes it seems feasible to compose a classification of reasons for measurement – a preliminary taxonomy of performance measurement purposes.

To attain this objective, the author will hold recourse to the works of Kerssens-van Drongelen (1999). In her dissertation project[34] she bases her thoughts on several

34 The development of this taxonomy is explained in depth in Kerssens-van Drongelen (1999).

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theories of control namely systems-theory (Anthony, 1965; Emmanuel et al., 1990 and de Leeuw, 1982), principal-agency theory (Jensen and Meckling, 1976) and empowerment theory (Vosselmann, 1996 and Macintosh, 1994)(see also section 4.1). As each of these control paradigms seems to be well-accepted in practice (Macintosh, 1994), she synthesised the referring rationales resulting in a preliminary taxonomy of performance measurement purposes as depicted in Figure 28.

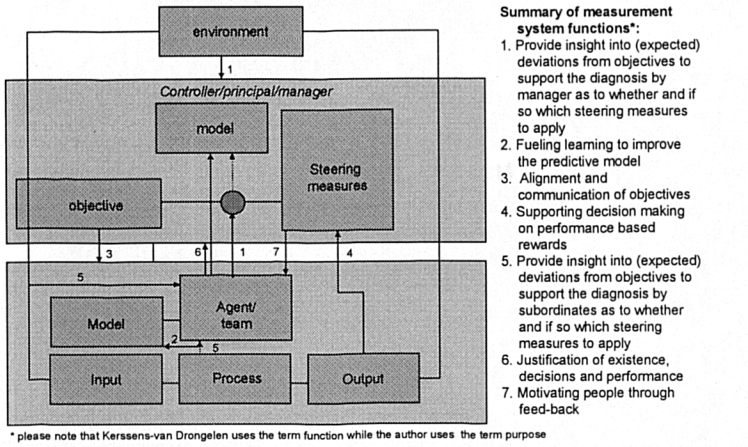


Figure 28: Preliminary taxonomy of performance measurement purposes in the performance control model (Kerssens-van Drongelen, 1999)

Having mapped this classification with the sources the author has analysed in sub-sections 4.4.1 and 4.4.2 it is considered to be appropriate for describing the major purposes of general performance measurement. Thus, a preliminary, general taxonomy of performance measurement purposes is proposed (Table 10).

No.	Purpose
1a	❑ Provision of insight into deviations from objectives / environmental factors to support diagnosis by managers as to whether / which steering actions to apply
1b	❑ Provision of insight into deviations from objectives / environmental factors to support diagnosis by subordinates as whether / which steering actions to apply
2	❑ Fuelling learning (for improvement of the predictive model)
3	❑ Alignment and communication of objectives through the organisation
4	❑ Justification of existence, decisions and performance
5	❑ Motivation of people through feedback
5a	❑ Support performance-based rewards

Table 10: Preliminary taxonomy of performance measurement purposes (based on Kerssens-van Drongelen, 1999)

Obviously, the purposes reported in the table above are not necessarily all equally ranking and their relevance might change over time, as well as across organisational entities. There are also certainly redundancies and interdependencies between those purposes. Still, as written, they present the most often assigned rationales according to best knowledge of the author.

4.4.4 Expanding the proposed taxonomy of purposes

The purposes stated above represent according to Kerssens-van Drongelen (1999) generic purposes for a performance measurement system suitable for R&D (NPD) environments as well. Innovative and knowledge-intensive organisations are challenged in the literature to create awareness and understanding to manage and improve reuse and invention, to understand their impact on the system's performance and finally to achieve a sound balance between reuse of knowledge and invention of knowledge (Sveiby, 2000; Ward, 2000, Amidon, 2000, Baird and Henderson, 2001; Clausing, 1998; Roos et al., 1997; Martensson, 2000). The analysis of the expert interviews

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confirms that organisations must try to improve knowledge reuse and invention to enhance overall NPD performance. These insights give further evidence to the initial proposition that this knowledge oriented perspective on a NPD system, in particular the equilibrium between knowledge efficiency and creation, is a relevant issue to tackle and to improve. However, the scientific discussions on performance management and measurement (subsection 4.4.1) did not provide a methodologically clear and explicit inclusion of these critical knowledge reuse and invention related issues and themes.

Building on this observation, the extension of the preliminary taxonomy with performance measurement purposes focusing on the reuse and invention related needs of knowledge intensive organisations is considered to be important. Therefore the following two additional purposes of performance measurement are proposed to be essential to further theory development:

- Support awareness, understanding and management of knowledge reuse and invention to improve NPD performance on a strategic as well as on an operational level.
- Understand and support the improvement of the balance between knowledge reuse and invention.

These two additional purposes lead into an extension of the taxonomy of performance measurement purposes, considered important for the proceedings of this thesis (Table 11) and acting as a cornerstone for the later specification of requirements and functions.

No.	Purpose
1a	❑ Provision of insight into deviations from objectives / environmental factors to support diagnosis by managers as to whether / which steering actions to apply
1b	❑ Provision of insight into deviations from objectives / environmental factors to support diagnosis by subordinates as whether / which steering actions to apply
2	❑ Fuelling learning (for improvement of the predictive model)
3	❑ Alignment and communication of objectives through the organisation
4	❑ Justification of existence, decisions and performance
5	❑ Motivation of people through feedback
5a	❑ Support performance-based rewards
6	❑ Support awareness, understanding, management of knowledge reuse and invention to improve NPD performance on a strategic as well as on an operational level
7	❑ Understand and support the improvement of the balance between knowledge reuse and invention

Table 11: Extended taxonomy of performance measurement purposes from a reuse and invention perspective for new product development

It should be noted that the additional purposes indicated above are certainly driven through the focus of this research. Other foci, like Total Quality Management (TQM) might result in additional more quality oriented purposes. Thus, the author does not claim that the collection of purposes is complete, instead he has expanded an existing, proven set of purposes through additional purposes which refer to the context of this research.

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4.5 Conclusion

The author learned that there are a lot of different understandings of the terms performance management and measurement. Based on this existing body of knowledge he has been able to provide sound definitions for both performance management and measurement. The specific context of this research is the knowledge reuse and invention theme in product development environments. The knowledge oriented view on performance management and measurement has therefore also been discussed in a great level of detail. The author learned that the body of literature focusing on this specific aspect is far less rich than for the wider and generic performance theme. He expanded the generic definitions for performance management and measurement to knowledge reuse and invention thinking.

Subsequently, a preliminary taxonomy of performance measurement purposes has been proposed and then expanded to incorporate the knowledge reuse and invention perspective which forms the context of this research. The elaborated purposes serve as a landmark for further theory development. The two reuse and invention related purposes have been rationally derived from the provided definitions, various bibliographical resources and expert interviews. Within this research work they are proposed for the first time in the specific context of performance measurement. It is not the primary objective of this research to discuss the validity of these purposes, although the author has provided some evidence that these purposes are valid and robust.

The author relied on a rational and well-structured research process deploying decomposition principles as suggested by (Pahl and Beitz, 1996), which are very well known from industrial product development. The author agrees with Kerssens-van Drongelen (1999) that those principles are very appropriate for developing management theory as well.

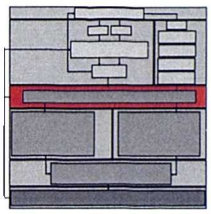
Overall this chapter contributes to a better understanding of performance management and measurement from a reuse and invention perspective in new product development and is therefore proposed as being important for further theory development. The chapter offers a strong fundament for the further proceedings of this research.

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5 Requirements Analysis

"It is thrifty to prepare today for the wants of tomorrow"

Aesop, Philosophist



The purpose of this chapter is to provide clear requirements and a functional specification for the novel performance measurement functions which will be elaborated in the context of this research. Based on the findings from the literature review in chapter 3 and the purposes elaboration in chapter 4, requirements for performance measurement from a reuse and invention perspective for NPD will be collected. The requirements will be clustered into a taxonomy in order to rationally decompose the rich and comprehensive performance measurement requirements knowledge for the further analysis and theory development. It will be shown that especially the knowledge reuse and invention orientation is an often neglected theme. Subsequently the leading PMS approaches in the field will be assessed against the taxonomy of requirement clusters to elaborate the gap and need for action. Based on this gap analysis a functional specification for an improved PMS will be proposed. Such a PMS shows an increased ability to support knowledge reuse and invention in NPD.
The functional specification is mapped using simplified Quality Function Deployment (QFD) with the needs of the user companies to verify whether it can potentially meet the users' needs and requirements. The chapter will close with a review of the research problem statement presented at the beginning of this thesis showing that the research problem set at the outset of this research is still valid and relevant.

5.1 Introduction

In the previous chapter the terms performance management and measurement have been defined for the context of this research and performance measurement purposes have been identified. Within this chapter, a set of requirements for performance measurement from a reuse and invention perspective for NPD will be established. The author thoroughly discusses the rich body of literature identifying some 24 general requirements which are clustered in a preliminary taxonomy of requirements. Emphasis is put on the knowledge reuse and invention orientation as this aspect is rarely discussed in the community. The author proposes, based on a deep analysis of the domain knowledge, four additional requirements to enhance the reuse and invention perspective.

The purposes suggested in the previous chapter will be mapped with the taxonomy of requirements serving as a counter-check as to whether all major purposes of performance measurement have been addressed within the requirements analysis activities. Some of the leading PMS frameworks will then be assessed against this taxonomy of requirement clusters to identify any gaps and concrete need for action. Based on the learning of this gap analysis, a functional specification for a PMS from a reuse and invention perspective for NPD will be proposed. The functional specification will be mapped using simplified QFD versus the needs of the 4 case companies to ensure the incorporation of the voice of the customer. The result of the QFDs is a prioritisation of the functions which helps to provide additional focus on the most important functions for detailed theory development.

This rational decomposition from purposes downwards to requirements and a functional specification allows the author while observing real-life experiences (chapter

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8 and 9) to reflect back on high level purposes and definitions (which might be very difficult to reflect on in a direct way, section 9.7 and 9.8) in a very analytical and sound way. This activity is therefore proposed to be beneficial for the understanding of the relationships between purposes, requirements and performance measurement functions. Chapter 9 will elaborate on this issue in greater detail.

Table 12 gives an overview on the process flow of this chapter explaining the referring objectives, actions, outcomes and novelty of each phase.

Chapter 5 Process Flow	Objectives	Actions	Outcomes	Comments
24 requirements for performance measurement derived from literature	Reuse domain knowledge to avoid "reinventing the wheel" and to base the further design work on a solid fundament.	Collection of the most important requirements (reqs) from literature.	A list of 24 reqs based on a very rich and deep literature review.	Very few reqs lists have been created so far which incorporate NPD, KM and PM aspects.
Decomposition through a taxonomy of 8 requirement clusters	Decomposition to support the derivation of the functional specification.	Design of a taxonomy of 8 req clusters Mapping of the 24 reqs into the clusters.	A group of 8 requirement clusters.	The taxonomy of clusters is novel in nature and bases on a deep understanding of the subject.
Mapping of purposes with the taxonomy of 8 requirement clusters	Verify whether the req clusters can meet the purposes to ensure coherence of the model.	Mapping of the purposes (previous chapter) with the requirement clusters.	Need identified e.g. the current requirements cannot meet the purposes set at the outset.	It has been shown that the reqs which are so far documented in literature do not meet knowledge oriented purposes.
Proposing 4 knowledge reuse and invention oriented requirements	To enhance PMS theory and understanding by establishing novel reqs to improve **reuse and invention**.	Derivation of four novel PMS requirements.	A set of 4 novel PMS reqs to fill the gap identified in the previous step (conceptual design level).	The proposed reqs are analytically derived from literature and are novel in the context of performance measurement.
Decomposition through mapping the 4 requirements into the taxonomy	Decomposition to facilitate the derivation of the functional specification.	Decomposition and mapping of the four new reqs with the taxonomy of clusters.	A decomposed list of detailed requirements from a reuse and invention perspective.	The provided detailed requirements are novel in nature and enriches therefore PMS theory and understanding.
Functional specification	To create a starting point and reference for detailed theory development.	Derivation of a set of design principles meeting the reqs in the clusters.	A functional specification describing what a PMs must do to improve **reuse and invention**.	The functional specification is novel in nature and contributes therefore to PMS theory and understanding.
Mapping of user needs and functional specification within user QFDs	To include the "voice of the customer" in the process. To focus and prioritise theory development.	QFDs at 4 case study companies (section 2.2.6).	Priorities of the 4 users to focus the theory development and implementation. work.	The QFDs deliver a first validation of the functional specification in business contexts.

Table 12: Overview on the process flow of the chapter 5

5.2 A taxonomy of PMS requirement clusters from a reuse and invention perspective for NPD

A performance measurement model reflecting on the definition presented in section 4.3 will have to meet a set of requirements in order to achieve the described purposes in the previous chapter. A study of relevant literature thereby provides references for the composition of a taxonomy of performance measurement requirement clusters. Sources of this review were academic reports, white papers, books, theses, conference proceedings and articles.

5.2.1 Requirements reported in literature

Several authors have elaborated on key requirements posed on performance measurement. This subsection will elaborate a profile of these findings.

The well-known financially oriented French Tableau de Bord (Epstein and Manzoni, 1987) explicitly suggests that measures should be integrated across organisation's functions and down its hierarchies. Klingebiel (1999) proposes an extensive list of requirements, such as, closeness to strategy, integration with information flows, systematic formulation of performance indicators, focus on critical subject areas, inclusion of monetary and non-monetary aspects, support of individual commitment, account for behavioural issues.

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Lynch and Cross (1995), as well as Keegan et al. (1989) demand for multi-dimensionality through providing a description of the different perspectives of performance in an organisation. Comprehensiveness or the possibility to map all considerable relevant measures onto a well accepted measurement framework is another widely acknowledged key requirement (Keegan et al., 1989; Neely et al., 1995 and Kaplan and Norton, 1996a).

Kaplan and Norton (1992) and Schneiderman (2001), emphasise the provision of a balanced picture of the organisation through delivering a balanced set of measures. According to them this means that the measurement approach should reflect on financial and non-financial measures, internal and external measures, short and long term-oriented measures and finally leading and lagging measures. Brown (1996), as well as Kaplan and Norton (1996a) and Fitzgerald et al. (1991) for example, stress the relevance of establishing cause-and-effect relationships. Similarly Kennerley and Neely (2000) require a PMS to explain how results are a function of determinates.

Commonly understood and accepted is the provision of a succinct overview of organisational performance. A performance measurement system would hence need to be easily understood and applied by users (Kennerley and Neely, 2000). Basing their thoughts on works of Freeman (1984), Kennerley and Neely (2000) have added the requirement of adopting a stakeholder-centric view of performance measurement. Martins (2000) provides an interesting overview on PMS characteristics in accordance with frequency of citations, which might, according to him, be a measure for relevance of the characteristic. Out of the 18 characteristics he identified congruence with competitive strategy, use of financial and non-financial measures, direction and support to continuous improvement, facilitation of understanding the cause and effect relationships and intelligibility to majority of employees are the most often cited ones.

Table 13 summarises the extensive review of functional PMS requirements. The author considers thereby the number of quotes referring to one specific requirement as an indicator of significance of the particular requirement. It should be noted that most part of the requirements are qualified for meeting performance measurement needs and purposes in general. However, with reference to authors like Hauser and Zettelmeyer (1997), Griffin and Page (1993), Packer (1983), Lim (1998), Beamont (1996), Hultnik and Robben (1996) representatives of the NPD/KM community have been included.

	Requirements	Reference
1	The system and measures are aligned with the mission, vision, goals and strategies of the user organisation.	Maskell, 1989; Maskell, 1991; Neely et al., 1995; Neely et al., 1996; Kennerley and Neely, 2000; Kaplan and Norton, 1996a; Kaplan and Atkinson, 1998; Kerssens-van Drongelen, 1999; Kerssens-van Drongelen and Cook, 1997; Kerssens-van Drongelen and Bilderbeek, 1999; Emmanuel et al., 1990; Brown and Svenson, 1988; Klingebiel, 1999; Goold, 1991; Goold and Quinn, 1990; Lynch and Cross, 1995; Fitzgerald et al., 1991; Fitzgerald and Moon, 1996; Griffin and Page, 1993; Griffin and Page, 1996; Lim, 1998; Martins, 2000; Beaumont, 1996.
2	The system provides a balanced, well-selected and customised set of measures, which reflects all relevant aspects and dimensions of performance over time which are presented in user-oriented formats (visualisation, reporting, operations, etc.).	Maskell, 1989; Maskell, 1991; Pritchard, 1990; Neely et al., 1995; Neely et al., 1996; Kennerley and Neely, 2000; Kaplan and Norton, 1996a; Kaplan and Atkinson, 1998; Kerssens-van Drongelen, 1999; Kerssens-van Drongelen and Cook, 1997; Kerssens-van Drongelen and Bilderbeek, 1999; Meyer, 1994; Lander et al., 1995; Emmanuel et al., 1990; Klingebiel, 1999; Anthony and Govindarajan, 1998; Lynch and Cross, 1995; Hauser and Zettelmeyer, 1997; Griffin and Page, 1993; Griffin and Page, 1996; Voss, 1992; Dimancescu and Dwenger, 1996; Lim, 1998; Schneiderman, 2001; Pawar and Driva, 1999; Hultnik and Robben, 1996.
3	Measures are effective, actionable, flexible and qualified over time, locations, hierarchies and different users.	Maskell, 1989; Maskell, 1991; Neely et al., 1995; Neely et al., 1996; Kennerley and Neely, 2000; Meyer, 1994; Brown and Svenson, 1988; Klingebiel, 1999; Dixon et al., 1990; Lynch and Cross, 1995; Packer, 1983; Ward, 1996; Lim, 1998; Pawar and Driva, 1999.
4	The system is simple, comprehensible and transparent for all users.	Maskell, 1989; Maskell, 1991; Emmanuel et al., 1990; Muckler and Seven, 1992; Klingebiel, 1999; Dixon et al., 1990; Turney and Anderson, 1989; Packer, 1983; Pawar and Driva, 1999.

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	Requirements	Reference
5	The system is reliable, stable and valid over time and locations.	Packer, 1983.
6	The system provides timely, efficient and effective feedback and signals in a positive, but attentive manner.	Maskell, 1989; Maskell, 1991; Pritchard, 1990; Kaydos, 1991; Kaplan and Norton, 1996a; Bonnet and Krens, 1994; Emmanuel et al., 1990; Anthony and Govindarajan, 1998; Flamholtz, 1996.
7	The system integrates with existing management-, control- and information systems and techniques supporting an effective and efficient data and information flow; i.e. acquisition, collation, filtering, analysis and dissemination.	Ballantine and Brignall, 1994; Clarke, 1994; Klingebiel, 1999; Kennerley and Neely, 2000.
8	The system is cost-effective with respect to design, build, implementation and maintenance.	Azzone et al., 1991; Packer, 1983.
9	Measures are process-oriented and aligned with cycle-time of activities.	Pritchard, 1990; Kaplan and Atkinson, 1998; Lander et al., 1995; Emmanuel et al., 1990; Klingebiel, 1999; Fortuin, 1994; Lynch and Cross, 1995; Griffin and Page, 1993; Griffin and Page, 1996; Voss, 1992.
10	The system is accepted, considered fair and used as an instructive tool in day-to-day operations.	Pritchard, 1990; Kaplan and Atkinson, 1998; Meyer, 1994; Bonnet and Krens, 1994; Emmanuel et al., 1990; Anthony and Govindarajan, 1998; Ward, 1996.
11	Users and measurement subjects are actively involved in system design, implementation and use.	Pritchard, 1990; Meyer, 1994; Emmanuel et al., 1990; Anthony and Govindarajan, 1998; Goold, 1991; Goold and Quinn, 1990.
12	The design and implementation pursues a systematic and consistent approach.	Kerssens-van Drongelen, 1999; Kerssens-van Drongelen and Cook, 1997; Kerssens-van Drongelen and Bilderbeek, 1999; Ward, 1996.
13	Measured factors are controllable by the measurement subject.	Pritchard, 1990; Neely et al., 1995; Neely et al., 1996; Kennerley and Neely, 2000; Bonnet and Krens, 1994; Anthony and Govindarajan, 1998.
14	The system minimises data- and information processing efforts.	Pritchard, 1990; Neely et al., 1995; Neely et al., 1996; Kennerley and Neely, 2000; Kaplan and Atkinson, 1998; Kerssens-van Drongelen, 1999; Kerssens-van Drongelen and Cook, 1997; Kerssens-van Drongelen and Bilderbeek, 1999; Meyer, 1994; Anthony and Govindarajan, 1998; Pawar and Driva, 1999
15	The system supplies key measures for aggregation and combination for example on management or corporate level.	Pritchard, 1990; Neely et al., 1995; Neely et al., 1996; Kennerley and Neely, 2000; Kaplan and Norton, 1996a; Kaplan and Atkinson, 1998; Bonnet and Krens, 1994; Emmanuel et al., 1990; Anthony and Govindarajan, 1998; Pawar and Driva, 1999.
16	The system and measures communicate targets (demanding, but achievable), achievement, contribution and agreements.	Kaydos, 1991; Kerssens-van Drongelen, 1999; Kerssens-van Drongelen and Cook, 1997; Kerssens-van Drongelen and Bilderbeek, 1999; Emmanuel et al., 1990; Anthony and Govindarajan, 1998; Goold, 1991; Goold and Quinn, 1990.
17	The system and measures focus on significant cause-and-effect relationships.	Neely et al., 1995; Neely et al., 1996; Kennerley and Neely, 2000; Brown, 1996; Kaplan and Norton, 1996a; Meyer, 1994; Lynch and Cross, 1995; Fitzgerald et al., 1991; Fitzgerald and Moon, 1996; Kennerley, 2000.
18	The system supports and facilitates strategic / ex-ante learning and continuous improvement.	Kaplan and Norton, 1996a; De Vreede, 1995; Turney and Anderson, 1989.
19	The system provides norms, standard methods and units of counting and documentation and reference values and benchmarks	Kerssens-van Drongelen, 1999; Kerssens-van Drongelen and Cook, 1997; Kerssens-van Drongelen and Bilderbeek, 1999; Lim, 1998.
20	The system includes measurement structures and techniques.	Kerssens-van Drongelen, 1999; Kerssens-van Drongelen and Cook, 1997; Kerssens-van Drongelen and Bilderbeek, 1999.
21	Measures distinguish R&D project levels from R&D program levels.	Hauser and Zettelmeyer, 1997; Griffin and Page, 1993; Griffin and Page, 1996; Kerssens-van Drongelen, 1999.
22	The system captures and reports external and internal R&D contributions.	Hauser and Zettelmeyer, 1997.
23	The system establishes clear standards of measurement and counting.	Lim, 1998; Hultnik and Robben, 1996.
24	The system provides a commonly agreed baseline.	Lim, 1998.

Table 13: Overview on major requirements of performance measurement

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5.2.2 A proposed taxonomy of requirement clusters

The collection of requirements from the discipline literature serves as a foundation for compiling a preliminary taxonomy of requirements. The following figure gives an overview on the relationships between the requirements described in Table 13 and the proposed requirement clusters which form the taxonomy. The clusters and therefore the taxonomy are novel in nature. The X-axis in Figure 29 shows the various clusters of requirements, namely Standardisation, Data Processing Mechanism, Transparency, Participation, Alignment, Comprehensiveness, Effectiveness and Operability. The mapping of the requirements into the clusters serves also as a test to verify whether the proposed taxonomy can cover all the various single requirements outlined in the previous section.

Characteristic Number	Requirements \ Requirement Clusters	1. Standardisation	2. Data processing mechanism	3. Transparency	4. Participation	5. Alignment	6. Comprehensiveness	7. Effectiveness	8. Operability
1	The system and measures are aligned with the mission, goals and strategies of the user organisation					■			
2	The system provides a balanced, well-selected and customised set of measures, which reflects all relevant aspects and dimensions of performance over time which are presented in user-oriented formats (visualisation, reporting, operations, etc.)			■		■	■		■
3	Measures are effective, actionable, flexible and qualified over time, locations, hierarchies and different users			■	■			■	
4	The system is simple, comprehensible and transparent for all users	■		■			■		
5	The system is reliable and valid over time and locations	■					■		
6	The system provides timely and effective feedback and signals in a positive, but attentive manner			■	■				■
7	The system integrates with exist-ing management-, control- and information systems and tech-niques supporting an effective and efficient data and information flow; i.e. acquisition, collation, filtering, analysis and dissemination		■					■	
8	The system is cost-effective with respect to design, implementation and maintenance	■						■	
9	Measures are process-oriented and aligned with cycle-time of activities					■			
10	The system is accepted, considered fair and used as an instructive tool in day-to-day operations		■	■	■				■
11	Users and measurement subjects are actively involved in system design, implementation and use				■				
12	The design pursues a systematic and consistent approach	■		■			■	■	
13	Measured factors are controllable by the measurement subject						■		
14	The system minimises data and information processing efforts		■						
15	The system supplies key measures for aggregation and combination (e.g. on management or corporate level)					■	■		
16	The system and measures communicate targets (demanding, but achievable), achievement, contribution and agreements				■				■
17	The system and measures focus on significant cause-and-effect relationships			■		■			
18	The system supports and facilitates strategic / ex-ante learning and continuous improvement						■		
19	The system provides norms, standard methods and units of counting and documentation and refer-ence values and benchmarks	■					■		
20	The system includes measurement structures and –techniques						■		
21	Measures distinguish R&D project levels from R&D program levels						■	■	■
22	The system captures and reports external and internal R&D contributions			■			■		
23	The system establishes clear standards of measurement and counting	■							
24	The system provides a commonly agreed baseline	■		■			■		

Figure 29: Relationships between performance measurement requirements (see also Table 13) and the requirement clusters of the taxonomy

In Figure 30 the author maps the rationales and purposes of performance measurement defined earlier in this thesis (section 4.4.4 and Table 10) with the taxonomy of requirement clusters. This mapping process serves as consistency check whether all measurement purposes have been addressed with the proposed taxonomy of requirement clusters.

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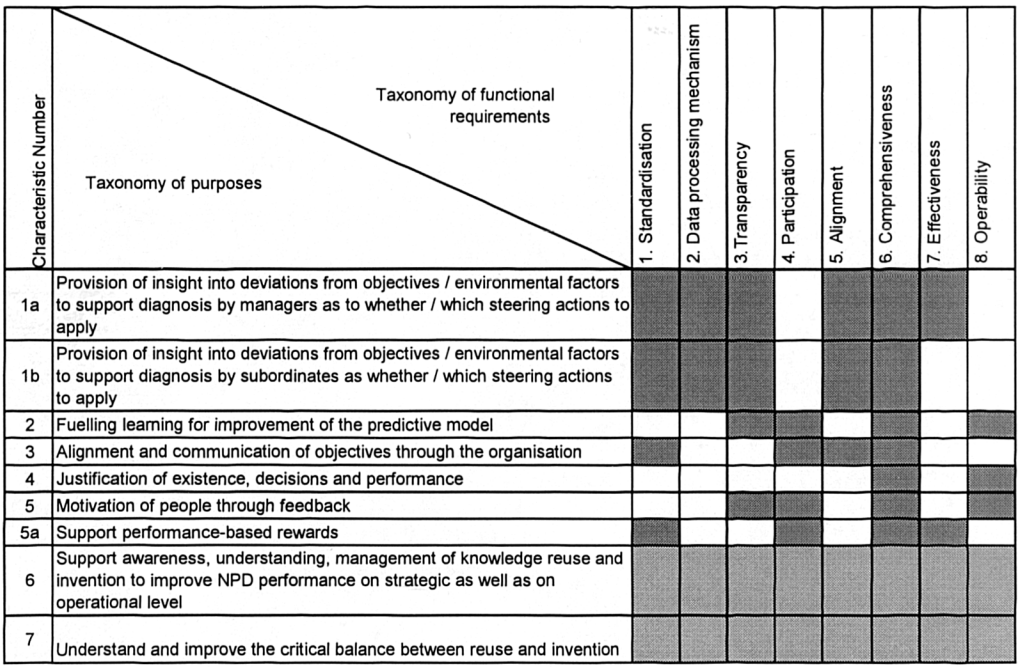


Figure 30: Graphical overview on the relationships between the PMS requirements taxonomy and taxonomy of purposes

Figure 30 indicates that the preliminary taxonomy of requirement clusters obviously covers the performance measurement purposes *for the most part*. Indeed, as both purposes and requirements are consistently derived from representative bibliographical sources, this congruence is a logic consequence. The fact that various requirements can be traced back to different and independent sources strengthens the contention of these factors being key to performance measurement. The aforesaid research of (Kerssens-van Drongelen, 1999) verifies this assumption. However the figure indicates as well (light shadow) that *purposes 6 and 7 are so far only implicitly and not sufficiently covered* through the requirements identified.

5.2.3 Expanding the proposed taxonomy of requirement clusters

In order to meet especially the purposes 6 and 7, the author suggests additional requirements taking special account of the knowledge reuse and invention orientation of this thesis. Therefore within this section, the so far generic collection of functional PMS requirements will be focused on the knowledge reuse and invention topic through expanding the preliminary taxonomy requirement clusters. Recently Marr et al. (2001), Baird and Henderson (2001), Edvinsson (2000) and Smith (2001) started (at least partly) to recognise that this aspect is so far a neglected topic in the PMS discussion (section 4.4.4).

Subsections 5.2.3.1 through 5.2.3.4 introduce therefore four knowledge reuse and invention oriented requirements and discuss the initial motivation to include them from a scientific point of view.

5.2.3.1 A catalogue of reuse and invention measures

A performance measurement model for knowledge reuse and invention in NPD requires a catalogue structure for new and systematically connected reuse and invention-focused (asset related) measures.

Long standing criticism of financial management accounting (Johnson and Kaplan, 1987) has been reinforced as academia and industries are repeatedly acknowledging the significance of knowledge for entrepreneurial success (Kaplan and Norton, 1996a). Goold and Quinn (1990) observed that most economic and social measurement is still focused on tangible assets and their countable, physical output. Likewise, researchers,

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managers and consultants have addressed the issue during the recent years (Sveiby, 1997; Stewart, 1997; Probst et al., 1997; Skandia, 1997; North et al., 1998 as well as Edvinsson and Malone, 1997).

Nevertheless, today, companies still seem limited to providing vague assessment of their knowledge capital (Roehl and Romhardt, 1997). This incapability stands in sharp contrast to the observation that knowledge adds more than 50% to value creation in many organisations (Bullinger et al., 1997). The disfunctionality of current performance management, measurement and accounting methods manifests itself more often as this proportion increases. Intangible assets and resources are so far, if any, only casually valued relative to tangibles (Sveiby, 1997). Critical and competitive knowledge is likely to be insufficiently described and accessible (Krogh et al., 2000). The required disclosure of such critical knowledge is deemed even more difficult when performance management and measurement are concerned about individual knowledge and competencies.

In addition, the dominant focus on aggregate financial figures neglects causal dependencies and the evolution and nurture of intangible resources over time (North et al., 1998). As a consequence of not being able to measure and value such assets, mission-critical resources of an organisation remain idle (O'Dell and Grayson, 2000) or even deteriorate over time. North et al. (1998) have observed that the inability to measure and reward individual and collective contribution to knowledge creation and transfer even adds to this grievance. Moreover, currently applied management and measurement systems frequently value historical achievements and short-term effects, but are not qualified for planning and justifying investment in long-run capabilities and intangibles, considered essential for future success (Kaplan and Norton, 1996a and North et al., 1998). Recently Marr et al. (2001) reflected on the knowledge orientation of performance measurement also providing a list of knowledge oriented indicators. However, in summary, the majority of contemporary indicators seem inadequate for knowledge-intensive organisations, where efficient reuse and creative generation of knowledge influence competitive lead, corporate strength and advancement.

If structured properly a catalogue can be a very useful guide when bringing performance measurement thinking into NPD, by providing a crucial checklist for the required steps and activities to be performed[35]. Thus, it is also the structure of the catalogue and the process of developing the catalogue of measures which is a decisive requirement for building and implementing a successful performance measurement system. Chapters 8 and 9 extensively reflect on this issue[36].

The stated requirements of the interviewed experts (section 4.4.2) even allude to the possible classification of such a catalogue. Obviously, the measures would have to capture the organisational, structural and technological aspects, as well as human and cultural factors impacting reuse and invention. The catalogue would have to ensure measures of finest granularity as well as measures of high aggregation level in order to address decision taking and monitoring on operational and management levels. Last, but not least, financial metrics still seem to be regarded as inevitably necessary to justify and communicate the impact of knowledge management efforts on business success.

A measurement catalogue reflecting on reuse and invention aspects is therefore proposed as being an important requirement for improved performance measurement from a knowledge reuse and invention perspective.

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35 This statement was made by the experts Scott Hawkins from Skandia and Atai Ziv from ECI Telecom.

36 Several interviewed experts like Scott Hawkins from Skandia stressed that the structure of the catalogue is much more important than the measures themselves. He sees little value in pre-defined as according to him they should be developed for the specific context of a company.

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5.2.3.2 A holistic framework to improve knowledge reuse and invention

A performance measurement framework for reuse and invention in NPD builds on a composition of various measurement perspectives[37], being a holistic knowledge reuse and invention view on NPD, sound navigation principles, graphical metaphor and coherent alignment to reuse and invention strategies.

Kennerley and Neely (2000) have stated the general need for organisations to implement a performance measurement framework, which is multi-dimensional and comprehensive. In other words, all aspects of performance relevant to an organisation's success would need to be reflected and all meaningful measures should possibly be mapped onto the framework. This complies with industrialists and academics commonly acknowledging the demand for a multi-faceted framework ever since. The four perspectives of the Balanced Scorecard (Kaplan and Norton, 1996a) or the categories of the European Quality Model (Bading and Frech, 1999) are renowned attempts to respond to this requirement. The existing and dominant models however, each provide only a very focused perspective on business performance; they fail to cover the variability of aspects and drivers for reuse and invention in NPD. This observed absence of a multi-faceted framework for knowledge-sensitive performance measurement suggests the particular function of a specific and tailored composition of measurement perspectives. A brief review of recent discussions on knowledge management and innovation will underscore the idea of multi-dimensional performance measurement:

The definition of knowledge as suggested by Amidon (1997) seems widely accepted as common sense: "Data are elements of analysis. Information is data with context. Knowledge is information with meaning." Davenport and Prusak (1998) add: "Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organisations, it often becomes embedded not only in documents or repositories but also in organisational routines, processes, practices and norms."

Eventually Nonaka and Takeuchi (1995), drawing on the discipline of epistemology, shape their understanding of knowledge around the notion of tacit and explicit knowledge and the diverse modes of knowledge conversion through personal interaction. A recent publication by Menon et al. (1998) identified several classes of knowledge management, such as strategic knowledge management, operational knowledge management, organisational learning, innovation management and intellectual capital accounting.

Edvinsson (2000) adds that the reuse of knowledge and invention of new knowledge are the core phases within the knowledge management value chain. These definitions and categorisations already suggest that it is necessary to approach the management of knowledge and innovation from different, but complementary perspectives. A strong argument for a multi-dimensional set up is Sveiby's (Sveiby, 2000) distinction of technology-focused and people-centred understanding of knowledge management[38]. The technology-focused fraction is believed to be mostly concerned about efficient reuse of knowledge, whilst those in favour of the people-centred approach are conversely more dedicated to creative knowledge generation. A performance measurement model for reuse and invention would obviously have to take both views into account.

Amidon (2000), reflecting on the nature of innovation adds: "And so, the innovation process operated more like a value system than a linear chain of events and activities.

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37 Please note that perspectives could be a synonym for dimensions or facets.

38 This distinction is common sense today (Pór, 2001; Bukowitz and Williams, 1999; Menon et al., 1998).

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This can only be understood by employing concepts and methodology of system dynamics (which refers to the innovation value system)." She then concludes that an organisation would have to establish a performance measurement structure, which integrates the cultural, the behavioural and the technological aspects of the firm.

Additionally the requirement of multi-dimensionality seems necessary with reference to principle works of Ulrich and Eppinger (1995). In their book they introduce a typical and generic product development process focusing on the conceptual design phase. By its very nature, such a process is crossing various disciplines and functions and cascades through hierarchies and structures. Thus, NPD regularly involves an entire organisation, and even goes beyond the boundaries of the enterprise and integrates third parties upstream and downstream within the supply chain. The point thereby is, that measurement merely directed at the distinct R&D function would fail to encompass all NPD implications and connections. By comparison of these contributions with the requirements observed across the case studies and interviews (section 4.4.2) the author feels confirmed in claiming the need for a multi-dimensional framework for reuse and invention management. Especially, the variability and diversity of measurement and management needs, elaborated in the field research, conflicts with a narrow and limited focus and therefore suggests the introduction of the diverse measurement and management perspectives.

The term holistic in the title of this requirement suggests the alignment of operational levels to business objectives from a knowledge perspective: Too often, NPD efforts fail because they are insufficiently aligned with an organisational objective and strategy (Petrash, 2000). Thus, the first step into purpose-oriented knowledge reuse and invention in product development is assumed to be an alignment with the overall business strategy from a knowledge oriented perspective. As dynamism and complexity in organisations continuously increase, people then need a picture of where the company intends to go to and how to direct efforts (Pinchot and Pellman, 1999). It is of utmost importance to recognise that knowledge management and innovation are merely a method to achieve a goal and execute a strategy, but not an end in itself. "When pursued in isolation, as normally is the case, these one-dimensional initiatives often lead to brief performance improvement followed by reduced effectiveness and undesirable side-effects." (Hilmer and Donaldson, 1996)

Several authors from the KM and NPD community like Klingebiel (1999), Driva (1997), Kerssens-van Drongelen (1999), Säubert and Bürgel (1998) demand more comprehensive navigation principles than purely organisational drill-down oriented functions. Given the multi-dimensional environment that NPD brings, this counts even more for the reuse and invention subject, demanding excellent navigation if a performance measurement system is to succeed. Several interviewed experts (Edna Pasher, Atai Ziv and Leif Edvinsson) confirmed this point of view.

The use of graphical metaphor to communicate knowledge reuse and invention performance thinking was extensively promoted by various interviewed experts. On a more general level the use of visulalisation techniques is a well-recognised requirement (Neely, 1998, Kaplan and Norton, 1996a, section 5.2.1).

Reuse and invention activity needs to be aligned with strategic thinking. Many interviewed experts agreed on that. On a general performance measurement level the alignment requirement is probably one of the most recognised ones (section 5.2.1).

Summarising it seems to be valid to include a performance measurement framework with reuse and invention oriented measurement perspectives, comprehensive navigation capabilities, visualisation metaphor and alignment principles into the list of PMS requirements.

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5.2.3.3 A performance measurement infrastructure

A performance measurement model and framework for reuse and invention in NPD is required to be integrated with a knowledge oriented infrastructure.

In recognition of the knowledge-intensity of NPD processes, especially of pre-development and conceptual design, it seems feasible to view the NPD process from a knowledge-asset based perspective (Prenninger et al., 1999 and Hofer-Alfeis, 1999). The translation of the development process systematically related to knowledge assets is likely to provide such a view. Make-IT (1999a); Prenninger et al. (1999); Warschat et al. (2000b) have done basic work in this field showing that semantic networks of knowledge assets so called "knowledge asset structure models" are a valuable means to provide the relevant reusable knowledge in the right context to the user. The total of those company-specific asset models forms an infrastructure, which supplies the measurement tool with genuine information and data about the reuse and invention assets and links reuse and invention measurement to operational reuse and invention processes (Roth et al., 2001).

Kennerley and Neely (2000) demand a generic, supporting infrastructure that enables data to be acquired, collated, sorted, analysed, interpreted and disseminated. Recently Marr et al. (2001) have built on these basic works through providing a set of generic knowledge assets and a referring knowledge asset map which are integrated into the Performance Prism concept (section 3.4.4).

Jukes (2000) agrees that performance measurement requires a sound infrastructure where the performance relevant information is kept. By constructing a high-level reuse and invention reference process, the performance measurement system is supposed to be more tangible and intelligible, but still flexible and adaptive to particular characteristics of the user organisation. Another point for such a performance measurement infrastructure can be made, holding recourse to the purposes assigned to performance measurement in general (see Table 11, page 75). The provision of insight into deviations from objectives/environmental factors (Purpose 1a and 1b, see section 4.4.4), for example, requires diagnostic data and information to be retrieved from this environment and its operating systems.

The arrangement of a holistic view on the NPD system (Purpose 6) must come with a tight integration of the performance measurement model into the business system. It is in particular this data and information processing mechanism, and the required integration into existing systems and the necessitated transparency of the approach, that suggests a performance measurement infrastructure being a relevant requirement of the performance measurement model.

The previous sub-sections give evidence that the consideration of such an infrastructure in the PMS context seems to be decent and valid.

5.2.3.4 A holistic build and implementation path

A performance measurement model for reuse and invention in NPD requires a sound and holistic build and implementation path (focusing thereby on the specific reuse and invention related issues).

"A major source of failure and frustration of measurement systems development in the past has been the involvement of too few people." (Sink and Tuttle, 1989)

This quote underscores the requirement to equip a performance measurement model with a detailed guideline and assistance for build and implementation. Recalling the functions reported from literature and practice it can be recognised that several authors are at least theoretically aware of this issue (Pritchard, 1990; Anthony and Govindarajan, 1998). Paradoxically, most current frameworks actually do not address this issue satisfactorily.

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This omission more often results in poorly designed systems (Kerssens-van Drongelen, 2000) or in under-estimation of the actual efforts and required resources (Weber and Schäffer, 1999b). The casual advice and recommendations of Kaplan and Norton (1996a) "first Balanced Scorecard can be created over a 16-week period" often lead astray the efforts toward implementation of the Balanced Scorecard (Weber and Schäffer, 1999b). The author's experience with PMS implementation projects gives indication that a PMS implementation can be far more comprehensive depending on the size and complexity of the organisation. If performance measurement is understood as an integrative approach to organisational improvement rather than just a tool for management control, it is likely to impact internal and external structures, processes, culture and people (NIMCube, 2000d). In particular in interdisciplinary and diverse environments, such as NPD, a wide range of implications, influential factors and relationships has to be taken into account when implementing a performance measurement model. Doppler and Lauterburg (1999) stated for instance, that the touchstone of any change and initiative is practical realisation of a theory and concept.

Several interviewed experts (Hawkins, Edvinsson and Ziv) stated that a sound build and implementation path is a key success factor for a PMS project. They state that the majority of today's PMS problems refer more to the way the PMS has been implemented rather than to actual design shortcomings.

Various comments on change management in literature (Reiß et al., 1997; Comelli, 1999; Doppler and Lauterburg, 1999), exemplary approaches, like the EFQM framework (Bading and Frech, 1999) or the Capability Maturity Model (Paulk et al, 1994) and the discussion with leading experts on the subject from Cranfield University, Intel, Work Frontier (section 2.2.2[39]), add strong evidence to this proposed requirement. Against these considerations it is reasonable to propose the inclusion of a diligent build and implementation path in a complete taxonomy of performance measurement requirement clusters.

Against these considerations it is reasonable to propose the inclusion of a holistic build and implementation method into the list of requirements.

5.2.3.5 Mapping of the knowledge reuse and invention oriented requirements into the taxonomy of requirement clusters

Figure 31 shows that the four requirements identified in the previous sections are mapped onto various requirement clusters. This means that each of the four requirements is decomposed in various sub-requirements referring to the various requirement clusters.

Characteristic Number	Requirements / Requirements Taxonomy	1. Standardisation	2. Data processing mechanism	3.Transparency	4. Participation	5. Alignment	6. Comprehensiveness	7. Effectiveness	8. Operability
25	Catalogue structure for new and systematically connected reuse and invention focused measures	■	■	■		■	■		■
26	A composition of reuse and invention oriented measurement perspectives	■		■		■	■	■	■
27	Performance Management Infrastructure from a reuse and invention perspective	■	■	■	■	■	■	■	■
28	A sound and holistic build and implementation path	■		■	■	■	■	■	■

Figure 31: Relationships between the reuse and invention oriented requirements (see also Table 13) and the taxonomy of requirement clusters

39 The detailed discussions are documented in NIMCube (2000b).

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The four additional requirements the author has derived from the discussion and reflections within this chapter, are obviously motivated by the overall research objective to provide reuse and invention oriented PMS functions and are novel in nature. Therefore, the author is well aware that any taxonomy of performance measurement requirement clusters is relative to the rationale behind it. The following Table 14 summarises the knowledge reuse and invention related sub-requirements within the final taxonomy of requirement clusters. Also this collection of sub-requirements represents a strong contribution to PMS theory and understanding. For transparency purposes the author won't recapture the already known requirements from section 5.2.1.

No	Requirement cluster	Relevant requirements
1	Standardisation	❑ Standardised aggregation principles for knowledge asset related measures. ❑ Standardised perspectives for reuse and invention measurement, reuse and invention indicator templates and a process for building and implementing the PMS functions.
2	Data processing mechanism	❑ Operative improvement tool for knowledge reuse and invention, enabled through software. ❑ Knowledge identification, storage and sharing support. ❑ Idea generation and evaluation support.
3	Transparency	❑ NPD Navigation functionalities. ❑ Clear and simple aggregation rules for asset related measures. ❑ Transparent and clear build and implementation methodology. ❑ Clear and simple indicators.
4	Participation	❑ Participative set-up of the build and implementation methodology, asset-related measure collection and reporting and operative improvement tools for reuse and invention (Definition of role concepts for reuse and invention). ❑ Alignment of performance measurement system to communities of practice.
5	Alignment	❑ Alignment to NPD goals from a reuse and invention perspective. ❑ Provision of strategic reuse and invention oriented measures.
6	Comprehensiveness	❑ Reuse and invention issues have to be covered in a holistic way (people, process and technology consideration). ❑ Sound balance between reuse and invention. ❑ Support of operative and strategic reuse and invention improvement. ❑ Consideration of the whole NPD system (systems thinking). ❑ Comprehensive set of measures for reuse and invention. ❑ Integration in day-to-day working environments supporting operative reuse and invention activities. ❑ Multi dimensional reflection of the innovation process. ❑ Superior systems performance in terms of efficiency (simple and clear processes, enabling technologies, integrated solutions).
7	Effectiveness	❑ Integration into existing reuse repositories, creativity and community tools. ❑ Provide a process for identifying the company specific reuse and invention assets and for identifying the right reuse and invention measures for the right context.
8	Operability	❑ Reflection and support of the reuse and invention process. ❑ Integration of a performance measurement framework into a day-to-day reuse and invention management tool. ❑ Intuitive procedures and tools. ❑ User-friendly enabling technology.

Table 14: Taxonomy of requirement clusters for a PMS from a reuse and invention perspective

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5.3 Assessment of some of the leading PMS approaches against the taxonomy of requirement clusters

In this section some of the most recognised existing performance management and measurement frameworks will be assessed against the set of requirement clusters the author has defined in the previous sections (Figure 32). Focus is put especially but not exclusively on the knowledge reuse and invention aspect. Some of the approaches are described in more detail in chapter 3 and some of them are outlined in Appendix A of this thesis.

The objective of this section is to identify the design gap with regard to the fulfilment of the requirements for a PMS from a reuse and invention perspective for NPD. This gap analysis serves as a concrete cornerstone for the formulation of a functional specification for reuse and invention oriented PMS functions suitable for NPD environments. It is key to understand that the assessment of those approaches took place according to the author's best knowledge and might even be biased through the research focus. The author therefore does not claim general validity of this assessment, instead he wants to give indication, for the context of this specific research, where there might be the biggest need for action for the development of new performance measurement functions.

Further even though reuse and invention oriented requirements have not been met so far by some of the frameworks it is possible to imagine some achievement of the requirements through (currently not existing) specific implementation methods.

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PMS approaches / Requirement Clusters	Shareholder Value Analysis (Rappaport, 1998)	Rouse management approach (Lim, 1998)	The CARDS approach (HQO, 1995)	Balanced Scorecard (Kaplan and Norton, 1996)	Performance Pyramid approach (Lynch and Cross, 1995)	Performance Prism approach (Neely and Kennerly, 2000)	Skandia Intelligent Enterprising (Skandia, 1998)	Knowledge Indicator Scheme (North et al., 1998)	CMM (Paulket al., 1995)	EFQM (Badiag and Frech, 1999)
Standardisation	- Shareholder value creation as main measure throughout the whole operation - Basing on standard accounting principles	- Explicitly recommended - Framework is potentially stable over time	- Explicitly supported through matrix framework, metric worksheet and automation - Framework is potentially stable over time	- Not explicitly supported, possible through customization - Standard framework is potentially stable over time	- Not explicitly supported, possible through customization - Framework is potentially stable over time	- Not explicitly supported, but possible through customization and use of catalogue - Framework is potentially stable over time	- The framework and tools serve as a company-wide standard; measures are subject to the particular user organization - The framework is potentially stable over time	- Not explicitly supported and therefore entirely subject to customization	-The approach provides standardised structures, measures and evaluation procedures	-The approach provides standardised structures, measures and evaluation procedures
Data processing mechanism	- Not explicitly provided, however data might be processed like in financial accounting environments	- Various mechanisms discussed (e.g. economic models, assessments, etc.)	- Explicitly supported through automation	- Not explicitly provided, however there are some commercial SW products on the market	-Not provided	- Not provided	- Originally not provided; recent Dolphin software addresses this issue partly	- Not provided	- Not provided	- The European project enatled developed an enabling IT
Transparency	- Only transparent from a financial point of view	- Framework allows for transparent set-up - Cause-and-effect relations are implicit - Not explicitly supported, but recommended in carrying out the six-step process	- Requires familiarisation with CARDS program - Distinction of causes and effects	- Four perspectives allow for transparent set-up - Cause-and-effect relations are a basic principle	- The various fields of the Pyramid allow for transparent set-up - Cause-and-effect relations are a basic principle	- Logical order of facets explicitly provides means-and-relations - Measurement catalogue explains purposes of each measure	- Transparency of intellectual values are the main ration-ale - Set-up of the Navigator assumes a means-end relation	- Addressed through reference model of knowledge- and financial balance sheet - Indicator categories support cause-and-effect relations	- Through clearly defined key process areas, a well recognised 1-5 scale, common features and a clearly defined process the system set-up is very transparent	- Through clearly defined dimensions and a clearly defined process the system set-up is very transparent
Participation	- Involvement of all shareholders	- Not explicitly supported, but recommended in carrying out the six-step process	- Not explicitly addressed	- Top-down design, but participation of users and proc-ess-owners in implementation recommended	- Top-down design, but participation of users and proc-ess-owners in implementation recommended	- Not explicitly addressed, but participation of users in implementation is recommended	- Recommended in the course of implementing the tool	- Not explicitly supported	- The model gives clear recommendation which stakeholders should be involved in the process, the overall set-up is very participative	- The model gives clear recommendation which stakeholders should be involved in the process, the overall set-up is very participative
Alignment	-Measures are aligned to corporate objectives	- Alignment through goal-question-metric paradigm	- Alignment through matrix framework	- Alignment with strategy is a basic principle - Purposive communication of strategy and goals	- Alignment with strategy is a basic principle - Purposive communication of strategy and goals - Focuses on internal *and* external perspective	- Alignment with stakeholder satisfaction is a basic principle	- Alignment to the each user organisation's goals and strategies is a basic principle	- Explicitly supported through indicator categories	- The alignment to strategic objectives is *more* done on an implicit manner and not explicitly supported	- The alignment to strategic objectives is more done on an implicit manner and not explicitly supported
Comprehensiveness	-Purely financial orientation - No explicit alignment to operations, like NPD	- Limitation to factors and aspects of software reuse - Clear addressing of the reuse perspective but no complete set of measurement perspectives - Provision of a rich set of reuse indicators - Provision of a *sound* reuse process and organisational framework - No supporting infrastructure	- Limitation to CARDS stakeholders, products and processes - Provision of a reuse metric definition process	- Explicitly supported through four perspectives - Balanced set of measures is a basic principle - The Learning and Growth facet might support the invention aspect - Focus on intangibles was the motivation for the framework	- Explicitly supported through the structure of the Pyramid - Balanced set of measures is a basic principle	- Explicitly supported through five facets and measurement catalogue - *Some of the suggested* measures could be interpreted as knowledge oriented measures - Knowledge Asset thinking - Provision of knowledge asset related measures	- Provides a comprehensive picture in combination with traditional accounting methods and –tools only - Comprehensive IC *measures* catalogue supports also knowledge perspective - Different measurement perspectives addressing the knowledge perspective with the renewal facet - Provision of an indicator development process	Comprehensiveness supported through combination of knowledge- and financial-based measures	- The system is comprehensive in a way that for each key process area measures are identified, however these measures might not be appropriate for operational PM	- The system is comprehensive in a way that for each key process area measures are identified, however these measures might not be appropriate for operational PM
Effectiveness	-Integration into existing accounting systems	- Effective integration in existing management systems is a basic principle - Matter of customization and implementation	- Explicitly supported through automation and CARDS franchise plan	- Not explicitly supported, but reported from practice - Matter of customization and implementation	- Not explicitly supported, but reported from practice - Matter of customization and implementation	- Not explicitly supported, but proposed by developers - Matter of customization and realization	- Integration in existing systems is a basic principle	- Explicitly supported	- As a CMM is carried out maybe one time a year there is no integration in existing systems	- As a EFQM is carried out maybe one time a year there is no integration in existing systems
Operability	- Framework is clear and simple but remains on a rather theoretical level	- Recommended integration in day-to-day processes and "Reuse driver" metrics	- Explicitly supported through "Process" matrices	- Supported through "Internal business process" perspective and "Learning and growth" perspective - Integration in daily practices addressed through setting of operational goals and initiatives	- Explicitly supported through the lower levels of the Pyramid ("The operations")	- Supported through transparent architecture and the "Process" facet and "Capabilities" facet - Matter of customization and realization	- Supports management tasks, but hardly routine operations - Rather a communication tool, than an instructive tool	- Considerably instructive (*limited though*) but rather on managerial level	- Not supported	- Not supported

Figure 32: Assessment table for some of the leading PMS

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The figure above shows that especially the knowledge reuse and invention oriented requirements (Table 14) have hardly been met by today's PMS framework implementations. Therefore emphasis will be put in meeting these requirements within this present research.

5.4 Functional specification for reuse and invention oriented PMS functions for NPD

In the previous sections, the author has provided a taxonomy of requirement clusters, which he mapped with existing solutions identifying the gap and revealing the detailed need for action.

Based on these findings and the identified gap, the author will propose here a functional specification for the knowledge reuse and invention oriented PMS functions presented in this thesis. The reader should note that the term functional specification should not be understood in the narrow and technically oriented sense. Instead the functional specification tries to translate the requirements into tangible features and design principles.

- Standardisation – the solution has to provide standard measurement procedures and techniques for measurement of reuse and invention assets. Clear and simple drill-down and aggregation mechanisms for asset related and non asset related measures using simple arithmetic operators should be envisioned. The implemented units of measure, frequency of measurement and reporting and formats have to be harmonised across the user organisation through provision of standardised reporting formats and templates. The system will support the coherent and standardised definition of measurement frequencies and responsibilities. These standards are intended to remain valid and stable over time, but are subject to frequent review. The model will define reference default standards (measurement frequencies, standard measures, standard reporting formats, partly standard target values), which can be adjusted to the user organisation's requirements and preferences. The measurement framework should provide standard measurement dimensions and subjects for reuse and invention. The model should support the consideration of important standard NPD assets, like CAD drawings, standard parts, procedures, work-flows or users manuals.
- Data processing mechanism – the solution has to provide a technological infrastructure and functionalities for the purposive collection, organisation, dissemination, analysis, storage and reporting of data and information especially for reuse and invention of knowledge. It must also support knowledge management functionalities, like storage, search and retrieval. Clear information flows will be provided which will be supported by an enabling IT system. This data processing infrastructure should be adjustable to the user organisation's requirements and capacities. The data processing should be supported through an infrastructure, which offers a knowledge oriented view based on knowledge asset structure models. This infrastructure has to represent on the one hand a process-oriented extension of strategic PMS and on the other hand the PMI provides an active improvement function for reuse and invention.
- Transparency – the solution has to be clearly and simply structured. The visualisation and reporting formats must ensure a succinct overview on different levels of granularity reflecting the very specific users' reuse and invention needs. The measures are significantly and logically interrelated using classification schemes. The system must be customisable to focus only on the most relevant user specific reusable knowledge. The solution has to provide navigation functionality which allows navigation along for example organisations, projects, processes or disciplines due to the complexity of NPD environments. The aggregation rules must be clear and simple using simple arithmetic operators. The number of measures should be very

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limited and measures should be common for the whole organisation. Standard measures for the knowledge assets should be defined. The build and implementation process must be repeatable using standard templates, milestones and graphical templates. The enabling technology must be clear, simple and intuitive.

- Participation – the system set-up must support the involvement of users and measurement subjects in design, build, implementation and operation. The system must enable the definition of a role concept for measurement collection and reporting as well as the definition of the various roles required for the build and implementation of the system. Reuse and invention related roles like reuse certifier or idea manager should be enabled to support a comprehensive reuse and invention process. The processes for target definition, access rights and personalised views must be as participative as possible and be supported by the systems functions. Communities of practice structures, being a very emerging organisational concept of communication (Wenger, 1997) should also participate in the reuse and invention management and measurement framework.
- Alignment – the solution has to support and reflect the formulation and reflection of goals, strategies and initiatives especially from a reuse and invention perspective. Through application of visual metaphors the alignment to strategy should be communicated throughout the organisation. Operations have to be consequently aligned to companies' strategic objectives, through a sound build and implementation process for measures which translate goals and strategies into action. On the other hand the strategy formulation should elaborate on the organisation's core competencies through taking into consideration the organisational knowledge base of the company. The solution should communicate these items purposively to all relevant stakeholders. The system should thus not only be aligned from top down instead also bottom up strategy definition should be supported through the system. The PMS should be aligned to existing reuse repositories and to invention, human-centred tools like Community of Practice tools.
- Comprehensiveness – the PMS should provide a balanced set of measures, which capture all tangible and intangible aspects of performance, especially from the very specific reuse and invention perspective. A multi-dimensional structure should provide a view on the measurement subject from diverse, complementary perspectives. The solution has to pursue a holistic set-up reflecting on the structure of the organisations, processes and disciplines which comprise the NPD system. The solution should support the definition of clear system borders ensuring that the considered NPD system is viewed in a holistic way. The PMS framework has to be integrated in day-to-day operative improvement tools for reuse and invention. The system has to be efficient, time and cost effective both with regard to use and with regard to implementation.
- Effectiveness – the solution should provide the capability to be limited to key requirements of the user organisation. It should integrate with existing management and control systems and procedures. Measurement and reporting procedures are functionally adjusted. The system has to offer a sound balance between costs and benefits. The system should be adaptable to the various needs of different customers. The solution has to provide procedures on how to identify the right reuse and invention assets in a company and on how to identify the right measures for the organisation. A supporting enabling technology has to be lean, clear and user-friendly.
- Operability – the solution has to realise the integration of measurement, reporting and analysis in daily routines and working environments. The system can be communicated and used as an instructive tool. It should provide a selection of measures controllable by the measurement subject. It should support strategic performance management but also operative day to day engineering decision support with

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regard to reuse and invention. The procedures and tools have to be intuitive especially with regard to the enabling technology.

This functional specification will serve as a concrete guideline and landmark for the following detailed design of the performance measurement functions in the following chapter. The validation activities will mainly verify whether the functional specification is sufficiently met by the provided theory.

5.5 QFD assessment of user needs against the functional specification

The purpose of this section is to elaborate on the relevance of the various constituent parts of the functional specification stated above for the different user companies. This activity will help focus for detailed theory development and contribute to subject understanding which satisfies the case study companies.

Different user needs are mapped within a simplified Quality Function Deployment (QFD) against the functional specification. The assessment of the functional specification through the "voice of the customer" will give further indication on which design principles emphasis should be put during the further development efforts. The detailed descriptions of the case studies presented in chapter 8 might support a better understanding of the QFD results. The QFD process started with the analysis of the users' needs and requirements (1st column in Table 15, Table 16, Table 16 and Table 18) which they identified within facilitated focus groups. Subsequently they were provided with the functional specification presented in section 5.4. The mapping of the needs with the functional specification has been facilitated by a company-internal champion. The QFD process is explained in greater detail in section 2.2.6. It should be noted that all user companies invested considerable effort in the elaboration of the QFDs, the resulting data are therefore to be proposed as being rich and deep.

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5.5.1 The Gear Manufacturer's needs

Characteristic Number	User needs / Functional Specification	Weighing factor of the user needs (WF)	1. Standardisation	2. Data processing mechanism	3. Transparency	4. Participation	5. Alignment	6. Comprehensiveness	7. Effectiveness	8. Operability
1	Decision support regarding reuse	8		2	2	2		2	2	2
2	Communication of reuse and invention strategy throughout the organisation	6		2		2	3			
3	Store for reuse and invention assets to become more efficient	10		2	2			3	2	2
4	Explicit measurement of customer contribution to NPD success	7	2	2		2				2
5	Specific measures for efficient reuse of knowledge	6			3	3	3			
6	User friendliness of the solution	8	2	2	3	2	2	2	2	2
7	Minimal additional effort in maintaing, migrating, processing data	8	2	3		2			2	2
8	Involvement of all stakeholders	5				2	2	2		2
9	Solutions should be based and rely on proven standards	7	3							
10	Easy and cost effective implementation of the PMS	8	3		3		2			2
11	Fulfilment of the "80-20" rule	9			3	3			3	
12	Improving the quality of the offer process through a controlled management of knowledge	6					2			
	Function Importance (FI)		91	102	129	129	90	72	95	108

	Need level (NL)
3	high need
2	moderate need
1	low need

FI = Sum (NL*WF)

Table 15: Overview on the QFD done at the GM

Result of the QFD:

The QFD diagram above clearly indicates that the operational aspect of performance measurement is very dominant at this company. The company needs an infrastructure which supports them on a day-to-day basis in managing their organisational knowledge base especially in terms of reuse and invention (cluster 2 and 3). The GM wants to have very few, but comprehensive measures. The importance of this aspect expresses their need in a comprehensive PMS set-up which allows them to manage NPD performance in a holistic way. Currently this company does not employ a complete strategic PMS. The importance of the cluster 2,3,4 and 8 reflects the company's desire for a clear, transparent, participative and efficient set-up of the whole system.

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5.5.2 The Financial Service company's needs

Characteristic Number	User needs / Functional Specification	Weighing factor of the user needs (WF)	1. Standardisation	2. Data processing mechanism	3. Transparency	4. Participation	5. Alignment	6. Comprehensiveness	7. Effectiveness	8. Operability
1	Efficient management of corporate and local knowledge	10		3			2		2	2
2	Extension of Navigator functionality to operations	8	2		3	2			3	2
3	Support the PD Community of Practice with a knowledge management and measurement solution	8	2	2	1	2	2	1	2	2
4	Measures for knowing how inventive the company is	8					3	2		
5	Simplicity of solution, apply 80:20 rule	10	3		3	2				3
6	Measures for top management assessment	7								
7	Minimal additional effort in maintaing, migrating, processing data	9		3		1				3
8	Involvement of all stakeholders in the design of the system	6			2	3				
9	Solutions should be based and rely on proven standards	8	3							
10	Easy and cost effective implementation of the PMS	8				3				
	Function Importance (FI)		86	73	74	103	60	24	60	109

	Need level (NL)
3	high need
2	moderate need
1	low need

FI = Sum (NL*WF)

Table 16: Overview on the QFD done at the FS

Result of the QFD

For the FS, the knowledge management and measurement aspect over different physical sites is of core interest. The company seeks support of their existing reuse and invention processes. The company needs a very operable and simple solution as due to the very fast and dynamic growth and lack of resources within the company usage training has to be reduced to a minimum. This need is mainly met by cluster 1, 3, 4 and 8. The extension of the company's existing strategic measurement system to operational levels is another core need which is mainly met by cluster 3, 7 and 8.

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5.5.3 The Automotive supplier's needs.

Characteristic Number	User needs / Functional Specification	Weighing factor of the user needs (WF)	1. Standardisation	2. Data processing mechanism	3.Transparency	4. Participation	5. Alignment	6. Comprehensiveness	7. Effectiveness	8. Operability
1	Engineering decision support for reusing existing knowledge or creating new knowledge	10		2	2	2		2		2
2	Measurement of fulfilment of strategy	6		2			3			
3	A tool for monitoring and controlling the company's NPD performance	5						3		2
4	Storage of the company's construction knowledge equipped with a quality indicator	9	2	2		2				3
5	Communication tool for promoting company's R&D strategy	5			3	3	3			
6	User friendliness of the solution	8			3					
7	Minimal additional effort in maintaing, migrating, processing data	8	2	3						
8	Explicit consideration of financial indicators	5					2	2		
9	Solutions should be based and rely on proven standards	6	3							
10	Easy and cost effective implementation of the PMS	7	3		3		2			2
11	Fulfilment of the "80-20" rule	7			3	3			3	
12	Understanding the impact of reuse and invention on the NPD performance	5					2			
13	Operative engineering decision support	8		3			2	3	3	
14	Strategic planning, monitoring and control support	7	2	3			3			
	Function Importance (FI)		87	119	101	74	104	69	45	71

	Need level (NL)
3	high need
2	moderate need
1	low need

FI = Sum (NL*WF)

Table 17: Overview on the QFD done at the AS

Result of the QFD

Similar to the GM, the primary need at this company is to have at its disposal a process-oriented performance measurement solution which supports the company in managing the NPD knowledge assets (cluster 2). Alignment to strategy (cluster 5) is also of great importance as the company wants to ensure that the overriding R&D strategy of being a prospector is communicated, monitored and ensured throughout the whole company.

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5.5.4 The High Tech company's needs

Characteristic Number	User needs / Functional Specification	Weighing factor of the user needs (WF)	1. Standardisation	2. Data processing mechanism	3. Transparency	4. Participation	5. Alignment	6. Comprehensiveness	7. Effectiveness	8. Operability
1	Quick results (from decision to first usable report)	8	1			1			3	
2	Ease of use for the end user	8	1		3	2			1	3
3	Integration with existing PMS systems	5	1	3		2	3		3	2
4	Low initial investment	5							3	
5	Triggers practical improvement efforts	10	2		1	3	3	2		1
6	Cost of maintenance (mainly administrator time)	4	3	3		1			3	2
7	Clear presentation of the performance	9	2		3	2	2	2		3
8	Trustable information	8		3		3	2	2		2
9	Ease of customisations according to specific units needs	8	1			2	2			
10	Provision of a good detailed and overall picture of the innovation issues	10			2	2	3	3	2	1
	Function Importance (FI)		79	51	81	146	125	84	94	105

	Need level (NL)
3	high need
2	moderate need
1	low need

FI = Sum (NL*WF)

Table 18: Overview on the QFD done at the HT

Result of the QFD

For the HT the alignment of measurement activities (cluster 5) is a crucial need. Further, the participation of users and process owners (cluster 4) is considered to be key: Therefore the operational support with regard to reuse and invention and usability aspect of the system is a high need. The HT requires efficient and simple decision support for reuse versus creation of new knowledge.

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5.6 Conclusion and problem validation

The overall discussion relies on a deep understanding of the performance measurement and knowledge management subjects, therefore the proposed theory is proposed to be rich, solid and analytically derived.

As in the previous chapter decomposition principles have been applied which proved to be beneficial in terms of complexity reduction and transparency of method supporting above all an easier communication with the user companies and a coherent alignment of PMS purposes, requirements and design principles.

This work has helped to confirm the belief that especially the knowledge reuse and invention oriented requirements are not sufficiently met by today's implemented PMS tools. The analysis of the existing tools led to the formulation of a novel functional specification for reuse and invention oriented performance measurement. The functional specification has been mapped within simplified QFDs against the various user needs to obtain further indication about where to put emphasis in the detailed theory development.

It is important to note that the investigations presented in this chapter are not of a positivist nature as the knowledge reuse and invention topic is too heterogeneous, multi-faceted and phenomenological in nature. The author had a very specific understanding of the reuse, invention and NPD topic in mind when defining requirements for performance measurement from a reuse and invention perspective. The fact that some of the frameworks do not currently meet these requirements does not mean that the existing systems may not address the knowledge reuse and invention topic at all. In fact many existing functions in today's PMS implementations could be interpreted as *implicitly* supporting reuse and invention.

However within the specific context of this research the functional specification for knowledge reuse and invention oriented PMS functions presented in this chapter is certainly of a novel nature.

Summarising it can be stated that the elaboration of a solution for the problem identified at the beginning of this research work

"Currently there is no sufficient set of performance measurement functions available which improves knowledge reuse and invention to enhance NPD performance"

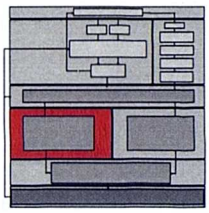
remains a decent and valid objective and provides a contribution to knowledge in this field.

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6 Design principles for reuse and invention oriented PMS functions

"Measurements - not data - are the foundation of management practice. Properly designed and used, measures can articulate strategy, drive change, shape behaviour, focus action, and align management around activities that lead to success. Without sensible, balanced measurements, most of your organisation's energy and actions are of no value to customers, to shareholders, or to employees.

Price Waterhouse Coopers



This sixth chapter presents design principles of novel performance measurement functions from a reuse and invention perspective. After a general introduction the author will present the measurement framework, introducing different measurement perspectives showing their relationships and discuss some visualisation metaphors for the measurement facets, navigation facilities as well as strategy alignment. Following that, a measurement catalogue which will help to make the measurement framework operational and which serves as a reference for build and implementation will be presented. The measurement framework and the catalogue rely on a Performance Measurement Infrastructure (PMI). The proven concept of mapping the NPD process into a reuse and invention asset structure model provides a sound basis for performance measures and metrics from an operational process-oriented perspective and provides at the same time a pro-active solution for reuse and invention performance improvement. Finally, the author will outline a software solution which enables the end-user to make use of the framework, catalogue and infrastructure concept in real-life industrial environments.

6.1 Introduction

Kennerley and Neely (2000) agree that any performance measurement system needs to offer a framework, a set of measures and an infrastructure for processing the measurement information. The author reflects on this basic need proposing a performance measurement framework, measurement catalogue and a performance measurement infrastructure (PMI) within this chapter from the specific knowledge reuse and invention viewpoint. These functions will be embedded within an innovative software solution (Figure 33). The fourth function provided is the holistic build and implementation path presented in the next chapter 7.

Thus, with knowledge reuse and invention being the focal point, these PMS functions allow for management of the organisational knowledge reuse and invention activity based on measurement. This complements, but also enhances traditional product-centred measurement approaches[40].

[40] During the course of the research this statement has been confirmed by many experts, like Scott Hawkins, Edna Pasher, Atai Ziv, Leif Edvinsson and practitioners who were involved in the design and validation.

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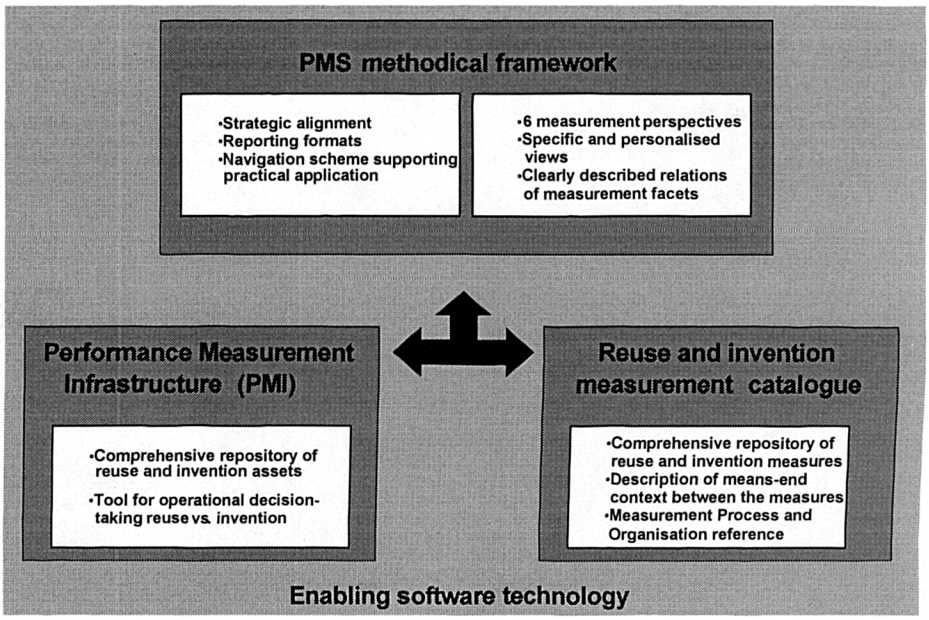


Figure 33: Overview on the reuse and invention oriented PMS functions (based on Kennerley and Neely, 2000)

6.2 The PMS framework

In the following sections the techniques, methods and rules applied and realised within the present performance measurement framework will be presented. On a high-level these they are divided into a classification of four: First, the design of performance dimensions of NPD to improve knowledge reuse and invention; second, the navigation aspect in complex performance environments, third, the use of graphical visualisation metaphors and finally the strategic alignment of the PMS framework.

6.2.1 Measurement perspectives

It is widely accepted that organisational performance needs to be viewed from several perspectives (Kennerley and Neely, 2000). The Balanced Scorecard (Kaplan and Norton, 1996a) meets this requirement by its four perspectives and the Performance Prism (Neely and Adams, 2000a) by its five facets. This counts even more for the unstructured and knowledge-intensive phases in NPD (NIMCube, 2000e). A composition of perspectives is hence vital to obtain the proposed multi-dimensional reflection of NPD. Indeed, it is found reasonable to derive the various measurement perspectives from the findings of the field research, the insights gained from the state-of-the-art review and the chosen definition of innovation which is innovation = (reuse + invention) x exploitation (section 4.3 and Dvir et al. (2000), Brockhoff (1993) and Hahner (2000)).

The following Figure 34 gives an overview on the NPD measurement perspectives and subjects proposed in this thesis. They will be discussed in detail in the following sections.[41]

[41] The reader should note that not all measurement perspectives are outlined in the same level of granularity within this thesis. The author preferred to focus more on the perspectives he considers novel, rather than gathering vast amounts of existing data with regard to well-known and recognised performance dimensions.

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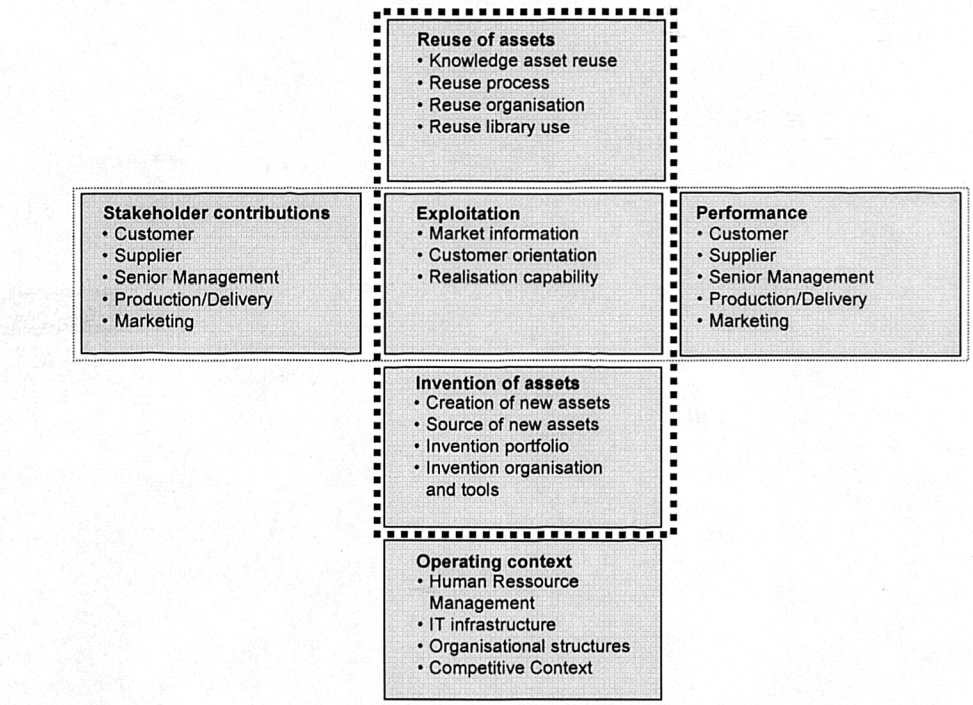


Figure 34: Overview on the measurement perspectives and subjects of the PMS framework

Stakeholder contributions

Since the early 1980s considerable attention has been paid to a stakeholder-oriented approach to management of strategy and organisation (Freeman, 1984). In terms of performance measurement, Kennerley and Neely (2000) have recently adopted such a stakeholder-centric view. The proposed inclusion of stakeholders in NPD reuse and invention management originates from the interdisciplinary nature of product development (Ulrich and Eppinger, 1995). Excellent NPD depends to a large part on the input of various parties; i.e. externals, such as suppliers, customers, regulators and the public, as well as internal functions and entities, such as marketing people, senior management and production engineers. Especially in a knowledge-intensive discipline hardly any organisation will be capable of operating autonomously. The acquisition and share of skills, experiences and know-how, are not by chance considered core knowledge management activities (Probst et al., 1997 and Bukowitz and Williams, 2000). In a similar vein, many popular performance management and measurement frameworks comprise measures and structures addressing their stakeholders. The Balanced Scorecard for instance reflects employees' contribution on the "Learning and growth" perspective (Kaplan and Norton, 1996a), the EFQM model has the enabler criteria "Leadership", "People" and "Partnerships and resources" (Bading and Frech, 1999) and the Skandia Navigator centres around the "Human focus" (Edvinsson and Malone, 1997).

A measurement perspective "Stakeholder contributions" is suggested to describe and understand what NPD requires from its stakeholders and how these requirements are met. It positions knowledge reuse and invention in a larger, inter-organisational context. To make the measurement system more operational a sub-categorisation of this dimension is recommended. This sub-categorisation of this dimension and all the other dimensions might be highly company specific. The author calls those sub-categories from now on "subjects". Those subjects must not be understood as a straight jacket for companies, instead it might be a stimulus for discussions Many discussions with users and experts have informed the creation of the following subjects as a prescriptive starting point for further company-specific refinement (chapter 7):

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- Customer

Customer needs for new products are one driver for NPD innovation and reuse (Edvinsson, 2000). Their direct, unfiltered, feedback is the highest quality information the NPD unit receives (Wheelwright and Clark, 1992). Companies may want to know how often the customer talks and feeds back to the NPD unit. For example, they may therefore measure the percentage of time that the NPD staff spend in direct customer contact.

- Supplier

Since the dramatic emergence of concepts, like "Just-in-time" the supplier contribution to NPD success is a key factor (Bidault et al. 2000 and Moerman et al., 1993). Supplier contribution can be measured in terms of timeliness, failure quotes, flexibility and costs.[42]

- Senior Management

The company's senior management regularly acts as sponsor of a product development programme (Graaf, 1996). Management finances and supports development projects and sets strategic objectives for invention and reuse. Senior management contribution can be measured in terms of personal involvement, awareness, funding and resources provided.

- Production/Delivery

In the age of concurrent and systems engineering with highly paralleled, integrated and systematic processes, it is more crucial than ever to align engineering and production processes as soundly as possible (Prasad, 1996 and Graaf, 1996). The contribution of production in the product development process can lead to a significant reduction of failure costs and therefore enhance NPD performance[43] and might be measured in terms of physical participation and communication. Therefore during product development, the production environment is one of the key stakeholders for successful product development (Blanchard and Fabrycky, 1997).

- Marketing

Marketing supplies key competitive and consumer feedback to NPD (Graaf, 1996). This feedback is a key driver of innovation (Cooper and Kleinschmidt, 1986). Firms may want to gain an understanding of the level of co-operation between these areas by explicitly measuring this aspect.

Operating Context

Innovation requires a particular environment to happen and to excel (Pasher, 2000). Several academics active in the theory and practice of knowledge and organisation have recently begun promoting the idea of the knowledge- or information ecology (Pór, 2000; Pór, 2001 and Nardi and O'Day, 2000). Pór (2000), one of the leading experts on the field stated: "An organisation learns what it knows by cultivating its knowledge ecosystem in which information, insights and inspirations cross-fertilise and feed one another...the study, design, and improvement of individual and organisational ecosystems are the focus of Knowledge Ecology (KE)." Nardi and O'Day (2000) have defined an information ecology as being an environment where people, practices, values and technology systematically interact. Alike, Amidon (2000) speaks of a new

[42] The case study 1 company developed a supplier contribution index which consists of the variables indicated above.

[43] Pfeifer (1996) describes this phenomena with the "10 rule of failure costs", which says that the later that failures are discovered in the value chain the more (up to factor 10) expensive the costs for remedies become.

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management architecture organisations would have to adopt in order to nurture reuse and invention of knowledge. The so-called I-form would integrate the human, the behavioural and technological aspects of an enterprise. The sequel of the 1995 best-seller "The Knowledge Creating Company" of Nonaka and Takeuchi (1995) introduces the term "Ba" (Krogh et al., 2000), which is Japanese for "place". Ba is, just like ecology, used as a metaphor for an environment fostering the emergence, dissemination and flow of knowledge. The capabilities of an organisation to shape and nurture such an innovation friendly context are reflected on this facet.

Moreover, an innovative organisation also requires sound knowledge of the context beyond company boundaries (Pór, 2001). In other words, awareness of for example competitors, of regulators and the community. From a systems theory viewpoint, the organisation is part of a whole and it has to familiarise itself with internal and external elements of the system as close as possible.

Last but not least, the Skandia Navigator has taken a similar position and deliberately captures the environment (Edvinsson and Malone, 1997). The Performance Prism (Neely and Adams, 2000a) provides measures describing the organisation's surrounding and the EFQM model (Bading and Frech, 1999) is also particularly aware of the contextual factors.

The author therefore addresses the need to manage and describe this enabling and influencing environment by the inclusion of an "Operating context" facet. It is designated to support the description and maintenance of an adequate system, of interior and exterior structures, facilities and relationships. Again, it is suggested a categorisation in company specific subjects. The following list suggests some subjects which were widely supported during our action research:

- Human resource management

  Changes in social and economic relationships, accompanied by developments in IT, have triggered a shift to people-centred business and management styles. In the new economy, employees' skills, and commitment are now key drivers of knowledge innovation and success. A vast majority of KM practitioners and researchers acknowledge human resource management as being a contributor to corporate creativity and innovation. This trend in KM is sometimes referred to the 3rd wave of KM (Sveiby, 2000). With this context in mind the Operating context's facet human resource management subject might support these sub-levels and measures:

  - Adaptable and flexible HRM processes: how quickly can the NPD unit respond to changing situations in a dynamic and volatile environment when it needs to identify and acquire new staff? If they are unattractive to potential NPD employees the firm's ability to acquire "new blood" (who bring fresh innovative perspectives to the NPD process) may need improvement. To understand how attractive they are to potential employees, companies might measure the length of time necessary to fill an opening in the NPD unit.
  - Investment in and review of personnel competence advancement: is the company making the necessary investment in training and skill development so it can fully understand and seize new opportunities in today's fast changing environment? Companies might understand their level of ongoing skill development by measuring the percentage of work time their NPD staff spend in training classes and programs.
  - Incentives, rewards and recognition plans: are peoples' efforts in effective invention and reuse recognised and rewarded? In the era of the "free agent", highly skilled knowledge workers are able to easily move to another company. Companies seeking to retain their staff (with their ability to quickly reuse prior

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solutions based on personal experience) must demonstrate their appreciation beyond salary and basic benefits. Above all in engineering environments people might appreciate other, non-financial ways of recognition much more than purely financial rewards[44]. As an example of how effective they are at recognising employee contribution to reuse and invention, a company might measure and report the percentage of NPD staff covered by incentive programs aimed at encouraging reuse and innovation.

❑ Technological infrastructure

Information and communication technology (IT) is a major enabler in NPD (Terwiesch et al., 1998). Technology is more than just the "glue" holding the company together. In today's wired economy the level of technological infrastructure is a key to determining how effective the firm can be at leveraging knowledge investments.

NPD staff and departments use IT to communicate with each other, external and internal customers. They use IT to increase their productivity by increasing access to research resources. Without a sound technological infrastructure the best invention and reuse strategy's effectiveness will be reduced. Therefore, as part of an ecological assessment of the NPD invention and reuse environment, understanding the current level of the IT infrastructure is crucial.

With this context in mind the operating context facet's technological infrastructure subject might support these sub-levels and measures:

- Connectivity: is the NPD unit "wired" to one another and to the larger outside world? People share knowledge and acquire new knowledge much easier by using the power of networked technology. Companies may want to understand their NPD staff's ability to harness this power, and they might measure the percentage of their NPD staff with network access to determine whether this powerful tool is being used.
- Up-to-date tools: in today's rapidly changing technological environment, software and hardware quickly becomes obsolete. The NPD unit's ability to fully realise technology's power is limited to how up-to-date their tools are. To understand whether their NPD staff have access to the best tools for innovation and reuse, companies may measure the "generational" difference between versions of their NPD tools and those on the current market.

❑ Organisational Structures

Assessing an organisation's adequacy and ability to respond to the requirements of an innovative and knowledge-intensive context is essential in shaping the NPD ecology (Filos and Banahan, 2000).

The way in which an organisation is structured has tremendous implications on operation efficiency and effectiveness (Boutellier et al., 1998). In a knowledge-intensive area like NPD, the levels of management hierarchy, organisational complexity, lines of report and communication are considered vital success factors in creating an environment that either encourages or inhibits innovation and reuse (Edvinsson, 2000). How does this occur?

Excess management layers between senior executives and shop-floor process owners is key to deployment of strategy, to feedback and to commonality of purpose. As strategy and communication are likely to get confused with increasing complexity, it is no surprise that innovative knowledge organisations tend to employ flat hierarchical management structures. This improves immediate vertical

44 This statement was confirmed by the interviewed experts Atai Ziv and Dr. Edna Pasher.

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communication and facilitates the dynamic exchange of know-how, of lessons and expertise.

Beyond flat management structures, knowledge workers are being empowered to take greater responsibility for their actions. As a result more and more companies refrain from command-and-control management and are embracing flexible team and project structures instead. These self-organising, autonomous work-groups, task–forces and temporary assignments increase the sharing of people (and their skills and knowledge) across the organisation. NPD, where the generation, exchange and reuse of knowledge assets are core requirements, benefits from such adaptively arranged organisations.

With this context in mind the Operating Context facet's organisational structure subject might support these sub-levels and measures:

- Communication ease: are concepts, ideas, and problems, difficulties and lessons learned being rapidly shared across the NPD process and unit? Slow communication inhibits an organisation's ability to recognise, understand and respond to new invention or reuse opportunities. Companies wanting to know whether communication is flowing or blocked might measure the frequency of team meetings to better understand this area.
- Management's formal and informal support for innovation: is innovation an explicit component of corporate vision and strategy and does management live up to this commitment? Companies may use employee surveys to find out if their staff feel that management is "walking its talk" by rating the alignment between published corporate strategy and actual management actions.
- Empowerment: does the NPD unit have the freedom and responsibility to carry out research projects without encountering a large management overhead? Being able to quickly realise, and seize, an innovation or reuse opportunity requires a relatively fast response. Companies might use the number of approvals needed to launch a new research project as one way to monitor if they are supportive or inhibitive of innovation.

❑ Competitive context

An organisation's performance depends on the competitive and financial context within which it operates. Competitors not only introduce new products, but they establish the external benchmarks that provide the relative background that NPD innovation and reuse occurs against. It is important to obtain deep understanding of the competition's current level of performance to respond to changes in this context.

With this context in mind the Operating context facet's competitive context subject might support these sub-levels and measures:

- New products: are the NPD staff aware of competitive new products? New products not only drive the consumer demand for innovation, they are also potential reuse opportunities. Therefore a company may decide it wants to know whether its NPD staff are tracking their competition's new product developments. One measure of this activity might be the number of trade shows attended by NPD staff.
- Best Practices: are the NPD staff aware of competitive best practices? Competitor best practices provide innovation opportunities by raising the quality bar. A company may want to know if its NPD staff by incorporating these best practices within their unit. To understand if this is occurring, a NPD unit may measure the number of industry quality conferences its staff attended.

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- Benchmarks: are the NPD staff aware of competitive benchmarks? Benchmarks are the standard against which a firm measures itself. This measurement encourages invention and reuse by providing a sense of whether it is succeeding or failing. Companies may want to know the percentage of competitive benchmarks they are exceeding to better understand their competitive position.

Reuse of assets

Reuse of knowledge assets is the first item of the innovation definition (section 6.2); the avoidance of "re-inventing the wheel" is often considered the low-hanging fruit of knowledge management (Bukowitz and Williams, 2000). The initial position of this research was declared to satisfy the need of a reuse and invention oriented performance management and measurement. Building on this, the reader learned earlier that knowledge reuse equates with efficiency and effectiveness in management of (in)tangible assets. This gives reason to the reflection of measures deliberately focusing on reusable assets and reuse processes. The rationale behind such measurement is, according to Lim (1998), to support an organisation in determining whether specified goals of a reuse program are achieved. This purpose necessitates describing contents and value of, as well as performance and investments in, the stock of reusable assets. Measures and metrics qualified for such assets bring forth whether, and if so, to what extent, the reuse potentials are realised. It allows for detection of overlooked opportunities, for leveraging under-utilised assets and for determination of knowledge efficiency as a whole (NIMCube, 2000e). Roth et al. (2000) and Säubert and Bürgel (1998) have stated that first, the direct business impact of reuse was difficult to measure, and second, operative and efficient knowledge management required a process-oriented view on reusable assets. The first concern is addressed by a particular "Reuse" perspective serving as a support function in illustrating the means-end relation of business success. The second point is answered by applying selective measures, which describe the particular reuse process. Against the background of the overall objective of this research and in consequence of the above arguments a specific "Reuse" measurement facet purports to be compulsory for purposeful management and measurement. The following listing shows some subjects which are proposed to be appropriate for managing and measuring reuse performance:

- Knowledge asset reuse

  Knowledge Assets are the core of an organisation's knowledge base or practices (Marr et al., 2001; Edvinsson, 2000). The management and measurement of reuse is therefore tightly aligned to those knowledge assets which are very company specific. Indeed the knowledge assets and their actual (re)use are a key success factor for business success in the knowledge economy (Warschat et al., 2000b). According to them the (re)use of these assets is a major contributor to a company's productivity performance. The knowledge asset reuse level is therefore a key subject to measure. The quality of knowledge assets is key if an organisation wants to ensure that only the "appropriate" knowledge of a company is being reused. A knowing company should also be able to forget knowledge (Nonaka and Takeuchi, 1995). Infrequently reused assets, for example, maybe candidates for potential commercialisation by external companies. Frequently used assets on the other hand might be continuously further developed. Section 6.4 provides a deeper insight into knowledge asset related performance measures. Lim (1998) stresses that different types of reuse of knowledge assets have to be established to manage the reuse process.

- Reuse process

  Reuse of knowledge and creation of new knowledge do not just happen, instead they are the integral phases of a knowledge value chain (Edvinsson, 2000).

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Knowledge Management processes are currently intensively discussed in literature (Probst et al., 1997; Wegemann, 1999, Säubert and Bürgel, 1998 and section 3.2). All the approaches have in common that the knowledge management activities are described through a sequence of activities. The efficiency and effectiveness of those processes should be measured like the efficiency and effectiveness of the NPD process itself (Gibbert et al., 2001). Typical phases of the knowledge management value chain can be knowledge identification, knowledge acquisition, knowledge storage, knowledge sharing, knowledge reuse and knowledge creation[45] (Roth et al., 2000, Probst et al., 1997, see also section 6.4).

- Reuse organisation[46]

Efficient and effective reuse has to be supported through an appropriate organisational model (Lim, 1998). The performance of reuse roles, like knowledge broker, knowledge champion, knowledge librarian, reuse facilitator and knowledge controller might have a significant impact on the overall NPD performance. The deployment of new organisational forms, like for example communities of practice (CoPs), might also contribute to a better reuse performance.

- Reuse library use

Lim (1998) suggests that reuse has to be supported through referring infrastructures like libraries and repositories. Performance criteria with regard to this subject might be the use and employment of the library(ies) and repositories, their quality in terms of structure, contents, accessibility and user-friendliness.

Invention of assets

Invention represents the second item of the innovation definition (section 4.3); as such, it is a further determinant of successfully innovating in NPD. In chapter 1, the author formulated the challenge for knowledge-intensive organisations to strike a balance between reuse of knowledge and invention of knowledge. Indeed, the reciprocal and complementary relationship between the two aspects is a common theme in research on and practice of knowledge management (NIMCube, 2000b and Menon et al., 1998). Having defined and justified a "Reuse" perspective, the idea of an "Invention" perspective would seem logical. However, the rationale behind this facet should be explained in more detail:

The perspective allows for the specific assessment of an organisation's creative abilities; the internal and external contributions to the knowledge base. Qualified measures diagnose whether and if so, to which extent, resources freed up through reuse, are employed for invention. Thus, an "Invention" facet describes the future value potentials created through newly generated knowledge assets.

Besides, some of the widely renowned and acknowledged performance management frameworks have applied similar perspectives. The Balanced Scorecard addresses invention within the "Internal business processes" and "Learning and growth"(Kaplan and Norton, 1996a) perspective. The Skandia Navigator assesses future capabilities on a "Renewal and development focus" (Christ, 1999 and Edvinsson and Malone, 1997), Sveiby's Intangible Assets Monitor provides the vertical dimension "Growth and development" (Sveiby, 1997) and the Performance Prism reflects inventive measures distributed over the three facets, "Processes", "Capabilities" and "Stakeholder contributions" (Neely and Adams, 2000a).

In summary, the symbiosis of reuse and invention, the need for knowledge-intensive companies to manage the intangible capabilities and the prevailing application of

45 The knowledge creation phase might also suit in the facet "invention"

46 This subject could also fit in the facet operating context. Discussions with the user companies and experts made the author suggesting this subject -as default solution- under the facet reuse.

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similar concepts in the domain of performance management, gives evidence to the required and fruitful inclusion of an "Invention" facet. The following subjects are proposed to be of special relevance:

- Creation of new assets

  The performance with regard to creation of new knowledge assets can be considered a key inventive capability (Amidon, 2000). Porter and Stern (2000) reflect extensively on ideas and patents being crucial invention assets. Beyond the pure number of created assets, also the exploitation potential, quality and feasibility might be important drivers to be measured.

- Source of new assets

  Knowing the sources for innovative ideas allows for feedback to contributors in future innovation development. Innovation coming from sources external to the company may indicate a need to increase the emphasis on internal idea generation. Conversely innovation primarily derived from internal sources may indicate a case of increasing "tunnel vision" and the potential loss of external innovations.

- Invention portfolio

  Hamel (2000) and Christensen (1997) identified different types of innovations and following the logic of the innovation equation presented in this thesis (section 4.3) also different types of inventions. A company should be well aware that the portfolio of inventions (for example small, continuous often technically oriented inventions or fundamental, "stressful" inventions) should be well aligned to the company's NPD strategy and goals.

- Invention process

  Thoroughly defined idea and patent generation processes with clearly assigned roles, gates and follow-up procedures might be appropriate as well to enhance the invention capability in a firm.

- Invention organisation and tools[47]

  The inventive capability of a firm can be supported through appropriate organisational structures (Wenger, 1999). According to Wenger (1999) communities of practice (CoPs) might be a very appropriate means to enhance the inventive capability in a firm as they fertilise cross-functional knowledge exchange which in return might be a source for invention. Further organisational structures might be think tanks, coaching principles and creativity teams. The application of creativity techniques and market scanning techniques might be measures for invention performance as well.

NPD Performance

NPD process performance measures the resultant quality, time, costs and flexibility of process execution (IDS Scheer, 2000). Brown and Svenson (1988) distinguish between NPD output measures such as patent, product and process oriented measures and NPD outcome measures such as cost, sales and product improvement measures.

Loch et al. (1996) have emphasised that an assessment of development process performance is vital to understand the important drivers of output. Such measurement is reflected on a particular "Performance" facet.

The author believes such control significant to ensure the effective and efficient translation of stakeholders' contributions into operations and eventually into output. As such, it presents the sum of "stakeholders' value created" (NIMCube, 2000e). A "Perform-

[47] This subject could also fit in the facet operating context. Discussions with the user companies made the author suggest this subject -as a default solution- under the facet reuse.

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ance" perspective then logically links the prior five perspectives to output (Figure 36). It measures the extent to which the NPD unit is meeting stakeholder expectations and indicates the current strengths and limitations of a NPD process. It presents the cumulative effect of contributions to NPD.

Thus, this facet contains the "classical" NPD performance and process output measures of for example time, cost and quality. Performance is the feedback mechanism for adjusting the contributions to NPD reuse and invention. As the notion of performance management in the context of reuse and invention builds on a process-oriented approach, the inclusion of this perspective is assumed obligatory. In order to provide a comprehensive picture and to address the mechanisms converting contributions into output, the author regards the facet necessary for the performance measurement framework. The same subjects as in the stakeholder contribution facet are suggested, following the approach from Kennerley and Neely (2000) as performance always should be expressed in terms of stakeholder expectations fulfilment.

Kaplan and Norton (1996a) stress that from a certain point of aggregation level most of the outcome measures are of monetary, financially oriented nature. Further on Kaplan and Norton (1996a) see in the product development process itself very much the innovation process which goes in line with the present approach innovation being the result of combined reuse, invention and exploitation throughput activities.

Exploitation

Efforts in creative and inventive R&D are unavailing, unless accompanied by a diligent exploitation and commercialisation strategy. In other words, reuse and invention have to contribute to the delivery of marketable products and have to be aligned to the strategic NPD themes of the company. The pitfall of creativity becoming an end in itself seems a widely held phenomenon of highly creative firms According to Smith and Alexander (1999) Xerox PARC's economically fruitless inventions are a very good example. Amidon (2000) emphasised: "Although innovation may be perceived as a creative process; creativity alone will not lead to prosperous innovation". She therefore explicitly adds a commercialisation phase to her understanding of an innovation process. The exploitation perspective addresses this problematic phase. It describes in particular how reuse and invention correlate with commercial and financial success. Porter and Stern (2000) agree that there is a gap between the ability of producing inventions (ideas) and the ability to translate inventions into measured productivity growth.

Hahner (2000) takes up the relationship of NPD and market performance in his recent dissertation project. He distinguishes innovation in a narrow sense, including invention and market introduction, from innovation in a broader sense, including market penetration and imitation. Figure 35 illustrates this understanding and underscores the demand for an outcome-oriented measurement perspective.

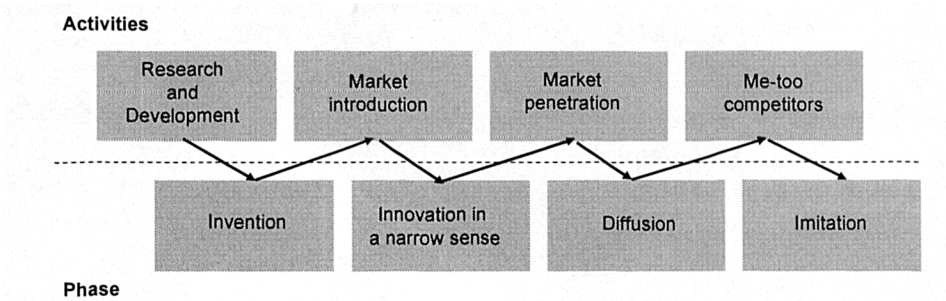


Figure 35: Generic innovation process in a broader sense (based on Brockhoff, 1993)

According to Roussel et al. (1991) R&D management and measurement went through three distinct phases. A first phase (1950 – 1970) considered technical performance measures exclusively, the second phase (1970 – 1990) focused on comparison of quantitative technical and economic criteria. Only when third generation R&D

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management emerged (since 1990), qualitative performance relative to market potentials and -success was determined and linkages to marketing and sales functions established. The importance of including marketability aspects in early NPD phases is also strengthened by a study of Commes and Lienert (1993), who estimated that hardly 12% of the observed R&D projects would be turned into commercially successful products.

Lim (1998) has performed a review of reuse economic models for cost justification in the area of reuse management. He observed that "...such models are important because they serve to gauge the economic worthiness of pursuing reuse." These theoretical and practical findings give considerable proof to the assumption that the definition of an exploitation-focused measurement perspective benefits the present performance management model.

For this facet the author suggests the following subjects:

- Market information

  As stated above, the possibility of activities in reuse and invention delivering saleable products have to be examined in the very early phases of NPD. Thus, a clarification of market opportunities and an analysis of market risks is vital to avoid developing at cross purposes. Market research, macroeconomic trend analysis and risk management are therefore regarded essential elements of NPD. Provided with reliable information, R&D would not only be capable of serving existing markets, but also support opening new markets.

- Customer orientation

  In today's buyer markets a product will eventually only be successful if it is suited to the customer's specific needs. Tailor-made solutions, which are fit for purpose are hence the decisive differentiator.

- Realisation capability

  According to Hamel (2000) and Christensen (1997) many companies are very inventive but fail to turn their inventive thoughts into marketable products. Engineers might very good in efficiently reusing knowledge but might not be effective in terms of goal achievement. Lynch and Cross (1995) align this realisation capability with effectiveness of operations. Thus, this subject addresses the alignment of the reuse and invention activities to the overall NPD strategic themes of the company.

The author is aware that his view on exploitation is driven through his knowledge oriented view on the subject. There are other authors like Kennerley and Neely (2000) who might see exploitation in a broader context elaborating on various subjects which the author outlined in the facet "operating context" (for example, infrastructures, processes, practices).

6.2.2 Interrelationships between facets

In Figure 36 the six defined measurement perspectives or facets are put into a causal relationship.

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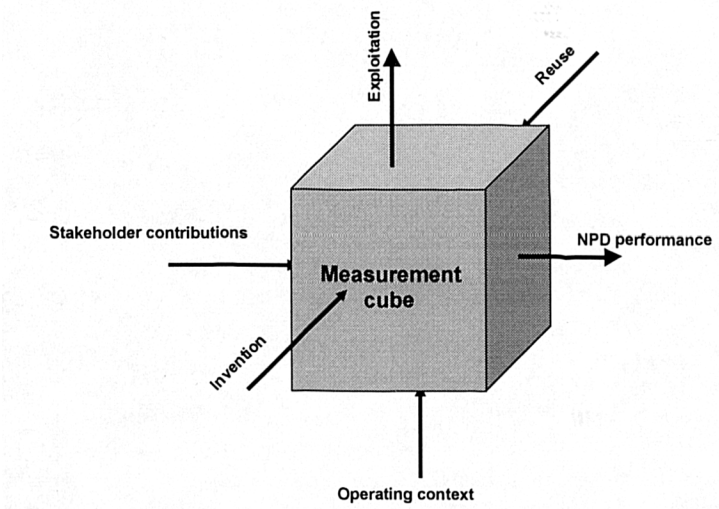


Figure 36: Measurement facet means-end relations

Looking at this figure it can be seen that the set-up of the measurement framework holds recourse to well-known input-output relationships which are a basic working principle for many performance management systems (Dorf and Bishop 1995). The input dimension is represented through the stakeholder contribution, the output measures are aligned to the final product (which can be of tangible and intangible nature) oriented NPD (output) performance dimension. The consideration of the traditional input – output relation supports the process orientation of the measurement framework. This is considered especially important for NPD environments as NPD itself is one of the major business processes in companies.

Further, the author defines as throughput or processing measures (Brown, 1996) the components of the innovation formula mentioned in section 5.2.3.2, namely reuse, invention and exploitation as well as the operating context. Those dimensions directly reflect on the required explicit consideration of knowledge related performance aspects which has been identified as being a major design requirement (section 5.2.2 and section 5.5). Brown and Svenson (1988) describe this in-process measurement also as activity related measurement. In this present framework the activities focus therefore on knowledge reuse and invention without neglecting the other NPD related activities, like researching, developing and testing.

The framework supports the establishment of a balanced measurement framework. The term "Balance" thus can refer to all the six measurement perspectives or only to a sub-set of the measurement perspectives. The chapters 8 and especially 9 will elaborate in more detail what a balanced measurement approach from a reuse and invention perspective actually means and how it can be realised in real-world companies. It should be highlighted that the implemented measures themselves within each facet (number of measures and nature of measures) are an important means to create a balanced PMS. Through the measurement catalogue presented in section 6.3 the model creates cause and effect relationships between the measures of the different facets.

Based on the experience the author gained during the action research in business contexts (see also the chapters 8 and 9) it is recommended that each user should use in most cases all of these facets.

6.2.3 Navigation

One of the most important design principles according to the QFDs presented in section 5.5 is transparency and easy data processing. The purpose of a sound performance management system is not to provide the user with large amounts of measures, instead a transparent and user-friendly system should provide very specific

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measures in a specific organisational, procedural and disciplinary context (Figure 37). In her dissertation project Kerssens-van Drongelen (1999) reflects extensively on the need that performance management solutions have to support measurement in terms of various, she calls them "subjects", like products, programs, total firm, projects, development teams, individuals, departments.

Therefore in the following sections a navigation concept will be presented which allows the user to navigate with the user specific 6 measurement facets introduced in the previous sections along the dimensions of process, organisation and discipline.

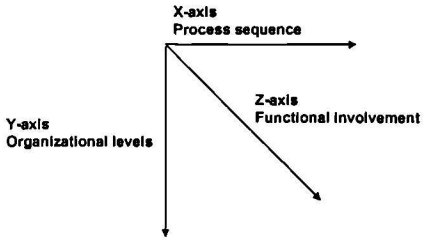


Figure 37: Navigation axes

This navigation scheme ensures that very specific measures or values of measures are provided to the user in the right context and contributes therefore to a complexity reduction and higher transparency of the measurement system. It is crucial to understand that each employee has his very specific, personalised view on the measurement facets. Depending on his rights he uses the three navigation dimensions to "browse" through, for example different process phases, different organisational entities and different disciplines to get the referring specific measures. The three axes process, discipline and organisation are suggested as default axes, however generally the selection should be company/NPD system specific and is therefore subject to the build and implementation of the function on-site (see also chapter 7). The case study 4 company for example has chosen "project" as its navigation dimension instead of "process". Driva (1997) confirms the importance of performance comparisons among projects.

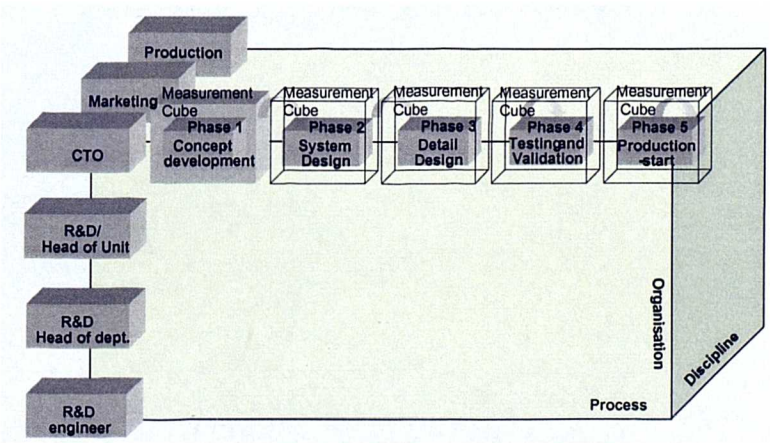


Figure 38: Navigation of the measurement facets along the navigation axes (example)

In the following, the three default axes organisation, process and discipline are illustrated and briefly discussed.

- The x-axis is proposed to capture performance and process information relative to the different activities and tasks performed in NPD. Klingebiel (1999) reflects intensively on the need to measure performance along the business processes. Kaplan and Cooper (1998) stress the importance of process orientation within their various activity based costing approaches, however focusing exclusively on financial measures. Ten (2001) confirm the importance of the process orientation as being critical for performance management and measurement. Obviously, each activity or

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process phase comes along with unique information needs and assignment of particular meaning to a measure. This process axis is of a very company specific nature.

- The y-axis reflects measures relevant to the involved organisational entities. Significance of and need for information varies between the diverse levels of hierarchy. The organisational dimension can be considered the standard navigation dimension of today's implemented PMS frameworks (Kaplan and Norton, 1996a, Edvinsson and Malone, 1997). Driva (1997) states that measures in product development are in some cases used to enable comparisons between divisions. An example: senior management is likely to require aggregate financial figures, such as "Return on investment in NPD project" and shop floor workers are probably interested in measures like "Process cycle-time". It is crucial to understand that the author does not limit this dimension to the reflection of purely organisational structures. The case study three for example, the Financial Service Provider; reflected their core competencies in this dimension. This organisational dimension therefore represents a refinement of the general demand of Rummler and Brache (1991) to equip a PMS with different organisational levels. They limit their considerations to the three levels Company/SBU, process and employee which certainly might have its limitations (Klingebiel, 1999).
- The z-axis supports the altering information needs of the functional departments and disciplines involved in NPD. Like the above, purpose and meaning of measurement changes across the various functions. An example: the marketing department would show high interest in "Customer satisfaction" while design would perhaps require measures, such as "Volume of inquiries for re-design". The provision of such navigation is clearly a result of operative user needs. The author is aware that the discipline axis might show redundancies with the organisational dimension axis in a way that the same entities might be subject of both dimensions. However this redundancy is on purpose and for the benefit of a transparent performance measurement and management in multi-disciplinary environments, like NPD[48].

Through establishing the three navigation axes the performance measurement framework satisfies the different information requirements and measurement requirements in NPD identified within the requirements analysis (section 5.2.3). Thus, the navigation function supports the focused and user-oriented employment of performance measurement and allows for qualified diagnosis and action.

6.2.4 Visualisation metaphors

It is considered necessary to equip the performance measurement framework with a visual architecture that supports the communication and explanation of the body of underlying principles and procedures, as well as for representation of actual performance.

Most of the existing and dominant performance management frameworks use a visual metaphor. The Balanced Scorecard (Kaplan and Norton, 1996) simply pictures the four perspectives (Figure 12), the Performance Pyramid (Lynch and Cross, 1995, Figure 18) arranges measures in the form of an isosceles triangle and (Kennerley and Neely, 2000; Neely and Adams, 2000a) use the shape of a prism (Figure 20).

This does not stand in contrast with the fact that performance information processed by the measured tool can be retrieved and presented by manifold means (for example spreadsheets, radarcharts and scoreboards). This can be done manually or supported by appropriate software (MS Excel™, ARIS™ Toolset, Ten™). However, in the course of this research, a physical and graphical metaphor based structure was found to

[48] Case study 4 company, with their very complex NPD process, was insistent on including this perspective in the overall design.

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facilitate the introduction of the PMS framework to the case study organisations and other potential users. It was also used for the later design of the software user interfaces (section 6.5).

Further, a coherent visualisation metaphor supports the creation of the measurement system identity and helps to communicate the performance topic throughout the organisation. The Skandia House metaphor for example certainly contributed to the establishment of the measurement system at Skandia[49].

Therefore, several alternatives for presenting the facet concept of the performance management framework have been developed. These proposals will be briefly explored. However, one should note, that the final selection of the visualisation metaphor is up to the PMS builder and user. The provided alternative metaphors are not intended to prevent user organisations from suggesting their own metaphor, they should rather be seen as a stimulus for discussion around this topic.

6.2.4.1 Innovation cube architecture

The original approach of combining the six measurement facets to a cube originates from the required multi-dimensionality of performance management. Thus, in accordance with the original project title "NIMCube" Figure 39 depicts this initial suggestion.

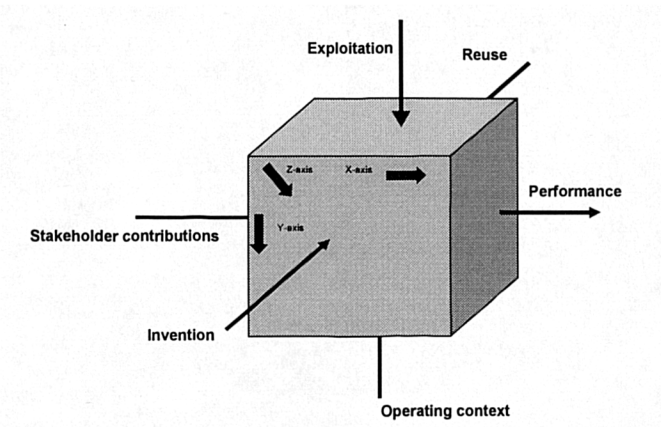


Figure 39 Innovation cube architecture

This allows for assigning a measurement perspective to each facet of the cube. For any specific user (say engineering manager for hardware looking at the detail design phase) the aim is to ensure that *all six facets* are considered when creating a measurement system. The according measures and performance information can then be mapped onto and displayed on the distinct facet. The three navigation axes (Figure 39) fit seamlessly into the format and correspond with the multi-dimensional approach. In a figurative sense, the cube would move along the process, down the hierarchy or across the functional disciplines to supply the focused information to the respective user.

6.2.4.2 Innovation house architecture – the Skandia metaphor

The second alternative graphical metaphor dispenses with the three-dimensional visualisation. It adopts the metaphor of a house of innovation. Figure 40 pictures this visualisation structure. In fact the development of this visualisation metaphor was very much driven by one of the sponsors of this thesis project. So the similarity to the Skandia Navigator metaphor (Edvinsson and Malone, 1997) is not accidental:

[49] Several people from Skandia the author talked to confirmed this viewpoint.

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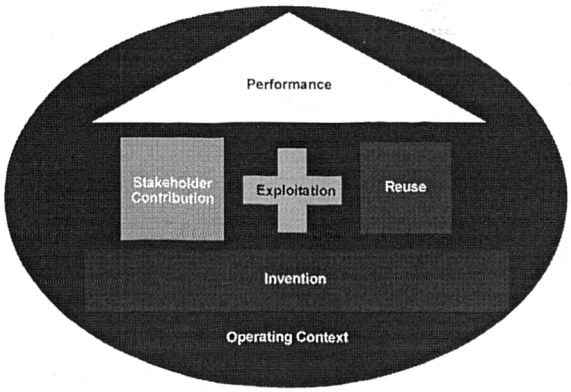


Figure 40: Innovation house architecture (based on Edvinsson and Malone, 1997)

The FS (case study 2) currently applies the model above for new product development environments enriching the original Skandia Navigator through a reuse and invention perspective. The Invention facet is aligned to the original "renewal and development" as this facet indicates the orientation of the company to the future and being the solid groundwork for continuity and sustainability. The stakeholder contribution facet is aligned to the customer focus dimension, as for the FS, being a financial service provider, the customer is the key stakeholder, both in terms of contribution and expectations. The human focus of the original Skandia Navigator is centred around the exploitation facet. On the one hand humans are key for successful exploitation, on the other hand it is the human capital itself which should be paid highest attention to in terms of exploitation. The former dimension process has been replaced by the facet reuse. Most of the Skandia local units are no or low growth companies, therefore process focus is highly aligned to process efficiency through reuse. The Financial focus representing the past-oriented ex post considerations has been replaced by performance which broadens up the scope beyond a purely financial driven perspective. The operating context is directly aligned to the former operating environment. The meaning and subjects within this dimension remained constant.

6.2.4.3 Innovation pipeline architecture

The third alternative is derived from the definition of innovation which has been presented in section 4.3. The mental model is that of an innovation pipeline or value chain, as shown in Figure 41.

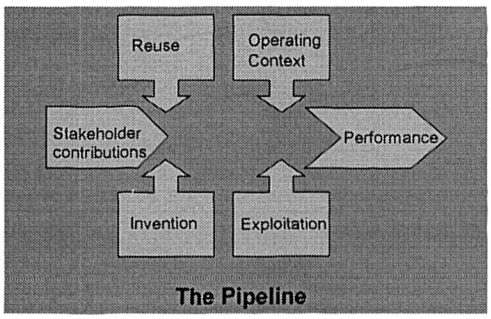


Figure 41: Innovation pipeline architecture

The simple and plain set-up adds to intelligibility of the entire performance management model. It allows for communication of the necessary perspectives and they interrelate and coincide in the course of the innovation process. "Stakeholder contributions" serve as input, whilst "Performance" is the NPD output contributing to business success. The four remaining facets are the forces influencing the process. Thus, these forces have to be well-balanced and controlled. Similar to the innovation house architecture it is most likely to present performance information by additional means, such as scoreboards or spider-charts. Thus, the pipeline architecture might merely be used

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for introduction and explanation. It is clear that each of the above graphic metaphors maintain the six-facet concept.

6.2.4.4 Conclusion

In the three sections above the author has described three alternative graphical metaphors for communicating the principles of the performance measurement framework to the user organisation and for presentation of performance information. The innovation cube would serve both purposes, but revealed limitations due its complexity. The innovation house is comprehensible and has the big advantage that the Skandia house is already well-known and recognised as a valid graphical metaphor. The plain and simple innovation pipeline is an easily comprehended visualisation of the present definition of innovation based on Dvir et al. (2000). It seems very suitable for engineering environments due to its well-known input-output oriented representation. The detailed lessons learned and findings with regard to the graphical metaphors within the case studies are discussed in section 9.3.

The "power of graphics" is one of the lessons learned in this project. The chapter 9 elaborates within various sections on this issue. At this juncture it is important to emphasise that powerful graphical metaphors are considered to be a major success factor for performance measurement design, implementation and use.

6.2.5 The strategic aspect of the PMS framework

6.2.5.1 Background

The alignment of a measurement framework to NPD strategy has been defined earlier as a key requirement for a PMS. According to Marr et al. (2001) and Christensen (1999) there are two basic ways to align strategy and operations: The company defines strategies and creates a knowledge base and operations accordingly or the company aligns the strategy to the company's (emerging) knowledge assets, organisational structures and activity. Christensen (1999) calls this intended versus emergent strategy making process.

The author reflects on this need through delivering a PMS framework that is not only derived from strategy, but also cascades strategies down to operations and in turn provide feedback to management levels focussing especially on reuse and invention. An example of a strategic plan, as being one major base-line for alignment activities, which also represents the different levels of strategy aggregation is shown in Figure 42. The plan is based on the case study 2 company and has been slightly modified for confidentiality purposes.

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Mission and Vision	Long-term Objectives	Competencies	Strategies	12-Month Activities
NEWCO, Inc. strives to be leading provider of widgets in its chosen market. NEWCO therefore: Continually strives to understand what kind of widgets the market demands Effetively designs, manufactures and distributes widgets to meet that demand and Provides world-class customer service to those who purchase our products	To achieve this mission and vision we must continually: Increase speed of growth Reduce time-to-market Reduce cost of quality and cost of growth Increase global collaboration and sharing Increase NEWCO's image and understanding among all stakeholders Enhance innovation strength	Product design	Develop and launch new internet-based widget	Review current widget portfolio
				Acquire deep understanding of customers' internet widget needs
		Manufacturing	Incorporate new web technology	Identify and acquire best web technology for internet-based widget manufacturing
				Acquire technical staff and train and develop tecnical skills
			Establish foreign manufacturing plant	Conduct market analysis
				Establish plant
		Distribution	Establish web-distribution system	Attract web distribution partners
				Identify and develop new distribution methods
		Customer service	Develop interactive web service	Conduct Market Analysis to understand customers' service needs
				Develop and implement service plan

Figure 42: Strategic plan (example, based on case study 2)

6.2.5.2 Linking the measurement framework to the strategic planning process

The present PMS framework is not a priori designed to replace strategic performance management and measurement systems. It can also interact with the existing management and measurement structures (Figure 43).

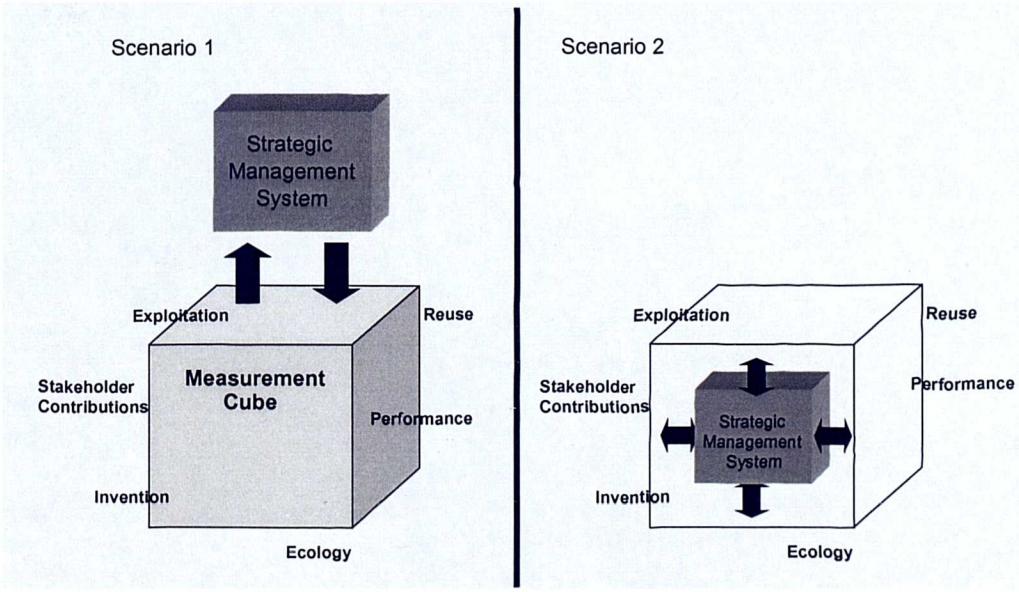


Figure 43: Link of the PMS methodical framework (represented in this case through the cube metaphor) and strategic management systems (2 alternative scenarios)

Strategic performance management and measurement systems, like the Skandia Navigator (Edvinsson and Malone, 1997) and the Balanced Scorecard (Kaplan and Norton, 1996a) consider the prior role of innovation in the business plan in an implicit way through defining referring measures in the various facets. Thus, one scenario would allow the PMS framework to address strategic measurement requirements and feed invention, reuse, exploitation measures and metrics as well as stakeholder

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contribution measures and metrics to those existing systems. An extended scenario however would consider the present PMS framework an integrative solution, which surrounds and incorporates the available strategic and operational measurement systems.

The PMS framework establishes a firm link between vision and strategy and the NPD operation; it directly ties business objectives (also from a reuse and invention perspective) to business strategy and establishes the feedback loops between strategic and operational management[50]. The example strategic plan in Figure 42 shows how this linkage is practically realised. Here, the company's product development strategy is to establish a new product line of internet-based widgets. In order to do this, two main tactics are identified, first, review of the current widget portfolio and second, obtaining an understanding of customer requirements for internet widgets. Figure 44 focuses on this section of the strategic plan.

Competencies	Strategies	12-Month Activities
Product design	Develop and launch new internet-based widget	Review current widget portfolio
		Acquire deep understanding of customers' internet widget needs

Figure 44: The PMS focus area in the strategic plan (example, based on case study 2)

Understand relationships between strategic planning and the navigation dimensions of the PMS framework[51]

The process described in this section assumes a rather well-organised strategic planning environment with existing strategic business plans and referring measures. Section 7.4.3 offers in addition a slightly modified process which is of a more emergent nature and does not require a sound strategic business plan (in case it does not exist). Depending on the nature of the implementation environment the process above or the one presented in section 7.4.3 might be more recommendable.

The potential PMS builder[52] starts with this section of the strategic plan and builds the cube recognising this context. Doing so, requires the implementer to ask what the invention, reuse and balance themes are for both the strategy and the 12-month activities. Some of these are ordained by the strategic plan's high-level measures, whilst others are derived from considering the strategic implications relative to each of the navigation axes. The PMS builder will eventually attribute the measures to a specific facet of the PMS framework (see next sub-section). Table 19 shows how the NPD strategy and the navigation functionality generate a preliminary PMS framework measurement list from a reuse and invention perspective. It is crucial to note that during the measure evaluation the users do not feel restricted or pushed into a certain

50 The linkage to operations is especially supported by the performance measurement infrastructure which is presented in section 6.4.

51 The process described in this section assumes a rather well-organised strategic planning environment with existing strategic business plans and referring measures. Section 7.4.3 offers in addition a slightly modified process which is of a more emergent nature and does not require a sound strategic business plan (in case it does not exist). Depending on the nature of the implementation environment the process above or the one presented in section 7.4.3 might be more recommendable.

52 The author is well aware that this section represents a partial overlap with the section 7.4, however due to the importance and different viewpoint this important aspect is also discussed in this chapter.

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direction. So an alternative might be to collect all measures first and then cluster them afterwards according to the various navigation dimensions.

Measurement Source	Measure
Strategic plan	❑ Projected return on new web widget
	❑ Projected cost of new widget development
	❑ Projected time-to-market
	❑ Level of understanding of customer needs
	❑ Percentage of widget portfolio that can be reused
Process axis (X-axis)	❑ Percentage of NPD staff access to web design tools
Organisational axis (Y-axis)	❑ Level of NPD staff web knowledge (senior mgmt)
	❑ Percentage of staff trained in web design (department)
	❑ Percentage of time spent in web-tool training (team)
Interdisciplinary axis (Z-axis)	❑ IT department technology level
	❑ Sales department web knowledge

Table 19: Preliminary PMS measurement list (example, based on case study 2, see also section 8.3)

The example shows, that by analysing the various axes several key measures of NPD process innovation and reuse efficiency were overlooked. For the process axis, a key measure was the NPD department's "Access to web design tools". Analysis of the organisational axis showed that the "Level of NPD staff web knowledge" had two sub-level refinements. The first was the departmental measure "Percentage of staff trained in web-design" and the second the team measure "Percentage of time spent in web-tool training". The interdisciplinary axis revealed the need to consider the IT and Sales departments' "Level of web technology and knowledge". These axes-generated measures, lay the foundation for the PMS framework when combined with strategic measures.

Understand relationships between strategic planning and the facets

The six facets provide a crucial checklist for assuring that all invention, reuse and balance measures have been identified, similar to the three NPD navigation axes. The result of these two combined approaches to measure selection and verification is to tightly link the PMS framework to strategic planning; and safeguard an in-depth analysis of the NPD innovation matters impacting strategy realisation. When the identified measures are mapped against the six facets the results shown in Table 20 are observed (example).

Measurement Source	Measure
Exploitation	❑ Projected return on new web widget
Exploitation	❑ Projected cost of new widget development
Exploitation	❑ Projected time-to-market
Stakeholder Contribution	❑ Level of understanding of customer needs
Reuse	❑ Percentage of widget portfolio that can be reused
Operating Context	❑ Percentage of NPD staff access to web design tools
Operating Context	❑ Level of NPD staff web knowledge (senior mgmt)
Operating Context	❑ Percentage of staff trained in web design (department)
Operating Context	❑ Percentage of time spent in web-tool training (team)
Operating Context	❑ IT department technology level
Operating Context	❑ Sales department web knowledge

Table 20: Preliminary PMS measurement list mapped against facets and NPD navigation axes (example, based on case study 2, see also section 8.3)

A (weighted) measure list is an opportunity to further identify missed measures and / or to verify the current selection. The company and NPD unit might have valid reasons not

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to measure distinct facets. Only the PMS builder and user can judge whether an empty facet is legitimate or an oversight.

Apart from identifying neglected facets, mapping also focuses the NPD unit on understanding if measures within already populated facets have been overlooked. For instance, in the example shown above, there is only a single measure for Contribution and Reuse. This may or may not be valid, but the PMS builder and user have to take the decision and justify it. Continuing the example shown above a finished PMS framework measurement list can be created.

Measurement Source	Measure
Exploitation	❑ Projected return on new web widget
Exploitation	❑ Projected cost of new widget development
Exploitation	❑ Projected time-to-market
Contribution	❑ Level of understanding of customer needs
Contribution	❑ Level of strategic partners' web skills
Contribution	❑ Level of Manufacturing's web skills
Reuse	❑ Percentage of widget portfolio that can be reused
Invention	❑ Number of new customer design requirements identified
Performance	❑ Percentage of widget portfolio reviewed
Performance	❑ Percentage of customers interviewed
Operating context	❑ Percentage of NPD staff access to web design tools
Operating context	❑ Level of NPD staff web knowledge (senior mgmt)
Operating context	❑ Percentage of staff trained in web design (department)
Operating context	❑ Percentage of time spent in web-tool training (team)
Operating context	❑ IT department technology level
Operating context	❑ Sales department web knowledge

Table 21: Completed PMS measurement list mapped against facets and NPD navigation axes (example, based on case study 2, see also section 8.3)

6.2.5.3 The strategic aspect of the PMS framework - conclusion

Building a holistic PMS framework for NPD to improve knowledge reuse and invention requires a multidimensional understanding of the NPD process. It necessitates a tight link to the strategic planning process and a process to verify the completeness of measurement identification. The performance measurement framework provides the methods and processes meeting these requirements.

It renders the level of customisation necessary to adapt the PMS framework to any company. It is, above all, this customisation that makes the framework a powerful tool for leveraging knowledge reuse and invention management. Basing it on a commonly accepted NPD process and shared organisational models facilitates building the PMS framework. The PMS Catalogue as described in the following chapter enhances the ability to identify potential measures and the catalogue's structure provides a powerful template for defining a measurement process and organisational roles assigned to measurement.

The strategic aspect of the PMS build and implementation will be revisited in the following chapter 7 being an important aspect of the overall PMS build and implementation path. However due the importance of the strategic aspect and its relevance for the PMS framework it has been partly presented here.

6.2.6 The performance measurement framework - conclusion

The previous sections 6.2.1 to 6.2.5 presented core elements of the performance measurement framework from a reuse and invention oriented perspective. The author discussed why the six performance dimensions "reuse", "invention", "exploitation", "operating context", "stakeholder contribution" and "performance" were chosen. The

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framework was shown to rely on a solid theoretical foundation as well as on feed-back from various users and leading experts in the field.

Coherent and transparent cause and effect relationships between the various performance facets are a critical element in PMS frameworks (Kennerley and Neely, 2000) therefore the author discussed this issue within a great level of detail.

The multi-dimensional navigation concept presented is considered to be novel as it provides more sophisticated and accurate ways of navigating through the NPD performance system (as opposed to purely organisationally oriented drill down mechanisms). Especially the case study 4 company, which shows a very complex NPD environment, extensively supported the development of this function through very rich user feed-back (section 8.5).

The alignment to the overall NPD strategy is considered to be key for PMS. The previous sections propose a link between the overall strategic planning process and the performance framework. The presented approach requires a certain maturity of the strategic planning process of a company, manifested for example in the availability of a business plan. Chapter 7 will offer in addition, an alternative strategic alignment process companies not having a sound and coherent business plan.

The author called the function performance measurement framework and not performance management framework for the following main reason: Most of the novel design principles are measurement oriented and provide therefore only an exclusive sub-set of performance management functions (section 4.3).

6.3 Reuse and invention measurement catalogue

6.3.1 Introduction

With the definition of the measurement facets and the navigation concept the author has proposed important principles of the PMS framework. This framework will have to be populated with relevant measures to supply affirmative and useful performance information via a performance measurement catalogue.

In contrast to many of the existing frameworks, which only provide superficial recommendations, the author considers the provision of a structured and systematic repository of suitable measures. The selection of measures represents an important tool for an efficient and effective build and implementation of the system.

The measurement catalogue's structure will serve as a reference for a user organisation in selecting performance measures relative to objectives and requirements. However, it is crucial to note that the biggest benefit of the measurement catalogue is not the delivery of a pre-defined measure list. Instead, it is the provision of a well structured template with well defined describing attributes for each measure, which represents (once completed by a company) the company-specific measurement reference in terms of measurement process, organisation and measure value collection and reporting. In fact, one of the lessons learned of this project (see also chapter 9) was that it is very difficult to introduce pre-defined or selected measures in a company. The measures themselves (not the way they are structured!) are always very unique and specific for a company and have therefore to be developed individually with a great level of detail and accuracy (chapter 7):

Five basic considerations guided the development of the catalogue:

- The repository is diverse and manifold and allows for measurement of all aspects of NPD performance of any user organisation especially the reuse and invention aspect.

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- Its structure complies with the six measurement facets and reflects on the NPD process.
- The measures are significantly interrelated and consistent and the structure of the catalogue has to support this interrelation.
- The completed measurement catalogue provides the company with a reference for their measurement process and organisation.
- It provides a means for explanation and documentation of the measures.

The following subsections describe how the final catalogue realises these considerations. In order to avoid the "re-inventing the wheel" phenomena, the catalogue relies on already existing sets of measures, like the ones from Kerssens-van Drongelen (1999), Kennerley and Neely (2000), Lynch and Cross (1995) or Griffin and Page (1996). A sub-set of this measurement collection, the asset related reuse and invention measures are presented, due to their importance and novelty, in greater detail in section 6.4. The actual measurement catalogue can be found in Appendix B of this thesis.

6.3.2 Diversity of measures

In the course of reviewing the relevant works on product development, it was found that there exists no consensus of what to measure nor how to measure (Griffin and Page, 1996), let alone a sound and complete list of adequate measures for successful NPD especially from the knowledge reuse and invention viewpoint. Nevertheless, the author detected numerous, but widely dispersed and unorganised listings and publications suggesting NPD measures (for example Griffin and Page, 1996; Loch et al., 1996; Beaumont, 1996; Kerssens-van Drongelen, 1999). The dominant frameworks provide some arrangement of general performance measures (Kaplan and Norton, 1996a; Lynch and Cross, 1995; Lim, 1998 and Pawar and Driva, 1999).

The Performance Prism measurement catalogue purports to be a comprehensive and structured inventory of measures (Kennerley and Neely, 2000). Drawing on all these references the author envisioned to filter those measures regarded fruitful, describe them according to novel describing attributes and categorise them in compliance with the purpose of this research. This preliminary list of measures was then verified and complemented in collaboration with the case study organisations. These proceedings allowed for the compilation of the nearly 200 performance measures suitable for measuring NPD performance in a holistic, knowledge reuse and invention oriented way.

All measures have been thoroughly classified, described and documented on a high level of reference. The measures reflect on the diversity paradigm as suggested by Schneiderman (2001): The measures are of financial and non-financial nature, of lagging and leading nature, internally and externally focused and short-term and long term oriented. Kerssens-van Drongelen (1999) suggests another comprehensive taxonomy of measures. She distinguishes measures according to three dimensions:

- Performance aspects: quantity, cost, timeliness, innovativeness, quality, general.
- Time span covered: distant, recent, near, future.
- Closeness to organisational goals: inputs, activities, output, outcomes.

This taxonomy may serve as countercheck for completeness of the measurement catalogue presented in this research.

The measures presented in Annex B combine well-known measures with novel knowledge reuse and invention asset oriented measures presented also in section

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6.4.3. The measures will be continuously advanced and extended as new insights are gained from research and practical experiences.

6.3.3 Compliance with the measurement facets and navigation dimensions

As mentioned previously, the measurement catalogue is diligently categorised and structured. The categorisation scheme is aligned with the measurement facets defined in subsection 6.2.1 and with the proposed subjects which cover some of the main performance drivers in NPD. Furthermore, the measure is aligned to the navigation dimensions process, organisation and discipline as defined in subsection 6.2.2.

The author is aware that the alignment of a measure to a specific facet, to specific processes and to organisational levels is highly company-specific. Nevertheless he wants to provide the user with a default solution which proved to be valuable for a fast implementation process (chapter 7).

The alignment to the facet is simply realised by associating the measures to the corresponding facet and eventually a specific subject of a facet (section 6.2.1).

The alignment of the measures to the specific process phases, organisational levels and disciplines is realised in a similar way through equipping the measures with referring attributes (section 6.3.6).

6.3.4 Interrelation of measures

The measures allow, if diligently selected, for the establishment of a chain of causes-and-effects. This is realised by assigning measures to the facets, which form a means-end relation themselves (Figure 36).

The catalogue describes how each measure might potentially impact others on first order level. The catalogue also indicates which other measures impact the considered measure on first order level (Table 22).

However during the research the limitations of cause and effect relationships in practical environments clearly have been recognised (chapter 9). As described above the cause and effect relationships established within this approach consider only on a first order level. The possibility to derive even such comparatively simple relationships is limited and needs to be customised in the course of adjustment to the user organisation.

6.3.5 The measurement process and organisation

The structure of the catalogue supports the definition and management of the measurement process and referring measurement related organisational roles. Each measure, once implemented in a company should be equipped with a clear process for collecting, reporting, acting and reviewing of the measure. The process has to be supported through assigning various roles, like a measure owner who is responsible for collecting and reporting (this might be a different role in some companies) of the measure, a measure actor who is responsible for deriving actions based on measurement results and a measure reviewer who is responsible for reviewing the measure's validity, the referring target values, collecting and reporting intervals and the location in the navigation scheme and the six facet scheme. The measurement process' features and organisational roles are documented as attributes in the measurement recording sheet (next section 6.3.6).

6.3.6 Description and documentation

The above characteristics eventually flow into the systematic documentation supporting each measure. The provision of a measurement recording sheet (based on Neely's (1998) thoughts) facilitates comprehension and communication of the measure and

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aids the purpose-oriented application of measurement. The measurement recording sheet is partly predefined and then adjusted and complemented at the user organisation. The highlighted columns in the following template of the measurement recording sheet (Table 22) show which information is provided as a default value to the user and which is presented in Appendix B of this thesis.

Measure	❑ What is being measured?
Metric	❑ How it is being measured?
Description	❑ Detailed description of purpose, contents, source, and why this indicator is measured
Relation to facet(s)	❑ To which facet(s) does the indicator belong to?
Impact on other measures (output)	❑ How does the measure impact other measures?
Impact by other measures (input)	❑ How is the measure impacted by other measures?
Target value / Benchmark	❑ What is the operational goal / reference mark for this measure? ❑ What are the aggregation rules for this measure?
Formula	❑ How is the value calculated? ❑ How can the measures be aggregated
Frequency	❑ How often is the value measured? ❑ How often is the value reported?
Data source	❑ Where does the data come from?
Responsibility	❑ Who is assigned responsibility / ownership for collecting the measure? ❑ Who is assigned responsibility / ownership for reporting the measure? ❑ Who is assigned responsibility / ownership for auditing the measure? ❑ Who is assigned responsibility / ownership for acting on the measurement result?
Next steps	❑ What are the consequences of measurement (Recommendations on generic level)?
Relation to subjects	❑ To which subject does the measure belong to?
Relation to process, organisation and discipline (X/Y/Z)[53]	❑ To which process, organisational level and discipline does the measure belong to?
Reference	❑ Where does the measure originate from?
Comments	❑ What are the experiences with this measure? ❑ Are there any best practice stories around this measure?

Table 22: Measurement recording sheet (template) (based on Neely, 1998)

The following subsections reflect on the various describing attributes, partly recapturing the characteristics elaborated within the previous four subsections:

❑ Measure

This attribute represents the primary identifier for the measure representing the name used for this measure. The name should be meaningful and understandable.

❑ Metric

The "Metric" attribute provides the referring metric to the measure.

❑ Description

This attribute describes the purpose and nature of the measure, may provide exemplary applications and best practices as well as potential application risks.

❑ Relation to facet(s)

Each measure should belong to one or more facets of the proposed measurement framework. For the benefit of user friendliness and accessibility a certain redundancy of measures within the measurement facets might be acceptable.

53 Here it is assumed that the company chose the three dimensions process, organisation and discipline as navigation dimensions for the performance framework.

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- Impact

  The two attributes belonging to "Impact" try to establish first order causes and effects between measures beyond the cause and effect relationships which are already given through the position of the measures in the framework (section 6.3.4).

- Target value / Benchmark

  This attribute elaborates on the target value/goal the measure might be measured against. If applicable the target setting might be based on benchmarking numbers. The target might also be set through boundaries (for example ±5%, ±10%, ±15%) which refer to an actual value for the measure done in the past (section 9.4).

- Formula

  The "Formula" describes how the measure is calculated. Some measures (like for example a customer contribution index, section 6.2.1) can consist of several parameters and different weighting factors. Aggregation rules is another important aspect: Above all the more management oriented measures are (or at least should) be derived from more operational measures. In order to ensure consistency and transparency, clear aggregation rules have to be formulated.

- Frequency

  The "Frequency" described the time periods for collecting *and* reporting of a measurement value.

- Data source[54]

  This attribute provides information where the actual measurement value can be retrieved from. Data sources can be the PMI (section 6.4), legacy systems, native data applications (CAD, CAM, CAE) or paper documentation.

- Responsibility

  This attribute describes the roles/people who are responsible for collecting and reporting the measurement values. This attributes defines a responsible person or entity who regularly audits the measure to elaborate whether the measure's set-up is still in line with the referring strategies. Finally, a person/entity has to be defined who is responsible for deriving actions if the measurements results demand for it.

- Next steps

  According to the author's opinion a PMS can not internally and automatically generate concrete actions based on measurement results, although there are some emerging technologies, like Case Based Reasoning (CBR) (Kolodner, 1993) which claim to be able, based on behaviour and solution patterns, to generate concrete actions for improvement. The author and several users and experts he talked to doubt the value of CBR in complex and dynamic real-life environments. "Next steps" in this context therefore means the provision of generic guidelines and suggested actions (for example whom to contact, if a measurement value runs out of target).

- Relation to subjects

  A measure might belong to various subjects within the measurement facets (section 6.2.1).

---

[54] It should be the primary objective to consider the PMI as single data source, which means that as much as possible measurement information should be provided via the PMI (section 6.4).

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- Relation to process, organisation and discipline

  This attribute provides the position of the measure in the navigation concept assuming that process, organisation and discipline have been selected as navigation dimensions. There can be multiple positions for each measure.

- Reference

  Some of the measures within the measurement catalogue might have to be developed for the specific context of the referring organisation (section 7.3). Some other measures however might originate from the literature. To those measures reference should be given.

- Comments

  During the use phase of the system people might want to document experiences and lessons with regard to a specific measure.

The measurement catalogue is thus an integral tool in the course of implementing and customising the performance management framework (chapter 7), as well as in using and maintaining it. The measurement catalogue should be fully software enabled (section 6.5) due to the complexity of today's business environments.

Reporting formats

Neely (1998) points out that the visualisation of measurement results is key for checking and communicating the current performance of companies. Measurement reports should therefore show the following features[55] (based on Neely, 1998; Brown and Svenson, 1998 and own experience gained during the field research):

- Measurement information should be presented in a numerical *and* graphical way.
- The measurement should support evaluation over time and cross-comparisons between different measures.
- The reports should focus on the most important measures.
- The measurement graphs should also indicate the measurement goals and referring boundaries.
- Measurement graphs should also provide extrapolation of current measurement results into the future based on arithmetic functions, like regression analysis.
- Colours like green, yellow and red might support the communication of current measurement results.

6.3.7 Summary and conclusion

The above presented measurement catalogue structure presents an important function for building and implementing the PMS framework and plays a central role in the architecture design of the enabling technology. The author learned during his research (see also chapter 9) that a pre-defined collection of measures is less important than the provision of a good catalogue structure and a sound build and implementation process for the measures.

[55] The author focuses here only on the more sophisticated features, he will not address generic report features like, name of person who generates the report or name of company/entity.

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6.4 Performance measurement infrastructure (PMI)

6.4.1 Introduction - The NPD process and the PMI

With the performance measurement functions provided in this thesis, the author wants to support the strategic performance management of reuse and invention (section 6.2.5) but above all facilitate the operational improvement from a reuse and invention perspective. The base-line is therefore the operational NPD process itself.

Within the context of this research the author looked especially at the very early, less structured phases of the new product development process, like conceptual design and pre-development (sometimes also called Advanced Technology Planning (ATP)). The reason for this decision was that those phases are less structured than later phases like manufacturing and therefore the need is higher to think about new ways of representing those processes than through pure process-oriented ontologies (section 1.1).

The present function, the performance measurement infrastructure (PMI) can be applied to all phases of the value chain but due to the complexity and knowledge intensity those early phases represent an excellent business case. The PMI supports the identification, acquisition and storage of the relevant NPD knowledge to create a sound basis for reuse and a wellspring for creation of new knowledge referring hereby to the NPD process.

To attain this objective a reuse and invention oriented "view" on NPD processes based on knowledge asset structures needs to be defined (Make IT, 1999a and b; Warschat et al.; 2000b; Röhrborn et al., 2000; Marr, 2001 and Prieto, 2001). The NPD process representation is "translated" into a reuse and invention ontology which is based on knowledge assets, describing attributes and relationships (see section below). Of course this "view" has to be highly company specific, as each NPD process and the referring knowledge asset structure is unique for each company. The author will enrich this asset structure with performance measures which provide operative support regarding the improvement of knowledge reuse and invention activity.

6.4.2 The PMI asset model concept

The overriding principle of the PMI is thus the representation of reusable knowledge in terms of assets. Assets in this context can be of tangible (CAD drawings, offers, modules) or intangible nature (idea, problem or solution).

The principle behind this systematic composition of assets is the required perspective on the physical NPD process from a knowledge-based angle (subsection 5.2.3.3).

The PMI builds on creation of knowledge maps as suggested by Eppler (1997), Semann and Cohen (1997). These authors proposals have been refined and further developed by designing and implementing knowledge asset structure models in the course of the EU projects MaKe-IT SME and NIMCube (Röhrborn et al., 2000 and Make-IT, 1999a; Make-IT, 1999b; Warschat et al., 2000b; Roth et al. 2000; Prieto, 2001) and finally been adapted by the author to meet the requirements (section 5.2.3) set through this research.

In constructing knowledge asset structure models, the applied, or potentially applied, (reusable) knowledge assets (for example documents, experts or ideas) are associated to the distinct phase within the NPD process. These assets are then referenced, attributed and put into contextual relationships (Prieto, 2001). There are different types of attributes[56]:

[56] It should be noted that the first three attributes are based on the reflections from Prenninger et al. (1999), Warschat et al. (2000b) and Prieto (2001). The application of these attributes in performance

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- Original information which describes the knowledge asset (O)
- Categorisation attributes (C)
- Context to other attributes or assets (K)
- Measures/Metrics which are fed into the six measurement facet concept (M)

This approach reflects very much the pragmatic definition of knowledge being information with a meaning in a certain context (Amidon, 2000). The relations between the assets hold out recourse to this context thinking. The following figure below represents a more formal description of a reuse and invention asset.

Reuse Asset Type: Problem	
O	Creator
O	Title
O	Description
C	Status (Pull Down)
K	Customer
K	Product
K	Order
M	Asset age
M	Reuse rate

Table 23: Overview on the structure of a reuse and invention asset (real-life example; based on case study 1 (section 8.2), Prenninger et al., 1999 and Roth et al., 2000)

The PMS build and implementation function (chapter 7) provides the procedures, connotations and templates required for building these structure models; the generation of the structure itself is determined by the characteristic of the user organisation and hence unique. Figure 45 shows an example of interrelated knowledge assets assigned to an example NPD process.

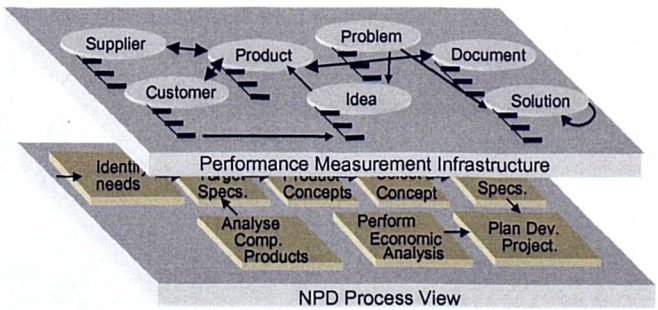


Figure 45: Asset structure model within the PMI (Prenninger et al., 1999; Roth et al., 2000)

The PMI is of a highly company specific nature representing the very specific (reusable) NPD knowledge. This approach is opposed to a recent approach (Marr et al., 2001) which provides a generic set of assets suitable for all companies. However still, as in section 6.2.1, the author wants to provide a generic set of reuse and invention assets which may serve as supporting tool for the build and implementation of the PMI in real-life contexts (section 7.3). The reuse and invention assets presented in the following represent the outcome of a highly iterative development process where many experts, practitioners and users were involved in the discussion and builds on research done by Prieto (2001), Marr et al. (2001), Sveiby (1997), Edvinsson and Malone (1997) and Prenninger et al. (1999):

measurement contexts and the expansion through a fourth describing attribute ("measure") is the author's contribution in this specific context.

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- Drawings and specifications

  Especially in engineering oriented environments, CA systems represent often one of the major knowledge generation sources. Inventive drawing capabilities might be an important driver for a firm's overall inventive capability. Drawings might be an important reusable asset as considerable knowledge is often embodied in them.

- Experiences and Lessons

  Experiences and lessons learned in the past might facilitate and support present and future decision making. Above all in the knowledge economy the experience of employees gained often over a period of decades can be an invaluable reusable asset.[57]

- Experts

  Experts and their expertise might be very valuable reusable knowledge for people having questions in the referring domains. The importance of this asset has meanwhile been recognised by various companies as many companies, like Robert Bosch, DaimlerChrysler and BMW have launched so called "Yellow Page Projects" which aim at realising such expert repositories[58]. Experts are suggested to be one of the most important reuse and invention assets in companies.

- Ideas

  Very often inventiveness is aligned with ability of a firm to generate ideas. Therefore ideas might be an important reusable asset for generating innovations.

- Measures

  Measures or measurement repositories are key assets, as beyond the pure measurement information, they provide the user with additional knowledge about the measurement process, organisation and experiences made with the measure assuming that the measures are documented in a similar way to that described in section 6.3.

- Offers

  Above all in industrial environments with small lot sizes the offer may contain a lot of knowledge about the product, customer and supplier. Therefore offers from the past might be valuable reusable knowledge which may contribute to a faster and higher-quality offer generation process.

- Stakeholders (Customers and Suppliers)

  Knowledge about stakeholders might be key for NPD success. This thinking is also reflected in the definition of the measurement facets earlier in this chapter. Due to the dynamics and high level of interaction and integration, above all in new product development, knowledge especially about the customer and the supplier is crucial for good NPD performance.

- Intellectual Property (IP)

  According to Marr et al. (2001), IP is the sum of patents, copyrights, trademarks, brands, registered design, trade secrets and processes whose ownership is

---

57 In case study 1 the author learned the following lesson: One of the most important phases in the production process of the toothed gears is the grinding process with a very complex CNC machine. The knowledge and experience in handling this machine was, until the research project started, completely embodied in one person. When this person is ill or on vacation this machine could not be used which caused significant losses of money in the past.

58 The author learned this during on-site visits at those companies.

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granted to the company by law. Katila (2000) stresses the importance of patents being a core driver and important reusable asset for innovation performance.

- Practices

  This asset includes work practices, formal and informal networks and routines. It can comprise process documentation and manuals, notes.

- Problems

  This asset captures the occurred problems in an organisation, documenting their reasons and symptoms.

- Processes

  The asset type "processes" can contain documentations of the various processes in an organisation. Processes can be value creating processes and supporting processes, like knowledge management, quality or training processes.

- Products

  Products, modules and components are one of the most important reusable assets at least in industrial environments. The knowledge previously generated might be reused and be a wellspring for inventions leading into innovations. Again a product can be of tangible (for example gear) or intangible nature (for example insurance policy).

- Solutions

  Solutions, especially when it refers to the asset problem might be very valuable for NPD practitioners in day to day work. They either may serve as a direct answer to the occurring problem or may serve as stimulus for the elaboration of a solution.

- Projects

  Project knowledge and lessons from past projects may be important reusable knowledge for future projects. Many firms like Siemens (Wolf, 2000) have invested considerable resources in making project knowledge reusable.

- Tools and Methodologies

  This asset category provides knowledge with regard to all the tools, methodologies and infrastructures applied in a company.

Thus, with the PMI the author aims at improving the reuse and invention of knowledge in an NPD context on an operational level. The PMI aims at monitoring and controlling the performance of this knowledge asset infrastructure in terms of reuse, invention and exploitation. Therefore each asset is equipped with specific performance measures which feed into the different facets described in the earlier sections. These measures assure a direct process-orientation as the assets refer directly to the NPD process. The PMI is reuse and invention oriented, as within the PMI performance is mainly managed from a knowledge reuse and invention perspective.

In the next section the author will provide an in depth overview of asset related reuse and invention measures. Of course, the assets can be equipped with further non reuse and invention related measures to measure the general performance of the assets (see also Marr et al., 2001).

6.4.3 The asset related performance measures

In order to provide the performance management framework and its catalogue with genuine reuse and invention asset related measures, the referring data is fed into the measurement framework (section 6.2) and accordingly processed. This mechanism

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warrants for seamless and purposive transfer of the required performance and object data.

Eventually, the performance measurement infrastructure ensures and maintains the tight integration of the performance measurement framework into the user organisation's information systems and development operations. The author suggests to distinguish two basic categories of measures: standard operational (task) measures, which are assigned to every reuse and invention asset of the PMI and standard management measures, which refer to distinct asset types (see Table 24 and Table 25). This distinction reflects on experiences made by Neely et al. (1996): They propose in the performance measurement process to divide up the procedure in two phases: Identifying, designing and implementing top level measures and identifying more operational performance measures.

Operational asset related measures			
Measure/ Variable Name	**Variable declaration**	**Formula**	**Description**
Asset i	A_i		Asset i of asset type A
Approved Asset i	AP_i		This measure shows that a specific asset has gone through a certification process and indicates therefore whether or not an asset is ready for reuse
Asset type A	A	$A = \cup(A_i)$	Asset type A
Creation date	$CRD(A_i)$		
Measurement date	$MRD(A_i)$		
Current date	$CUD(A_i)$		
Reuse action	$RA(A_i)$		This measure describes in which context the reuse of an asset took place and whether any changes have been made to the asset
Asset age	$AA(A_i)$	$AA(A_i) = CUD(A_i) - CRD(A_i)$	This measures shows the age of an asset
Asset reuse rate	$ARR(A_i)$	$ARR(A_i) = \sum RA(A_i)$	This measure counts the number of reuses of a specific asset type
Reuse Approval Status	$RAS(A_i)$		This measure describes the status of an asset:: "Approved", meaning ready for reuse, "not approved" or "currently certified for reuse".

Table 24: Overview on the asset related operational measures

The operational measures therefore provide the user with very operative decision support giving the user indication whether the reuse of a specific asset in a specific context might be appropriate or not. The process of reusing requires a certain organisational framework as for example the process of certifying assets (see table above) might indicate. However as this aspect is beyond the scope of this research the author will not go in detail at this juncture. A suggestion for a reuse and invention process and an organisational model can be found in Roth et al. (2000).

Management asset related measures			
Measure/ Variable Name	**Variable declaration**	**Formula**	**Description**
Asset number	N(A)	$N(A) = \sum (Ai)$	Number of Asset i of type A
Approved asset number	N(AP)	$N(AP) = \sum (APi)$	This measure shows the sum of the approved assets of a specific type
Added Asset j per period (T2,T1)	Nadd(A)	$Nadd(A) = \sum (Aj)$ | $(T1-T0)<=AA(Aj)<=(T2-T0)$	Number of added assets j of type A in the period between T1 and T2
Deleted number of Assets k per period (T1,T0)	Ndel(A)	$Ndel(A) = \sum (Ak)$ | $\exists Aj(T0) \wedge \nexists Aj(T1)$	Number of added assets j of type A
Mean Asset Age	MA(A)	$MA(A) = (\sum (AA(Ai))) / N(A)$	This measure shows the mean age of an asset type
Mean Asset approval rate	MAAR (A, AP)	$MAAR (A,AP) = N(AP) / N(A)$	Mean % of approved assets of asset type

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Asset Addition Rate	AAR(A, T2, T1)	AAR (A,T2,T1)= Nadd(A, T2, T1) / N(A,T1)	This measure informs of the number of assets of one specific asset type which are added over a certain period of time (e.g. on a monthly basis) to the repository.
Asset Delete Rate	ADR(A, T2, T1)	ADR (A,T2,T1)= Ndel(A,T2,T1) / N(A,T1)	This measure informs of the number of assets of one specific asset type which are deleted over a certain period of time (e.g. on a monthly basis) from the repository.
Asset Renewal Rate	ARN(A, T2, T1)	ARR (A,T2,T1)= Nadd(A,T2,T1) / Ndel(A,T2,T1)	This measure provides at the end of a measurement period (e.g. on a monthly basis) the absolute number of assets within asset type.
Mean asset reuse rate	MARR(A)	MARR(A) = Σ ARR(Ai) / N(A)	This measure counts the number of reuses of a specific asset

Table 25: Overview on the asset related management measures

The management measures provide more aggregated information to support the management of the knowledge reuse and invention activity. Those measures which mainly feed into the measurement facets reuse (for example mean asset reuse rate) and invention (for example asset renewal rate) provide in combination with the navigation a sound concept for analysing the performance of the organisational knowledge base in terms of reuse, invention and its exploitation. The measures mentioned in the table above can refer to asset types and batches of asset types referring to specific process phases, organisational levels and disciplines.

It is important to understand that the measurement framework presented earlier allows the integration of non-reuse and non-invention asset related measures in the measurement facets. For example the assets might be equipped with further measures elaborating on the product performance.

6.4.4 Summary and conclusion

In sections 6.4.1 to 6.4.3 the author has presented the PMI, which is the knowledge and process-oriented infrastructure for the management of reuse and invention **assets** providing a reuse and invention oriented view on the NPD process. Those assets are equipped with operational measures which provide operative decision support in terms of reuse versus creating new knowledge. Those operational measures can be aggregated to management measures which support more strategically oriented reuse and invention management.

The integration of the PMI with the performance measurement framework represents the synthesis of a diagnostic management oriented measurement function with an operative, NPD process oriented improvement function for reuse and invention. This integration represents therefore a remedy for the demanded operationalisation and process orientation of a PMS framework.

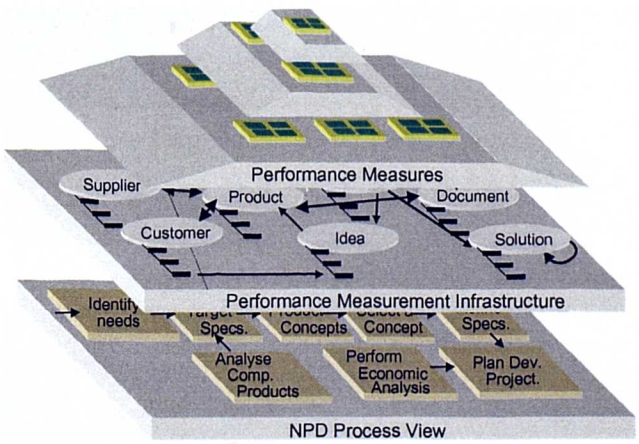


Figure 46: Relationship between the NPD process, the PMI and the performance framework

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The proposed conceptual integration of a reuse and invention oriented PMS framework into an operational, knowledge oriented infrastructure, the above proposed PMI represents a major contribution to knowledge in the field and has received considerable attention in the community within international workshops, conferences and fairs.

The following list summarises the major advantages of the proposed concept towards existing concepts:

- The PMI reflects directly on the operative NPD process and delivers therefore a truly process oriented PMS function.
- The PMI provides an operative day-to-day working environment with a fully embedded PMS function.
- The PMI, together with the measurement catalogue and the PMS framework represents a complete performance measurement package suitable for NPD environments.

6.5 The software realisation

Within the European research project <<IST-1999-11926 NIMCube>> the performance measurement framework, the measurement catalogue as well as the performance measurement infrastructure have been implemented within an enabling technology. This software solution provided a very good support tool to verify and validate the functions in business environments.

The software helps to meet the requirements within the cluster "data processing mechanisms" which has been presented earlier in this thesis.

The software solution has been turned into a pre-commercial software product. This might also give indication of the industrial relevance of the methodical concept of the performance measurement functions and design principles presented in this thesis. In the following sections, an overview of the developed software solution will be given as this will provide further understanding of the developed theory outlined in the previous sections[59]:

6.5.1 The systems architecture

The basic software solution has been defined as a fully web-based product, which follows scalable principles in order to be able to provide a range from standalone desktop solutions to more complex three tier architectures (NIMCube, 2000b).

The software is based on the following commercial IBM/Lotus based platform:

- IBM/DB2 Universal Database being a relational datastore for structured data and metadata.
- Lotus Domino for keeping unstructured data and knowledge, providing a collaboration infrastructure. The Lotus layer is not mandatory. All the functions have been realised in the course of the project to work directly with the IBM/DB2 database.
- IBM WebSphere Application Server has been used to provide scalability and the environment for running the middle-tier business logic.

The software relies on open standards, like XML, HTML 4.0, JSP 1.1, Servlet 2.2 and SQL 92. This ensures a coherent integration of other non-IBM related products, like

[59] The actual software code was developed by a professional German software solution provider. The author's role within the software development was to ensure that the reuse and invention oriented measurement functions represented through the methodology, the catalogue and the performance measurement infrastructure have been coherently "translated" into software through guiding the system architecture design and the functional specification.

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ORACLE server and partially with Microsoft SQL server. The vision regarding the database is to support completely XML based database.

Further key features regarding the systems architecture are:

- The architecture is based on a web architecture pattern, providing at least the following logical layering: presentation, business logic, and data services (Three tier architecture).
- The chosen programming language for the business logic has been JAVA. The communication with the presentation layer is ensured through JAVA server pages.
- Basic functionalities which support the methodology, the measurement catalogue and the performance infrastructure functions has been realised through using components, mainly Java Beans. The components have been developed by the software solution provider. The components exclusively rely on CORBA for communication in distributed environments. The performance measurement infrastructure is additionally supported through existing powerful knowledge management software from InXight™, called Star Tree™ (currently (June, 2001) still in a test version).
- The user interface is fully web-enabled, i.e. the software client requires only a commercial web browser, like the Netscape Navigator™ or the Internet Explorer™ from Microsoft. The Java Virtual Machine (JVM) is required for some specialised User Interface functions.
- All server components are compliant to Java 2 Enterprise Edition platform.

Implementation Scenarios

The software provides to different kinds of implementation scenarios:

- ASP (Application Service Providing) solution hosted by the software solution provider. It is based on three-tier deployment architecture, including the application server at the 2nd tier.
- Black box - the complete SW solution is installed on-site at the customer. The solution is also based on a three-tier deployment architecture.

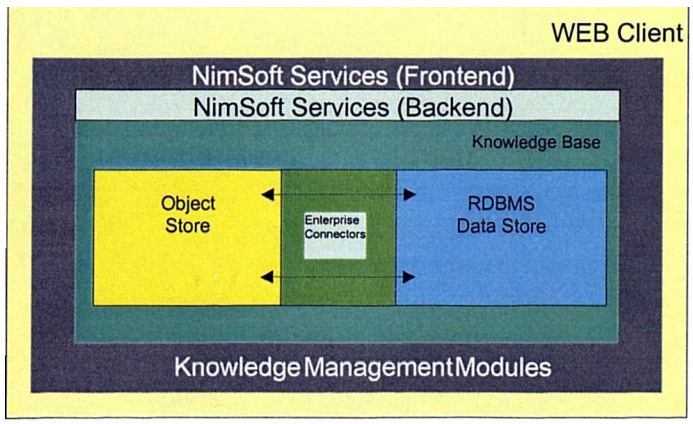


Figure 47: Overview on the Software Architecture (NIMCube, 2000b)

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6.5.2 The functional specification

The major functionalities of the NIMCube software are described in the following table:

Functionalities concerning the PMI	Functionalities concerning the measurement framework
❑ Visualisation, Retrieval, Storage, Classification, Dissemination, Creation of Reuse and Invention Assets	❑ Cascaded Representation of the measurement model with the six facets
❑ Community of Practice Support	❑ Classified Metric Catalogue
❑ Meta-Data Administration	❑ Three Axis Navigation Structure
❑ Context Representation	❑ Automatic Report Generation
❑ Push-/Pull Mechanisms	❑ Cockpit Functionality (Dashboards)
❑ Provision of Asset-Oriented Metrics	❑ Aggregation of Metrics with Weights
	❑ Assign and Maintain Metric to Measurement Level
	❑ Design and Run a Measurement Usage Report

Table 26: Overview on the basic functionalities of the Software

In the next sections the author will reflect on some of those functionalities. However as the software is not the primary focus of this thesis the author will give an overview rather than an in depth description of the various software features. Figure 48 shows a screenshot of the overall login screen showing the PMI Module ("Operations Support") and the performance management framework ("Performance Management") logins.

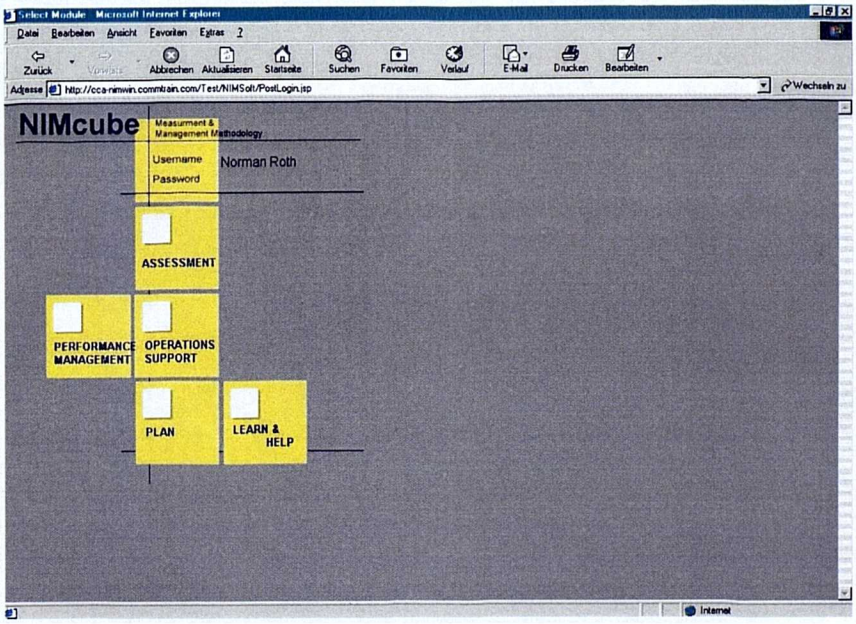


Figure 48: Overview on the login screen of the software solution (NIMCube, 2001c)

6.5.2.1 The measurement concept

The 6 measurement perspectives are the guiding design principle in the performance module. The user gets his user specific view on the unfolded cube. The navigation axes are realised at the left frame of the measurement screen. The selection of the navigation dimensions impacts the selection of the measures presented in the facets (Figure 49).

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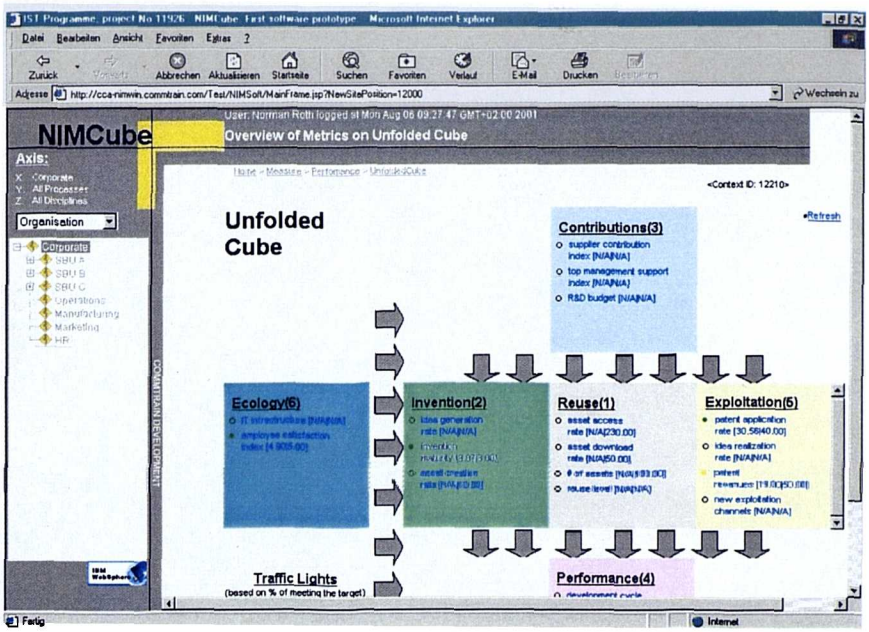


Figure 49: User Screen of the performance management framework from a reuse and invention perspective (NIMCube, 2001c)

The software can be customised according to the various graphical metaphors presented earlier in this thesis. The software proposes the navigation axes process, discipline and organisation as default settings. Customisation to specific user needs is easily possible. All the measures presented from the cube are documented within the measurement catalogue (see next section). The traffic lights scheme is based on a standard default setting but can also easily be customised. The system supports push mechanisms through warnings and automatic provision of measurement reports and reminders. The invention aspect is supported through provision of a creativity space, which is a virtual teamroom where people can meet virtually having at their disposal various creativity and brainstorming tools. The system incorporated aggregation and weighting principles in order to minimise the effort of entering data manually for all nodes at the hierarchical axes. Reports can be generated individually through using a wizard functionality. Reports can be exported into MS Excel to enable manual editing of measurement results. Charts can be drawn in 2D and 3D and the chart axes can be selected freely.

6.5.2.2 Reuse and invention measurement catalogue

The measurement catalogue provides all standard functionalities necessary for creating, editing, reporting and visualising performance measures. The measurement catalogue can be, via XML interfaces, integrated in legacy systems (like Enterprise Resource Planning (ERP) Systems) that already existing measures or their values can be coherently integrated in the measurement catalogue. Figure 50 shows an exemplary user screen indicating how people can enter the measure's attributes.

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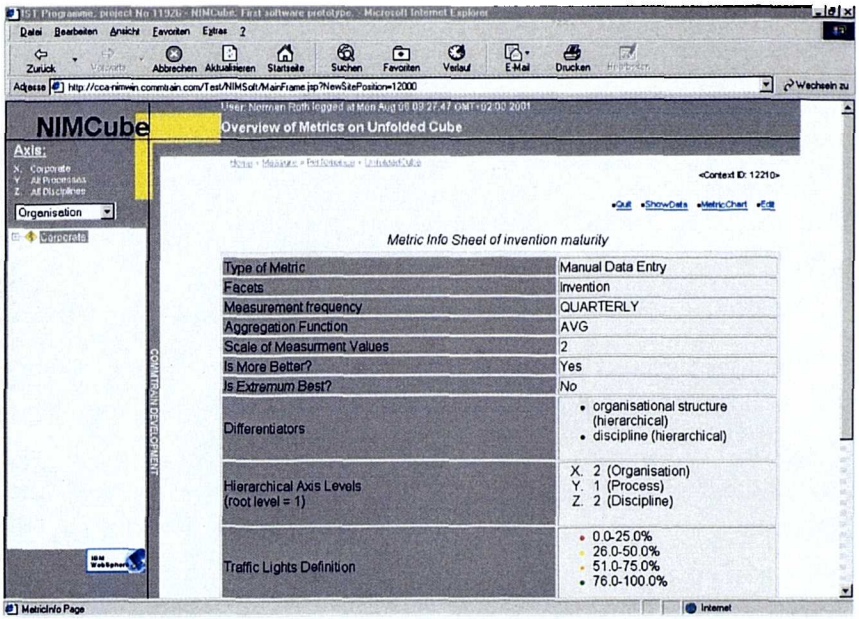


Figure 50: Screenshot of a measurement catalogue screen (NIMCube, 2001c)

The measurement catalogue is fully customisable to individual users' needs. Attributes can be added or deleted, collection and reporting periods can be individually defined as well as the position in the navigation space and the position in the measurement model, represented for example through the cube.

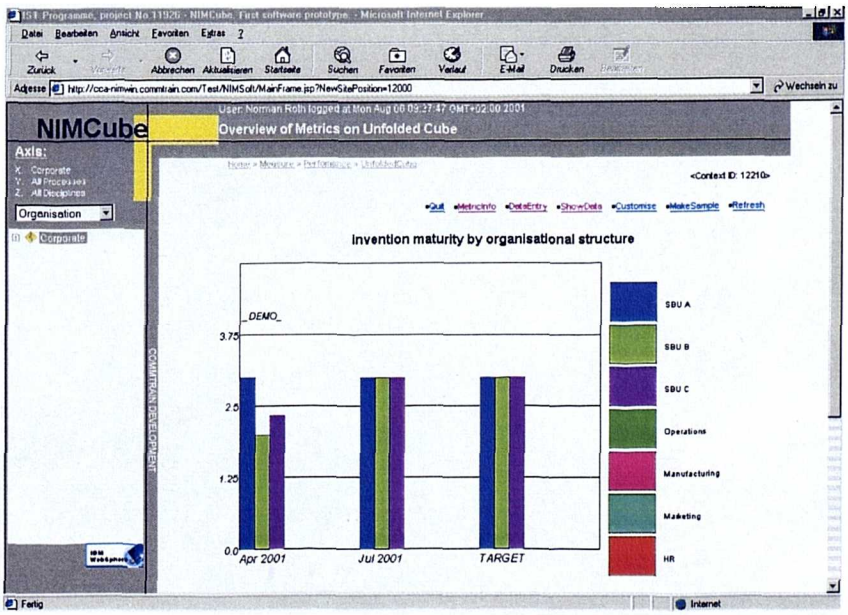


Figure 51: Visualisation of the measurement results for the measure invention maturity within the navigation dimension "organisation level" (NIMCube, 2001c)

6.5.2.3 Performance measurement infrastructure (PMI)

The PMI is based on relational data structures. The figure below shows the asset data model of one of the case study companies.

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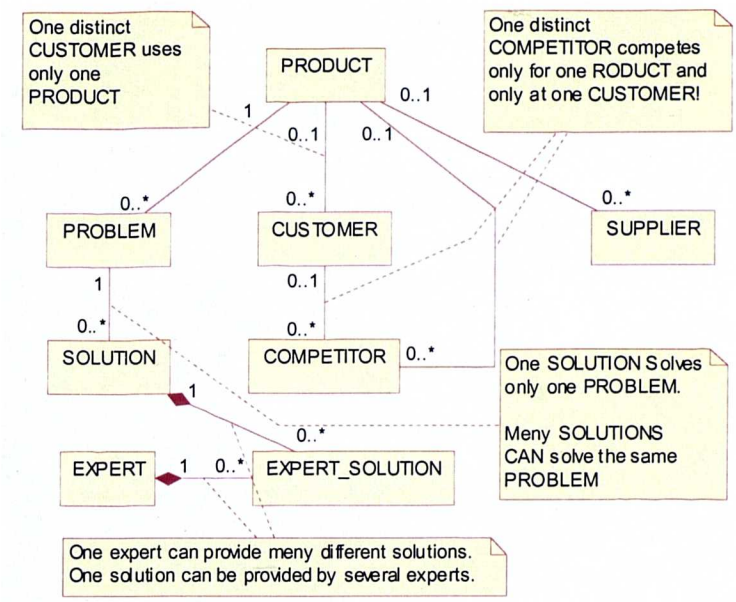


Figure 52: Overview on the data model of the performance measurement infrastructure (NIMCube, 2001c)

The PMI offers standard KM functionalities like storage, retrieval and search (also semantic search). New assets, asset descriptions and associations can be generated easily through a comprehensive UI. The whole administration back-end is not visible to the user.

Figure 53 shows a screenshot of an asset of the asset type "SW module" with its describing attributes.

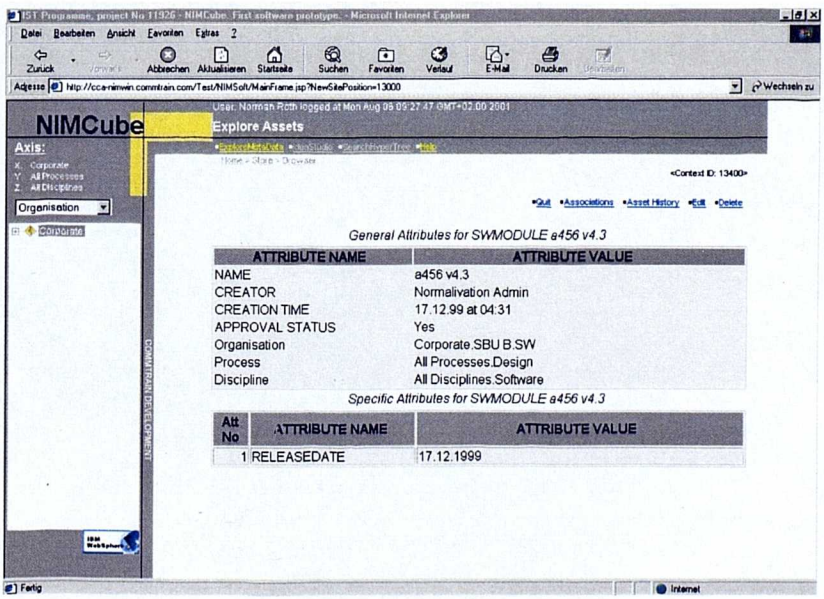


Figure 53: Overview on the asset type "SW module" with describing attributes (NIMCube, 2001c)

In order to increase user friendliness a commercial knowledge visualisation tool, the Hyperbolic Tree™ from Inxight™[60], is currently tested and might be integrated in the system.

60 See www.inxight.com (accessed 10th of July 2001).

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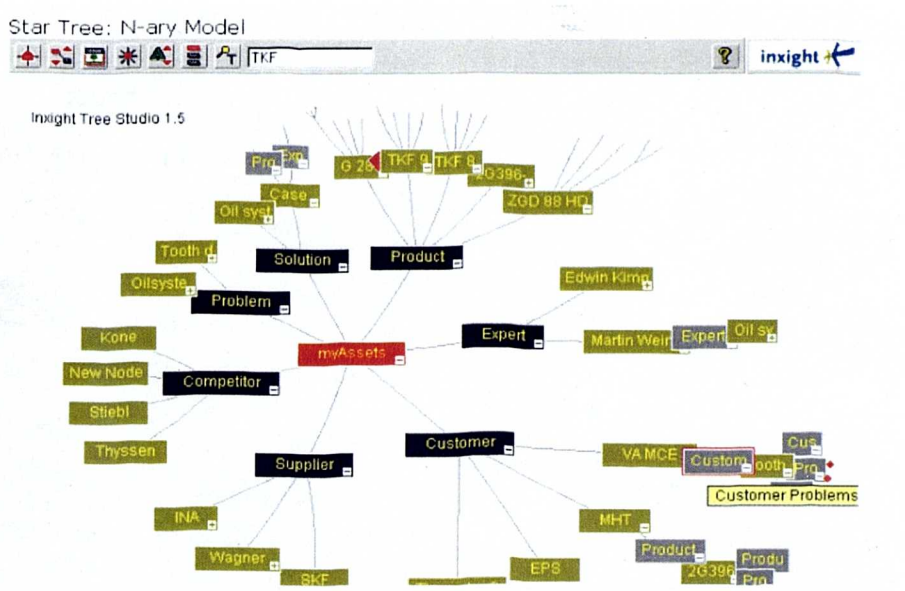


Figure 54: User Screen of the performance measurement infrastructure based on Inxight™ technology (NIMCube, 2001c)

Figure 54 gives an overview of the reuse and invention asset structure model like it has been realised at one of the case study companies.

6.6 Summary, conclusion and review of the functional specification

Within subsection 6.2 the author has delivered a novel 6 facet measurement concept. The design of the six measurement facets, "Stakeholder contributions", "Exploitation", "Operating context", "Reuse", "Invention" and "Performance" relies on a very sound and deep derivation from a considerable amount of bibliographical sources, expert interview outcomes and user feed-back. The six measurement perspectives have meanwhile received a considerable amount of attention within the community (see chapter 9).

The provided PMS navigation concept, with NPD process, organisational hierarchies and functional disciplines as the default navigation axes reflects on the need of companies to have much more sophisticated navigation principles than purely organisational oriented ones. This design principle has been extensively requested by companies with very complex and distributed NPD processes (like case study 4 company, section 8.5). In complex NPD companies, this concept was seen as preferable to the well-known organisational drill-down structures.

Various graphical metaphors for the measurement framework have been delivered. Chapters 8 and 9 will show in detail that users prefer clear and straight-forward metaphors towards comprehensive and complex metaphors. Visualisation is proposed to be a very important enabler for communication of measurement results.

A sound process aligning the measurement framework to the strategic planning process is presented in a great level of detail in this chapter as well. The process uses the six measurement facets and the navigation concept for measure verification and selection and development ensuring thereby a coherent derivation of performance measures from the NPD objectives and strategies. The development of this process has been supported by leading experts in the field and has been extensively exposed in the community.

The operationalisation of this framework is facilitated by the evolution of a manifold measurement catalogue; which is a reference structure for measures and an extensive repository of reuse and invention qualified measures. It enables the user organisation to select and define measures relative to its goals and requirements. The accompany-

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ing measurement recording sheet supports the comprehension and documentation of measures.

In completion, the author has added a Performance Measurement Infrastructure (PMI) with developing knowledge asset concepts in the specific context of performance measurement. These serve as a data processing mechanism, translation and integration tool for the performance measurement framework. The PMI represents the process orientation of the overall measurement concept and proved to be very beneficial for operative day-to-day decision support (see chapter 9).

Finally the author has presented an innovative software architecture which has been built upon the three modules described in this chapter. The software is proposed to be an important enabler of the previously presented PMS functions in business environments. Without enabling IT the management of the vast amount of information and knowledge would be very difficult if not impossible (see chapter 9).

Revisiting the functional specification presented in section 5.4 the author has been able to develop theory through the three functions PMS framework, catalogue and PMI (including the enabling technology) which meet many design principles outlined in the functional specification. The case studies will give further evidence and justification for this statement (see chapter 8).

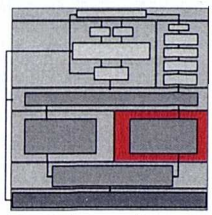
This chapter represents the final outcome of a highly iterative design process. In the chapters 8 and 9 the most important design decisions made during the design work are recaptured and reflected.

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7 Design principles for the PMS build and implementation function

"Anyone who tells you it is easy to change the way groups of people do things, is either a liar, a management consultant, or both."

The Economist



Within this chapter the author will explain how the functions presented in the previous chapter can be implemented in business contexts. The build and implementation function itself consists of two major modules which are realised partly in parallel: the implementation module for the Performance Measurement Infrastructure (PMI) and the implementation module for the PMS framework. Once these modules are fully implemented they may be supported by an enabling information technology (IT). As the implementation of the IT is beyond the scope of this thesis the author will not elaborate on this issue except where the implementation of the other modules described above interacts with the software implementation.

7.1 Overview on the PMS build and implementation function

In subsection 5.2.3.4 it has been stated that the implementation of the performance measurement functions will impact the structural, the cultural, the personal and the technological systems and characteristics of the user environment. Against this background thoroughly planned change management is considered key to a successful introduction which may result in comprehension, acceptance, adaptation and continuous use of the provided performance measurement functions. The build and implementation function presented in this chapter builds on the attainment of critical success factors in change management as shown in Figure 55 (based on Doppler and Lauterburg 1999) and the functional specification set earlier in this thesis.

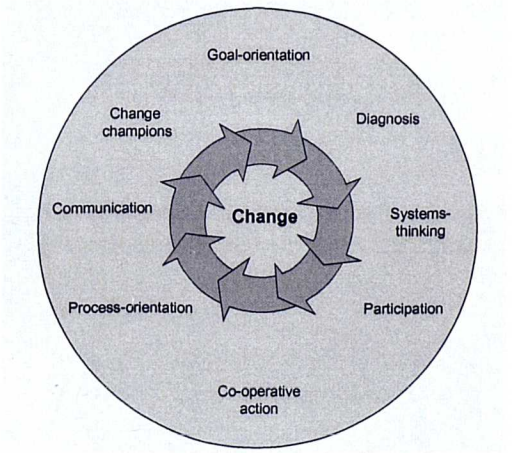


Figure 55: Critical success factors in change management (based on Doppler and Lauterburg, 1999)

The critical success factors can be briefly described as (based on Doppler and Lautenburg 1999):

- Goal-orientation

  For any change project clearly defined goals and targets have to be agreed on before the project starts in order to set a commonly agreed and understood base-line

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for the change efforts. Goals and targets may contribute to a straight forward implementation project.

- Diagnosis

  In order to avoid the "re-inventing the wheel phenomen" a thorough analysis of the as-is situation is recommended. This action is also important from a human factors point of view as it expresses the work previously done.

- Systems Thinking

  The context of the implementation project has to be considered as a system with clearly defined borders, subsystems, input and output relations. Systems thinking may help reducing the complexity of contexts through systematic decomposition.

- Participation

  Any change project should pursue a very participative style. Indeed, the more people who are involved in the project the higher the acceptance of the users might be.

- Co-operative action

  Actions should be performed in a very co-operative manner. Often due to the systems scale, people can work only on fractions of the overall solution, therefore co-operation among individuals is crucial.

- Process orientation

  Often in companies organisational structures are difficult to change (Doppler and Lautenburg, 1999). Therefore the focus should be on changing processes which often leads to a change of the organisational structures subsequently.

- Communication

  Open, clear and frequent communication among all stakeholders is key for a successful implementation project.

- Change champions

  Each implementation project should have an internal driver who acts as sponsor internally promoting and disseminating the project.

Doppler and Lauterburg (1999) assume recognition of the above factors forming an effective change management concept. Driva (1997) adds that especially with regard to performance management in product development the human oriented success factors communication, co-operation and participation are key for a successful PMS implementation.

Besides the school of change management and performance measurement also the engineering school influenced the author in designing the build and implementation function. In her dissertation project Kerrsens-van Drongelen (1999) bases her measurement design process on systematic design principles (Pahl and Beitz, 1996 and Simon, 1981) assuming thereby an engineering oriented view on her PMS implementation concept. She reflects on the principles "hierarchical decomposition", "abstraction", "systematic variation" and "selection on the basis of the satisfying principle" (Kerssens-van Drongelen). Consequently, she proposes the design phases "problem definition phase", "conceptual design phase", "detail design phase" and "implementation phase" which is in turn based on Simon's IDC cycle which consists of the phases "**I**ntelligence", "**D**esign" and "**C**hoice" (Simon, 1981). She discusses and justifies that the development of business solutions, like a PMS, can be very much aligned to the development of technical solutions referring thereby to well-known researchers, like Simon (1981), Pugh et al. (1983) and Pahl and Beitz (1996).

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Reflecting on the systematic design principles and the functional specification, the author structured the overall PMS build and implementation function into the well-known development phases awareness, launching, requirements analysis, solution development (preliminary and detailed), testing through piloting, roll-out and continuous improvement (based on Wheelwright and Clark, 1992; Pahl and Beitz, 1996 and VDI, 1997). While bearing in mind the critical success factors derived from the change management discussion based on Doppler and Lauterburg (1999) as well as the functional specification (section 5.4).

Due to resource and time constraints of a PhD project, the focus of this methodology is certainly the build and implementation of the PMS functions and not the support of the actual use of the PMS, although ensuring an excellent use of the PMS has been a guiding principle for the design, build and implementation of the PMS functions. As stated in chapter 9 the in depth investigation of the use aspect of PMS functions might be rather challenging due to the fact that the use aspect is heavily correlated with human behaviour. The impact of PMS functions on human behaviour however is certainly a long term process which could not be investigated sufficiently in this project. Therefore the author will not elaborate in detail on the use related issues, like how to make people work with the system, how to train the user, how to implement performance based rewards or installing of actions based on measurement results.

The build and implementation function relies on two main modules: The build of the PMI and the build of the PMS framework including the build of the catalogue. The author proposes to separate the overall build process in those two modules for the following reasons:

- The build of the two modules requires the participation of partly different stakeholders: While the PMI development is rather operative and process-oriented, the development of the PMS framework also requires the deeper involvement of NPD management.
- The separation into two modules proved to be beneficial in terms of complexity reduction of the overall build and implementation methodology.[61]
- The PMI and the PMS framework can be built in a highly parallel manner, two different but very well aligned build procedures seem to be appropriate.
- The build and implementation of the PMI and the PMS framework might be funded from different budgets in business environments, therefore a separation into two "projects" might be appropriate.

The software implementation being the third major module is not elaborated in this research work due to the focus of this research. However, where the implementation of the software technology contributes to the understanding of the PMI and PMS framework build and implementation, referring comments and explanations will be given.

The build and implementation function presented in the following section is not of an in depth workbook nature instead it represents a generic, high-level methodology which shows the necessary steps and actions.

Figure 56 below gives a high level overview of the overall PMS build and implementation function presenting the various process steps, applied tools and methods. Subsequently, the various process steps will be elaborated in greater detail.

61 The separation into two modules meets the design principle "hierarchical decomposition" as suggested by (Pahl and Beitz, 1996).

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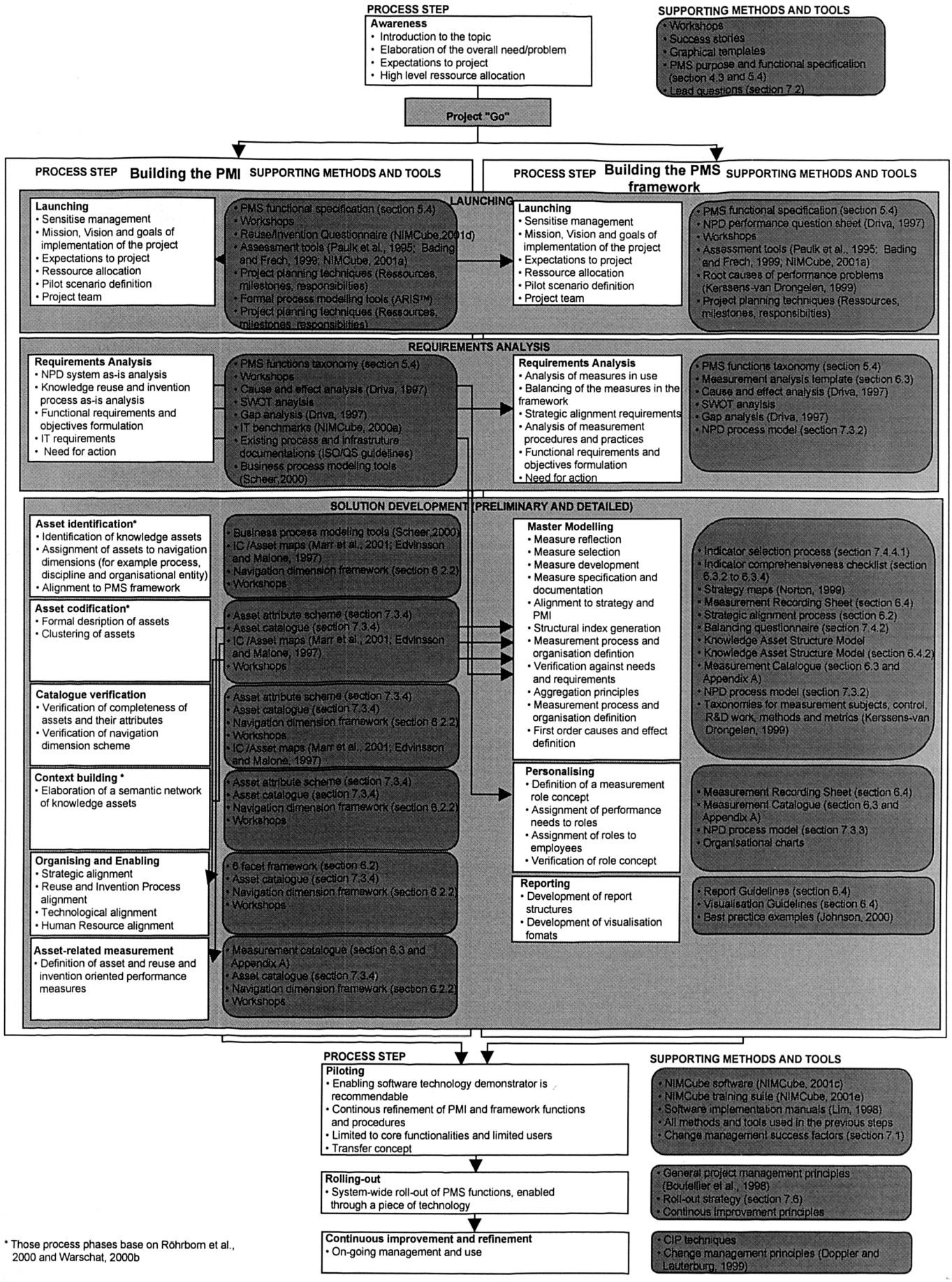


Figure 56: Overview on the PMS build and implementation function

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7.2 Awareness

The build, implementation and effective operation of the PMS functions at users' site must build on awareness and comprehension of the approach, its rationale, its purpose and its implications. An initial introduction and awareness-raising phase will therefore precede any PMS build and implementation. This is typically performed in an open workshop format, moderated by (external) facilitators[62]. The facilitators would present the PMS references, white papers, articles, success stories and slide shows to the participants.

The target audience of such a workshop should include the users' top-management, accountable representatives of the NPD entity, information technology specialists and operational staff, such as engineers or designers.

The introducing sessions will first of all be subject to the characteristics of the user organisation. Nevertheless, it should eventually provide answers to main questions as follows:

- What role do knowledge and knowledge management take in today's economy and society?
- What is the trade-off between creative generation of new knowledge and reuse of existing knowledge?
- What challenges arise from this context with respect to product development, especially with regard to management and measurement?
- How is a PMS solution supposed to address these challenges?
- Which specific PMS solution might apply to the user organisation?
- What preconditions and efforts are required on the part of the user organisation?
- What implications come along with respect to structure, people, technology and culture?
- Which objectives and achievements can be considered within the short-, medium-, and long-term?

The workshop should lead to an open, interactive and critical discussion of performance management and measurement from a reuse and invention perspective in the user organisations' NPD environment. It should pose questions on feasibility, suitability, readiness and expectancies of and for the PMS solution on a very high level. The awareness phase should end with a clear commitment to the project, high level agreement on resource allocations, project roles, scope, mission and vision of the project.

7.3 Building the PMI

The process presented in the following sections is based on findings of the EU Projects "Make IT SME" (Make IT, 1999a; Make IT, 1999b; Prenninger et al., 1999 and Prieto, 2001) and "NIMCube" (NIMCube, 2000c) and has been adapted for the context of this research. These projects take a knowledge asset approach which has been adapted to performance management and measurement thinking. The adaptation has been through incorporating a measurement dimension in the asset structure, through aligning the build and implementation process to the specific features of the PMS framework

[62] In the context of this research there are currently reflections to found a start-up company providing facilitation services around this research topic. Neely et al. (1996) reflect extensively on the profile a good facilitator should have.

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(six facet thinking, navigation dimensions) and through focusing on the specific NPD context.

The PMI build (and implementation) is basically fulfilled by an internal, cross-functional project team, which is supported through consultants (which may be internal or external)[63]. The composition of the team might slightly change according to the specific stage of the implementation process. A fully accountable and committed reuse champion (for example an internal manager or an external consultant) should head the project team. The entire process of building the PMI needs to have enduring and substantial management support.

Figure 56 (left side), on page 144 gives an overview of the build and implementation path and indicates where the PMS methodical framework building interacts with the implementation of the PMI. The interactions are described in detail in the following sections.

7.3.1 Launching

Activity 1: Sensitise management and major stakeholders

The "Launching" step is based on the previous awareness-raising activities and concentrates in this section on the PMI. Consultants sensitise top-management as well as NPD management and all the other stakeholders with respect to improved management and measurement of their knowledge reuse and invention system. A case study from a previous project may be used to clarify the general purpose, the methodology, the requirements, the benefits and also the challenges for realising the PMI.

Based on a commitment to a PMI build and implementation project and comprehension of the implications coming along with it, the target group opens clarification and verification of the problem in detail, their overall vision with regard to reuse and invention management and measurement in the area of NPD. These initial activities are typically carried out in a focused interactive workshop format. A carefully selected company internal champion should co-ordinate and control the various activities.

The "Launching" stage would commence with a brief reuse and invention assessment workshop, to identify in a time and cost efficient way the main enablers and inhibitors within the considered NPD system with regard to reuse and invention. A referring assessment tool and a questionnaire have been developed within the EU Research project <<IST-1999-11926 NIMCube>> (NIMCube, 2001a; NIMCube, 2001d). The application of generic assessment tools like the CMM (Paulk et al., 1994) and EFQM (Bading and Frech, 1999) can support the identification of potential enablers and inhibitors, although they are of rather generic nature. One of the most important objectives of this phase is to involve all major stakeholders.

Activity 2: Define the goals of the project. Develop jointly a detailed project plan and select a pilot scenario and a cross-functional project team

The step closes with the precise definition of a pilot scenario (for example a selected NPD system in terms of affected processes, organisational units and disciplines), a project team and a project plan. Once this is determined a team of process owners and accountable managers clarifies and perhaps redefines the goals and strategies assigned to innovation.

Performance measures give way to quantify goals, limitations and allow for monitoring of progress of the build and implementation project. At this juncture some interaction with the PMS framework building is reasonable. The interaction should elaborate on

63 The author learned during the course of this research that a facilitator who is not involved in the project subject may be very beneficial for the quality of the outcome of the interactive sessions.

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the requirements of the PMI and the PMS framework, the time horizon and on the definition of further synchronisation points.

7.3.2 Requirements analysis

Activity 1: As-is analysis

The actual construction of the PMI commences with the analysis and structuring of the identified new product development, reuse and invention pilot scenario. The building team might thereby reuse existing process documentations, work procedures or ISO guidelines. The team investigates strengths and limitations along the process, their root causes and associates them to the distinct stages. The assigned roles and responsibilities, the information flow, relevant interdependencies and information media are explored and clarified. Process modelling tools, such as ARIS Toolset™ or Enterprise Modeller™ are likely to facilitate this activity.

Eventually, the PMI implementation team obtains a transparent and visualised model of the NPD, reuse and invention process of the pilot area. In Figure 57, there is an example of such a formal process representation, originating from case study 1, which is presented in the following chapter 8.

Interactive workshops might provide a good frame for the described activities.

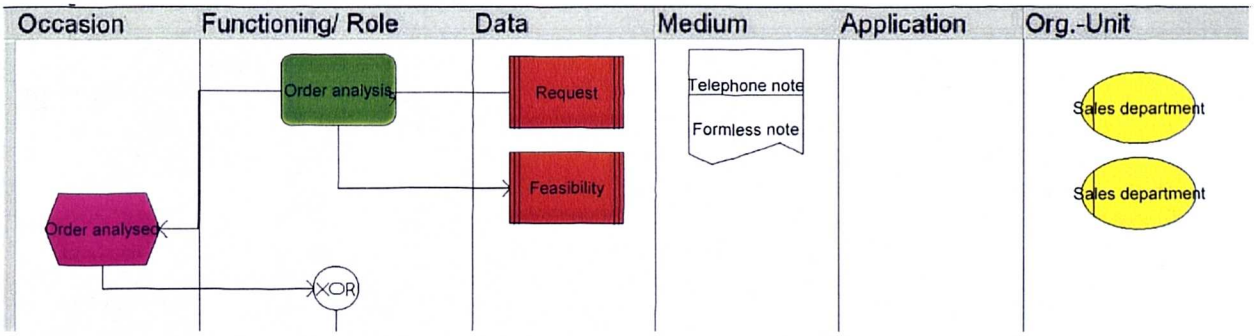


Figure 57: Process model (example, done with the ARIS Toolset™)

Activity 2: Formulation of requirements

The captured as-is situation leads to the specification of objectives and requirements for the design of the PMI relative to user organisations' unique characteristics and conditions. Thereby, the project team strives for consideration of all relevant NPD stakeholders and system users. A diligent SWOT-portfolio of the current practices or techniques are likely to support the derivation of those requirements. The PMI builders and implementers should keep the essential generic PMS requirements (section 5.2.1, 5.2.2 and 5.2.3) in the back of their minds when guiding the project team through such a session. Further tools which may support the elaboration of detailed requirements are cause and effect analysis (Driva, 1997) and the Gap Analysis (Driva, 1997).

At the end of "Requirements analysis", the PMI building project is supposed to be understood and well defined. The newly recruited and accountable project team has a clear direction and is provided with the necessary abilities and resources.

This phase should also reflect on the issue whether and if so to which degree an enabling information technology is needed.

7.3.3 Asset identification

The PMI build team then determines the reuse and invention assets, which are potentially relevant for reuse and invention. These assets are related to a specific activity along the process. They therefore achieve a reuse and invention asset-based view on their NPD system. Thus, the assets are assigned to specific phases of the NPD process. Depending on the complexity of the organisation the assets might be further clus-

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tered according to the performance navigation dimensions presented earlier in this thesis (section 6.2.2). The capture and appropriation of those assets is the vital prerequisite of an asset structure model. Figure 58 below shows an example of such an assignment.

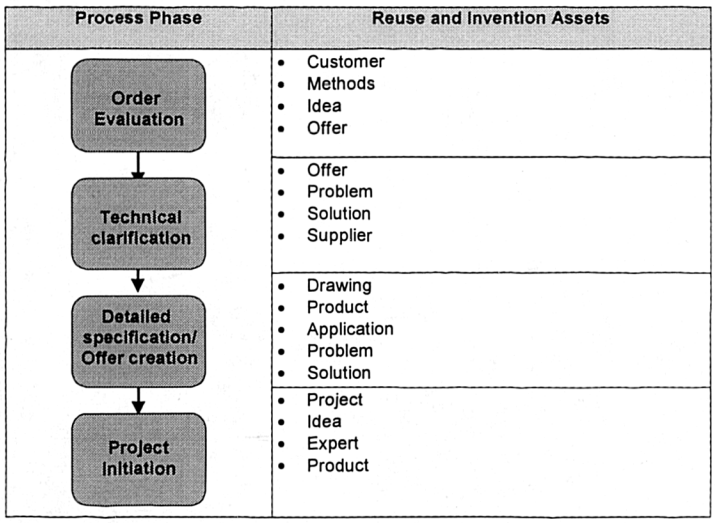


Figure 58: Assignment of knowledge assets the NPD process (example, based on case study 1; Prenninger et al., 1999; Roth et al., 2001)

The list of "standard" assets (as defined in the previous chapter) may serve as a counter-check for completeness. Further, IC maps as suggested by for example Edvinsson and Malone (1997), may provide additional support in ensuring that the most relevant reuse and invention assets have been captured.

7.3.4 Asset codification

Within "asset codification", the identified reuse and invention assets are described and documented in asset recording sheets. These templates provide four different parameters or attributes for referencing the asset (based on Warschat et al., 2000b):

- O (Original) – indicates genuine information describing the asset.
- A (Association) – refers to the asset's context; the relation to other assets.
- C (Category) – is a categorisation parameter organising the asset in different subcategories.
- M (Measure) – links to specific measures and metrics, which elaborate on general performance but especially on the reuse and invention aspect. This description interfaces the asset to the PMS methodical framework (section 7.4) In Figure 59 the author presents an example for the generic asset "method". The in depth elaboration of measures is done at a later stage (section 7.3.8).

The addition of any newly acquired asset basically follows a similar codification scheme.

Reuse Asset Type: Method	
O	Name
C	Category
O	Description
A	Expert
M	Reuse Quality
O	Tips

Figure 59: Asset recording sheet (example based on case study 1; Prenninger et al., 1999; Roth et al., 2001)

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The single asset recording sheets are then summarised in an aggregate reuse and invention asset catalogue. The resulting comprehensive documentation is the very core of a company-specific PMI application. Figure 60 provides an excerpt of such a catalogue.

Reuse and Invention Asset Type		Contents	Explanation
Competitor			
Customer			
Product			
Offer	O A C M	Offer number Product Industry Sector Reuse potential	 Level between 1-5
....			

Figure 60: Reuse and invention asset catalogue (example based on case study 1; Prenninger et al., 1999; Roth et al., 2001)

7.3.5 Catalogue verification

It is necessary to check the catalogue for completeness from bottom up and top down. The bottom up "catalogue verification" is carried out against the specific NPD process phases, the organisational levels and entities involved and the contributing disciplines. The navigation axes shown in Figure 61 serve as a three-dimensional framework for this verification being a guiding navigation principle of the PMS framework (see also section 6.2.2). By these means omissions and imbalances are identified and corrected.

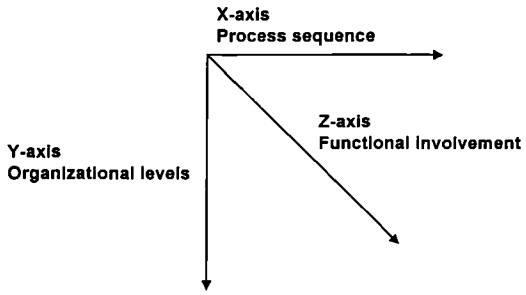


Figure 61: Navigation axes for verifying the reuse and invention asset catalogue

It should be noticed however, that not all organisations would want and / or need to apply all three axes. The scope of verification and of coverage is therefore determined by those user organisations. During the top down verification, the assets are mapped again against the "standard assets" described earlier in this thesis and known IC schemes, like the one from Edvinsson and Malone (1997) or Marr et al. (2001).

7.3.6 Context Building

The information implied in the structure so far, is not operative unless put into context and order. Thus, the reuse and invention assets, documented and structured in a catalogue are logically related and linked to each other. Defining, constructing and visualising the multi-faceted and interdependent relationships eventually leads to complete knowledge asset models within the PMI (based on Marr et al., 2001; Prieto, 2001; Warschat et al., 2000b). The illustration below presents an example of such a connected system.

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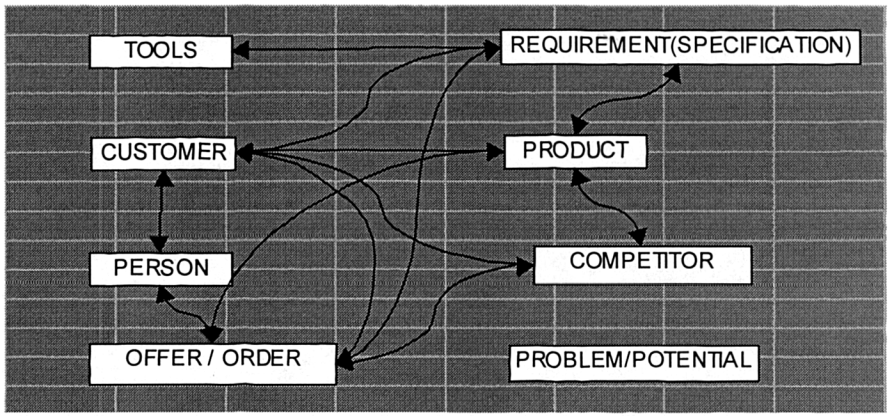


Figure 62: Knowledge asset model (based on case study 1)

Depending on the complexity of the NPD organisation it might be useful to structure the overall (and complex) asset structure model according to the various navigation dimensions indicated for example in the previous section.

7.3.7 Organising and enabling

The process of building, implementing and operating the PMI is intertwined with the strategic alignment of the PMS build. The builders of the PMI should therefore be aware of

- the strategic direction for knowledge reuse and –invention in the pilot system,
- the technological infrastructure to operate the PMI effectively and efficiently,
- the need for the reuse and invention process to be stable
- the process owners and the reuse team to be assigned

From this baseline, the PMI building team, top-management and NPD staff will have to drive permanent initiatives to satisfy those critical factors mentioned above. This process phase clearly suggests a synchronisation point with the building process of the PMS framework where the alignment of the reuse and invention topic to the NPD strategy is a major issue.

7.3.8 Asset related measurement

The implementation team defines a set of key measures describing the stored assets in quantitative and qualitative terms. These measures are assigned to each asset and serve as additional attributes. It is recommended to facilitate information supply by linking the PMI to legacy systems and databases through the enabling software. One of the guiding design principles of the PMI building should therefore be to minimise the user's effort for manually collecting or creating any kind of information. Existing information should be brought into context, equipped with measures which are maintained by a supporting technology.

The asset and process-oriented measurement aspect forms an integral part of the PMS methodical framework. The measures generated through the PMI are fed into the overall PMS framework mostly, but not exclusively, into the measurement facets reuse, invention and exploitation (see also section 6.2.1).

7.4 Building the PMS framework

This module is regarded as a reference for user organisations and consultants for realising and applying the PMS framework. Against this background, each user assigns unique priorities to the build and provides different preconditions and characteristics, therefore the author refrains from going into every detail. This specification is then

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subject to particular customisation (section 7.4.4). However, there will be introduced considerable means, practices and enablers, wherever feasible. Figure 56, page 144 gives an initial overview of the build and implementation path for the PMS framework.

It is again (see also section 7.3) assumed the typical composition of an internal, cross-functional project team, which is supported by skilled consultants. From a company internal perspective the project requires a champion who has at his disposal full top management support and who is recognised as being capable of leading such a project.

The steps described in the following sections are regularly carried out in a focused workshop format moderated by a consultant or the internal champion. Some steps may require repetitive sessions, others may be completed after brief discussion. This however is up to the user organisation and often situation-specific depending on the abilities of the project team (Prieto et al., 2001).

7.4.1 Launching

Activity 1: Sensitise senior management and major stakeholders

The "Launching" step draws on the awareness-raising activities proposed in section 7.2, but concentrates on PMS framework building. Consultants again sensitise top-management by communicating and explaining the vital functions of a performance management system from a reuse and invention perspective in the context of NPD. An exemple scenario (for example a case study from reference users) aids the clarification of purpose, method, requirements and possible benefits of the PMS function.

As management has committed to a PMS implementation project and comprehends the implications, it clarifies and underscores the mission and vision of the implementation project. The tasks include the definition of a dedicated project planning team.

Activity 2: Define the goals of the project. Develop jointly a detailed project plan and select a pilot scenario and a cross-functional project team

This project planning team is in charge of setting up a well-structured project team within a different physical meeting.

Such an interdisciplinary project team is usually composed of external or internal consultants, championing and facilitating the project. Managers, process-owners and representative users are recruited into the team from the diverse internal NPD stakeholder groups (for example purchasing and marketing). Essential management support is, last not least, exemplified by provision of an adequate funding.

The team clarifies the goals and strategies assigned to NPD and how knowledge-focused performance management and measurement is believed to contribute to achievement and realisation of these odds given. In the event of not having performed the NIMRate assessment (see section 7.3.1) prior to this workshop, it is suggested to commence with a brief evaluation of performance measurement in terms of reuse and invention practices and goals.

The step ends with the definition of a detailed and well structured pilot scenario (alignment with the framework building is required) and project plan.

7.4.2 Requirements analysis

Activity 1: As-is analysis

Once the team has gained a common understanding of its NPD system supported by process analysis techniques, its measurement mechanisms and practices and its used measures, are subject to in-depth analysis for qualification and comprehensiveness. They are thereby set against the organisational structure of the area, this leads into an examination of which measurement mechanisms and practices are applied in which

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organisational unit. The documentation and consideration of the involved operational processes and functional disciplines for instance, may serve as a means to counter-check the analysis. The team might hold recourse to previous efforts performed in the turn of building the PMI when discussing processes and disciplines. It might also be recommendable to cluster the NPD system according to product groups to make the analysis of the applied measures and procedures more transparent (Neely et al., 1996). The measures are documented using the measurement recording sheets (section 6.3.6, page 123). The current NPD goals and strategies are identified through either elaborating them in joint session with senior management involved or through considering the business plan of the company[64].

Activity 2: Balancing of the current measures in the measurement framework

At this point, the team disposes of a comprehensive picture of the applied measures, measurement processes and organisational structures, the NPD goals, business objectives and NPD strategies. In the turn of this session the team sets its measures, practices and systems against its goals, business objectives and strategies. The consultant opens the discussion with a brief reflection on and repetition of the matter of knowledge reuse and invention. He then guides the implementers through the discussion by asking questions such as:

- "Do our measurement practices support our goals and business objectives?"
- "Do our measures cover all six facets of innovation?"
- "Are we able to achieve and measure an appropriate balance between reuse and invention?"
- "Which balance is required and which measures are needed to strike this balance?"
- "Which are the preferred levers for improving reuse and invention performance?"

The step closes with an in-depth understanding of the implication of goals, strategies, balancing and measurement. At this point it is of importance to emphasise again that neither "Balancing" nor any subsequent steps allow for strategic planning. The building of the PMS builds on a previously defined strategic direction and themes supporting its realisation.

The model of the six measurement perspectives (facets) as well as the navigation dimensions guides the project team through verification of completeness helping them in assessing and balancing whether all perspectives of innovation are adequately addressed (see also section 6.2.5.2).

A facet not covered and blanks on a measurement-recording sheet, point to an opportunity for improvement. The deliverable of the step is some shared understanding of the actual measurement system and of the relationship of measures to distinct stages and contributors in NPD.

Activity 3: Formulation of requirements

This exploration leads over to the specification of objectives and requirements for the customisation of the PMS framework relative to user organisations' unique characteristics and conditions. Thereby, the project team strives for consideration of all relevant NPD stakeholders and system users. A diligent SWOT-portfolio of the current practices or techniques are likely to support the derivation of those requirements. The PMS builders and implementers should keep the essential generic PMS requirements (Section 5.2.1, 5.2.2 and 5.2.3) in the back of their minds when guiding the project team through such a session. Further tools which may support the elaboration of

64 The reader might reflect on the section 6.2.5 where the strategic alignment issue is discussed starting from a company's business plan.

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detailed requirements are the cause and effect analysis (Driva, 1997) and the Gap Analysis (Driva, 1997).

In a next step these needs and identified functions can be used as input for a PMS-QFD (Quality Function Deployment) in which the specific needs are mapped with the functional specification of a reuse and invention oriented PMS for NPD environments (section 5.5). This activity is proposed to be important for focusing the PMS build and implementation work.

The step closes with an in-depth understanding of the specific requirements for the PMS framework. It reveals the vital needs for improvement, which have to be addressed in the following.

7.4.3 Master modelling

The composition of a master model of the PMS marks the core task within the implementation path. It is therefore likely to run over several workshops. The team must be aware of the master model applying to the entire pilot area; i.e. all involved entities, process phases and disciplines. Thus, this model contains all considerable measures and warrants for consistency. This eventually allows for assigning selected measures to particular roles, functions and process steps. Whether and how measures differ through the organisation is subject to the structure and arrangements of the user organisation.

Activity 1: Measure selection, development and specification

Previously, during "requirements analysis", the builders have discovered the gaps and limitations of their current measurement system through collecting and documenting the measures currently in use and then analysing the needs for improvement also with regard to strategic alignment and balancing of reuse and invention. Those improvement potentials result from comparison of the "as is" situation with those requirements proposed essential for a qualified PMS. They form the foundation for selecting and developing a suitable and balanced set of measures.

It is suggested to entrust appropriate and named team members with the selection and development of measures satisfying the requirements. They would thereby basically hold recourse to the measurement catalogue (section 6.3). This however does not restrict the development of additional measures. The consultant ensures that each facet of the PMS is assigned to someone responsible, warranting for covering all vital measurement perspectives. They support the team members with advice and recommendations where needed.

As all measures are associated to strategies, the interrelations of measures and facets become obvious (For this activity graphical charts might be very helpful). In case a measure can not be related to a strategy, it is probably not necessary and may be skipped. If a strategy is still without measure, the team would consequently have to select and develop an additional measure.

The graphical charts would eventually illustrate the measurement concept and allow for a critical review of the achievements so far. Depending on the number of selected measures a prioritisation of the measure and the referring driver in terms of relevance or importance might be useful. The succinct overview adds to transparency, practicability and ease-of-use.

Activity 2: Measure specification, documentation and verification against the needs and requirements of the entire NPD process

The team then draws on this visualisation and fills out the measurement-recording sheets for each measure collectively. The specification of the parameters determining a measure or the definition of an adequate formula for example usually results from joint

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discussion. This provides the opportunity to agree on responsibilities and action items and deepens the understanding of the measurement system once more. The facilitator reviews these procedures by questions similar to those asked in the course of "Requirements analysis" (section 6.3.6, page 123). The completed measurement-recording sheets are then combined and categorised to form the customised and specific measurement catalogue. The entire measurement catalogue has to be sent to other NPD entities to verify whether the created framework can potentially be applied in other areas.

Activity 3: Structural index

Anticipating the personalisation of the measurement tool, the organisational structure of the pilot area is indexed. The team would thereby define the appropriate entities and put them in a logical and hierarchical order. By purposively combining those entities the implementers create sub-indices, which reflect for example the NPD process, the interdisciplinary implications, project settings. The completion of this task is rather subject to adjusting and installing the software device (section 6.5). The implementers of the PMS would however have to determine the given structure and communicate it to those answering for the software solution.

Activity 4: Master verification

Eventually, the master measurement model will be verified against the needs and requirements of the entire NPD organisation; i.e. the necessities discussed on the level of the pilot area (see "requirements analysis") are now investigated at the level of the NPD system as a whole. In addition the master is exposed to all the stakeholders of the specific NPD environment. The implementers will thereby complement the team with representatives of other NPD units or departments. In the event of unreasonable disagreement and inconsistency, the master might be modified. It should be flexible enough to allow for adaptation within the other NPD units. This last task prepares a possible NPD-wide rollout.

7.4.4 Personalising

The PMS framework features numerous views, tailored to the information needs of the individual user / user group. These different views, scope of access and authorities have to be predefined for adjusting the software technology. The step "Personalising" builds on the indexed structure, which has been established during the "Analysis" and "Master modelling" phases. The responsible implementers would proceed as follows:

- Define the selected roles in the organisational structure which are to be equipped with a personalised view on the PMS.
- Elaborate the performance information needs of these roles. These information needs determine the particular view assigned to a role. Each role obtains an exclusive view on the master model. Since roles are derived from organisational structure, the levels of measurement granularity and the provided measures are shared across the entire organisational layer.
- The roles are assigned to specific employees. Management selects those employees allowed for using the PMS relative to distinct preferences and policies.
- Verify that views and authorities are in line with rules, practices and procedures of the user organisation (e.g. through top-management approval)

7.4.5 Reporting

The task "Reporting" prepares the formats of reporting performance measures. The implementers would draw on the information needs examined previously (section 7.4.2) and agree on the means, directives and visualisation form for reporting to superordinate entities. It is suggested to integrate these with existing reporting schemes

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and mechanisms of the organisation. It should be noted that "reporting" exceeds the permanent monitoring of performance through the measurement cube. It is of a rather diagnostic nature and involves interpretation, analysis and verification of information. The "Who acts on the data?" field on the measurement-recording sheet obviously indicates who needs to be supplied with reports and who takes action on the results.

7.5 Piloting

As all preparations are completed (measures defined, goals and strategies clarified, measurement views and routines established, the asset structure model defined (section 7.3), data migration concept elaborated, organisational roles identified, processes established) the model is put in exemplary real-life operations in the pilot area.

This usually happens via the installation of the enabling software technology[65]: Once the steps above have been completed, the software provider customises the software technology off-site and installs it in the pre-defined pilot scenario. In the future probably most software solutions will be offered as hosted solutions (section 6.5), therefore the pilot installation will be comparatively easy as no additional hardware is installed at the user site. Issues like realisation of the data migration from the legacy systems to the hosting server, user rights and login definitions, security concepts, integration in the existing working environment, connectivities to other applications are final steps in the piloting phase. One of the main objectives of this task is to review the practicability of the asset structure model, measures, of indexed structure and responsibilities. Certainly the user feedback during the piloting phase should have an impact on the design of the system. Typically, the pilot runs with limited core functionalities to avoid overburdening users and systems. The pilot operation will always take place with a limited number of users, providing smooth transition.

7.6 Rolling out

The entire process is supposed to close with the NPD-wide installation of the PMS functions mostly probably enabled through the software application. Therefore, the implementation team should hold a comprehensive project review, document and analyse lessons learned (which is a reusable knowledge asset) and propose steering measures, if need be. Management would then take the final decision after reflecting costs and benefits. "Rollout" comprises two dimensions; i.e. in terms of functionality and in terms of user groups.

7.7 Continuous improvement and refinement – the management and use of the PMS functions

This phase focuses on the management and use of the implemented PMS functions. Review procedures have to be established and the functions have to be embedded in budgeting, reward, incentives and human resource management processes and programmes. It has to be noted that the management and use aspect is beyond the scope of this research work, therefore the author won't go in more detail at this juncture.

7.8 Conclusion and review of the critical success factors and functional specification

This chapter provides a strong contribution, as for the first time a build and implementation methodology for performance measurement functions to improve

[65] Generally the PMS approach presented in this research work could be applied without any software, however due to the complexity and vast amounts of data in today's industrial environments the application of an enabling software technology seems to be very recommendable.

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knowledge reuse and invention has been proposed. There are several processes proposed which elaborate on the issue on how to build a measurement framework, but very few of them include the implementation of an infrastructure, none of them includes the implementation of knowledge oriented infrastructure.

Based on the functional specification (section 5.4), the critical success factors for the presented build and implementation methodology (section 7.1) and the systematic design principles (section 7.1) the author has been able to meet and cover them providing a pragmatic and user-friendly build and implementation process for the PMS functions presented in the previous chapter. A more detailed discussion on this issue will be provided within the case study analyses in chapter 8 and the concluding discussion presented in chapter 9.

Summarising, this chapter represents the outcome of a very intensive learning process the author went through the last years. The outcome of this chapter is a result of the strong dialogue with the case study companies, the many talks with leading experts, an the intensive study of literature and the broad experience the author gained in the consulting business over the last years. The author believes that the proposed build and implementation function has potential to become even more recognised and accepted in the community.

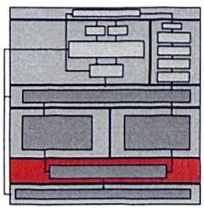
The case studies outlined in the following chapter will give further evidence on the quality and validity of this function.

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8 Theory testing within case studies

"A customer is not dependant on us. We are dependant on him"

Leon L. Bean, Founder, L.L.. Bean &Co.



Within this chapter, the author will investigate how the performance measurement functions behave in business environments. To attain this objective, the build and implementation methodology presented in the previous chapter has been applied in 4 companies. It will mainly investigate whether the PMS functions have been able to meet the needs of the company and whether the system fulfils the functional specification set earlier in this thesis. In a first step, the companies' needs will be recaptured, detailed requirements presented and the solution scenarios outlined. Subsequently, an in depth analysis incorporating the outcomes of the research tool application at each of the 4 case studies will follow. The implemented functions have been shown to be able to meet the major needs of the companies and to meet the functional specification respectively. The author will analyse the appropriateness of such an integrated solution to different NPD environments.

8.1 Introduction

The developed theory and referring PMS functions are so far of generic nature and can be applied to all potential target companies.

Within this chapter the developed functions will be applied in a real-life environment as pilots. The author applied therefore the build and implementation methodology presented in the previous chapter. In all the four case studies, the solution has been embedded in an enabling information technology. As the enabling technology and its implementation is beyond the scope of this thesis the author will not elaborate this in greater detail. However, where it is necessary for the understanding of the four pilot scenarios the author will give also in this chapter referring descriptions and definitions.

The various pilot teams were involved from the very beginning of this research, therefore it has been possible to develop over time a high level of understanding and trust which proved to be very important for the later delivery of the pilot. Various research tools have been applied throughout the research process. The four cases will be presented and discussed in four different sections. Each section starts with describing the company background, the problems, needs and requirements and the implemented solution. The second part of each case study is explanatory, where based on the findings of the research tool application, an in depth analysis of the case study is provided.[66] Table 27 below gives an overview on the research tools used, the number of people involved, the resources the author invested in on-site activities and the financial investments the company made. More details about the design and use of the employed research tools can be found in section 2.2, page 11 .

66 The author wants to thank especially Juan Prieto from Fraunhofer IAO, Ron Dvir from Innovation Ecology, Scott Hawkins from Skandia, Edwin Kimpl from Eisenbeiss Ltd., Oliver Beck from Hoffmann Ltd. and Atai Ziv from ECI Telecom at this juncture who supported the comprehensive on-site activities.

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		Case Study 1 Gear Manufacturer (GM)	Case Study 2 Financial Service Company (FS)	Case Study 3 Automotive Supplier (AS)	Case Study 4 High Tech Company (HT)
Size of the company (Employees)		150	7000	45	6000
Size of the unit where the case study activities took place [Employees]		15	18	7	50
Users involved in the on-site activities		15	30	10	8
Number of days the author spent on-site		25	18	20	17
Investment the company made [Euros]		115.000	143.000	45.000	199.000
Applied research tools (Number of times applied)	QFD, date	4th month	4th month	4th month	4th month
	# participants	8	7	6	6
	Survey, date	2 times panel survey 4th month, 18th month	-	18th month	18th month
	# respondents	8		10	8
	Semi-structured focused interviews	3	4	4	2
	Focus Groups	9	5	3	3
	Knowledge Cafés	1	1	1	-
Implemented Functions (Yes, No)	Measurement Framework	Y	Y	Y	Y
	Measurement Catalogue	Y	Y	Y	Y
	Performance Measurement Infrastructure	Y	Y	Y	Y
	Software	Y	Y	Y, but with no native data	Y, but partly with no native data
	Build and implementation method	Y	Y	Y	Y

Table 27: Overview on resource allocation and research tool application

The case studies therefore test and explain the theory developed in the previous chapters based on an existing problem (being a typical example of problem-oriented research design, see section 2.1.6, page 11).

8.2 Case study 1: The Gear Manufacturer (GM)

8.2.1 Description

8.2.1.1 Company background

The Austrian company represents a typical "old economy" company, specialised in highly customised gear manufacturing. Currently the company employs 150 people and makes a turnover of approximately 17 million Euros (in 2000). The annual investments amount to 3 million Euros. The company shows a typical matrix organisation, with quality, sales, finance, IT and purchase being support functions for the different product divisions which are heavy industry and extruder industry. The company is also employing a small central R&D unit which supports the divisions in their development efforts. Currently the company is going through a transition phase; its mission is currently changing from being a low price gear manufacturer to a vendor of highly innovative, high quality gears: In the last decades the company was very successful through offering low cost – good quality products, however increasing competition from

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low-salary countries like Romania made the company change their mission recognising that their extensive knowledge in gear manufacturing is a truly valuable asset.

The company has been one of the industrial partners in the EU funded research project <<IST-1999-11926 NIMCube>>. The motivation for this company to join this project was to develop a management system which helps them to be efficient through reusing existing knowledge and on the other hand being inventive through creating new knowledge due to the shift in the company's mission. New product development takes place in the divisions supported by people from sales, manufacturing, purchase, maintenance, and R&D.

The extruder division is certainly the most innovative division of the company. The division currently employs ten people and is very fast growing both in terms of staff and in terms of turnover. The big need to manage the reusable knowledge (new employees, big market competition, large scale competitors with very stable and efficient processes) and to be creative (the mission is to be and remain technology leader worldwide) makes this division a very good candidate for the pilot case.

8.2.1.2 Main problems, needs and requirements

The following list of problems and the presented needs have been elaborated within an interactive, facilitated focus group workshop (section 2.2.4, page 17): 8 employees from the company contributed to this list which represents only those findings which the users considered to be most important. The other case study companies used a very similar process with a similar number of people being involved.

The main problems at the GM

Process particle	Problem/Opportunity
Management process	The company shifted from cost to technology leader, currently the company has no system in place which brings this new strategy into action.
Reuse of knowledge happens ad-hoc in manufacturing and not in a controlled way	The production processes are extremely knowledge-intensive and the quality of the product highly depends on the knowledge of the worker. For example, there is one specific grinding machine which only can be used by one specific set-up. Therefore also in the production environment there should be provided means which allow storage of intangibles, like experience, problems, solutions *as well as* tangibles like blueprints or machine settings.
Product innovations happen ad-hoc and not in a controlled way	Another important issue is the fact that there is not a very controlled reuse or innovation process. Through specific metrics these processes could be controlled and monitored. Due to this fact innovations happen "by accident" or based on an urgent customer need. Product innovations should happen as result of a controlled monitored innovation process. For example, specific measures, like number of new products introduced in the last year, or number of patents, might help to control this process.
There is no documentation and storage of quality control know-how	Concerning quality assurance there are a lot of parameters which are based on pure experience and are documented nowhere. For example a certain surface dimension has to be at the upper limit so that the product life-time can be extended. An identification, acquisition and storage of this knowledge could make it easier for others to use this valuable information.

The main needs

The main needs basing on the problems mentioned above have already been outlined within the GM QFD presented in section 5.5.1 of this thesis and are documented in the voice of the customer:

- Decision support regarding reuse.
- Communication of (reuse and invention) strategy throughout the organisation.
- Store of reuse and invention assets to become more efficient.
- Explicit measurement of customer contribution to NPD success.
- Specific measures for efficient reuse of knowledge.
- Minimal additional effort in maintaining, migrating, processing data.
- Involvement of all stakeholders in the performance measurement activities.
- Solutions should be based and rely on proven standards.
- Easy and cost effective implementation of the PMS.
- Improving the quality of the offer process through management of knowledge.

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Requirements for the PMS at the GM

The general requirements for the PMS solution for the GM can be derived from the results of the QFD presented in section 5.5 of this thesis. It should be recaptured that all case study companies went through the QFD process with 3-8 people being involved in it. The author took an observer role. The highest rated functions in the QFD correlate to the most important requirements for the PMS at the GM. One of the main requirements for the company is to have at their disposal a process-oriented performance management and measurement infrastructure which supports the company in managing the NPD knowledge assets and measuring the company's reuse performance. Alignment to strategy, participation and transparency are also of great importance as the company wants to ensure that the overriding R&D strategy of being a prospector is communicated, monitored and understood throughout the whole company in a very participative way.

8.2.1.3 The PMS framework, the PMI and the measurement catalogue for the GM

The extruder unit decided to go for a full-size pilot. This means that all the functions described in this thesis were implemented on-site. The companies used and still uses the system with real life data, which indicates that the system and its functions have been thoroughly tested. Before the PMS had been built and implemented the company had no existing PMS.

Following the build and implementation process for the PMS (chapter 7) a performance measurement infrastructure has been created with 10 reuse and invention assets and with the asset related reuse and invention measures: asset age, asset reuse rate, asset creation rate and asset deletion rate. On the basis of the PMI, the PMS framework for NPD has been built. 15 people use the PMI and another 10 people employ the associated PMS framework. For the facet "stakeholder contribution" and NPD performance, the company defined customer, supplier, manufacturing and top management as subjects. For reuse, invention, exploitation and operating context the company chose the standard subjects presented in section 6.2.1. For the facets NPD performance and stakeholder contribution the companies had already been using a comprehensive set of measures whereas for the other facets measures mostly had to be developed. Altogether the measurement system consists of 15 leading measures for the unit.

An organisational role "measurement champion" has been defined, being an individual who is responsible for the overall system's quality. Each measure is assigned to a specific person who is responsible for collecting and reporting it. Supporting processes, like a reuse and idea generation process equipped with referring measures have been implemented as well. The pilot is currently rolled out to other units of the company which might be a measure of success at this company.

The strategic aspect of PMS was set up in a way that it supports the NPD system of the whole company. As the company develops and manufactures products with a lot size of one to three the organisation is very project driven, therefore the navigation dimensions project, process and organisational level have been defined. Generally a pragmatic and operative solution has been provided: The boundaries for each measure are according to a fixed pre-defined interval for each measure, the reports are provided in a standard format allowing for a simple evaluation over time and a simple comparison of two measures in an x-y graph.

An interesting aspect of the implementation is the fact the PMI has been applied in a specific unit while the PMS framework has been set up for the whole NPD system resulting in a limited coherence of the asset related performance measures. The further roll-out of the PMI is a remedy for this current limitation. Another interesting aspect is that in this company very few measures were implemented which control the "deletion

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of assets". Generally such measures might be very powerful for ensuring that the available knowledge is up-to date and not outdated. However in this case due to the fact that the company has made bad experiences by deleting information (knowledge) those type of measures were not implemented.

8.2.1.4 The IT solution for the GM

The final implementation of the PMS at the GM has been realised through an enabling technology. Although the IT point of view is not the focus of this thesis, the author will outline in this section how the PMS is supported through IT at the GM as this is important for the understanding of the use of the system (see also section 6.5). The GM decided to go for a hosted solution, i.e. no physical hardware has been installed at the GM site. The PMS application is installed at the server of the IT solution provider and all activities from the GM side take place via the web. The GM already had in place a very mature IT infrastructure at the beginning of the project where almost all the native data of other legacy systems, like CAD systems, CAE systems or NC systems is kept in one backbone Enterprise Resource Planning (ERP) system called I/Open™. This constellation made the interfacing from the PMS to native data comparatively simple. I/Open exports all required information in a Comma Separated Value (CSV) file which can be directly accessed through an XML connector which the software solution provider has provided. Generally the PMS supports exclusively "read-only" functionalities, for security reasons writing in the ERP system via the PMS application is not permitted. The CSV file can be generated according to the current specific needs. At the moment one file is generated per day. Each user can access easily the PMS application via MS Internet Explorer 4.0 or higher or alternatively Netscape Navigator 3.5 or higher. As both the software solution provider and the GM have at their disposal a 2MBit/s internet connect runtime performance is no problem for the GM. The login to the PMS application and the role is for the user's convenience directly correlated with the Windows NT login.

8.2.2 Analysing and evaluating the case study 1

8.2.2.1 Introduction - Getting the evaluation data

The evaluation of the PMS solution at the GM is challenging as the whole solution is very comprehensive and "messy" due to the nature of real-life environments. Generally in all the four cases the evaluation will mainly investigate whether the solution has met the functional specification set at the beginning of this research setting quite a narrow scope for the evaluation procedure. The author will still provide some findings with regard to the use of the system. In the following section the outcomes of the application of the various research tools within case study 1 will be discussed.

8.2.2.2 Key findings from the analysis and evaluation of case study 1

The survey results (Annex E, question C1 and C2) showed that the company had quite a good invention performance before the implementation (in the 4th month of the project): 7 out of 8 asked engineers thought that the invention performance is good, 1 thought that the performance is moderate. This rating remained constant during the second survey cycle (in the 18th month of the project). One reason for that might be that the company has very creative engineers with very good ideas. The reuse performance was considered to be good but not as good as the invention performance (Annex E, question C3): In the first cycle 5 engineers indicated that the reuse performance is good, 3 indicated that the performance is moderate. In the second cycle a slight improvement can be observed: 1 engineer changed his opinion stating that the reuse performance is very good now. The company rated its innovation performance moderate. As the reuse and invention performance was considered to be good, there is indication that the third component of the innovation formula, the exploitation is considered to be moderate (this innovation definition is based on Dvir et al. (2000)): In

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the first cycle 7 out of 8 engineers were of the opinion that the innovation performance is moderate, while in the second cycle only 5 engineers were still of this opinion. Two engineers changed their mind from "moderate" to "good".

The above paragraph gives some indication that people in this company think that the implemented functions helped to improve innovation performance.

The balance between reuse and invention was considered important (Annex E, question C5): In the first cycle 3 people thought the balance is important and 5 thought it is reasonably important. In the second cycle one person shifted from "reasonably important" to "important". During the on-site activities the company decided to make a strategic shift from being cost leader to becoming technology leader. This strategy shift made a careful review of the reuse activities versus the invention activities necessary and helped to create awareness for the balance issue. The need for balance was kept at a rather implicit level through definition of measures for both themes. The company was especially interested in the asset related reuse and invention measures, namely the asset age, asset reuse rate, asset addition rate and idea generation rate. This number of measures for reuse and invention and some aggregated guidelines and bottom-lines for reuse and invention were considered to be sufficient.

Within question D.1. *"In your opinion, can the explicit management and measurement of reuse and invention performance have a positive impact on New Product Development performance?"* the general impact of reuse and invention performance management and measurement on the NPD performance was investigated. People were asked whether reuse and invention PM contributes to improve various NPD outcome performance measures (Figure 63).

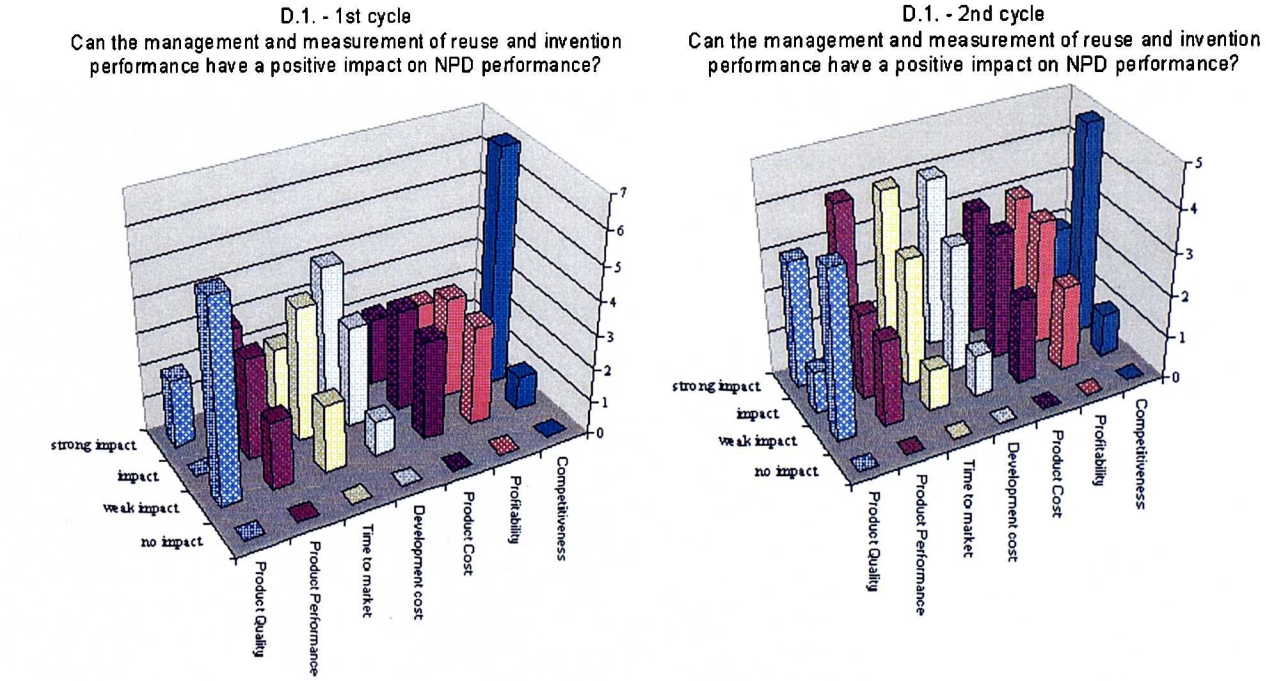


Figure 63: Overview on the impact of reuse and invention performance measurement on the overall NPD performance at the GM (n=8)

The figure above shows that the people asked think that the management of NPD performance from a reuse and invention perspective might have a positive impact on the overall NPD outcome performance: The x-axis in the figure above shows well-known NPD output performance measures, the y-axis shows the number of people and the z-axis indicates the impact people assume. The second survey seems to confirm this statement (Figure 63). Looking at the right chart in Figure 63 it can be observed that the implemented PMS functions seem to have above all a positive impact on the

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product performance, time to market and development cost. People thought that the implemented functions contributed only minor to the improvement of competitiveness. The semi structured interviews showed that people aligned competitiveness with innovativeness of the product. The reason for this rating might be that the provided functions are more reuse than invention oriented (section 10.3).

The facets reuse, invention, performance and stakeholder contribution were considered to be of special importance (Question D5, Figure 64). The second evaluation shows that the exploitation/commercialisation facet gained importance whereas the invention facet slightly lost importance. The reason for that might be that the company realised that they are doing quite well in invention, however that the exploitation/commercialisation aspect is finally critical for turning inventions into money. So far this dimension had been comparatively neglected. The operating context facet (in Figure 64 called ecology) also gained some relevance as people recognised that good reuse, invention and exploitation depends also on a good context.

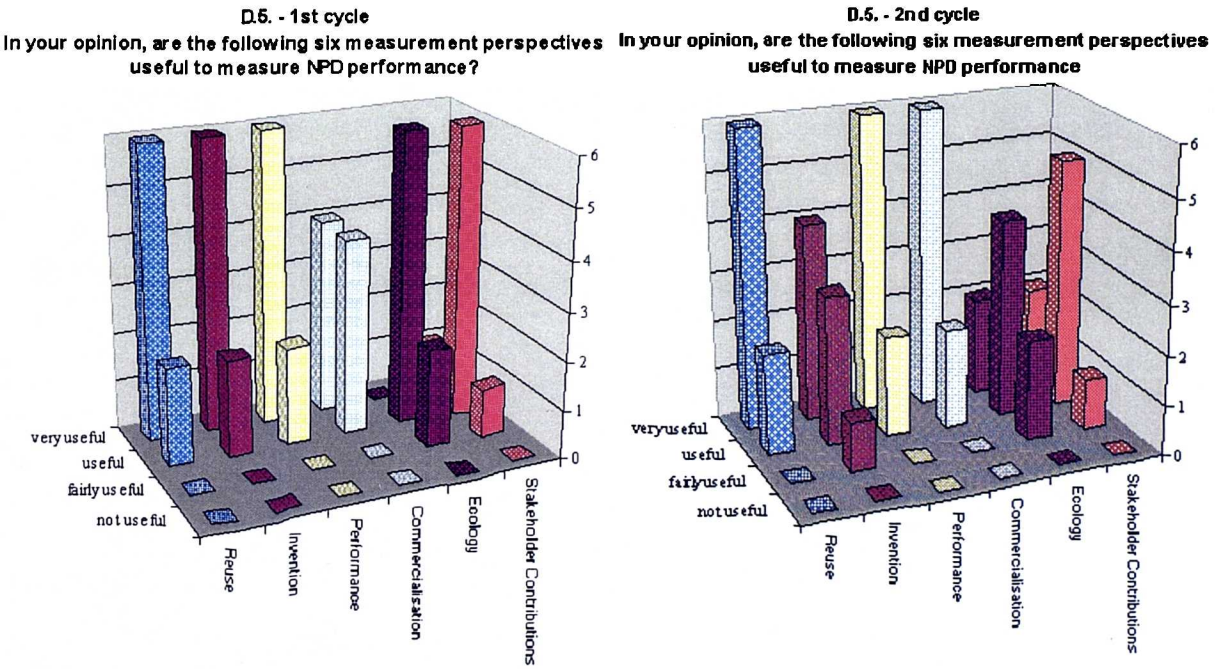


Figure 64: Importance of the six measurement facets at the GM (n=8)

In the first evaluation people considered "IT" the most important subject in the first survey within the performance dimension "operating context" (Figure 65).[67] However the second survey's results shows that softer issues like reuse and invention culture, a good HR Management and a physical environment gained relevance and are therefore considered important drivers for NPD performance.

67 The reader should note that the names of the various subjects changed meanwhile slightly.

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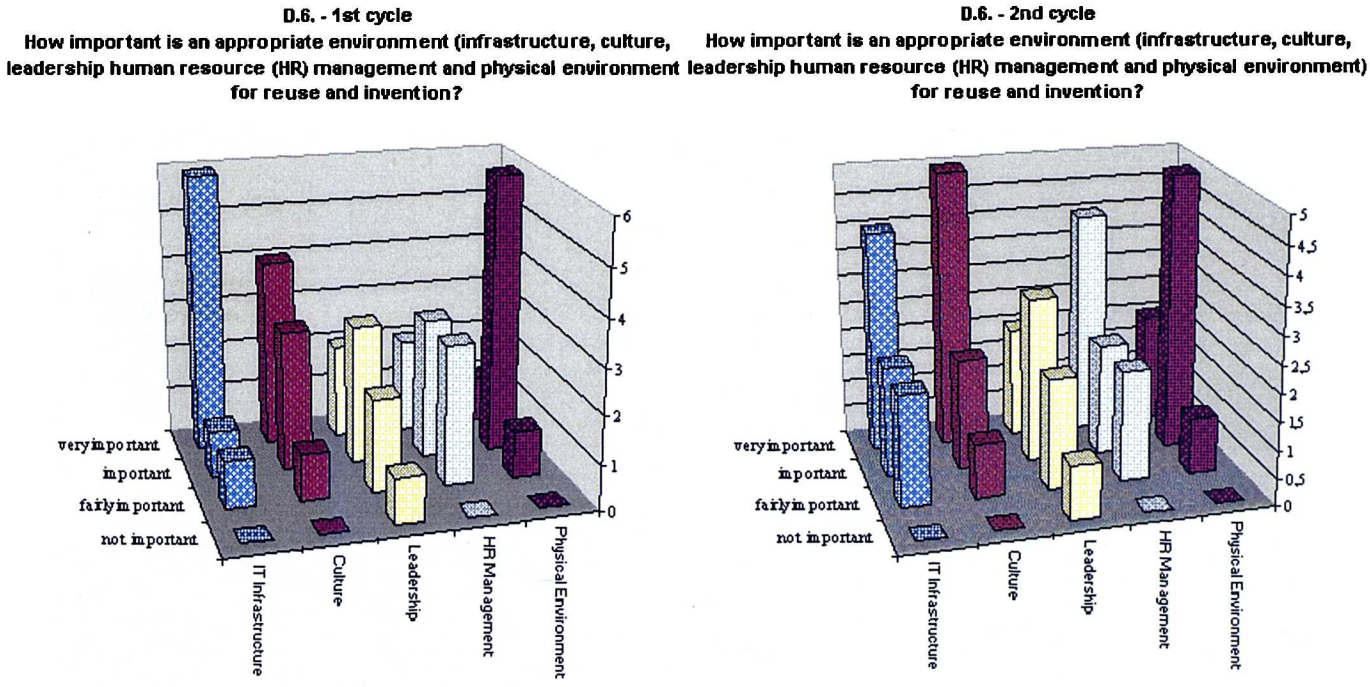


Figure 65: Importance of the subjects within the performance facet "operating context" (n=8)

The on-site interviews give indication that the interviewed people appreciated the completeness of the system providing an operational solution for reuse and invention and a powerful performance management and measurement function for different levels of hierarchy. It has been recognised that the comprehensive navigation facility might be more appropriate or beneficial for medium and large companies especially with regard to asset navigation. In this case the scenario and maybe the whole company was not big enough to require navigation functionalities for the asset structure model, as for the pilot scenario around 10 asset types with "only" several 100 assets have been identified.

The implementation of the full size PMS solution presented in this thesis proved to be a challenge from a project management and resource allocation point of view. Due to the large amounts of data which are used in day-to-day business in this company a software application was a must from the beginning.

The interviews showed that people appreciated the personalising function of the SW (Appendix C, question C1). This function certainly contributed to the user acceptance of the overall system. It was and is critical that all users used the system as single point of entry for any activities. The quality of the management of reuse and invention is heavily dependant on the fact that people act as entirely as possible according to the defined processes, for example indicating why they reuse or why they create a new module. Otherwise good data quality can not be ensured.

The comparatively big effort in customising the functions has been criticised. In fact the dilemma between a highly customised and efficient solution versus a less customised, less efficient solution is not new. At the beginning people were very sceptical with regard to the measurement of knowledge. However the explanation that not the knowledge itself but the reuse or creation of knowledge is measured (supported through giving some examples) overcame this scepticism. The interviewees saw the biggest contribution of the system in the provision of an operational reuse and invention management system and a company wide system which brings the NPD strategy into action pinpointing also to reuse and invention issues (Appendix C, question C1).

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The company sees the provision of benchmarking data for target definitions of measures a big opportunity and enrichment for the system (Appendix C, question C3). A potential threat was the fact that the four Balanced Scorecard dimensions are the "quasi" standard for PM (Appendix C, question C4). The company recommended that the author should provide a sound process on how the PMS functions presented in this thesis can be embedded in the existing well known performance management systems, like the Balanced Scorecard or the Skandia Navigator.

8.2.3 Conclusions

Case study 1 represents a comprehensive testing environment for the developed theory. Over a period of almost two years altogether more than 20 people have been involved in the on-site activities. All the provided functions, including the enabling software, have been fully implemented within a pilot. Especially the build and implementation phases which refer to the PMI have been intensively validated at this case study. Currently the company is elaborating roll-out concepts which aim at implementing the majority of the provided functions throughout the company. It can be concluded that the theory developed in this thesis has been able to meet the needs and requirements set by this company.

An interesting question to answer is why the developed theory satisfied this company to this high extent. The author addressed this question to the employees of this company. The following list highlights some of the written answers to this question given by the employees of this company during interviews and informal talks.

- The provided functions are clear and comprehensive.
- The reuse and invention issue has been addressed explicitly.
- The overall solution combines a more operational reuse and invention infrastructure with a more management oriented performance framework supported by a comprehensive IT.
- The well structured and time efficient build and implementation processes contributed considerably to the user acceptance of the system.
- All the functions are highly customisable and can therefore be adjusted to the individual users needs.

This case study shows that the research question set at the outset of this research is valid and that on developed theory seems to behave as predicted in real-life environments. This case study therefore gives good indication that the developed theory represents one solution to the research problem.

It has been stated earlier that the research process outlined in section 2.2.7 has not been sequential. Instead the process has been highly iterative. The main learning from this case study which impacted the theory development are (based on authors notes made during various focus groups events, formal interviews and informal discussions):

- The implementers should aim for simple solutions.
- Comprehensive guidelines, implementation processes and users manuals should be provided.
- A software can be an important enabler.
- Metaphor and graphical visualisation can be powerful tools for explaining principles and system features.
- Simple language should be used at on-site activities.
- The language barrier can be a big one.
- People like to have a pre-defined set of measures, it makes them feel safer.

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- People seem to appreciate a high number of measures, put effort in explaining to them that a small number of measures might be more goal oriented.
- While designing processes and functions the implementers have to ensure a maximum of user involvement as this might be a key factor to get user acceptance.

8.3 Case study 2: The Financial Service Provider (FS)

8.3.1 Describing the case study 2

8.3.1.1 Company background

This Swedish company offers financial services company with offices in 22 countries and 6,700 employees. The group's 1999 assets under management were 833 billion Swedish Kroner (BSEK). The main operating unit is Assurance and Financial Services (AFS) consisting of 17 companies (as of December 1999) working together to provide long-term savings solutions to investors through financial intermediaries.

These solutions are primarily annuities, mutual funds and corporate pension plans; but also include sales supporting service, software and training. The objective of each company is primarily to work in its own local market niche, often in competition with companies that sell similar insurance and investment products.

AFS is structured as a federative virtual network organisation of independent, yet inter-dependent, local business units and multiple centres of competence and innovation. In this type of organisation, the network replaces the traditional "Head Office". This allows each unit to adapt quickly to local environmental changes, yet still be able to draw upon the resources and knowledge of the global entity. AFS neither manages money nor distributes products directly to individual investors. Instead, AFS forms strategic partnerships with top-quality firms specialising in investment management and distribution. This "Specialist in Cooperation" formula requires that AFS be the conduit between independent, well-known fund managers and independent well-established financial retailers. As a conduit, AFS provides value-added products, operations, and delivery systems. This combination of fund manager, AFS and distributor allows each specialist to add their own value, creating superior service to the long-term savings client. Furthermore, since the formula is based on using networks of established retailers and the established fund managers, the alliance can cope with almost unlimited growth.

The company has been one of the industrial partners in the EU funded research project <<IST-1999-11926 NIMCube>>. The motivation for this company to join this project was to develop a management system which helps them to be efficient through reusing existing knowledge and on the other hand being inventive through creating new knowledge within one unit but also or especially between the various local units.

New product development takes place directly in the various projects. Strategic NPD is partly covered by the global business development team. The project was executed on two levels: On a corporate level providing a solution for the intra-company issues and in the local German subsidiary with 18 people involved in the pilot.

8.3.1.2 Main problems, needs and requirements

The following list of problems and the presented needs have been elaborated within an interactive, facilitated focus group workshop (section 2.2.4, page 17): 6 employees from the company contributed to this list which represents only those findings which the users considered to be most important.

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The main problems at the FS[68]

Process particle	Problem/Opportunity
Idea generation	Idea generation is the research and development of new knowledge to help local business units become more effective. It begins from two different points. One point is that management makes a strategic decision to identify and gather specific information; the second point is that someone within the company discovers a piece of information and decides to act upon it. Currently no structured process exists to direct identification and gathering. As a result time and money is spent identifying and gathering information that may or may not be relevant to the global core competencies. Beyond this hard dollar cost, there is a qualitative cost resulting from less trained personnel attempting to identify and gather information. The FS has realised that it now must provide methods, processes and infrastructures to improve the effectiveness of performance relevant information identification and gathering.
Conceptual and preliminary design	So far there are very few standards for developing information so it can be presented for decision making to the board of management. There is no standard process on how to develop and present the information, very few supporting tools and methods (like check-lists, milestones, templates, lessons-learned documents from former specifications or quality gates). This means some projects begin without any design or approval at all. This results in projects being undertaken without the support of management. Generally decision making lacks a good basis. So far efficiency was not the main objective of this company, a lot of processes were ad-hoc driven. Increasingly due to higher competition and company size there is a big problem in managing and measuring the NPD process from an efficiency perspective. As knowledge is the main production factor (all the products are purely intangible) the efficiency thinking has to include knowledge management issues.

The main needs

The main needs basing on the problems mentioned above have already been outlined within the FS QFD presented in section 5.5.1 of this thesis and are documented in the voice of the customer:

- Efficient management of corporate and local knowledge.
- Extension of Skandia Navigator functionality to operations.
- Support the product development Community of Practice with a knowledge management and measurement solution.
- Measures for knowing how inventive the company is and for top management assessment.
- Minimal additional effort in maintaining, migrating, processing data.
- Involvement of all stakeholders in the design of the system.
- Solutions should be based and rely on proven standards.

Requirements for the PMS at the FS

The general requirements for the PMS solution for the FS can be derived from the results of the QFD presented in section 6.2.1 of this thesis. The highest rated functions in the QFD correlate to the most important requirements for the PMS at the GM. The major requirements at this company are:

- have at their disposal a sound catalogue of measures for the six facets of the present PMS to enrich the IC oriented body of knowledge performance measures,
- to have a process-oriented "extension" of the already existing strategic performance management system to manage and enhance efficiency on operational level.

8.3.1.3 The PMS framework, the PMI and the measurement catalogue for the FS

The main site for operative testing was the German subsidiary located in Berlin. The pilot scenario covered one specific product area which had been developed by the time the pilot was implemented. The full pilot covered 18 users. It has been recognised that

68 The author will only present those problems which are relevant for this thesis.

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due to the reduced complexity of the NPD process in this (service) company an extension of the pilot to marketing and sales could be realised.

The performance measurement infrastructure has been built upon the existing "7P asset model" the corporate intellectual capital unit has been proposed: 7 main assets among them for example people, processes or projects have been equipped with a number of reuse and invention oriented measures, like asset age, asset reuse rate, asset creation rate, asset deletion rate.

The six facet concept has been aligned to the existing strategic PMS, the NPD goals from the local business plan represented the base-line for the development of more detailed measures. The navigation axes have been named product/project and competence representing the company's core competencies (for example NPD, marketing, customer relationship management). With regard to subjects the company relied mostly on the standard suggested in this thesis (section 6.2.1).

Simple, clear report templates mostly showing the evaluation over time of a measure have been realised. In alignment with the already existing corporate performance management system, all measures have been equipped with traffic light targets. The targets have been either set through cascading targets from the business plan and/or through 2 referring workshops with senior management, one in Berlin and one in Shelton, Connecticut. The company invested roughly 25 days in the workshops which were part of the overall build and implementation procedure. Overall the potential applicability of the solution at other local units and at corporate level was an important design parameter. Figure 66 depicts the measurement framework indicating the corporate NPD measures.

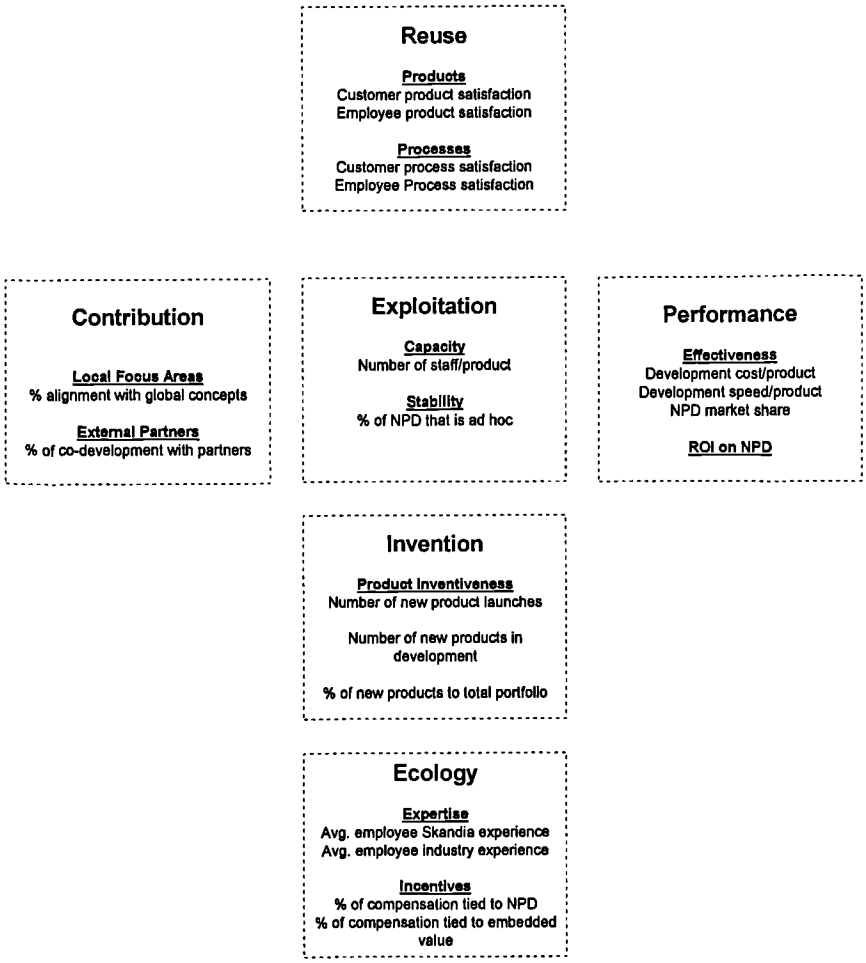


Figure 66: Overview on the measurement framework for corporate NPD of the FS

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8.3.1.4 The IT solution for the FS

Also in this case study the full implementation of the PMS at the FS has been realised through an enabling technology.

The FS selected a hosted solution as well. The PMS application is installed at the server of the IT solution provider and all activities from the FS side take place via the web. The FS already shows a mature IBM AS400 based server environment. Most of the legacy data are stored in this environment. However at the time the pilot was implemented also a considerable amount of important data was stored in a paper-based system. The company invested resources in transferring this data to an electronically accessible form. Similar like in the GM case the "read-only" function relies on the CSV standard leading into the open XML standard. The company exclusively supports MS Internet explorer 4.0 and higher.

Security proved to be a critical aspect: Currently (November 2001) the company decides whether a complete Virtual Private Network (VPN) should be realised between the company and the host or whether a secure AT&T line is sufficient. The 2MBit/S internet connect ensures good web performance.

8.3.2 Analysing and evaluating the case study 2

8.3.2.1 Introduction - Getting the evaluation data

In order to get a deep insight into the pilot a broad selection of research tools has been applied (section 2.2.1.2 and section 8.1). It is important to note that as data source the local project team in Berlin and the corporate intellectual capital unit proved to be very valuable data sources. The following section summarises the key findings from case study 2.

8.3.2.2 Key findings from the analysis and evaluation of case study 2

This case study showed as well that the explicit management of reuse and invention based on performance measurement may imply big improvements with regard to development time and innovativeness of the products. Basically an intangible product, like an insurance policy might appear to be less complex than an industrial product like a gear. However due to the fact that for these intangible products very often a supporting IT is developed in parallel, the overall product development process can be very interdisciplinary, dynamic, parallel and complex.

As the Berlin site increased tremendously in a few years in size from 20 to 150 employees there is now a big need to become more efficient, and to become better at reusing existing knowledge. On the other hand the company does not want to risk losing its reputation as being one of the most inventive companies on the market.

The focus groups showed that the people interviewed appreciated bringing reuse, invention and exploitation in the context of innovation through the innovation equation being innovation = (reuse + invention) X exploitation (Dvir et al., 2000). Several users stated within focus group workshops that the innovation equation makes the very complex innovation topic more explicit than in the Balanced Scorecard or in the Skandia Navigator where the innovation aspect is implicitly covered through incorporating referring measures from for example the business plan into all measurement facets.

The interviews give indication that people appreciated the completeness of the functions combining a more diagnosis oriented management tool with an operative reuse and invention management function, realised through the PMI (Appendix C, question C1). The interviewees saw a big opportunity in integrating the functions presented in this thesis in an existing PMS in this case the Skandia Navigator. Therefore the six measurement dimensions of the model presented in this research

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have been mapped onto the six dimensions of the Skandia Navigator using the house metaphor of the Skandia Navigator (Edvinsson and Malone, 1997).

People within the focus groups and the interviews saw a threat in the overall complexity of the provided functions. The three dimensional navigation function had been reduced to a two dimensional function with competence and project as navigation dimensions. The reason for that might be that the number of products which are developed at any time is around 2-3. The need might therefore be smaller than in case study 4 where maybe 100 development projects are done concurrently. The navigation function implies a considerable amount of measurement data which has been considered a potential threat.

Another important feedback from the focus groups was that people in the new economy do not want to invest a lot of resources in making a perfectly customised solution. They stated as main reasons that a) the company does not have the time for extensive and detailed implementation projects and b) that the company needs light solutions which can be adapted and changed easily due to the dynamic environments. Several users stated therefore that a more or less acceptable solution which meets the majority of the requirements might be sufficient. Above all with regard to the reuse and invention assets and the measures the author had many discussions with the users to which degree these items can be built and implemented out of the box, derived for example from the measurement catalogue or from the standard asset model.

The more knowledgeable employees of the KM subject posed during a focus group workshop the question about the tacit knowledge of a company which is embodied in the people themselves. This question was often answered through using a metaphor: The user has a certain amount of time, if a company manages to enhance reuse resulting in higher efficiency, people have more time to be more creative and maybe more time to make implicit knowledge explicit. Generally it has to be stated that the question of how to extract embodied knowledge is not answered by the functions provided in this research.

With regard to the build and implementation function, people appreciated in the interviews and the focus groups the balance between a bottom-up driven approach through the PMI building and the more top down approach realised through the PMS framework. As opposed to other building guidelines (Kaplan and Norton, 1996a) the analysis of existing measurement structures proved to be beneficial in terms of reusing existing knowledge and avoiding the "re-inventing the wheel" phenomena. People also appreciated the straight forward and goal-oriented approach.

The nomination of an internal champion proved to be beneficial also in this case study. Through having one person out of the company staff being the driver of the project, the acceptance of the function has been positively impacted. With regard to asset related measures the users were interested in very simple measures, like the age of the asset, or the number of times it had been reused before including the referring "comments section" where former reusers have the possibility to comment on their way of reusing the asset. The master modelling phase (section 7.4.3) where all the stakeholders of the system participated resulted in very fruitful discussions aligning the company's knowledge base (represented through the assets and their referring measures) to the company's strategic themes and NPD goals. This proved to be very beneficial as so far there was only a very implicit link between those two aspects of the company.

The company was pushing hard in limiting the number of measures to an absolute minimum. The final measurement system will probably contain between 15 and 20 measures which goes in line with Neely (1998) who suggests that even for big companies 10 to 15 measures should be sufficient. The users agreed that in terms of aggregation and transparency the policy should be pursued that a highest possible percentage of the measures in the user specific facet views are the same.

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The exact definition of the system borders proved to be crucial: The main testing site was the Berlin site, however due to the tight alignment of the Berlin site to the corporate R&D community and the close relation to the corporate FS function in Stockholm also requirements coming from those two entities had to be considered in the build and implementation work.

At this site it has been decided to establish two types of reuses basing on Lim (1998): Black-box reuse which means that the asset is reused without changing it and white-box reuse which means that the asset has been modified in order to reuse it.

8.3.3 Conclusions

Due to the fact that this company is probably one of the most mature companies in the world with regard to performance measurement of knowledge and intellectual capital, this case represented a big challenge for the author. Prof. Leif Edvinsson, a former member of the board of this company, has been involved in this research, both on a formal level through the expert interview and an informal level through many meetings, discussions and workshops. Another great expert working for this company, Scott Hawkins, participated in many on-site events and discussions. Thus, within this case study, the provided theory has been tested in a challenging and critical environment.

Over a period of almost two years more than 30 people in three sites Berlin (Germany), Shelton (USA) and Stockholm (Sweden) have been involved and provided very rich and deep feed-back. In the early phases of this research a meeting with Prof. Leif Edvinsson showed that the company has a big need in improving development performance especially from a knowledge reuse and invention perspective. During the on-site activities mainly at the Berlin site concrete needs and requirements have been identified which gave further indication that there is a need for action even in this world-class company. The research outcome has been validated within the considerable on-site activities which took place mainly at the Berlin site, within the corporate Open Business Exchange (OBX) unit and through leading experts.

The FS company has worked through more than 10 people to create a full implementation of the PMI and the measurement framework. Specifically a 2D navigation method is preferred and integration with existing PMS infrastructure (both physical and as concept) was critical. Especially the build and implementation phases which refer to the PMS framework, strategic alignment aspects and knowledge asset structure creation have been applied with a great level of detail.

Overall the company's feedback was very positive, currently (November 2001) the Berlin site is elaborating a feasibility study which investigates whether the provided functions can be implemented at large scale within a 150 seats software environment.

The following list highlights some of the major learning the author made which influenced the design of the provided theory (The author made the referring notes during various focus groups events, formal interviews and informal discussions):

- Make important things explicit.
- Buy top management in.
- Try to reuse existing and implemented infrastructures, methods and tools where appropriate.
- The performance measurement problem is less a design, more a build and implementation problem.
- Comprehensive navigation functionality for a measurement framework is key.
- A PMS has to focus on the past *and* the future.
- People at the FS want "out of the box" solutions with little customisation effort.

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- The measurement framework should not contain more than 10 to 15 measures.
- A knowledge asset structure model for a 150 people company may not contain more than 10 key knowledge assets.

8.4 Case study 3: The Automotive Supplier (AS)

8.4.1 Defining the case study 3

8.4.1.1 Company background

The AS employs 45 people and makes a turnover of 11 MEuro. Being a supplier in the automotive environment, the AS is facing one of the most competitive markets in today's industrial environment. Besides cost and quality above all the speed to market is of crucial importance. A typical development project at the AS starts with the development of the part itself before the development of the tooling for high volume production is being started. A part in this context can be a spring, a contact clip, a metal sensor or an orifice plate for a fuel injector. This happens in very close co-operation with the customer as it is part of a big system, like an ABS system.

The main knowledge the AS can contribute in this phase is knowledge about the functionality of the part *and* manufacturing knowledge as the company's main objective is very high volume production (lot size up to 6.000.000 per year) of those developed parts. Efficient high volume production is one of the key success factors of the company. In order to produce the parts, manufacturing tools have to be developed. This phase is extremely knowledge intensive as the tool-making itself, the adjustment of the punching machines, the choice of the right material requires a lot of experience and engineering knowledge. Especially here the company has a big need for reuse e.g. solutions to problems, modules or expertise.

The company also has been involved in the EC research project <<IST-1999-11926 NIMCube>> as a Business Support Group member. The initial motivation for the company to join the project was to enhance both efficiency and creativity.

8.4.1.2 Main problems, needs and requirements for the PMS

The following list of problems and the presented needs have been elaborated within an interactive, facilitated focus group workshop (section 2.2.4, page 17): 4 employees from the company contributed to this list which represents only those findings which the users considered to be most important.

The main problems

Process particle	Problem/Opportunity
Conceptual Design	Many designs are developed from scratch, the knowledge is embodied in the brains of the engineers. There is no overview on the efficiency of knowledge reuse, has it to be improved, is the company doing all right? Generally the "Reinventing the Wheel" phenomena is supposed to be a big problem.
All NPD phases	No sufficient solution which manages the NPD performance. So far it is based on subjective information and of very implicit nature. The quality of the communication of the NPD goals into the company is not sufficient.

The main needs

The main needs based on the problems mentioned above have already been outlined in section 5.5.1 and are documented in the voice of the customer:

- The methodology has to focus only on the most important reuse objects.
- Reuse has to be supported on operative process-related level.
- The methodology has to be scalable as today's environment is very dynamic.
- The methodology has to be user friendly.

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- The measurement system has to support the practical use of reuse objects.
- Financial Figures would be very convincing measures.
- Support for reuse of experts knowledge who leave the company.
- The IT solution has to allow a good level of data integration.
- The user interface has to be simple and web-enabled.
- The use should be as simple as possible, not only academics might use this tool.

Requirements of the AS

The main requirements based on the QFD analysis with 3 people being involved (section 5.5) are as follows:

- Methods and tools for storing, reusing and creating knowledge.
- A set of measures which support them in deciding whether it is worth reusing a certain module as the parts as well as the tools show a highly modular structure.
- Measurement functions for managing the reuse and creation of knowledge.
- Elaboration of a monetary dimension for reuse. Classification numbers, i.e. metrics, like the cost of reinvention would be a very helpful monitoring instrument.
- An enabling SW technology which allows the efficient use of the methodology.

8.4.1.3 The PMS solution for the AS including the IT solution

Altogether 10 people from the AS, including the CEO, extensively tested the PMS functions provided and customised them for their specific needs. The main activities of the AS were therefore to validate within focus groups and semi structured interviews the major design principles and implementation procedures. The AS invested also effort in customising the enabling technology through defining measures, specific user views, roles and procedures. An integration concept with the local infrastructure has been elaborated as well. The AS decided to go for a hosted solution as well. Currently (December 2001) the AS has started to implement a full size PMS installation.

8.4.2 Analysing and evaluating the application scenario

8.4.2.1 Introduction - Getting the evaluation data

The list of applied research tools at this company has already been outlined in section 2.2.1.2. The following section provides an insight into the most important findings from the research tool application. In addition to the application of the research tools the author obtained very valuable insights through more than 10 informal talks, 3 focus groups and 3 semi structured interviews, and one QFD. The data collection for theory testing has been done over a period of almost two years.

8.4.2.2 Key findings from the analysis and evaluation of case study 3

Users think that the focus in this case study is on reuse efficiency aspects (Figure 67). Before the project started there was already existing a very rich knowledge base but its knowledge was very difficult to identify, access and finally to (re)use. Therefore the PMI was highly appreciated as giving engineers and managers a tool that might enable reuse of knowledge in a controlled way. The reuse measures proved to be useful for decision support with regard to reusing an asset or inventing a new one. The focus groups showed that also in this case a number of 8-10 company-specific assets for the whole NPD environment were considered to be sufficient.

Figure 67 shows that the operating context (ecology) dimension was thought to be less useful to measure NPD performance - a phenomena which the author observed quite often in smaller companies operating in traditional branches, like automotive or

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aeronautics. The importance of the output performance facet shows that the company is still very final product oriented rather than activity oriented. As stated above the invention side was considered to be less important (useful) than the reuse (efficiency) side. The reason for that might be that the company considers itself as being an inventive company within its limited space for creativity as part of other companies supply chains. The interviews showed that invention subjects like invention process or invention organisation are thought to be less important in this company. Due to the small size of the AS, the interviews showed that they think that inventions can be treated on an ad-hoc, more informal level.

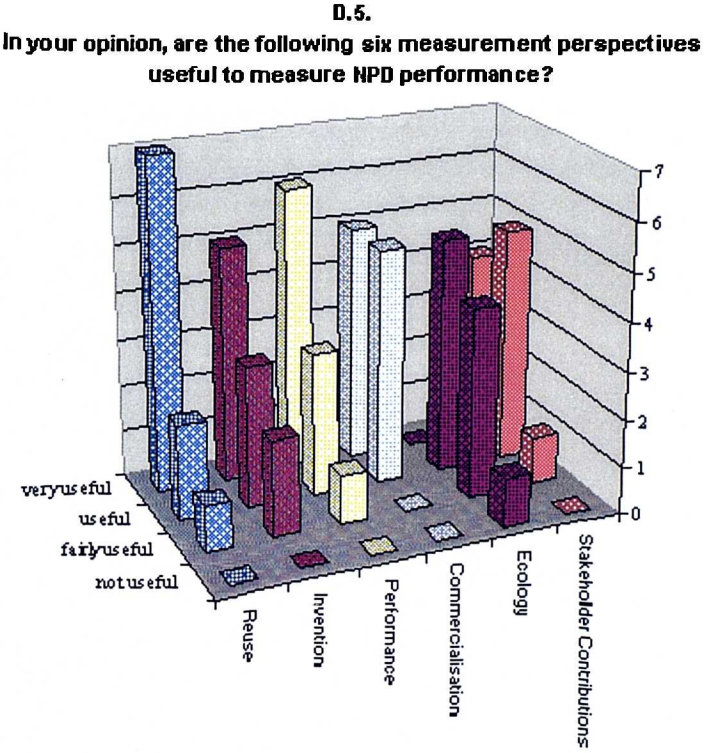


Figure 67: Importance of the six measurement facets at the AS (n=10)

Figure 68 shows that users think that the implemented performance measurement functions seem to have the biggest impact on the NPD output measures time to market and development costs. As the tooling at the AS is highly modular an enhanced reuse is likely to support significantly the development costs through reducing the number of reinvented parts and modules. Enhanced reuse performance management and measurement reduces also the development lead time significantly according to the AS' opinion. The impact on product quality is considered to be smaller. The reason for that might be that the AS decided to go for quite an emergent, informal asset certification process: A specific role has been created for a reuse asset certifier but due to the complexity and variety of the product he has more the role of an administrator than a certifier. The company wants to leave it up to the reuser whether he reuses the asset or not. This might cause the danger that components and modules might be reused which imply quality problems.

An interesting point is the fact that people indicated that the impact on product cost is moderate. A reason for that might be that most of the people make reuse and invention decisions based on quality parameters or strategic aspects but less based on product or asset cost aspects.

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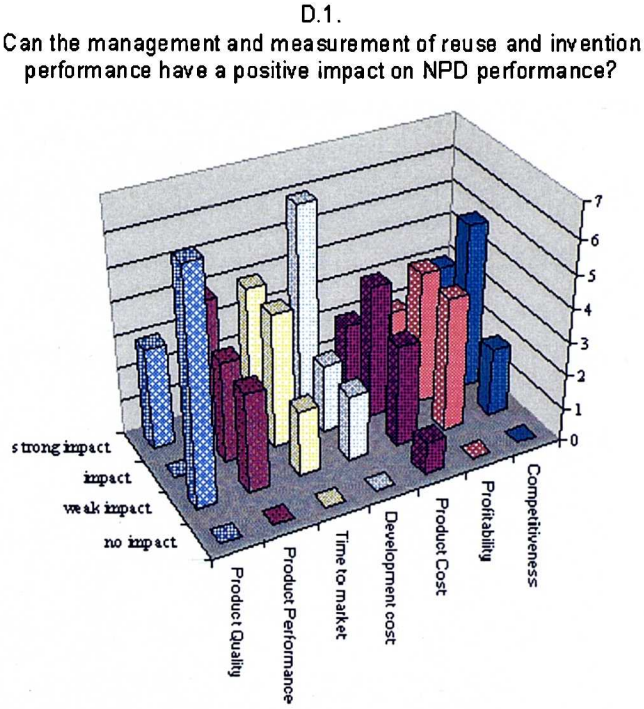


Figure 68: Overview on the impact of reuse and invention performance measurement on the overall NPD performance at the AS (n=10)

The two major strategic themes (Norton, 1999) of the company are efficiency and growth. The reuse and invention thinking is reflected in these themes in a way that reuse is a performance driver for efficiency and invention is a driver for growth. The balance of reuse and invention has been realised implicitly through definition of referring measures. Figure 69 gives indication that people think that so far the balance is shifted towards the invention side, meaning that the reuse aspect has been neglected so far. It proved to be sufficient for bringing the balance to life through clearly communicating the NPD strategy and goals and provide the engineers with a good decision base for reuse and invention. Again in this case study the measures were very company-specific and only suitable for the specific context.

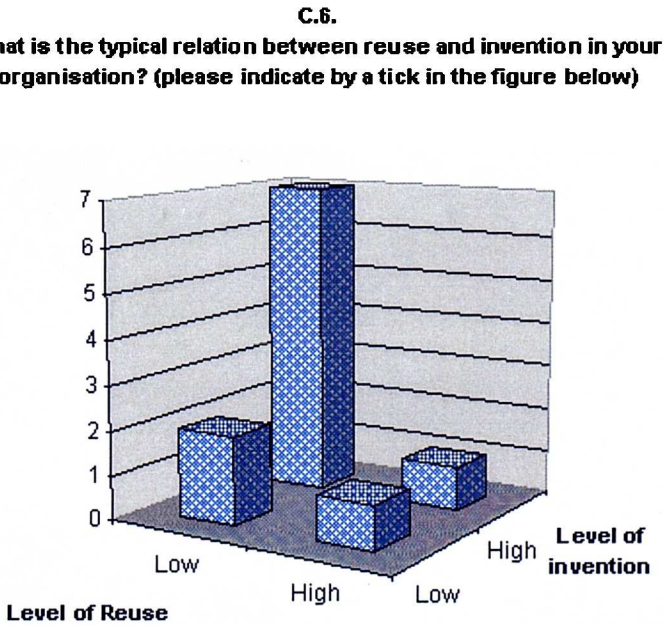


Figure 69: Overview on the estimated reuse and invention level at the AS (n=10)

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The interviews showed that customising the PMS functions for the AS, the company became aware that the customisation of the asset models and definition of a sound set of measures is a resource intensive, iterative task (Kerssens-van Drongelen, 1999).

For the small AS, the three navigation axes concept was considered to be too complex. Most people in the interviews and in the focus groups were of the opinion, that a navigation along the organisational and one additional axis (project) should be the maximum.

Incentive schemes were considered to be a very important instrument for managing the reuse performance. Awards like the "most intelligent re-user" or "most frequent reuser" were suggested during the course of the testing phase. In order to make the reuse of knowledge more efficient a thorough elaboration of types of reuse should be pursued. Also in this case study following the suggestion of Lim (1998) two categories of reuse have been identified: Black box reuse happens when a knowledge asset is reused without any changes and white box reuse happens when the asset is modified before being reused. This modification should be captured for future reuse.

With regard to reuse measures it was the simple measures like asset age, asset reuse rate, asset addition rate or asset quality which were considered to be powerful for operative decision support. Within the focus groups, the users indicated that those simple measures are very powerful for reuse vs. invention of assets in operations. The users considered the asset addition rate the most important operative invention measure. They stated that this measure is very good and powerful for measuring the invention performance through monitoring the creation of knowledge assets. The management of the reuse and invention process through dedicated organisational entities (see also above), for example asset certifiers or idea managers were considered to be important in order to make reuse and invention a smooth process in the company. This finding goes in line with conclusions made by Lim (1998) and Wolf (2000). Cole-Gomolski (1997b) also suggests simple incentive schemes for awarding frequent and intelligent reuse and knowledge creation to increase the acceptance of the system at least at the beginning.

The build and implementation process has been extensively discussed within 3 semi-structured interviews and 3 focus groups. The main feedback was that the parallel implementation of the PMI and the PMS facets and navigation concept is very challenging as several different stakeholders are involved in the process. The company sees an opportunity to align the PMI directly to a process modelling tool, like for example the ARIS™ tool-set from the IDS Scheer company. This alignment might shorten the process of identifying reuse and invention assets and aligning them to the NPD process.

Some people at the AS see a potential threat in the general nature of monitoring and control systems. Performance management and measurement systems are important to bring strategies to life, however in the age of new complexity based organisational forms where self-organisation is a guiding principle (Kauffman, 1996) the role of measurement and its importance for business might be rethought.

8.4.3 Conclusions

This case study company has been involved in this research over a period of almost two years. Various people at this company, among them the CEO, head of engineering and several shop floor workers and engineers tested the provided theory. This case study is beneficial for the quality of the validation findings above all from a pragmatic point of view. For example, some of the users involved have never heard before of the terms performance measurement or knowledge reuse. Therefore above all those phases of the build and implementation method which refer to pragmatic process-

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oriented aspects and basic strategic aspects have been deployed with a great level of detail.

Overall people felt that their needs and requirements stated earlier have been met in a satisfactory way. The following major learning is considered important by the organisation (The author made the referring notes during various focus groups events, formal interviews and informal discussions):

- People can become very nervous when talking about measurement, therefore effort should be put in explaining the true purpose of measurement.
- Knowledge reuse has to be managed in a professional way as one key determinant of overall productivity.
- People should go for only few and meaningful measures.
- "I do not want to have too much effort in crunching and maintaining measurement data."
- "You need to link to operational decision support measures with more strategic management oriented measures."

8.5 Case study 4: The High Tech Company (HT)

8.5.1 Describing the case study 4

8.5.1.1 Company background

This Israeli company is a provider of integrated network solutions for digital communications and data transmission systems employing more than 6000 people. The company designs, develops, manufactures, markets and supports end-to-end digital telecommunications solutions for today's new services and converging networks. The HT's equipment supports traffic in more than 500 service networks in over 145 countries. Since 1993, the organisational structure is based on SBUs (Strategic Business Units) that are responsible to development and marketing. The SBUs are organised according to specific product lines and ethnological areas.

The company has been one of the industrial partners in the EU funded research project <<IST-1999-11926 NIMCube>>. The motivation for this company to join this project was to be involved in the development of reuse and invention performance management system for product development. Within the project the HT had the role of an industrial user and provider of a test site. The testing and validation of the pilot took place within the corporate quality department (50 employees) which is also involved in various product development projects.

8.5.1.2 The main problems, needs and requirements of the HT

The following list of problems and the presented needs have been elaborated within an interactive, facilitated focus group workshop (section 2.2.4, page 17): 4 employees from the company contributed to this list which represents only those findings which the users considered to be most important.

The main problems

Process particle	Problem/Opportunity
NPD	**Opportunity expressed in the President message at the annual meeting 1998** "We don't get enough value for the large investment in R&D", i.e. effectiveness and efficiency problem. Potential synergies between SBUs are not fully exploited, i.e. barriers to free knowledge sharing and reuse.
NPD	**Opportunities expressed at the annual CTO unit meeting, March 2000** ❑ Lack of significant IP (Intellectual Property) protection becomes a big risk and also can lead to missed opportunities. This refers mainly to patents management. ❑ Although reinforcement of reuse is postulated by senior management nobody knows how the company is doing in reuse.

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NPD	**Opportunities expressed in the annual Management Quality Review, 1999:** Growing number of customer complaints and calls regarding reliability: product maturity, "Dead on Arrivals". Large number of cards returned with NFF results (reported as failed by the customer, shipped to case study 4 company, tested and No Failure Found)

The main needs

The main needs basing on the problems mentioned above have already been outlined within the HT QFD presented in section 5.5.1 of this thesis and are documented in the voice of the customer:

- Quick results (from decision to first usable report).
- Ease of use for the end user.
- Integration of operations with existing PMS systems.
- Low initial investment.
- Triggers practical improvement efforts.
- Cost of maintenance (mainly administrator time).
- Clear presentation of the performance.
- Ease of customisations according to specific units needs.
- Provision of a good detailed and overall picture of the innovation issues.

Requirements of the AS

The main requirements based on the QFD analysis (section 5.5) for the to be developed solution are as follows:

- Methods and tools for providing operative decision support for reuse and invention.
- A communication instrument for communicating the NPD goals and strategies including reuse and invention aspects throughout the NPD system.
- Measurement functions for managing the reuse and creation of knowledge.
- Elaboration of a monetary dimension for reuse. Classification numbers, i.e. metrics, like the cost of reinvention would be a very helpful monitoring instrument.
- An enabling SW technology which allows the efficient use of the methodology through integration of already existing knowledge repositories.

8.5.1.3 The PMS solution

By the time the on-site activities of the project started the company had already been employing a rich infrastructure for reuse and invention management mainly using repositories. The PMI was therefore applied differently than in the previous three case studies. The reuse and invention assets of the PMI of the HT were complete asset repositories, like idea repositories, tool repositories or expert repositories. The PMI acts therefore as a "metalayer" which interconnects and unifies the various repositories. The six measurement facets have been implemented with focus on operating context but within a second scenario the functions have been integrated into a BSC framework: Various aggregated measures from the PMI have been delivered mainly into the BSC facet "internal processes".

8.5.1.4 The IT solution

The IT solution has been realised as a hosted solution. Currently, the software solution provider realises a PMI portal based on XML technology which can read from most of the existing repositories. The measurement data are partly retrieved from legacy systems and partly entered manually.

8.5.2 Analysing and evaluating the case study 4

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8.5.2.1 Introduction - Getting the evaluation data

The following section provides an insight into the most important findings from the tools' application. As some employees of the HT have an outstanding knowledge on the knowledge management and performance management subject the company provided two different perspectives on the solution. On the one hand users tested the functions and provided operational feed-back on the other hand the experts in the company provided very much in depth feed-back with regard to the conceptual set-up of the various functions. The evaluation at this company was also more than a one year activity.

8.5.2.2 Key findings from the analysis and evaluation of case study 4

The survey (question C.6.) showed that the users see a bigger need in the improvement of the reuse performance than in the invention performance (Figure 70). Therefore the company's interest was higher in the reuse aspect of the provided functions.

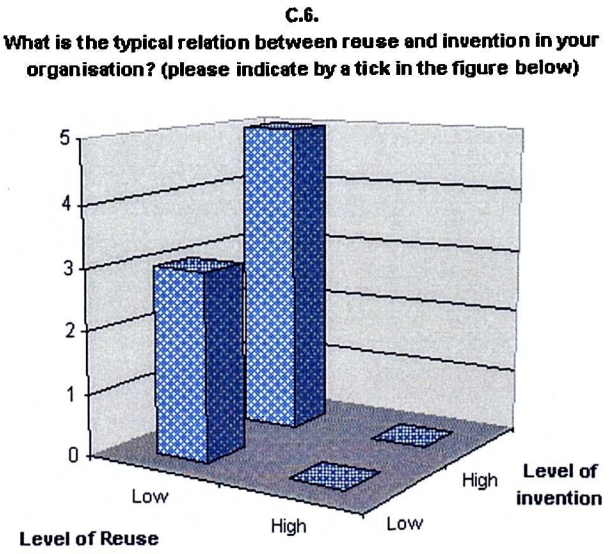


Figure 70: Overview on the estimated reuse and invention level at the HT (n=8)

The interviews demonstrated that people appreciated very much the integration of an operational reuse improvement tool (the PMI) into a coherent reuse oriented performance framework or into the existing Balanced Scorecard application. People did recognise that the explicit consideration of the dimensions reuse, invention and exploitation certainly might help to make these issues more explicit, however they also saw a big advantage of keeping the already established corporate BSC framework.

HT was the user company which was intensively pushing forward the whole navigation concept within several focus group workshops. Due to the complexity of the HT's NPD system a very detailed navigation concept has been elaborated for both the measurement framework as well as the underlying asset models. At the beginning the author had concerns that the whole navigation might be too complex and the amount of generated data too high, however people from the HT convinced him that users accept a certain complexity as long as the resulting benefit dominates the costs of complexity.

Some people pointed out that they have concerns in establishing targets for the various measures, especially in the facets reuse and invention where little existing benchmarking data are available. Therefore the company established several measures without targets only tracking the relative change referring to a certain starting point.

The survey showed that people think that measurement of reuse and invention performance mostly seems to impact product quality, time to market and development cost, less competitiveness or product performance (question D.1. in Figure 71). One

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might see that this estimation might be reuse driven as enhanced reuse management based on measurement can enhance quality through relying more on "approved" reusable knowledge, saving time by not re-inventing the wheel and therefore saving resources. Enhanced reuse might not necessarily lead to a better competitiveness or product performance, these outcome measures might be more aligned with the inventive capabilities of a firm (Figure 71).

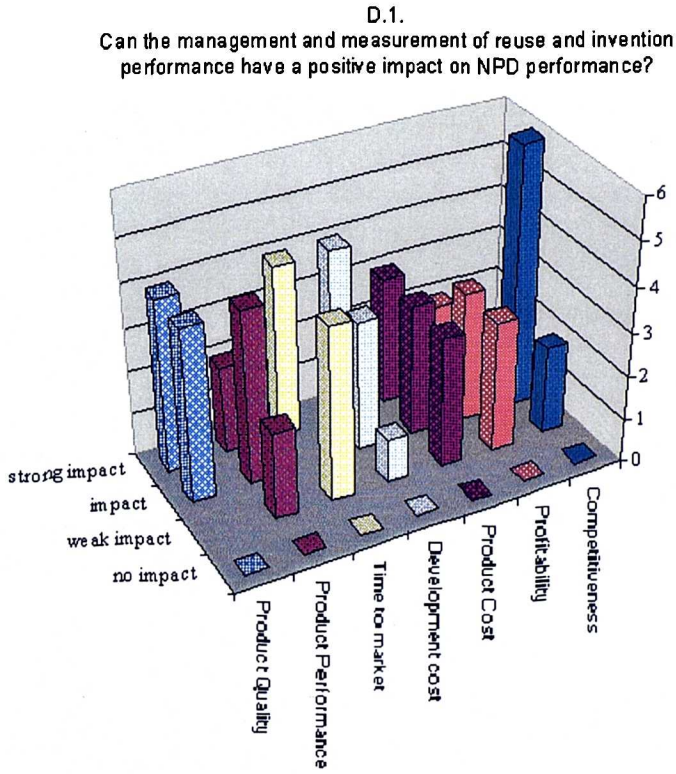


Figure 71: Impact of reuse and invention performance measurement on NPD outcome measures at the HT (n=8)

The people who participated in the case study see a need to deliver measures which are unique to their organisation. They agree that a pre-defined measurement catalogue might serve as stimulus for the discussion but in the end a measure is highly dependant on its context and should therefore be defined for the particular context of the firm (Figure 72).

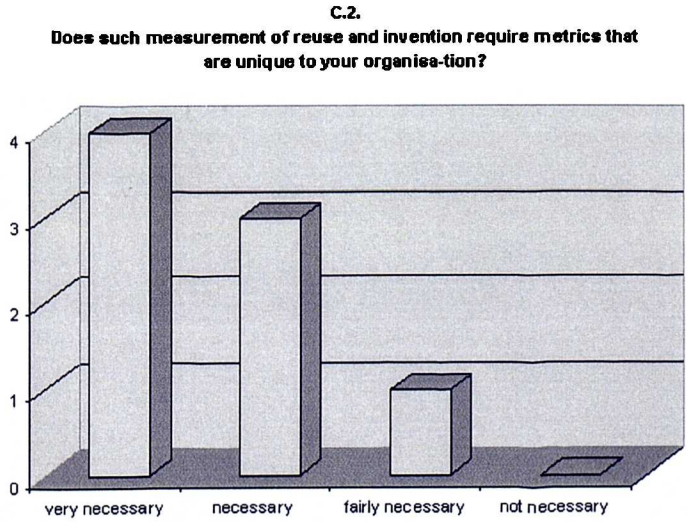


Figure 72: Need to develop specific reuse and invention measures for the organisation at the HT (n=8)

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As already indicated earlier people saw the biggest benefit in having at their disposal the reuse, commercialisation[69], stakeholder contribution and operating context (Figure 73)[70] measurement facets while the invention facet was slightly less important to them probably due to their efficiency orientation.

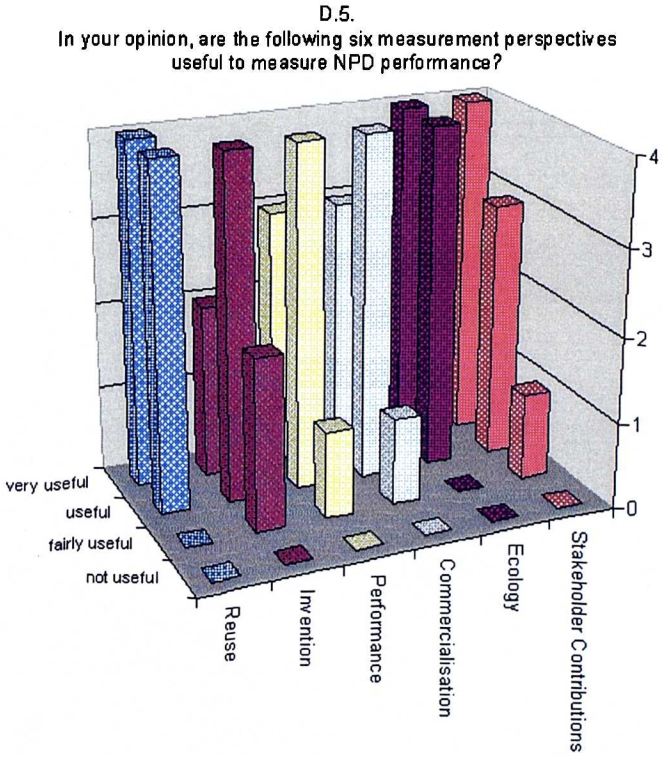


Figure 73: Relevance of the six measurement facets at the HT (n=8)

Within the interviews the author learned that exploitation is a key challenge at this company. The company is very inventive and becoming better in reuse, but according to some users this does not guarantee financial success through delivering inventive products in an efficient way. The company not only needs to be efficient and inventive but also effective to meet their NPD goals.

Especially with regard to reuse and invention the operating context was considered to be key (Figure 73). Efficient reuse needs to be supported through appropriate processes and infrastructures but according to this case study above all through an appropriate culture. Trust, recognition, team-spirit are important key words for good reuse. The same goes for invention. Only if the freedom that inventive thinking requires is supported by highest management levels acceptable results will be achieved. Therefore the leadership style was rated as being very important for this company (Figure 74).

69 Please note that since conducting the case study the facet commercialisation has been replaced by the term "exploitation".

70 During the course of this research the term ecology has been replaced by operating context.

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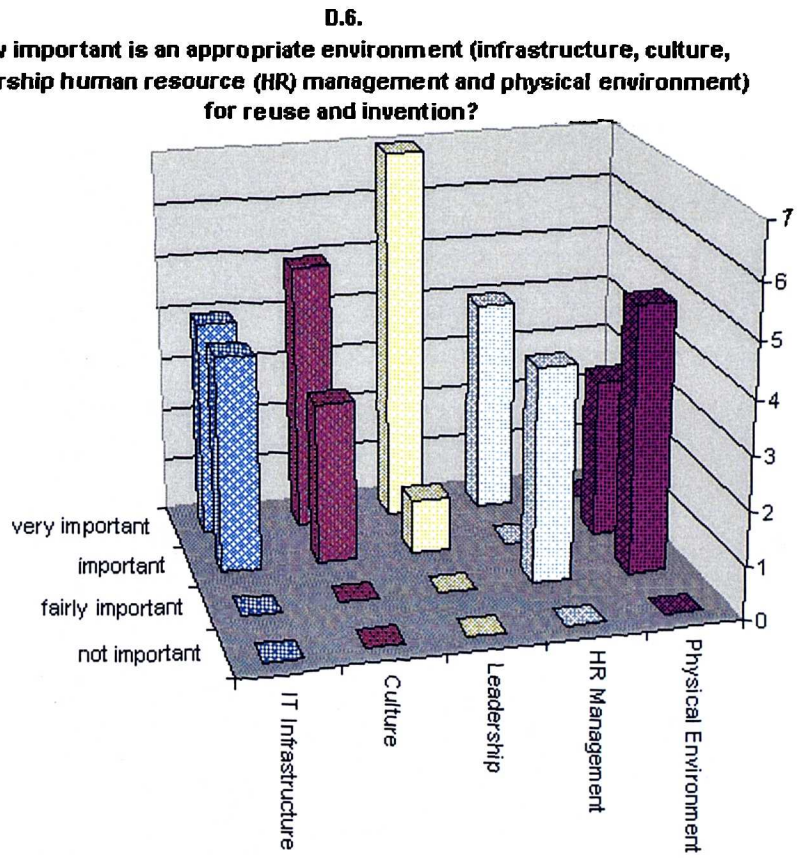


Figure 74: Subjects of the operating context dimension and their importance at the HT (n=8)

This case study showed that it might be difficult to buy-in top management for issues which do not directly refer to the core value creation process, like the reuse and invention topic. The author found within focus groups that senior management awareness is easier to gain when it directly improves the value creation process, through for example installing a new CAD system or reorganisation of the NPD process. Dealing with issues like reuse and invention can be considered to be a luxury by top management and a nice add-on to the core value creation processes.

Overall the company felt that the solution has to be, due to its complexity, introduced very thoroughly in order to make the people truly understand the functions (Appendix C, question C3). Also in this case the "power of graphics", like the six facet graphical metaphors was well recognised. The users felt that the concept of a reusable asset repository might be very dangerous, if people enter assets without very careful screening of their reliability. A non-reliable asset can according to them cause serious problems in terms of quality deficiencies in the long term (Appendix C, question C4).

This is why at case study 4 the concept of "Known Good Modules" has been established. This means that all assets have to go through a certifying process where they are either made a "Known Good Module" or put in a special restricted area and not given free for reuse. However this procedure might also be risky because usually companies do not have resources allocated and organisational roles for certifying assets which may end up in empty repositories. Therefore the asset certifying process should be accompanied by referring organisational roles and represent a good balance between a restrictive asset certification process and a self-organising, unrestricted mechanism.

The company felt the need to have at their disposal a professional and powerful enabling technology. The emphasis on IT was so high that at the beginning the company was not willing to implement a pre-commercial prototype. The company

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pushed the software solution provider very hard to make the SW reliable, fast and comprehensive.

Another opportunity was seen in the fact that out of the six facets of the measurement framework the reuse facet is the one which is supported the most through operative improvement tools, like in this case the PMI. Of course the invention and exploitation facet are also supported and "fed" by the PMI performance measures but still, the overall solution could be enriched through integration of operative tools to enhance invention, like a Communities of Practice tool, chatrooms and brainstorming tools (Appendix C, question C3).

The concept of the 6 facets reflects real and distinct issues and challenges that the HT faces. Reuse, invention, exploitation, operating context, performance, contributions – these are among the most important issues that require explicit and dedicated management. However, due to limited amount of management resources, people thought that it might be better to focus on only 3-4 of them.

The concept of multi-axis navigation is according to the users asked in this case study, adding value in terms of transparency and comprehensiveness of the provided measurement functions:

- The organisational axis is a must, because the HT still has hierarchical management.
- The process axis will help in long term improvement processes, by allowing an in depth analysis of the reuse perspective in the complete development lifecycle.
- The importance of the third axis is in helping professionals quickly focus on their area – a SW engineer for example does not care about mechanical engineering oriented issues. Comparisons between the disciplines SW and HW development were considered to be very important by management.

According to the HT, it is important to allow the organisation to select its own 2nd and 3rd axis. The system should be customisable to fit the language and needs of the organisation.

The HT sees the following opportunity with regard to the build and implementation of the functions (Appendix C, question C3): The management is very concerned about R&D effectiveness which is linked to poor reuse (and to other problems). It might be easier and also more logical to start from this point of view than from the measurement point of view (through stating that there is a problem with measurement). Engineers might not see the value of measurement. Thus linking measurement to an operative system (which they do appreciate and use) will also increase the chances of implementing an adequate measurement culture.

8.5.3 Conclusions

The NPD environment of this case study is very complex, distributed and multi-disciplinary. The company being one of the most innovative companies in Israel already had a variety of performance measurement systems and knowledge repositories in place when the research started. The significant challenge was therefore to come up with new and convincing concepts.

The company was very interested in improving reuse, therefore strong emphasis has been put on infrastructures and elaboration of measures for knowledge reuse. The company decided to incorporate the PMI, navigation functionality and reuse and invention measures into the Balanced Scorecard framework which the company already employed. Indeed the integration into existing PMS frameworks like the Balanced Scorecard proved to be important as many potential users of the developed theory already have such a framework in place. The build and implementation function

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for the PMS framework *and* the PMI has been applied and discussed with a great level of detail.

This company provided a very rich case as several domain-knowledgeable experts as well as several users were involved in the on-site activities. The pilot scenario was truly of real-life nature as being messy through involvement of various departments and sites. This case study company went also through the ups and downs that many high tech companies went through over the last 2 years.

Below is a list of important findings which influenced the development of theory (The documentation presented below is based on notes the author took during interviews and focus groups):

- All functions must be adaptable to existing solutions in companies.
- Any measurement solution's success is dependant on the people working with it.
- The user interface aspect is a very important IT aspect.
- The continuous management of reuse and invention infrastructures is as important as the design, build and implementation.
- Metaphors, guidelines and build and implementation processes are essential for winning the users' confidence.

8.6 Summary and conclusion

This chapter has discussed how the developed theory behaves in real-life environments. Due to the heterogeneous nature of the different case studies a rich body of data could be analysed and interpreted. In this section the author will reflect on some concluding observations, cross-case aspects will be given in chapter 9:

- All the four case study companies were overall very satisfied with the outcome. They stated that the implemented functions are pragmatic and user-friendly. It was the richness of the environment within which this research work has taken place (people from industry *and* academia, large scale and small case study companies from different branches) which made the provided theory this universal. At least two out of the four cases continue to apply the delivered tools and methods after the end of the project. This gives the author confidence in the method which has been able to solve (at least partly) a relevant problem. The author learned that industrial environments are the most critical and challenging context for a PhD project. If people who work at these companies and are involved in the action research would have been unsatisfied they would have stated it very clearly and directly. Therefore these 4 on-site validation cases render a high quality validation for the provided theory.
- The case studies (especially the answers to the question D.5. of the survey) showed that the issue of performance management and measurement from a knowledge reuse and invention perspective is considered an important factor to enhance product development performance. The research has shown that even small and quite conservative companies are very aware of the knowledge performance measurement topic.
- Although the service NPD domain is currently relatively immature (compared to industry NPD domain such as automotive and high tech environments) with regard to process and systems thinking, it is becoming more and more competitive. The author thinks that today the automotive and high-tech domains are still more dynamic, complex and distributed which may suggest that for these domains the need for the provided functions might be slightly higher.

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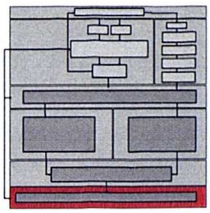
- The implemented PMS functions were generally largely accepted. A main point of criticism was the overall complexity, the resource intensive build and implementation of the functions and the little operational support of invention improvement.
- People like the explicit reuse and invention orientation, the linkage between diagnostic and operative improvement functions and the extensive use of graphical metaphors. The clear build and implementation was well accepted above all in engineering oriented environments.
- It became obvious that throughout the different branches and company sizes, the enabling technology was considered to be important to make the functions more operational in a day to day real-life environment. Also from an implementation point of view the IT was important as the IT supported some users in providing more concrete feedback with regard to methodical issues.
- It could be seen that the full scale solution might be more appropriate for large NPD environments with complex, distributed and multi-disciplinary processes There might be some indication that companies showing these characteristics like case studies 2 and 4 have a bigger need for comprehensive navigation and aggregation schemes. The reason for that might be that in smaller companies the system complexity is lower and the performance management related tasks may be carried out by a very limited number of people.

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9 Discussion, reflections and cross-case learning

"I now recognise that with each discovery, the extent of the unknown grows larger, not smaller"

James Lovelock, Author



This chapter discusses the findings from all four case studies, the experience gained by the author within 2 presentations at large companies, 10 expert interviews, 3 knowledge cafés at 2 conferences and one international fair, 1 conference workshop and several EU workshops with research and industry participants. The chapter tries to broaden the focused, problem-oriented scope of this research to a general level of understanding of the subject of this thesis. The cross-case findings from the case studies are outlined and discussed in detail. The section starts with general reflections with regard to the overall research topic, followed by an in-depth discussion of each of the provided PMS functions being the major contributions to knowledge within this research. The chapter will also reflect on the use aspect and on the research focus, the chosen research approach and tools applied.

9.1 Introduction

The nature of this research is characterised as problem-oriented: a real world problem has been identified, existing solutions have been analysed, requirements for a new solution have been derived, the gap to existing solutions has been outlined which finally led into the specification of a taxonomy of performance measurement functions. The provided theory has been critically and in depth exposed to four real-life environments. The relating findings from the case studies have been discussed in the previous chapter of this thesis. This chapter leads into a more general discussion incorporating additional learning from presentations, knowledge cafés, conference workshops and expert interviews manifesting the overall lessons learned with regard to the research topic. The author will therefore start with a general reflection on the research topic leading into a discussion mainly about the knowledge oriented PMS functions presented in chapters 6 and 7.

9.2 Reuse and Invention performance management and measurement in NPD - some thoughts on general lessons learned

Today there is a rich body of literature with regard to performance management and measurement and a whole series of case studies available (for example Norton, 1999; Gibbert et al., 2000; Neely, 1998; Maskell, 1989; Edvinsson and Malone, 1997; Kaplan and Norton, 1996a) which give some evidence that performance measurement and management is a truly established subject in business. However, during recent years, the author realised within consulting projects, discussions with PM practitioners, expert discussions, workshops and seminars that especially in the new product development context performance management is a far less established topic in real life industries than literature might suggest. The reason for this gap might be that often the strategic performance management systems, like the Balanced Scorecard or the Skandia Navigator are true top management instruments and therefore often used by a minimal number of senior users.

A large German automotive supplier for example provided a case stating that the Balanced Scorecard (BSC) has been established throughout the organisation. When visiting this company and talking to some senior managers the author realised that less than 50 people out of the more than 150.000 really applied the BSC. Even in world

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leading companies like the FS (case study 2 company), PMS like the Skandia Navigator is only used by a very exclusive selection of people, often CEOs of local units and Vice Presidents.

Many people from the case studies companies which have been involved in the on-site, action research activities have a very traditional input-output oriented understanding of performance management and measurement. Due to the history of performance management and measurement originating from financial control the financial based measurement of outcomes is probably the best understood aspect of the performance topic. Increasingly people begin to realise (see also Neely and Adams, 2000) that the explicit involvement of stakeholders matters. In the NPD context especially the consideration of the supplier being one of the key stakeholders for NPD was widely accepted. In all the case studies presented in this thesis and most of the consulting projects the development of measures for measuring supplier contribution was a high priority activity.

Of course innovation is also a very popular topic at the moment. Almost all the companies the author worked with wanted to be somehow "innovative". It proved that for many practitioners -and also academics- innovation equals invention or creativity. Being innovative often equals the amount of new ideas which are generated, or the number of patents a company released per year. In many companies the author visited the innovative aspect is not too much more than the referring part in the company's mission and vision statement. When asking engineers how is your daily work impacted by the company's mission to be innovative, a good number of them replied that the impact is very implicit not explicit. In fact most companies do not know how innovative they are and therefore it is difficult for people to know whether they should be more or less innovative. Part of the reason for that might be that innovation is a very complex topic and very difficult to rate and quantify.

With regard to the BSC and the Skandia Navigator people complained that the innovation dimensions are too implicit, the desire was high to have explicit dimensions for measuring innovation. In fact this was the motivation to equip the PMS functions presented in this thesis with explicit dimensions for innovation, which are reflected in the present PMS facets reuse, invention and exploitation. This three part model was well accepted as it offers an explicit structure supporting the analysis of innovation performance. Using this model, the author could show in several case studies very nicely that being inventive is not enough if there are not strong capabilities to turn the invention into a marketable product. The case studies have shown that two of the four companies were aware that they have to be more inventive, however there were not sufficient processes, methods, tools and organisational entities in place which might have been able to enhance the invention performance. Looking to the learning from the expert interviews and the conference workshops there is indication that in today's industry to a high degree inventions happen in an ad-hoc manner.

The author learned during the expert interviews and case studies that the shortcomings of PMS solutions can be roughly categorised into two themes: Design shortcomings and implementation shortcomings. A design shortcoming is a potential weakness in the overall design of the system. For example the implicit consideration of innovation within the facets of the Balanced Scorecard may be for users a potential design shortcoming[71]. Implementation shortcomings are shortcomings which refer to the way a PMS has been built and implemented in a company. In case study 2 for example some years ago the Skandia Navigator has been implemented without involving the users sufficiently. The PMS failed because the users rejected it, not primarily because of a design weakness. With regard to the reuse and invention perspective there can be observed both types of shortcomings, the design shortcomings (see also Figure 32) as

[71] Case study 2 company identified this issue as a major design shortcoming.

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well as the implementation shortcomings. Several users from case study 2 and three of the interviewed experts propose that one major design shortcoming of present PMS is the lack of explicit consideration of reuse and invention and the missing reuse and invention process orientation. According to them, the most often observed implementation shortcomings originate from lacking user involvement, missing data processing mechanisms and a too strategic set-up of the overall PMS.

The situation with reuse is very similar to the situation with invention: One of the leading high tech companies in Israel (the case study 4 company), being awarded the most innovative company in Israel in 1999 and holding a level 4 in Carnegie Mellon's Capability Maturity Model (Paulk et al., 1994), has been asked by their CEO to enhance the reuse level by 20%. This task proved to be very difficult as almost nobody in the company could really state what the current level of reuse was. They also had no reuse processes or organisational models available. The examples given for reuse and invention might be quite typical for NPD environments. Of course there are exceptions to the picture drawn above: Siemens SBS and Lockheed Martin for example have already established some years ago a very sound reuse process and organisation supported by enabling technologies (Wolf, 2000) and (Poulin, 1997). However both of them hardly apply performance measurement thinking to manage reuse activity. What Wolf (2000) proposes instead is to equip the captured project knowledge with different describing attributes like "approval status" or "lessons learned".

The expert interviews, the conference workshop and the knowledge cafés outside the case studies give indication that reuse of knowledge, invention (creation) of knowledge and exploitation are quite new subjects in the context of performance management and measurement thinking. The rich body of knowledge management literature however has raised in most visited companies a high awareness of its relevance. Therefore the elaboration of the company's management and measurement problem from a reuse and invention perspective was often quite an easy task. The establishment of causes and effects within the case studies proved to be a very challenging task above all with regard to intangible assets and reuse and invention. Many practitioners and experts the author met and talked to doubt the validity of complex cause and effect relationships. They state that the real world is much too complex to squeeze it into the jacket of a cause and effect relationship network. However most of the people agreed that *the first order* impacts of measures to other measures and the impact they are exposed to by other measures can profitably be discussed and understood more deeply. This research proposes therefore that those first order relationships contribute to the understanding of the measurement system, measures and their impact but are not accurate, positivist cause and effect chains (In fact this first order thinking is reflected in the set up of the measurement catalogue in section 6.3 of this thesis).

Finally the operating context, (or operating environment, as Skandia's Navigator model calls this measurement perspective Edvinsson and Malone, 1997) proved to be crucial for reuse and invention performance measurement (see also next section 9.3): Good reuse of knowledge and creation has a lot to do with an appropriate reuse and invention culture, trustworthiness and empowerment. The case studies show that IT infrastructures are a very powerful support tool for reuse and invention performance management and measurement.

The author noticed that a rapidly emerging body of literature regarding performance management in the context of knowledge management could be identified, like Marr et al. (2001), Schiuma (2001) or Baird and Hendersson (2001) and Kaplan and Norton (2001). This might give additional evidence that the overall research topic addressed has been an appropriate topic for a Ph.D. research.

The reuse and invention issue finally is currently visited on a meta level within the KM community. There is on the one hand the people who favour the efficiency (reuse) oriented approach which relies on application of technologies, like knowledge banks

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(Prenninger et al., 1999) and the definition of structured KM processes (Probst et al., 1997) on the other hand there are the people who favour the more human centred approach through for example establishing communities of practice (Wenger, 1999). The author experienced very intensive discussions between people from both groups on the issue as to which is the better approach. The author believes that either/or is not even the right question. A better KM performance will come from a balanced solution starting with human centred community activities adding, after a certain level of maturity, structures and processes.

9.3 The PMS framework

The development of the six facets of the PMS was a highly iterative process. At the beginning the author faced the question why suggest new measurement facets when the Balanced Scorecard, the Skandia Navigator or the Performance Prism already provide well established frameworks? Indeed the motivation was that all the three approaches address the innovation topic only on an implicit level. However during the requirements analysis for the PMS functions presented in this thesis the author recognised the high need for clear and explicit consideration of the innovation theme and its various components (section 4.3 and 6.2).

Therefore the definition of the facets "reuse" and "invention" was quite obvious given the vision of the research. The author experienced that the communication of the reuse aspect was apparently much more easily understood by PMS practitioners than the invention aspect. The reason for that might be that dealing with existing things and managing them is closer at hand than managing something which is not existing yet.

The "exploitation" facet proved to be an additional mandatory facet to truly address the innovation equation as suggested by Dvir et al. (2000) and Hahner (2000). The exploitation facet and its purpose was not easy to communicate, however some good examples like the famous DOW Chemical patent story (NIMCube, 2000e) which were told in the course of the communication of the facet concept proved to be beneficial for the understanding of this facet.

The incorporation of the "stakeholder contribution" facet as suggested by Freeman (1984) and (Neely and Adams, 2000) proved to be widely accepted among practitioners (see section above).

The use of the "operating context" facet was sometimes difficult to communicate above all in the smaller companies (case study 1 and 3) with a comparatively low maturity level regarding reuse and invention thinking. Several times at both companies statements were made, like "These soft issues are not relevant for us as they do not impact our product success". This thinking is reflected in the results of the survey carried out at those companies: At case studies 1 and 3 this facet was considered to be the least important facet (question D.5. in the survey). An interesting finding is that during the course of this research the relevance of this facet increased at case study 1 where a panel survey has been carried out (section 8.2.2.2, page 161). The result of the survey at case study 4 and the outcome of the semi structured interviews at case study 2 suggest that this facet was considered one of the most important performance dimensions for reuse and invention success and consequently for NPD success. One might assume therefore that the maturity of the company (FS (case study 2) and HT (case study 4) are very mature companies) correlates with the importance given to this facet. At the beginning of this research the "operating context" facet used to be called "ecology". However due to the fact that leading experts like Pór (2001) align this term exclusively with human centred issues the author chose to use a broader term describing the human, organisational and structural context.

The final product oriented facet in this PMS called "NPD performance" was in almost all the cases the facet where most referring measures were already existing (although

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they were mostly financially oriented) and where people had the clearest idea on *what* to measure. It should be noted that the NPD performance facet clearly related to output or outcome measures. All the other facets contribute of course to the overall NPD performance as well.

The author had many discussions about how straight the measurement facet jacket should be based on the thoughts developed by Weber and Schäffer (1999b). A completely free selection of measurement facets might not be goal-oriented as the measurement facets are an important communication tool for performance and should therefore be coherent throughout the whole NPD system for the benefit of intuitive understanding. Besides, issues like aggregation become very difficult if a stable set of facets is not used throughout the organisation. The flexibility of the present framework is ensured through free selection of measurement subjects (section 6.2.1). In fact the author went through a lessons learned process that the various facets themselves are less important than a clear understanding of the relation between the facets. A clear communication strategy supported by graphical metaphor proved to be extremely beneficial for the understanding of the measurement facet concept and its relationships between the facets (section 6.2.4).

The semi structured interviews and expert interviews have shown that the use of graphical metaphor has been stated by many users and people from academia as being important to improve the communication of performance measurement information. Therefore emphasis in this thesis (section 6.2.4) has been put on the elaboration of various graphical metaphors suitable for explaining the facet concept. In the following sections some user feed-back with regard to the three graphical metaphors is presented (see also section 6.2.4):

3-dimensional Innovation Cube architecture: Even though this architecture is considerably innovative and in line with the underlying purposes and requirements of the performance measurement model, first testing with potential users at the case study organisations revealed definite limitations of the approach. First, the complex three-dimensional visualisation conflicts with the function of transparency and simplicity. A user, only casually familiar with the mental concept and rationale behind it is likely to be overcharged and confused. Second, the innovation cube does not consequently reflect the sequence of an innovation process; i.e. the assignment of the facets is more or less arbitrary. Last not least, the cube does not picture the critical balance between reuse and invention, which should primarily be supported. Obviously, the proposed architecture did not meet entirely the objective of clear and substantiate communication as intended.

(Skandia) House architecture: This metaphor is comprehensible and intelligible, especially with respect to explaining the required balance between reuse and invention. A big advantage of this graphical metaphor is that the original Skandia Navigator metaphor is well-known and recognised as being a sound concept. Therefore the communication of the reuse and invention thinking through this metaphor proved to be very sound and robust. However, the architecture fails to visualise directly the concurrent consideration of process, hierarchy and functions.

Innovation pipeline architecture: Even though this metaphor is a rather conventional presentation, it serves the primary purpose of communicating the principles and procedures of the performance management model. For the time being, feedback from the case study organisations strengthens the author in his intention of applying the pipeline architecture, as most practitioners above all engineers are familiar with such a process-oriented set-up.

During the course of this research there were many discussions as to whether the incorporation of a strategy facet similar to the Performance Prism (Neely and Adams, 2000a; Neely and Adams, 2000b) might be appropriate. Finally the author decided not

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to incorporate this dimension as the strategies should be implicitly represented in all the other facets which of course have to be aligned to the company's NPD strategy (see section 6.2.5). Above all the exploitation facet reflects largely on the operationalisation of strategies.

The navigation function is a function which has been heavily driven by mainly the bigger companies. Almost all of the state of the art approaches offer a drill down functionality from corporate level, down to the individual level (Kaplan and Norton, 1996; Kaplan and Norton, 2001; Lynch and Cross, 1995). However due to the very high system complexity of NPD it became clear quite early in the research project that a more sophisticated drill down or navigation functionality is a must if the system wanted to be used in real-life NPD environments. Therefore it was decided to provide a multi-dimensional navigation concept for the PMS (section 6.2.2). This function allows the differentiation of measures not only according to the organisational level (like the BSC or the Skandia Navigator have implemented) but also according to processes, disciplines or projects. This allows for an assessment and comparison of different phases of the NPD process, for example comparison of the reuse performance of conceptual design and preliminary design. Increasingly project based NPD projects gain relevance. Therefore performance management based on project performance proved to be a very important need. The multi-dimensional navigation concept implies a high complexity of the PMS system correlating with the number of navigation dimensions. Therefore the number of navigation dimensions has been reduced to three with default differentiators of process, discipline and project. The author learned that the HT user company with complex and distributed NPD processes was very willing to invest more effort to design and build the 3 axes concept than smaller companies with less complex NPD process, like case study 1 and 3. Although being a large company the case study 2 considered a two axes navigation concept as being sufficient. The on-site work the author did in service, industrial and high tech environment makes him suggest that so far service environments are less complex and distributed than the other environments. At the beginning of this research there were major concerns by the author and the user companies because of the big amount of measurement data which would have to be generated to feed all the different measurement combinations in such a two or three dimensional navigation structure. The case studies have shown that if a company wants to apply this navigation function, the application of an enabling software technology is recommended.

Beyond the desire for personalised performance information was a requirement which the author faced at almost all the case studies: The user wants to have in addition to the navigation functionality, his very specific view, for example depending on his rights in the organisation, on the PMS facets providing him with a very personal view on relevant performance information.

With regard to reporting, people demanded also very specific and personal formats in addition to pre-defined formats and customising functionalities (This has been solved through a wizard SW functionality for creating very specific, personal charts and diagrams: In several steps the wizard would ask for selection of the measures, scales of the axes and type of representation (for example pie chart or bar chart)). Several users demanded export functionalities to be able to edit the generated reports in commercial SW applications, like MS Excel™. The evaluation of a measure over time was the most often demanded type of reporting format. Beyond users wanted comparisons between different measures (for example the reuse level vs. the invention level) in an x-y-graph or in three dimensional charts. Of course free selection of reporting periods was a basic requirement which people used extensively.

The balance between reuse and invention is one of the PMS purposes demanded earlier in this thesis. Therefore emphasis has been put on elaborating this issue. Section 6.2.2 and chapter 8 already gave indication that this balance has a lot to do with the

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way the facets are equipped with referring measures. But against which baseline/targets should reuse and invention activities be balanced? Generally there are two possibilities (Section 6.2.5 already gave some indication): One possibility is that the balance between reusing or creation of an asset is driven through the quality of the knowledge assets. If a knowledge asset is of good and reusable nature it might be reused otherwise a new asset might have to be created (invented). The resulting competence profile of the knowledge base might impact the strategic themes of the company. The other possibility is that the reuse and invention topic is driven through the strategic themes/strategic plan of a company. There might be stated thoroughly defined goals for reuse and invention which might be turned into action through referring measures leading to a top down creation of the knowledge base and referring knowledge assets. It turned out that the bottom up driven approach seems to be more appropriate as several companies (case study 1, 3 and 4) want to keep on building on their existing knowledge and competence. The FS case study company decided to pursue a strict top down reuse and invention balancing process.

Another observation made during the case study research was that the whole strategic planning process runs much more implicitly than one thinks and good employees have a good "feeling" of the NPD strategies and in which areas to put improvement effort.

The outcomes of the semi structured interviews, the conference and fair workshops, the knowledge cafés and the presentations to industrial companies give rich indication that the PMS framework was well accepted by the users and the community. The proposed navigation functionality seems to be more beneficial for organisations with complex and distributed NPD processes.

9.4 The Performance Measurement Infrastructure (PMI) and the measurement catalogue

The PMI was often explained as the operational "front-end" of the PMS framework during the case study implementations and consulting projects. The PMI is truly process-oriented (and has been understood in the case studies as such) as the NPD process is "translated" into a referring model of reuse and invention assets (section 6.4).

Recently Baird and Hendersson (2001) reflect on this idea stressing that such an infrastructure is an appropriate means to enhance knowledge performance measurement and management. In fact, the PMI not only represents a powerful infrastructure for hosting and providing the reuse and invention relevant performance information. It also represents a concrete solution for performance improvement. Therefore it could be argued that the approach presented in this thesis represents a synthesis of a more management oriented performance management and measurement function (the PMS framework presented in section 6.2) and a more operational, knowledge (reuse and invention) oriented infrastructure. Therefore the present approach combines diagnostic as well as reuse and invention performance improvement functionalities.

In fact, this set-up caused some challenges during the build and implementation of the full scale solution: The main challenge to overcome was that for both functions, the PMI and the framework, the key stakeholders were different. While the PMI build and implementation required participation of the engineering functions and Technical Managers, the build and implementation of the PMS framework required the involvement of the NPD senior management team and partly even corporate senior management (see also Norton, 1999).

However to start the build and implementation with the operational PMI proved to be very beneficial, because of two facts: First with the build and implementation, the implementation team was able to show "quick hits", through fast improvement of the reuse performance and second through the definition of the reuse and invention assets and referring asset related measures a very transparent and pragmatic bottom up

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approach could be realised in addition to the more strategic build and implementation part of the PMS framework. The management of the reuse and invention performance through controlling the reuse and creation of the assets, the reuse and invention processes as well as the referring organisational functions, seems to be a pragmatic and accepted way by user companies. It has been challenging to align the outcomes of the bottom up build and implement process with the strategic top down measure definition process (see also previous section and Christensen (1999)); quite often, due to an insufficient communication of the company's NPD strategy, there was a mismatch between the results which had to be overcome through a critical review of the identified measures.

Above all industrial product development benefited from the infrastructure function as the knowledge intensity there still might be higher than in other domains and therefore the need is higher to manage the performance relevant knowledge accordingly. The PMI is mainly suitable for medium and large scale companies with high system complexities. Even if the application case for the PMI might be very comprehensive (in terms of asset types and assets) the vision must be -for the benefit of transparency and consistency- to have one consistent structure model of assets. In case the model might be very complex, navigation functionalities similar to the measure navigation functionality (section 6.2) might be appropriate. This navigation functionality provides only a specific view on the whole model and helps therefore to increase transparency.

Case study 4 shows a large NPD system with corporate functions and functions within each strategic business unit. A single view on the asset model would be too complex and maybe even confusing, therefore specific views according to the navigation axes (for example along the organisational dimension) proved to be an appropriate remedy. The provision of user specific views on the assets proved to be a key factor for user acceptance. Above all in complex NPD environments the support of an enabling technology might be very beneficial. The asset related measures (section 6.4.3) proved to provide excellent engineering decision support for reuse and invention. The engineers were interested in comparatively simple information to enhance their reuse decision support. The age of an asset, the experiences by others reusing the asset, the number of reuses of an asset and the type of reuse were probably the most important asset related reuse measures. With regard to invention the assets "ideas", "patents", "experts" and "processes" proved to be the central knowledge assets in most user companies. The definition of measures to monitor and control the idea generation and realisation performance has been established in all the case study companies. It might become quite apparent that without IT support the management of operative reuse and invention can become a very challenging task whereas an enabling technology, as presented in this thesis can retrieve and analyse most of the measures described above entirely automatically without additional data collection and analysis effort.

At the beginning of this research there have been many discussions on the issue of how much additional effort can be demanded from the user when they reuse an asset or create an asset. From the beginning the strategy was to keep the additional effort (for example indicating for what purpose the user wants to reuse an asset or ticking which type of reuse he envisions) as small as possible, however during the on-site activities at the case study companies the author learned that "as little additional effort as possible" is a too simplified of a view on things. Instead it is more relevant that there is a very good cost versus benefit relationship between additional activities. If a user does recognise the value add an additional activity provides to him and/or to the whole system, he might accept the extra effort.

The acceptance of the PMI and the PMS framework was also correlated with the way the system was introduced into the company. Reuse of knowledge and creation of knowledge has a lot to do with trust, openness and recognition of others' work; thus people need to be made very thoroughly aware that the provided functions are really

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beneficial to the whole organisation in the short and above all in the long term perspective and is not just a control and cost cutting tool (chapter 7).

Overall performance measurement infrastructure (PMI) was very well accepted by all user companies. Users liked that the PMI provides a day-to-day working environment for reuse and invention management which is coherently integrated in a powerful measurement framework.

"I do not care which measures you put in your pre-defined catalogue just select them and I will agree", this quote reflects the opinion of a well-known expert in measurement from the FS company. With this statement the person wants to stress that a pre-defined catalogue of measures is irrelevant and might even be counterproductive. According to him any set of pre-defined measures will never truly be able to bring a company's strategy into action. Therefore *the process* of developing measures might be of much higher importance (section 7.4 and section 9.6) than providing pre-defined measures. Still the author sees a value in having a sound catalogue of measures at his disposal as this might help during the build and implementation of the PMS functions serving as a stimulus for the discussions. Several users confirmed this proposition.

There are some 200 measures which are currently (December 2001) in the catalogue (Appendix B) which are under continuous refinement and due to the fact that the measures are public (www.nimcube.com, accessed 5th of October 2001) the measures in the catalogue experience a continuous validation. Beyond each measure has been reviewed by the four case study partners and various experts[72] who gave approval to put it in the catalogue.

The provision of a standardised format for the measures with standardised describing attributes is crucial for the consistency and understanding of the PMS. Neely (1998) and in their latest book also Kaplan and Norton (2001) have already set a very good standard for a measurement template which serves as the basis for the template presented in this research work. In the following sections the most important describing fields for a measure will be commented and following general remarks about the measures for the various facets will be given[73]: Generally the measurement catalogue distinguishes between describing attributes which are in the generic catalogue available and attributes which remain for customisation during the build and implementation project (section 6.3).

With regard to generic attributes the two attributes "Measure" and "Metric" led above all in German speaking countries to some confusion among the users as the difference between the two attributes seemed to be marginal to a good number of users.

The "Description" attribute proved to be very helpful for the understanding of the measure. This attribute might be enriched with best practice application examples to give further indication for use of the measure.

The "Measurement Formula" which has to be elaborated during the build and implementation is of great importance as this attribute also implies aggregation rules which may have a big impact on the overall measurement system set-up. It proved that later changes with regard to aggregation were often very resource intensive above all with regard to the IT realisation.

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72 The following experts have reviewed the measurement catalogue provided in Annex B in detail:
- Scott Hawkins, Skandia
- Dr. Fiona Lettice, Cranfield University
- Ron Dvir, Innovation Ecology
- Dr. Edna Pasher, Pasher Management Consultants
- Atai Ziv, ECI Telecom Ltd.

73 For a better understanding the reader may revisit section 6.3.6 of this document where an overview of the various describing attributes of the measurement template is given.

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The "Target Values" for the measures often proved to be difficult to be determined. Mostly the user companies decided to establish fixed boundaries around the as-is value related to specific actions. In case study 4 some measures were even established without setting targets at all. Benchmarking measures might be a helpful means to determine target values, however they imply the danger that for the specific context of this company they may be invalid. For some of the measures above all the reuse and invention oriented ones there are, due to their novelty, no benchmarking values available so far.

It has again to be stressed that the attribute "Next Steps" can only give very rough recommendations of what to do based on the results of a measurement action. According to the author's experience at the moment a PMS may never give good quality active recommendations for operative improvement actions. Although case based reasoning techniques are quite an emerging subject (Kolodner, 1993) the existing solutions might not be mature enough to meet the complexity of real-life environments.

It proved to be very difficult to establish cause and effect relationship networks between different measures (section 6.2). At the beginning of this research the author had the vision to establish a complete set of causes and effects between all measures in a company. This objective proved to be difficult to realise in business environments due to their complexity. Causes and effects between measures have therefore been established through creation of first order impact chains ("Impact by/on other measures"). Causes and effects through aggregation of measures have been realised and established vastly and proved to be very beneficial. In fact several of the users among them also great experts in measurement agreed that the causes and effects between measures are less important than assigning the right measure to the right performance driver.

Simple first order cause and effect relationships have been institutionalised through assigning the measures to the various measurement facets and through the referring attributes in the measurement template (section 6.3.6). Further, and as described in Kaplan and Norton's latest book (2001) cause and effect relationships have been established through assigning performance measures to the various performance drivers during the build and implementation process of the PMS framework. Kaplan and Norton (2001) call this type of cause and effect relationship network strategy maps while Neely and Kennerley calls it success map[74].

The "Frequency" and "Responsibility" are very powerful describing attributes for a measure as they define implicitly the measurement process and underlying organisational structure.

The "Relation to subjects/navigation dimensions" aligns each measure to the overall PMS framework and is therefore important for the consistency, transparency and usability of the overall PMS.

Looking at the sections above it can be seen that the measurement catalogue is a very powerful part, as it provides a unique reference which constitutes the overall performance measurement system of an organisation.

The completed measurement catalogues by the users, the survey outcomes and the semi structured interviews give indication that today still NPD outcome measures are the dominant type of measures in the user companies, although they learned over the last two years that using reuse and invention related measures complements the outcome oriented financial measures positively impacting overall NPD performance.

[74] The author discussed this issue with Dr. Mike Kennerley from Cranfield's Centre for Business Performance on 2nd of April 2001. Mike presented thereby the success map concept which bases on the strategy map concept of Kaplan and Norton (2001).

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9.5 The enabling software technology

The enabling IT proved to be very beneficial for the practical use of the PMS framework and for the PMI including the measurement catalogue. The positive impact on having at the users disposal an enabling IT was manifold: First of all the IT can support basic tasks (*data collection, storage, retrieval, representation, reporting*) in a very efficient way. Beyond the author had the experience that for some people a running piece of software is more tangible than the intangible explanation of PM methods and procedures in terms of testing and validating the implemented solution. The final customisation of the PMS functions through the enabling IT proved to be goal-oriented and supported the achievement of a best possible user acceptance.

The objective of the IT was, from the beginning to be integrated in the users' day-to-day working environment as coherently as possible. In practical terms this means that the IT serves, with regard to reuse and invention management and measurement, as a *single point of access for the user.*

Having of numerous applications on their desktops, the users' acceptance of the IT proved to be very much dependant on the user friendliness of the solution. Visualisation aspects proved to be key for user acceptance, which was the main reason to integrate a powerful, commercial knowledge visualisation tool into the application (section 6.5). In the future hosted Application Service Provision (ASP) solutions might become more and more standard. In all the four case studies hosted solutions were preferred over a black box solution. The reason for that might be that meanwhile there are very secure web connections and that the performance of internet connections is constantly increasing. The test cases offered at least 2MBit/s connections which ensured an excellent performance of the SW package.

Basically, customers want to have as little customisation effort as possible. So called "out of the box" solutions are therefore currently very successful on the market. However, people accepted some additional effort if they truly saw the benefit resulting from this additional effort. People do expect fully web enabled solutions and applications of latest technologies like, XML or JAVA. In the future, XML might become an even more important standard. The application of XML supports a coherent data migration and integration of the IT solution into legacy applications, an aspect which is in real life IT implementation projects often a very big challenge.

At the beginning, the author was not sure whether there is a market for a "combined" KM and PM software as potentially the target customers in companies might be different. However so far the pre-sales and sales activities of the pre-commercial SW product look very promising.

Many users agreed that software can be a major enabler for performance measurement to improve reuse and invention activity. There is indication from the case studies that software can help to manage the vast amount of (measurement) information and reuse and invention assets through offering storage, retrieval, search, *controlling and reporting functionality.*

9.6 The build and implementation function

"The best PMS principles are worthless if they are not implemented properly" (Kerssens van Drongelen, 1999). The author made the experience that in engineering oriented environments the application of engineering design principles for the build and implementation of the PMS was very helpful for the understanding and acceptance of the PMS build and implementation. Other authors share this opinion (Kerssens van Drongelen, 1999; Lobo et al., 2000).

Thus the build and implementation process for the PMS presented in chapter 7 is very much aligned to problem-oriented research principles which in return are reflected in

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new product development approaches ((Blanchard and Fabrycky, 1997), (Ulrich and Eppinger, 1995), Wheelwright and Clark, 1992)). Therefore "classical" phases of launching, requirements engineering, conceptual design, detail design, testing and validation represent the cornerstones of the present build and implementation approach (chapter 7). Users agreed that the application of change management and systematic engineering design principles (chapter 7) was very beneficial for the operability of this function.

The problem for any change project is to answer the question where to start with the improvement activities. To attain this objective the European project the author was involved in has developed a fast readiness assessment tool which gives the company a quick overview on the biggest improvement potentials in specific entities. However there is some evidence from the case studies that people often know quite well where a potential improvement project should start and which its boundaries should be. Still, a very clear project definition including referring budget allocations has to be done during the initiation phase in order to ensure a stable and continuous process.

To start with, analysing the existing performance management and measurement environment during the requirements analysis phase created confidence among the project team. It also indicated appreciation of previous work, being an important human factor for the acceptance of the new PMS functions. It is certainly helpful for a consultant to have a solid set of tools available, like checklists or templates to ensure a goal-oriented process. Generally however the consultant (who may be internal or external) should take more of a facilitator role than an active advisor role.

The case studies showed that the definition of the project team can be considered a key success factor for successful implementation projects: There needs to be an internal champion who is highly recognised in the company and who has the power to recruit excellent resources from the various disciplines needed. In those case studies where top management truly was involved in the process the project proved to become a success. One might take this therefore as indication that top management involvement is another key success factor.

The author learned that companies often do not use systematic tools like strategy maps (Norton, 1999) for aligning the strategic themes to performance measurement thinking. However experienced senior management often has a very clear understanding of the themes and its performance drivers and measures. The elaboration of strategic measures was therefore in most cases a comparatively easy task. During the build and implementation activities the extensive use of graphical metaphor was very helpful.

Above all the various graphical metaphors for the six facet concept supported the PMS build and implementation considerably. The selection of the navigation dimensions proved to be a very important task as later changes in the specific set-up of the navigation caused significant rework. The alignment of the PMS framework and the PMI proved to be a challenge in real-life companies: Often the stakeholders and their needs were different in a first step. While the typical need for a PMI build and implementation was to improve reuse and invention management with the performance aspect being an important aspect, the need for the PMS was very clearly performance measurement driven. Therefore basically both modules could be implemented as a stand alone solution, however the innovation and greatest benefit is in the synergy of applying both modules: The PMS is enriched by a process-oriented infrastructure being also a reuse and invention improvement solution and therefore going beyond being a purely diagnostic function of a typical PMS. On the other hand through the PMS framework the PMI is enriched by a full size performance management and measurement backbone for NPD. For those companies which clearly were interested in both modules the entrance point via the performance management aspect proved to be more goal-oriented. Also with regard to the pre-commercial software solution it has

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been agreed that only both modules will be sold as a performance management software from a reuse and invention perspective for product development.

During the implementation processes on-site at the case studies the author became aware that performance measurement is a very sensitive topic. People align with the terms "performance management" and "reuse" the concepts of efficiency, improvement and control resulting in laying off workforce. Therefore the atmosphere in which the project took place is key. The author tried to explain the *benefit* of enhancing efficiency through the following metaphor: A person has a certain amount of time at his disposal. Part of this time he uses for basic activities and the other part he uses for value-adding, maybe creative activities. If he gets support in becoming more efficient he will have more time for value-adding activities and maybe even be more creative.

An aspect which has been brought up in three of the four case studies is the integration aspect into existing, well known performance management systems like the Balanced Scorecard or the Skandia Navigator. Those companies see a big advantage in the huge implementation base and existing lessons learned with these systems. Some of the major lessons learned with regard to BSC implementations is that well proven sets of measures according to the 4 perspectives of the BSC are available for various branches and company sizes and that meanwhile a very proven and stable strategic alignment process is available.

Beyond, one of those systems might be already be existing and therefore such a company might wish to maintain only one system. The build and implementation function presented in chapter 7 supports the integration of the presented functions into an already existing PMS.

Chapter 7 represents the final outcome of an iterative development and testing cycle. Therefore the build and implementation process as documented in this chapter represents a synthesis of learning made at the four case study companies. Certainly, all the companies went through a similar build and implementation process, but due to the "messy" real-life context with different foci, priorities and sequences.

9.7 A word on the use of the PMS

The previous sections have elaborated on the issue as to whether the PMS functions have been realised appropriately to work in business contexts meeting the various user needs. This elaboration was therefore of rather a short-term oriented, operational and technical nature. The intention of this section is therefore to broaden the testing scope and elaborate briefly on the more long-term oriented use and management aspect of the provided functions.

The investigation of the use and management aspect of the PMS functions might be a long-term effort, as the fulfilment of PMS purposes (like improvement or communication) are very difficult to measure within a Ph.D. time horizon. It has to be noted that the in depth investigation of the management and use aspect of the provided functions is beyond the scope of this thesis. Still, the users gave positive preliminary feedback that the purposes seem to be addressed sufficiently through the use and management of the provided functions.

At this juncture the author wants to reflect on a lesson he learnt during his field work at the FS. This company has employed the Skandia Navigator concept for many years. However, to the author's astonishment in real-life at least at the Berlin site very few people use it in day to day work. When asked the question why the Skandia Navigator is not used in day to day work, people gave the following answers:

- "We have been asked to use it but nobody ever explained to us what is the purpose of this system."

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- "The navigator is a strategic management system and is therefore of limited importance for us being "normal" employees."
- "The performance of the enabling software technology is very poor, therefore user acceptance is very low."
- "There is no internal sponsor for the system."
- "Management does not care about it either."

Another lesson with regard to the use of the system at the HT, who have been trying to establish the Balanced Scorecard for many years:

- "We think we have been able to establish good enabling measurement tools, good measurement processes and roles, but due to the fact that we missed to truly buy in the users through showing the benefit of measurement they always find and will find a way to play around the system."

The author took those comments very seriously and tried to consider them in the design, build and implementation work (chapter 6, 7, section 8.3).

9.8 Have the provided functions met the novel demanded purposes?

As the functions presented in this thesis have been designed to meet the purposes, the fulfilment of the functional specification set at the beginning of the theory development should imply the satisfying fulfilment of the knowledge reuse and invention oriented purposes presented in section 4.4.4. The applied analytical decomposition principles in chapters 4 and 5 should give further confidence for that. The following short reflections might therefore also serve as a counter-check as to whether the overall set-up of the research is consistent[75].

The first purpose -to support awareness, understanding, management of reuse and invention to improve NPD performance on strategic as well as on operational level- could be met. The provided functions with their powerful graphical metaphors certainly contributed in the case studies to support awareness and understanding of the reuse and invention aspect. The whole measurement aspect of reuse and invention proved to be beneficial for the overall management of the reuse and invention theme in the companies. This finding goes in line with Lingle and Schiemann (1996) who state that if a company improves measurement of a subject the company may better manage the subject. Beyond, especially the PMI provides an operational management solution for reuse and invention of knowledge assets. The structure and attributes support the performance management framework in better managing reuse and invention. The case study findings presented in the previous chapter seem to confirm that the provided functions are believed to have a positive impact on important NPD outcome performance measures.

The second purpose -to understand and support the improvement of the balance between reuse and invention- has partly been discussed in section 9.3. The provision of a PMS framework which explicitly addresses the reuse and invention issue certainly contributed to the understanding of the balance between reuse and invention. Also the field work, above all the semi-structured interviews confirmed this point of view. The author found out that the word "balance" has to be seen in a broader context. The author finds that there is not a "more-less" relationship between the reuse and invention balance. It is possible that companies become better in reuse and invention at the time. Of course there may be a point when too much reuse blocks invention or the other way round but this statement is very context specific and can not be as made

[75] The previous section 9.7 elaborated on the difficulty to measure the fulfilment of purposes but still the author will try to give some indication through providing relevant user findings and thoughts in this section.

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a generally valid paradigm. Summarising it can be stated that the provided functions have the potential to improve the balance between reuse and invention. The field work confirmed this statement in all the four case study companies.

9.9 The Research focus, approach, tools and research process design

The Research focus

The key words of this research are new product development, knowledge reuse and invention management, performance management and measurement. The author has shown that his work is placed in the performance management and measurement domain. Due to the fact that performance management is very often seen in the context of the management of people and organisational design the author focused on the more narrow subject of performance measurement. For both terms he provided his own definitions which are based on a solid understanding of the most relevant literature.

The focus of the theory development is the design, build and implementation of reuse and invention oriented performance measurement functions rather than the actual use of the functions. An *in depth* elaboration of use aspects would have opened up a whole new field implying also the in depth consideration of people management, appraisals, rewards, incentives, employment policies to mention only some potential topics in this context.

With regard to reuse and invention the author had many discussions on whether to put emphasis on the broader knowledge orientation or the tighter scope of reuse and invention being core phases of the knowledge management value chain (Edvinsson, 2000). In order to make the research more focused the author decided to focus on the reuse and invention aspect within the KM domain. For a long period the author wanted to provide exclusive reuse and invention performance management and measurement framework (not addressing other relevant NPD performance dimensions) which could have been integrated into existing NPD performance frameworks. However finally the author recognised that people want to have integrated solutions and do not want to run several tools and applications in parallel. Another question to answer is what makes the provided functions NPD specific? Can the provided functions be applied also in other phases of the value chain or can they only be applied in the NPD contexts they have been designed for? The answer is that the design of the functions allows in principle to apply them also in other phases of the value chain, however some specific features seem to be most value adding in NPD environments, due to the specific characteristics of the NPD context (section 3.1.4):

- The author learned that the reuse and invention topic is of special interest in NPD.
- The navigation mechanisms can create most benefit in distributed, complex and dynamic environments, like many NPD environments.
- The provided measures are centred around the reuse, invention *and* product development topic, referring for example to performance drivers which are most important in product development, like for example supplier involvement.
- The PMI is more powerful in the context of unstructured, dynamic process like NPD than in more structured processes, for example manufacturing.

Driva (1997) points out that most people who speak about product development refer to new product development. In reality however most development projects focus on relaunched, existing products. The motivation of the author to refer to new product development is the fact that for new products the reuse aspect might be even more important as well as the reuse and invention balance. According to the author's experience people generally know how to relaunch similar development projects and have for these kind of projects often quite stable and predictable processes in place. The value

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added through functions like the PMI is possibly greater in unstructured, dynamic and less predictable environments. However this does not mean that the developed functions are not suitable for variant product development.

The Research approach

Overall the research approach with its cornerstones of phenomenology, problem-oriented research, qualitative data analysis and participant-as-observer role proved to be the right choice for this research. Indeed the real-life context was as messy as expected, the real-life problem has been a true and valid threat for companies and the focus on qualitative data resulted in the expected rich and deep understanding of the research subject. However due to the novelty of the subject the research offers also a strong exploratory facet: The development of the new PMS functions provides an explorative aspect which leads into a testing-out oriented research phase in real-life environments. This thinking goes in line with for example Philipps and Pugh (2000) who suggest that the various types of research (problem-oriented research, testing-out research and exploratory research) should not be seen as a strait jacket (see also section 2.1.2). Instead a well-balanced research set-up may be composed of elements from two or three research types chosen to meet the research objectives.

Research tools

The collection of research tools is considered sufficient and rich enough to meet the triangulation requirements as demanded by for example Patton (1987). The selection of longitudinal case studies being the application environment for most of the other research tools in the explanatory testing phase of the research proved to be the right choice in order to be able to study the PMS functions in a real-life context (section 2.2.1). However, besides the "formal" research tools presented in section 2.2 also the "informal" research tools like discussions during conferences, workshops and fairs provided valuable insights and helped to increase the author's understanding of the research subject.

Research process

Overall the selected engineering oriented research process fits coherently with the overall problem-oriented research type: As one of the main outcomes of this research is the operative solution for a problem, it proved to be beneficial to rely throughout the whole research on the research process design for problem oriented research as suggested by Philipps and Pugh (2000) (section 2.2.7).

It is crucial to note that the research process presented in section 2.2 has not been purely sequential. Therefore, the results of the theory development which are presented in this thesis (especially in chapter 6 and 7) reflect the outcome of an iterative research process. The author was less interested in telling the story of how the research outcome evolved rather than in presenting the final results accompanied by extensive documentation of testing, discussions and reflections.

9.10 Conclusions

This chapter offers a rich and deep discussion of the research subject. Findings from the 4 case studies, presentations at industrial companies, expert interviews, knowledge cafés and several workshops delivered a considerable amount of data. After some broad reflections of the overall research topic the author discussed in a great level of detail the learning made through presenting, discussing and implementing the provided performance measurement theory. The appropriateness of the chosen research focus, approach, applied tools and the research process have been discussed as well. It is challenging to summarise the essence of such a chapter in a few words and statements, therefore the following list of some of the findings does not claim completeness:

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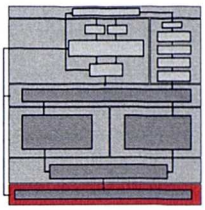
- The research subject matters, both in academia and industry.
- The PMS framework has been well accepted in the community and the user companies. The proposed navigation functionality seems to be more beneficial for organisations with complex and distributed NPD processes.
- This research shows that there is indication that NPD outcome measures are still the dominant type of measures in the user companies, although they learned over the last two years that using reuse and invention related measures complements the outcome oriented financial measures positively impacting overall NPD performance. Reuse and invention measures had mostly been used on a more implicit level when the project started.
- The research has shown that the use of graphical metaphor has been stated by many users and people from academia as being important to improve the communication of performance measurement information.
- The performance measurement infrastructure (PMI) was very well accepted by all user companies. Users liked that the PMI provides a day-to-day working environment for reuse and invention management which is coherently integrated in a powerful measurement framework.
- The provided measurement catalogue with its set of measures stimulated user companies in defining their specific set of measures. It has been learned that less a set of pre-defined is important, it is more the process of developing the right measures. The structure of the catalogue represents thereby an important reference.
- Many users agreed that software can be a major enabler for performance measurement to improve reuse and invention activity. The software can help to manage the vast amount of (measurement) information and reuse and invention assets through offering storage, retrieval, search, controlling and reporting functionality.

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10 Conclusions

"If all economists were laid end to end, they would not reach a conclusion"

George Bernard Shaw, Author



This final chapter recaptures the outcome of the research presented in this thesis stating that the main research objectives have been met and that the envisioned research outcome has been delivered. In a next step the contribution to knowledge is elaborated leading into the identification of further research opportunities. The thesis closes with a concluding remark from the author.

10.1 Research conclusions

The research question set at the outset of this research was *"What does a performance measurement system have to provide in order to improve knowledge reuse and invention in new product development environments?".*

In order to answer this question several research objectives and envisioned research outcomes have been set at the outset of this research (section 1.3):

Research objectives:

- To understand and learn from existing theories and approaches in the new product development, knowledge management, and performance management & measurement domains to create a solid base-line for theory development.
- To deliver a sound definition of performance management and measurement as well as a taxonomy of performance measurement purposes to improve knowledge reuse and invention in new product development.
- To develop novel performance measurement functions based on a concrete need for action identified in literature and real-life companies.
- To test and validate the developed functions in real-life environments.

Research outcome:

- A sound overview and understanding of relevant literature and experts' opinions in the subjects of new product development, knowledge management, performance management and measurement.
- A definition for performance management and measurement to improve reuse and invention in new product development, a taxonomy of PMS purposes and associated requirement clusters.
- Novel, pragmatic and validated performance management functions and design principles which meet the functional PMS requirements identified.

Discussion:

The **first research objective** is to understand and learn from the NPD, KM and PM domains and identify concrete needs for action. A thorough review of relevant literature and interviews with leading experts in the field helped to achieve this objective. The author has reflected on the most relevant concepts, theories, approaches and tools as a basis for understanding the research subject. His motivation to describe the existing performance management and management solutions (section 3.4) in great detail was to share this knowledge with the reader and to make the contribution to knowledge of this research explicit. Interviewing experts in the field increased the author´s learning on the subject considerably (section 2.2.2.2 and 4.4.3)

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The **second research objective** to deliver a definition for performance management and measurement, from a knowledge reuse and invention perspective, has been met (Chapter 4). When the author started his research in the KM and PM domain he was overwhelmed by the richness of literature – and partly confused by the many different definitions, terminologies and existing understanding on similar subjects. For example the terms performance management and performance measurement, metric and measure, purpose and function are used interchangeably in the literature. In order to set a clear base-line, the author developed his own working definition for performance management and measurement which he later expanded to a definition of performance management and measurement from a knowledge reuse and invention perspective (section 4.1). It has to be noted that validation and verification of these definitions was not the primary objective of this research although the author derived those definitions as thoroughly as possible. Subsequently the author collected the various existing purposes for measurement and clustered them using the structure proposed by Kerssens-van Drongelen (1999). He expanded this collection of purposes by adding two additional knowledge reuse and invention oriented purposes. Again it was not the primary objective of this research to elaborate on the validity of these purposes although the author is very confident in their validity: As the later defined functions have been derived from those purposes and as the functions have been exposed to severe theory testing, this implies that the validity of the purposes has also been tested.

The **third research objective** and outcome to deliver performance measurement theory resulting in novel reuse and invention oriented PMS functions and design principles represented the major work to be done within this research. The author is aware that PMS has been on the agenda of researchers for a long time and a rich body of literature exists. Therefore clear contributions to theory on a "generic" PMS level would be difficult. The author recognised that it might be easier to consider the overall PMS topic from a very specific perspective in order to show a clear contribution to knowledge in the field. As knowledge management, including the important reuse and invention topic, is currently an intensively discussed topic as well, especially in the context of measurement it was pertinent to bring the two domains together within the specific application case of NPD. In fact, during the writing up phase of this research the author became aware of an increasing body of literature discussing KM in the context of PM (Neely, 2001; Neely et al., 2000; Marr et al., 2001; Kaplan and Norton, 2001; Baird and Hendersson, 2000). In particular, Kaplan and Norton (2001) stress the suitability of their BSC to manage performance from a knowledge perspective in knowledge-based environments. They define "knowledge perspective" as the ability to manage intangibles like skills, competencies and motivation (Kaplan and Norton, 2001).

To attain this research objective the first question the author had to answer was "What are the functions of a generic PMS suitable for NPD environments?". The author invested considerable effort in understanding the literature and opinions of leading experts in the field to provide a definition and taxonomy of purposes and requirement clusters for a generic PMS. Following that, the author started to investigate the additional purposes which reflect specifically on the reuse and invention topic and which requirement clusters should be provided to meet those purposes. With regard to the question "What makes the functions NPD specific?" the answer might be that some of the design principles of the functions like the navigation or the PMI knowledge asset structure are especially suitable for NPD due to complexity, inter-disciplinarity and knowledge-intensity (section 3.1.4). Thus the author showed through the case studies that the functions provided work in the case NPD contexts, given the range of the cases it is reasonable to propose that the functions would be appropriate for NPD in general.

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The **fourth research objective** to test and validate the functions was met. The PMS functions provided have been implemented 4 times within companies. The author was very careful to offer a complete PMS solution for NPD therefore a majority of the design principles (also the more "generic" ones) demanded within the functional specification have been addressed although again, the main emphasis was on the novel knowledge reuse and invention oriented functions and design principles. The real-life case studies provided valuable insights and impacted the design of the functions significantly. Thus, the PMS functions as they are presented in this thesis reflect the outcome of an iterative development process. Altogether around 60 people were involved in the on-site case studies, more than 30 users did operative testing of the provided theory. This number is certainly not high enough to provide empirically confident outcomes, however it is sufficient to get valid insights into the PMS design, build, implementation and use process. The functions have also been presented at one international fair (over 20.000 visitors) and two conferences within knowledge cafés (200 and 250 participants), to over 50 participants in one workshop held at an international conference (200 participants) and to additional industrial companies (being 210.000 and 25.000 employees) which significantly contributed to the validation and verification of the functions.

Summarising it can be stated that the author has been able to meet the research objectives and to provide the demanded research outcome which enabled him to answer the research question.

10.2 Contribution to knowledge

The delivery of definitions, principles, structures, methodologies and functions which address the research problem stated at the beginning of this research *"Currently there is no sufficient set of performance measurement functions available which improves knowledge reuse and invention to enhance NPD performance"* contributes to the knowledge in the field in several ways:

- The terms Performance Management and Performance Measurement are often used interchangeably. The author provided an overview on current definitions for both resulting in the provision of his own *definition* enriching it with the very specific focus of this research – the knowledge reuse and invention orientation in new product development contexts.
- For the first time the disciplines *Knowledge Management and Performance Measurement have been brought together within in an NPD context.* The author attained this by conducting a thorough review of the relevant literature. This was then used as a basis to develop a definition, purposes and requirement clusters for performance measurement from a reuse and invention perspective.
- For the first time an *extensive assessment of the leading PMS systems from a reuse and invention perspective* has been provided. The assessment criteria have been elaborated within a very comprehensive analysis, based on the state of the art in performance management and knowledge management.
- Provision of comprehensive design principles for a *performance measurement framework* targeted to knowledge reuse and invention in NPD.
- Delivery of a well-structured *reuse and invention measurement catalogue* embedding a set of specific *reuse and invention focused measures.*
- Using the knowledge asset model concept from Knowledge Management and *integrating this with* performance measurement principles. This is embodied in a novel *Performance Measurement Infrastructure* which applies measures directly to knowledge asset reuse and invention in NPD.

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- *Design principles* for an enabling information technology solution for the above modules.
- A build and implementation methodology which embodies knowledge on *how to build and implement* reuse and invention oriented performance measurement functions.

Discussion:

The PMS framework function provided can certainly be considered novel as no other existing framework elaborates explicitly on the reuse and invention paradigm. The PMS framework offers several design principles which are considered to be unique, like the 6 facet concept, the navigation functionality, the alignment principles and the consequent use of graphical metaphor. The existing frameworks do not provide such a coherent and deep integration of an operative reuse and invention management improvement tool (the PMI) with a PMS framework which explicitly addresses the reuse and invention perspective.

The Performance Measurement Infrastructure (PMI) function relies on well-known asset structure models which have been previously applied in the KM environment (Prenninger et al., 1999). The author's contribution to knowledge in this context is the application of knowledge asset structures in the performance measurement domain and their enrichment with a performance measurement perspective.

The two other deliverables, the catalogue function and the build and implementation function are not new in nature. There are various catalogues, for example by Kennerley and Neely (2000) and there are build and implementation guidelines (Kerssens-van Drongelen, 1999) but none of the existing catalogues or guidelines reflects explicitly on the reuse and invention paradigm. Therefore, these deliverables show a clear contribution to knowledge: With regard to the catalogue it is the structure which reflects on specific features of the PMI and the PMS framework and the measures themselves. In particular for reuse and invention, novel asset related reuse and invention measures have been provided. The build and implementation methodology is novel because it reflects, whilst relying on well-proven change management and systematic design principles, directly on the other three PMS functions.

The proposed design principles and architecture of the software have shown that they can meet the requirements set through the proposed theory which therefore presents a contribution to knowledge. The most important design principles are the three tier architecture, the use of a relational datastore for structured data and metadata, the deployment of an Application Server concept to provide scalability and an environment for running the middle-tier business logic while also using open standards.

10.3 Recommendations for further research

Performance management and measurement as well as knowledge management are large fields of research. Therefore numerous aspects could not be discussed in this thesis and must remain for further research:

- Although the author carefully selected the four case studies to represent different branches, the impact of different branches like financial service or heavy industry on the PMS subject in NPD must be explored in greater detail. Certainly the author has been able to draw some lessons from the different case studies, however an in depth empirical comparison between the different cases coming from different branches was beyond the scope of this thesis. A very interesting research question might therefore be: "How do different branches like service, heavy industry or high technology impact the use of the performance measurement functions provided in this thesis?".

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- The investigation of the use aspect of a PMS is a long term effort. Often, it is only after years that the true impact of PM at a company can be shown when for example the PMS starts to change the thinking and behaviour of people. This in depth investigation of the use aspect could not be covered within this research. What could be covered was the investigation of the user feed-back on the provided functions at an operational level. Current performance management literature speaks apart from the use aspect from the ongoing management aspect of the PMS. Although some answers could be given in the context of this research further investigations have to be done to learn how the provided functions can be continuously managed in business contexts.
- The build and implementation concept presented in this thesis is described on a rather theoretical level. The elaboration of a detailed and pragmatic implementation workbook basing on the principles presented in this research could be a very interesting challenge. During the course of this research the power of graphical facilitation of group processes has been discovered. The creation of a supporting set of graphical implementation templates could be another very interesting opportunity.
- The validation and verification of the research outcome took place within a limited number of cases. To obtain truly statistically robust data build and implementation projects have to be carried out at more sites in the future.
- The case studies in this research give some indication that the maturity of understanding of the subjects reuse and invention correlates to the importance people give to the performance facet "operating context". It would be interesting to elaborate on this hypothesis in greater detail.
- More focus has to be put on the invention part of the solution. Through the PMI a very powerful reuse improvement tool has been provided which also supports the generation of new knowledge. However the invention, human oriented side should be additionally supported through integration of operative tools, like brainstorming tools or Community of Practice (CoP) tools.
- The exemplary measures presented in this research have to be continuously refined and completed. The elaboration of a truly validated and verified set of measures, especially taking into account the causes and effects between the different measures, is definitely subject to further research. Further investigations are necessary to be able to improve the set of target and benchmarking values for the knowledge asset related indicators.
- The focus of this research work has been the measurement aspect with the broad performance management subject. Therefore it has to remain subject of further research to align the provided performance measurement functions to more management oriented functions, like for example organisational design, budget planning and human resource management.
- The provided functions generally support performance measurement in an organisational context. However the principles and functions can generally -although not specifically outlined in this thesis- be applied to manage employee performance. It would be interesting to investigate how the provided functions can be integrated in an employee performance appraisal concept. Above all in the United States the term performance management is intensively correlated with people's performance.
- The character of the provided PMS framework character is more of a theoretical nature although various implementation scenarios have been presented. It has to remain to future research how reference guidelines for specific aspects like the various subjects can look like. For example the PMS framework has shown that "suppliers" are an important subject in the stakeholder contribution facet. But a subsequent, logical supplier appraisal which may help in determining the supplier

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contribution could not be given due to time and resource constraints of this research work.

- Today NPD is characterised through extremely networked organisations and distributed processes and organisations. It has to remain for further research to investigate the impact of those emerging distributed and networked environments on the provided theory within this research.
- One limitation of this research is the basic assumption that the terms invention, reuse and innovation as defined in the glossary are clearly and uniformly understood by respondents in the fieldwork. It would be interesting to explore whether respondents did have a clear and uniform understanding of these terms and what the implications of this might be.

10.4 The last word

This research has studied the problem of reuse and invention using the subject domains of NPD, measurement and KM. Immersion in four case-study companies has been used to test many concepts embodied in the functions.

This forms one part of a much bigger body of work which is using and developing concepts of KM and measurement to improve NPD performance. Best wishes to my colleagues on their own journeys.

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References

Adler, P.S. (1989). Technology strategy: A guide to literature research. Technological Innovation, Management and Policy, 4:25-151.

AIT (1998). *D3.1 Generic Enterprises Change Management Methodology - INITIAL DESCRIPTION (confidential).* ESPRIT Project AIT Implant (No. 24771), the AIT consortium, Toulouse.

Al-Ani, A. (1996). Continuous Improvement als Ergänzung des Business Reengineering. *Zeitschrift für Organistion*, 3, 142-148.

Allee, V. (1997). Knowledge and self-organisation. *Executive Excellence*, 1, 7.

Alter, A.E. (1997). Know-how pays off. *Computerworld*, 2, 72.

Amidon, D.; Mahdjoubi, D. (2000). *Atlas of Knowledge Innovation: Beyond Business Planning* (WWW document). http://www.entovation.com/whatsnew/index.htm. (accessed 1st of September 2000).

Amidon, D.M. (1997). *Innovation Strategy for the Knowledge Economy: The KEN Awakening.* Butterworth-Heinemann, New York.

Amidon, D.M. (2000). The great Gurus on New Use and Innovation. In*: Domain Knowledge Collection and Best Practice in New-use and Innovation Management: WP 1 Requirements Engineering & Knowledge Acquisition – Task 1.2 / 1.3 Research State of the Art and Industrial Practice (confidential).* The NIMCube consortium, Stuttgart, 338-342.

Anonymous (1993). *Final Report on Readiness Assessment for Concurrent Engineering (RACE) for DICE, CERC TECHNICAL REPORT SERIES, CERC-TR-TM-93-075.* West Virginia University, Morgantown.

Anthony, R.N.; Govindarajan, V. (1998). *Management Control Systems,* 9th ed. Dow-Jones Irwin, Homewood.

Ash, J. (1998). Managing knowledge gives power. *Communication World*, 3, 23-26.

Azzone, G.; Masella, C.; Bertele, U. (1991). Design of Performance Measures for Time-based Companies. *International Journal of Operations & Production Management*, 3, 77-85.

Bading, A.; Frech, J. (1999). *Umfassendes Qualitätsmanagement und das EFQM Excellence Modell.* Fraunhofer IAO Press, Stuttgart.

Baird, L.; Henderson, J. (2001). *The Knowledge Engine.* Berrett-Koehler, San Francisco.

Ballantine, J.; Brignall, S. (1994). *A Taxonomy of Performance Measurement Frameworks.* Warwick Business School Research Paper, Warwick.

Basili, V.R.; Rombach, H.D. (1987). Tailoring the software process to project goals and environment. In*: Proceedings of the 9th International Conference on Software Engineering*, cat. No. 87ch2432-3, 345-357.

Beaumont, L.R. (1996). Metrics: A Practical Example. In: *The PDMA Handbook of New Product Development,* edited by M.D. Rosenau, jr; A. Griffin; G.A. Castellion; N.F. Anschuetz, John Wiley & Sons, New York.

Beer, S. (1985). *Diagnosing the system for organisations.* Wiley, Chichester.

Berndes, S.; Stanke, A.; Piller, J.; Wagner U. (1996). A Concept for Revitalisation of Product Development. In: *Concurrent Simultaneous Engineering Systems, The Way to Successful Product Development*, edited by H.-J. Bullinger and J. Warschat. Springer Verlag, London.

Berns, A. (1994*). Informal technical report for the software technology for adaptable, reliable systems (STARS): Metric concept report.* HGO Technologies Inc., Morgantown.

Bidault, F.; Despress C.; Butler, C. (1998). New product development and early supplier involvement (ESI): the drivers of ESI adoption. *International Journal of Technology Management*, 15(1/2), 49-69.

Bielinsky, D. (1996). *Economic Value Added Management Tool* (WWW document). http://www.snc.edu/socsci/chair/333/eva_1.htm. (accessed 25th of July 2001).

Binney, D. (2001). The knowledge management spectrum – understanding the KM landscape. *Journal of Knowledge Management*, 1, 33-42.

Bititci, U.S.; Turner, T.J.; Bourne, M. (2000). Performance Measurement Process V. Model. In: *Performance Measurement-Past, Present, Future – the second International Conference on Performance Measurement proceedings*, edited by A.D. Neely. Cambridge, July 2000, 48-56.

Blake, P. (2000). The future of knowledge management. *Information Today*, 3, 14-15.

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Blanchard, S.; Fabrycky, B. (1997). *Systems Engineering and Analysis.* Prentice Hall, New Jersey.

Bonnet, M.P.B.; Krens, F. (1994). Hoofdstuk 1: Prestatie-indicatoren. In: *naar een betere beheersing van bedrijfsactiviteiten*, edited by A. Jorissen. Prestatiemeting, MAKLU Uitgevers, Antwerpen, 13-74.

Bonsdorff von, C.; Andersin, H.E. (1995). Supporting the Business Process Management Paradigm by Means of Performance Measurements. In: *Proceedings of the CE95 Concurrent Engineering 1995 conference*, Pittsburgh, 529-539.

Boutellier, R.; Gassmann, O.; Zedtwitz, M.v. (1998). *Managing Global Innovation.* Springer Verlag, Zürich.

Brockhaus (2000). *Brockhaus: Die Enzyklopädie.* Bibliographisches Institut & F.A. Brockhaus AG, Mannheim.

Brockhoff, K. (1993). Forschungs- und Entwicklungs- Kostenschätzmethoden. In: *Vahlens großes Controlling Lexikon*, edited by P. Horváth. Vahlen Verlag, München.

Brookes, N.J.; Backhouse, C.J. (1998). Measuring the Performance of Product Introduction. In: *Proceedings of the Institute of Mechanical Engineers (IMechE) Part B: Journal of Enineering Manufacture*, 212(B1), 1-11.

Brown, M.G. (1996). *Keeping Score: Using the Right Metrics to Drive World-Class Performance.* Quality Resources, New York.

Brown, M.G.; Svenson, R.A. (1988). Measuring R&D Productivity. *Research-Technology Management*, 6, 11-15.

Brown, W.B.; Gobeli, D. (1992). Observations on the measurement of R&D productivity: A Case study. *IEEE Transactions on Engineering Management*, 39(4), 325-331.

Bukowitz, W.R.; Williams, R.L. (1999). *The Knowledge Management Fieldbook.* Prentice Hall, New Jersey.

Bullinger, H.-J.; Frielingsdorf, H.; Roth, N.; Wagner, F.; Zeichen, G.; Fürst, K.; Brandstätter, T. (1999), *Marktstudie: Engineering Data Management Systeme: EDM als strategischer Erfolgsfaktor im innovativen Unternehmen, 2. Auflage*, IRB Verlag, Stuttgart.

Bullinger, H.-J.; Warschat, J. (1996). *Concurrent Simultaneous Engineering Systems, The Way to Successful Product Development.* Springer Verlag, London,.

Bullinger, H.-J.; Wörner, K.; Prieto, J. (1997). *Wissensmanagment heute.* Fraunhofer IAO Studie, Stuttgart.

Bürgel, H.D; Haller, C.; Binder, M. (1997). *FuE Management.* Verlag Vahlen, München.

Busby, J.R.; Williamson, A. (2000). The Appropriate Use of performance measurement in Non-production activity. *International Journal of Operations & Production Management*, 20(3), 336-358.

Butler, R. (1995). What You Measure is What You Get – An Investigation into the Measurement of the Value Added by the Purchasing Function. In: *Proceedings of the IPSERA, 4th International Annual Conference, Service Sector and Manufacturing Procurement*, The University of Birmingham, April 1994, Birmingham, 1-14.

Caffyn, S. (1997). Extending Continuous Improvement to the New Product Development Process. *R&D Management*, 27(3), 253-267.

Centre for Business Performance (CBP) (2000). *Web-site of the Cranfield Centre for Business Performance.* http://www.cranfield.ac.uk/som/cbp. (accessed 10th of January 2001).

Chelsom, J.V. (1994). Concurrent Engineering case studies: lessons from Ford Motor Company experience. In: *Concurrent Engineering, Concepts, implementation and practice*, edited by C.S. Syan and U. Menon. Chapman & Hall, London.

Chennel, A.F.; Dransfield, S.B.; Field, J.B.; Fisher, N.I.; Saunders, I.W and Shaw, D.E. (2000) OPM: A system for organisational performance measurement. In: *Performance Measurement-Past, Present, Future – the second International Conference on Performance Measurement proceedings*, edited by A.D. Neely. July 2000, Cambridge, 96-103.

Chester, A.N. (1995). Measurement and Incentives for Central Research. *Research-Technology Management*, 7/8, 14-22.

Chiesa, V.; Coughlan, P.; Voss, C.A. (1996). Development of Technical Innovation Audit. *Journal of Innovation Management*, 12, 105-136.

Christ, O. (1999). *Wissensorientierte Führung.* Seminararbeit, Universität St. Gallen – Hochschule für Wirtschafts-, Rechts- und Sozialwissenschaften, St. Gallen.

Christensen, C.M. (1997). *The Innovators Dilemma – When new technologies cause great firms to fail.* Harvard Business School press, Boston.

Christensen, C.M. (1999). *Innovation and the General Manager.* Irwin McRaw-Hill, Boston.

© Cranfield University 2001. All rights reserved.
No part of this publication may be reproduced without the permission of the copyright holder

Clark, K.B.; Fujimoto, T. (1991). *Product Development Performance: Strategy, Organisation and Management in the World Auto Industry*. Harvard Business School Press, Boston.

Clark, L.A.; Zirner, U. (1993). How to design, develop & implement successful PMS. *Quality and Productivity Management*, 10(3), 61-80.

Clarke, L. (1994). *The Essence of Change*. unknown, UK.

Clausing D. (1998). Reusability in product development - keynote paper. In: *Design Reuse: Engineering Design Conference '98*, edited by S. Sivaloganathan and T.M.M. Shahin. June 1998, Brunel, 57-66.

Cole-Gomolski, B. (1997a). Chase uses news apps to ID best customers. *Computerworld*, 35, 49-50.

Cole-Gomolski, B. (1997b). Users loath to share their know-how. *Computerworld*, 46, 6.

Cole-Gomolski, B. (1998). Vendors cram knowledge-ware market. *Computerworld*, 5, 55-56.

Coleman, I.; Eccles, R. (1997). *Pursuing Value: Reporting Gaps in the United Kingdom*. PricewaterhouseCoopers, New York.

Collier, D.W. (1977). Measuring the Performance of R&D Departments. *Research Management*, 3, 30-34.

Comelli, G. (1999). Organisationsentwicklung. In: *Führung von Mitarbeitern*, edited by L.v. Rosenstiel, E. Regnet, M. Domsch. Beck Verlag, Stuttgart.

Commes, M.; Lienert, R. (1993). Controlling im F&E Bereich. *Zeitschrift für Führung und Organisation*, 63, 347-354.

Cooper, R. G. (1985). Overall corporate strategies for new product programs. *Industrials Marketing Management*, 14(8), 179-193.

Cooper, R. G.; Kleinschmidt, E.J. (2000) New Product Development Performance: What distinguishes the Star Products. *Australian Journal of Management*, 25(1), 17-46.

Cooper, R.G. (1990). Stage-Gate Systems: A New Tool for Managing New Products. *Business Horizons*, 5/6, 44-54.

Cooper, R.G.; de Brentani U. (1984). Criteria for screening new industrial products. *Industrial Marketing Management* ,13 (3), 149-156.

Cooper, R.G.; Kleinschmidt E.J. (1986). An investigation into the New Product Process: Steps, Deficiencies, and Impact. *Journal of Product Innovation Management*, 3, 71-85.

Cooper, R.G.; Kleinschmidt, E.J. (1995). Benchmarking the Firm's Critical Success Factors in New Product Development. *Journal of Product Innovation Management*, 12, 374-391.

Cooper, R.G.; Yoshikawa, T. (1994). Inter-organisational cost management systems: The case of the Tokyo-Yokohama-Kamakura supplier chain. *International journal of production economics*, 37, 51-62.

Crowe, R. (1997). Winning with Integrity. In: *The Guardian*, 27th November 1999.

Davenport, T.H.; Prusak, L. (1998). *Working Knowledge: How Organisations Manage What They Know*. Harvard Business School Press, Boston.

Deasley, P.J.; Lettice, F. (1997). A Concurrent Engineering Approach to Construction: Learning from Cases in Manufacturing Industry. In: *1st International Conference on Concurrent Engineering in Construction,* The Institution of Structural Engineers, July 1997, London, 296-305.

Dimanescu, D.; Dwenger, K. (1996). *World Class New Product Development: Benchmarking Best Practices of Agile Manufacturers* (WWW document). http://www.meansbusiness.com/Products-and-Services-Books/World-Class-New-Product-Development.htm. (accessed 31st of August 2001).

DiMattia, S.; Oder, N. (1997). Knowledge management: hope, hype, or harbinger?. *Library Journal*, 15, 33-35.

Dixon, J. R.; Nanni, A. J.; Vollmann, T. E. (1990). *The New Performance Challenge - Measuring Operations for World-Class Competition*. Dow-Jones Irwin, Homewood.

Doppler, K.; Lauterburg, C. (1999). *Change Management – Den Unternehmenswandel gestalten*, 8. Auflage. Campus, Frankfurt – New York.

Dorf, R.C.; Bishop, R.H. (1995). *Modern Control Systems,* 7th ed. Addison-Wesley, London.

Driva, H. (1997). *The Role of Performance Measurement during Product Design and Development in a Manufacturing Environment*. Ph.D. Thesis, University of Nottingham, Nottingham.

Drucker, P.F.(1993). *Post-capitalist Society*. Harper Business, New York.

Dvir, R.; Evans, S. (1998). Mapping Knowledge Reuse in R&D Processes – The Implementation of Quality tools. In: *Proceedings of the 1998 Tel Aviv Quality Conference*, June 1998, Tel Aviv.

© Cranfield University 2001. All rights reserved.
No part of this publication may be reproduced without the permission of the copyright holder

Dvir, R.; Evans, S.; Pasher, E.; Prieto, J.; Roth, N. (2000). New-Use , Innovation & The Delicate Balance Between Them. In: *Productivity & Quality Management Frontiers 9 Conference Proceedings*, edited by E. Dar-El; A. Notea; A. Hari. July 2000. Israel MCB University Press, Bradford, 115-120.

Dyson R.G.; Thanassoulis, E.; Boussofiane, A. (2001). *The DEA Tutorial* (WWW document). www.deazone.com/tutorial. (accessed 25th of may 2001).

Easterby-Smith, M.; Thorpe, R.; Lowe, A. (1991). *Management research: An Introduction.* Sage, London.

Eccles, R.G.; Noriah, N.(1992). *Beyond the Hype – Rediscovering the Essence of Management.* Harvard Business School press, Boston.

Edvinsson, L. (1997). Developing intellectual capital at Skandia. *Long Range Planning*, 3, 366-373.

Edvinsson, L. (2000). The balance between reuse and innovation. In: *Domain Knowledge Collection and Best Practice in New-use and Innovation Management: WP 1 Requirements Engineering & Knowledge Acquisition – Task 1.2 / 1.3 Research State of the Art and Industrial Practice(confidential)*, the NIMCube consortium, Stuttgart, 363-366.

Edvinsson, L.; Malone, T. (1997*): Intellectual Capital: Realising your Company's True Value by Finding its Hidden Brainpower.* Harper Business, New York.

Ehrlenspiel, K. (1995). *Integrierte Produktentwicklung: Methoden für Prozeßorganisation, Produkterstellung und Konstruktion.* Carl Hanser Verlag, München.

Eisenhardt, K. M.; Tabrizi, B. N. (1995), Accelerating Adaptive Processes: Product Innovation in the Global Computer Industry. *Administrative Science Quarterly*, 40, 84-110.

Eisner, H. (1997). *Essentials of project and systems engineering management.* John Wiley & Sons, New York.

Emery, P. (1997). Knowledge management. *Inform*, 10, 2.

Emmanuel, C., Otley, D. and Merchant K. (1990). *Accounting for Management Control.* Chapman & Hall, London.

Eppler, M. J. (1997). Führer durch den "Wissensdschungel". *Gablers Magazin*, 8, 10-13.

Epstein, M.J.; Manzoni, J.F. (1997). The Balanced Scorecard and Tableau de Bord: Translating Strategy into Action. *Management Accounting*, 2, 28-36.

Evans, S. (2000). The balance between reuse and innovation. In*: Domain Knowledge Collection and Best Practice in New-use and Innovation Management: WP 1 Requirements Engineering & Knowledge Acquisition – Task 1.2 / 1.3 Research State of the Art and Industrial Practice (confidential),* the NIMCube consortium, Stuttgart, 366-371.

Fan, I.-S.; Heslop, A.; Heras, M.; Heretia,J. (2000). Measuring the performance of eBusiness and eWork based on their business processes. . In: *E.business: Key issues, Applications and technologies*, edited by B. Stanford-Smith and P.T. Kidd. October 2000, IO press, Amsterdam, 1010-1016.

Feurer, R.; Chaharbaghi, K. (1995). Performance Measurement in Strategic Change. *Benchmarking for Quality Management and Technology*, 2(2), 64-83.

Filos E.; Banahan, E. (2000). Towards the Smart Organisation – An emerging Organisational Paradigm and the contribution of the European RTD programmes. *Journal of Intelligent Manufacturing,* Special Issue: "Virtual Enterprises" (to be published).

Fitzgerald, L.; Johnston, R.; Brignall, T.J.; Silvestro, R.; Voss, C. (1991). *Performance Measurement in Service Businesses*, The Chartered Institute of Management Accountants, London.

Fitzgerald, L.; Moon, P. (1996). *Performance Management in Service Industries: Making it Work.* The Chartered Institute of Management Accounts, London.

Flamholtz, E. (1996). Effective Organizational Control: A Framework, Applications, and Implications. *European Management Journal*, 6.

Fleming, Q.W.; Koppelman, J.M. (1998). Project Teams: The Role of the Project Office. *Cost Engineering*, 40(8).

Fortuin, L. (1994). Hoofdstuk III: Operationele prestatiementing:onmisbaar op de weg naar voortdurende verbetering. In: *Prestatiemeting, naar een betere beheersing van bedrijfsactiveiten*, edited by A. Jorissen. Antwerpen 1994.

Freeman, R. E. (1984). *Strategic Management: A Stakeholder Approach.* Pitman Series in Business and Public Policy, Boston.

Gardner, D. (1998). Get Smart. *Infoworld*, 4, 97-98.

© Cranfield University 2001. All rights reserved.
No part of this publication may be reproduced without the permission of the copyright holder

Gibbert, M.; Kugler, P.; Völpel, S. (2000). Getting real about knowledge sharing: the Premium-on-Top bonus system. In: *Knowledge Management Case Book*, edited by G. Probst and T. Davenport. Publicis MCD Verlag and John Wiley & Sons, München.

Gill, J.; Johnson, P. (1997). *Research Methods for Managers*, 2nd ed. Paul Chapman Publishing Ltd., London.

GKEC (2001). *The Global Knowledge Economics Council* (WWW document). http://www.gkec.org. (accessed 20th of August 2001).

Glaser, M. (1995). Measuring Intuition. *Research-Technology Management,* 3/4, 43-46.

Goffin, K. (1994). *Repertory Grids in Market Research: An example,* Cranfield Working Papers List No 8, Cranfield University, Cranfield.

Goldense (1996). *Metrics for Measuring Product Development* (WWW document). http://wwwsoce.org/papers/gglmetrics/GGImetrics.htm. (accessed 1st of March 2001).

Goldman, S.F.; Hoogenboom, D. (1997). *No Brains, No Value.* Amstelveen-Breukelen.

Goold, M. (1991). Strategic Control in the Decentralised Firm. *Sloan Management Review*, Winter, 69-81.

Goold, M. and Quinn, J.J. (1990). The Paradox of Strategic Controls. *Strategic Management Journal*, 11, 43-57.

Gopal, C.; Gagnon, J. (1995). Knowledge, information, learning and the IS manager. *Computerworld*, 25, 1-7.

Graaf, R. de (1996). *Assessing Product Development: Visualizing Process and Technology Performance with RACE.* Dissertation Technische Universiteit Eindhoven, Eindhoven.

Grafström, G, (1999). *Words of Value – a conversation with Leif Edvinsson and Arne Richter.* Skandia Insurance Company Ltd., Stockholm.

Grafström, G. and Edvinsson, L. (1999). *Accounting for Minds.* Skandia Insurance Company Ltd., Stockholm.

Grant, R.M. (1991). The resource-based theory of competitive advantage: implications for strategy formulation. *California Management Review*, 3, 1991, 114-135.

Grant, R.M. (1997). The knowledge-based view of the firm: implications for management practice. *Long Range Planning Review*, 3, 450-454.

Griffin, A.; Page, A. (1993). An interim report on measuring product development success and failure. *Journal of Product Innovation Management,* 10, 291-308.

Griffin, A.; Page, A. (1996). PDMA Success Measurement Project: Recommended Measures for Product Development Success and Failure. *Journal of Product Innovation Management*, 13, 478-496.

Grimaldi, R. (2000). Measuring the performance of collaborative RD projects: the case of the UK "Link" programme. In: *Performance Measurement-Past, Present, Future Conference,* edited by A.D. Neely. July 2000, Cambridge, 178-185.

Gummerson, E. (1991). *Qualitative Methods in Management Research.* Sage, Thousand Oaks.

Guth, R. (1996). Where IS cannot tread. *Computerworld*, 1, 72.

Guthrie, J. (2000). Intellectual Capital review: measurement, reporting and management. *Journal of Intellectual Capital*, 1.

Hahner C. (2000). *Berwertung von Innovationsideen mit Hilfe von Lebenszyklusaufwand.* Disseration Universität Stuttgart, Stuttgart.

Hamel, G.; Prahalad, C.K.; Thomas, H. and O'Neal, D. (1998). *Strategic Flexibility: Managing in a Turbulent Economy.* John Wiley & Sons Ltd., Chichester.

Hamel, G. (2000). *Leading the revolution.* Harvard Business School press, Boston.

Hart, S.; Hultink, E.J.; Tzokas, N.; Commandeur, H. (1998). How industrial companies steer their new product development processes: empirical evidence from Dutch and UK firms. In: *Proceedings of the 5th International Product Development Management Conference,* July 1998, Como, 503-521.

Hauser, J.; Zettelmeyer, F. (1995). *Metrics to Value R&D Groups, Phase 1: Qualitative Interviews. Working paper.* MIT Sloan School, Massachussetts.

Hauser, J. (1996). *Metrics to Value R&D: An annotated bibliography, working paper.* MIT Sloan School, Massachussetts.

Hauser, J. (1997). *Research, Development and Engineering Metrics, Working paper.* MIT Sloan School, Massachussetts.

Hauser, J.; Zettelmeyer, F. (1997). Metrics to evaluate R,D&E. *Research-Technology Management*, 7/8, 32-38.

© Cranfield University 2001. All rights reserved.
No part of this publication may be reproduced without the permission of the copyright holder

Hering, E.; Triemel, J.; Blank, H.-P. (1993). *Qualitätssicherung für Ingenieure*. VDI Verlag, Düsseldorf.

Herriott, R.E.; Firestone, W.A. (1983). Multisite qualitative policy research: Optimizing description and generalizability. *Educational Researcher*, 12, 14-19.

HGO Technology Inc. (1994). *Metrics Concept Report, Central Archive for Reusable Defense Software (CARDS)*. Unisys Corp, Virginia.

Hibbard, J. (1997). Knowing what we know. *Information Week*, 1, 46-64.

Hilb, M. (1997). *Integrierte Erfolgsbewertung von Unternehmen*. Luchterhand, Neuwied – Kriftel – Berlin.

Hill, T.J. (1989). *Manufacturing strategy: text and cases*. Irwin McRaw-Hill, Boston.

Hilmer, F.G.; Donaldson, L. (1996). *Management redeemed: debunking the fads that undermine corporate performance*. Free Press, New York.

Hofer-Alfeis, J. (Editor) (1999). *Geschäftsprozessmanagment*. Tectum Verlag, Marburg.

Horváth, P. (1997). *Balanced Scorecard – Strategien erfolgreich umsetzen*. Schäfer Pöschel, Stuttgart.

Horváth, P.; Kaufmann, L. (1998). Balanced Scorecard – ein Werkzeug zur Umsetzung von Strategien. *Harvard Business Manager*, 5, 39-48.

House, C.H.; Price, R.L. (1991). The Return Map: Tracking Product Teams. *Harvard Business Review*, 2, 92-100.

Hultnik, E.J.; Robben, H.S.J. (1996). Measuring Product Development Success and Failure – A framework defining success and Failure. In: *The PDMA Handbook of New Product Development,* edited by M.D. Rosenau, jr; A. Griffin; G.A. Castellion; N.F. Anschuetz, John Wiley & Sons, New York.

Humphrey, W.S. (1989). *Managing the Software Process*. Addison-Wesley, New York.

IDS Scheer AG (2000). *Process Performance Management*. Strategy Paper November 2000, Saarbrücken.

Ilgen, D.R.; Fisher, C.D.; Taylor, M.S. (1979). Consequences of Individual Feedback on Behaviour in Organisation. *Journal of Applied Psychology*, 64(4), 349-371.

Jankowicz, A.D. (2000). *Business Research Projects,* 3rd ed. International Thomson Business Press, London.

Jensen, M.C.; Meckling, W.H. (1976). Theory of the Firm: Behaviour, Agency Cost and Ownership Structure. *Journal of Financial Economics*, 3, 305-360.

Jick, T. (1979). Mixing qualitative and quantitative methods: Triangulation in action. *Administrative Science Quarterly*, 24, 602-611.

Johnson, A. (2000). *Building performance measurement systems to improve co-development capability*. Ph.D. thesis, Cranfield University, Cranfield.

Johnson, T. H. (1992). *Relevance Regained. From Top-Down Control to Bottom-Up Empowerment*, Free Press, New York.

Johnson, T. H.; Kaplan, R. S. (1987). *Relevance Lost*. Harvard Business School press, Boston.

Jukes, S. (2000). *Understanding the successful improvement of co-development*. Ph.D. thesis, Cranfield University, Cranfield.

Kablouti, G. (2000). *A Requirements Engineering Approach for the development of a Concurrent Engineering reference model for aeronautics*. Masters Thesis, Fraunhofer IAO, Stuttgart.

Kalila, R. (2000). Using patent data to measure innovation performance. *International Journal of Business Performance Management*, 2(1/2/3), 180-193.

Kao, J.J. (1997). The art and discipline of business creativity. *Planning Review*, 4, 6-11.

Kaplan, R.S.; Atkinson, A.A. (1998). *Advanced Management Accounting*, 3rd international ed. Prentice Hall, Upper Saddle River.

Kaplan, R.S.; Cooper, R. (1998). *Cost & Effect: Using Integrated Cost Systems to Drive profitability and performance*. Harvard Business School press, Boston.

Kaplan, R.S.; Norton, D.P. (1992). The Balanced Scorecard – Measures that Drive Performance. *Harvard Business Review*, 1, 71-79.

Kaplan, R.S.; Norton, D.P. (1993). Putting the Balanced Scorecard to Work. *Harvard Business Review*, 5, 134-147.

Kaplan, R.S.; Norton, D.P. (1996a). *The Balanced Scorecard*, Harvard Business School Press, Boston.

Kaplan, R.S.; Norton, D.P (1996b). Using the Balanced Scorecard as a Strategic Management System. *Harvard Business Review*, 1, 75-85.

Kaplan, R.S.; Norton, D.P. (2001). *The strategy-focused organization*. Harvard Business School Press, Boston.

© Cranfield University 2001. All rights reserved.
No part of this publication may be reproduced without the permission of the copyright holder

Karandikar, H.M.; Fotta, M.E.; Lawson, M.; Wood, R.T. (1993). *Assessing Organisational Readiness for Implementing Concurrent Engineering Practices and Collaborative Technologies.* CERC TECHNICAL REPORT SERIES, CERC-TR-TM-93-006, West Virginia University, Morgantown.

Kauffman, S. (1996). *At home in the Universe: The search of self-organisation and Complexity*, Oxford University Press, Oxford.

Kaydos, W. (1991). *Measuring, Managing and Maximising Performance.* Portland, Productivity Press.

Keegan, D.P.; Eiler, R.G.; Jones, C.R.(1989). Are your performance measures obsolete?. *Management Accounting*, 12, 45-50.

Kennerley, M. (2000). *Performance Measurement and Cause and effect Relationships within Inventory Management of Manufacutring Planning and Control Systems.* Ph.D. thesis, University of Manchester, Manchester.

Kennerley, M.; Neely, A. D. (2000). Performance Measurement Frameworks – A Review. In: Performance Measurement-Past, Present, Future, Conference proceedings, edited by A.D. Neely. July 2000, Cambridge, 291-298.

Kerssens-van Drongelen, I.C. (1999). *Systematic Design of R&D Performance Measurement Systems.* Ph.D. thesis, University of Twente, Enschede.

Kerssens-van Drongelen, I.C.; Bilderbeek, J. (1999). R&D Performance Measurement: More than just choosing a set of Metrics. *R&D Management*, 1, 35-46.

Kerssens-van Drongelen, I.C.; Cook, A. (1997). Design principles for the development of measurement systems for research and development processes. *R&D Management*, 27(4), 345-357.

Klaila, D. (2000). Knowledge Management. *Executive Excellence*, 3, 13-14.

Klingebiel, N. (1999). *Performance Measurement.* Gabler Verlag, Wiesbaden.

Kolodner, J. (1993). *Case based reasoning.* Morgan Kaufmann Publishers, San Francisco.

Krahn, A. (1998). Indikatoren für ein Prozeß-Monitoring-System. *Information Management*, 4, 57-63.

Krause, I.; Liu, J. (1993). Benchmarking R&D productivity: Research and Development; Case Study. *Planning Reviews*, 21(1), 16-21.

Krause, O. (2000). Management Knowledge Engineering-A tool-kit to engineer adaptive management systems. In: *Performance Measurement-Past, Present, Future, Conference proceedings*, edited by A.D. Neely. Cambridge, July 2000, 307-315.

Krogh, L.C.; Prager, J.; Sorensen, D.P.; Tomlinson, J.D. (1998). How 3M evaluates its R&D programs. *Research-Technology Management,* 1, 40-43.

Laberis, B. (1998). One big pile of knowledge. *Computerworld*, 5, 97.

Landauer, J.; Blach, R.; Bues, M.; Roesch, A.; Simon, A. (1997). Toward Next Generation Virtual Reality Systems. In: *IEEE International Conference on Multimedia Computing and Systems Proceedings*, Date, Ottawa.

Lander, L.; Matheson, D.; Menke, M.M and Ransley, D.L.. (1995). Improving the R&D Decision Process. *Research-Technology Management*, 1, 40-43.

LaPlante, A. (1997). Sharing the wisdom. *Computerworld*, 22, 73.

Leeuw, A.C.J. de (1982). Organisaties: management, analyse, ontwerp en verandering: een systeemvisie, Assen.

Leonard, D.; Sensiper, S. (1998). The Role of Tacit Knowledge in Group Innovation. *California Management Review*, 40(3),112-132.

Leonard-Barton, D. (1995). *Wellsprings of Knowledge: building and sustaining the sources of innovation*, Harvard Business School press, Boston.

Lewin, K. (1946). Action Research and Minority Problems. *Journal of Social Issues*, 2, 34-6, 286, 438.

Lim, W.C. (1998) *Managing Software Reuse.* Prentice Hall, Upper Saddle River.

Lingle, J.H.; Schiemann, W.A. (1996). From Balanced Scorecard to Strategy Gauge: Is Measurement Worth it?. *Management Review*, 3, 56-62.

Lobo, C.; Cochran, D.; Duda, J. (2000). Using axiomatic design to support the development of a Balanced Scorecard. In: *Performance Measurement-Past, Present, Future, Conference proceedings*, edited by A.D. Neely. July 2000, Cambridge, 347-354.

Loch, C.; Stein, L.; Terwiesch, C. (1996). Measuring development performance in the electronics industry. *Journal of Product Innovation Management* , 13, 3-20.

© Cranfield University 2001. All rights reserved.
No part of this publication may be reproduced without the permission of the copyright holder

Longerstaey, J.; More, L. (1995). *Introduction to risk metrics.* JP Morgan Guaranty Trust Company, Risk Management Services, New York.

Lynch, R.L.; Cross, K.F. (1995). *Measure Up! The Essential Guide to Measuring Business Performance.* Mandarin, London.

Macintosh, N.B. (1994). *Management Accounting and Control Systems.* John Wiley & Sons, Chichester.

Maginnis, N. (1986). Specialist: reusable code helps increase productivity. *Computerworld*, 11, 12-18.

Maglitta, J. (1995). Smarten up!. *Computerworld*, 23, 84.

Maier R. (2001). *State of the Art des Einsatzes von Wissensmanagement-Systemen.* Assessment Questionnaire, University of Regensburg, Regensburg.

MaKe-IT SME Consortium (1998). *MaKe-IT SME Deliverable D-3-A Methodology to increase acceptance towards Knowledge Management – Work Package 3: Human Resource Management (confidential).* The Make IT consortium, Stuttgart.

MaKe-IT SME Consortium (1999a). *MaKe-IT SME Deliverable D-5-B Organisation Model – Work Package 5: Knowledge Engineering Scenario (confidential).* The Make IT consortium, Stuttgart.

MaKe-IT SME Consortium (1999b). *MaKe-IT SME Deliverable D-5-C Information and Communication Model – Work Package 5: Knowledge Engineering Scenario (confidential).* The Make IT consortium, Stuttgart.

Manville, B.; Foote, N. (1996). Strategy as if knowledge mattered. *Fast Company*, 4/5.

Marr, B.; Schiuma, G.; Neely A.D. (2001). *Measuring capabilities and knowledge in the eEconomy* (WWW document). http://www.cranfield.ac.uk/som/cbp/measuringcapabilities.html. (accessed 15th of may 2001).

Mårtenson, M. (2000). A critical review of knowledge management as a management tool. *Journal of Knowledge Management*, 3, 204-216.

Martin, J. (1996). *Systems Engineering Guidebook: a process for developing systems and products.* CRC Press, Boca Raton.

Martins, R.A. (2000). Use of performance measurement systems: some thoughts towards a comprehensive approach. In: *Performance Measurement-Past, Present, Future, Conference proceedings*, edited by A.D. Neely. July 2000, Cambridge, 363-371.

Maskell, B. H. (1991). *Performance Measurement for World Class Manufacturing.* Productivity Press, Portland.

Maskell, B.H. (1989). Performance Management for World-Class Manufacturing. *Management Accounting*, 5, 32.

Matheis, M.; Schalch, O. (1999). Balanced Scorecard and Economic Value Added. *IO Management*, 4, 37-43.

Matheson, D.; Matheson J. (1998). *The Smart Organisation.* Harvard Business School press, Boston.

Mayo, A. (1998). Memory bankers. *People Management*, 2, 34-38.

McClure, C. (2000). *Successfully implementing the Practice of Software Reuse working paper* (WWW document). http://www.reusability.com/papers3. (accessed 31st July, 2000).

McGrath, M.E.; Romeri, M.N. (1994). From Experience. The R&D effectiveness index: a metric for product development performance. *Journal of Product Innovation Management,* 11, 213-220.

Menon, A.G.; Dekkers, R.C.; Oosterhof, J.F.; Oppelland, H.J. (1998). *Creating tomorrow's business: managing knowledge.* Learning Center for Strategy and Leadership "le manageur", Rotterdam.

Merle, C. (1994). *New Products Management.* University of Michigan, Michigan.

Meyer, C. (1994). How the right measures help teams excel. *Harvard Business Review,* 3, 95-97.

Michalisn, M.; Smith, R.; Kline, D. (1997). In search of strategic assets. *International Journal of Organizational Analysis*, 8, 1-39.

Miles, M.B.; Huberman, A.M. (1985). *Qualitative Data Analysis.* Sage, New York.

Mintzberg, H. (1979). *The structuring of organisations.* Prentice Hall, Englewood Cliffs.

Moerman, P.A. (1998). Lean production: een methode voor efficiëntere en flexibelere productie?. *MB*, 64(4), 111-125.

Moerman, P.A.; Commandeur, H.R.; Weken H.A.M. (1993). Eerste lijn of langs de lijn van de automotive industrie: studie naar de concurrentiestrategieën van toeleveranciers. *Tijdschrift voor Economie en Management*, 38(2), 149-174.

Montoya-Weiss, M.; Calantone, R. (1994). Determinants of new product performance: A review and meta analysis. *Journal of Product Innovation Management* , 11(5), 397-417.

© Cranfield University 2001. All rights reserved.
No part of this publication may be reproduced without the permission of the copyright holder

Muckler, F.A.; Seven, S.A. (1992). Selecting Performance Measures: 'Objective' versus 'Subjective' Measurement. *Human Factors*, 34, 441-455.

MSN (2001). *Microsoft Encarta Reference* (WWW document). http://dictionary.msn.com/. (accessed 8th of November 2001).

Nalder, D.A. (1980). Feedback and Organisational Development: Using Data-Based Methods, Addison-Wesley, New York.

Nardi, B.; O'Day, V. (2000). *Information Ecologies: Using Technology With Heart*. MIT Press, Boston.

Neely, A.D.; Mills, J.F.; Platts, K.W.; Gregory, M.J., Richards, A.H. (1994). Realising strategy through measurement. *International Journal of Operations and Production Management*, 14(3), 140-152.

Neely, A.D.; Gregory, M.; Platts, K. (1995). Performance Measurement System Design. *International Journal of Operations & Production Management*, 15(4), 80-116.

Neely, A.D.; Mills, J.; Gregory, M.; Richards, H.; Platts, K.; Bourne, M. (1996). *Getting the measure of your business*. Findlay Publications, Holton Kirby, London.

Neely, A. D. (1998). *Performance Measurement*. Economist Books, London.

Neely, A.D.; Adams, C. (2000a). *Perspective on Performance: The Performance Prism*. Cranfield University, Cranfield.

Neely, A. D.; Adams, C. (2000b). *The Performance Prism Can Boost M&A Success*. Cranfield University, Cranfield.

Neely, A.D (2000). The great Gurus on New Use and Innovation. In: *Domain Knowledge Collection and Best Practice in New-use and Innovation Management: WP 1 Requirements Engineering & Knowledge Acquisition – Task 1.2 / 1.3 Research State of the Art and Industrial Practice (confidential)*. The NIMCube consortium, Stuttgart, 371-380.

Neely, A.D.; Adams, C.; Marr, B. (2000). *Measuring eBusiness Performance* (WWW document). http://www.cranfield.ac.uk/som/cbp/index.html. (accessed 1st of December 2000).

Neely, A.D. (2001). *Drowning in data – The new measurement crisis, a one day Cranfield conference and accompanying workshop*. Cranfield University, Cranfield.

NGMS (1997). *A Framework for Action*. Next-Generation Manufacturing (NGM) Project Report Volume I- IV, Boston.

NIMCube (2000a). *D 1.2 / 1.3 Domain Knowledge Collection and Best Practice in New-use and Innovation Management: WP 1 Requirements Engineering & Knowledge Acquisition – Task 1.2 / 1.3 Research State of the Art and Industrial Practice*. The NIMCube consortium, Stuttgart.

NIMCube (2000b). *D 4.2 SW platform decision document*. The NIMCube consortium, Stuttgart.

NIMCube (2000c). D 2.1 Performance Management Infrastructure (PMI) Concept and company-specific catalogues of reuse and innovation assets. The NIMCube consortium, Stuttgart.

NIMCube (2000d). *D 3.3 High level NIMCube methodology architecture*. The NIMCube consortium, Stuttgart.

NIMCube (2000e). *D1.1 Industrial Requirements*. The NIMCube consortium, Stuttgart.

NIMCube (2001a). *D6.2 Design of a New-use and Invention Readiness Assessment tool*. The NIMCube consortium, Stuttgart.

NIMCube (2001b). *The NIMCube whitepaper*. The NIMCube consortium, Stuttgart.

NIMCube (2001c). *D4.3 First SW prototype*. The NIMCube consortium, Stuttgart.

NIMCube (2001d). *NIMLight assessment questionnaire* (WWW document). http://www.nimcube.com. (accessed 20th of July 2001).

Nonaka, I.; Takeuchi, H (1995). *The Knowledge-Creating Company*. Oxford University Press, Oxford.

North, K. (1999). *Wissensorientierte Unternehmensführung: Wertschöpfung durch Wissen*. Gabler Verlag, Wiesbaden.

North, K.; Probst, G.; Romhard, K., (1998). Wissen messen - Ansätze, Erfahrungen und kritische Fragen. *Zeitschrift für Organisation (zfo)*, 3, 158-166.

Norton, D. (1999). Use strategy maps to communicate your strategy. *Balanced Scorecard Report*, 1(2), 1-4.

Norton, D. (2001). Building strategy maps: Testing the hypothesis. *Balanced Scorecard Report*, 3(1), 1-4.

O'Dell, C.; Grayson C. J. (2000). *Identifying and Transferring Internal Best Practices: APQC White Paper*. American Productivity and Quality Association (APQC), New York.

Öhman, P. (1996). *Knowledge in the Annual Report*. Högskolan, Luleå.

Oliver, N.; Gardiner, G.; Mills, J. (1997). Benchmarking the Design and Development Process. *Design Management Journal*, 8, 72-77.

© Cranfield University 2001. All rights reserved.
No part of this publication may be reproduced without the permission of the copyright holder

OPM (2001). *Performance Management Overview* (WWW document). http://www.opm.gov/perform/overview.htm. (accessed 1st of August 2001).

Ostro, N. (1997). The corporate brain. *Chief Executive*, 5, 58-62.

Oxford Advanced Learner's (1989). *Oxford Advanced Learner's Dictionary*, 4th ed. Edited by A.P. Cowie. Oxford University Press, Oxford.

Oxford Dictionary of English (ODCE) (1982). *The Concise Oxford Dictionary of English*, 7th ed. Edited by J.B. Sykes. Guild Publishing, London.

Packer, M.B. (1983). Analysing Productivity in R&D Organisations. *Research Management*, 1, 13-20.

Pahl, G.; Beitz, W. (1996). *Engineering Design: A Systematic Approach*. Springer Verlag, London.

Park, R.E.; Goethert, W.B.; Florac, W.A. (1996). *Goal Driven Software Measurement – A Guidebook*. Software Engineering Institute, Carnegie Mellon University, Pittsburgh.

Pasher, E. (2000). The great gurus on new-use and innovation. *Domain Knowledge Collection and Best Practice in New-use and Innovation Management: WP 1 Requirements Engineering & Knowledge Acquisition – Task 1.2 / 1.3 Research State of the Art and Industrial Practice (confidential)*. The NIMCube consortium, Stuttgart, 358-363.

Patton, M.Q. (1987). *How to use qualitative methods in evaluation*. Sage, Newbury Park.

Paulk, M.C.; Weber C.V.; Curtis, B.; Crissis, M.B. (1994*). The Capability Maturity Model; Guidelines for Improving the Software Process*. Addison-Wesley, New York.

Pawar, K.S. (1994). Organizational and managerial issues. In: *Concurrent Engineering, Concepts, implementation and practice*, edited by C.S. Syan and U. Menon. Chapman & Hall, London.

Pawar, K.S. and Driva, H. (1999). Performance measurement for product design and development in a manufacturing environment. *International Journal of Production Economics*, 60/61, 61-68.

PDMA (2001). *Product Development and Management Association – Glossary* (WWW document). http://www.pdma.org/library/glossary.html. (accessed 6th of November 2001).

Petrash, G. (2000). The great gurus on new-use and innovation. *Domain Knowledge Collection and Best Practice in New-use and Innovation Management: WP 1 Requirements Engineering & Knowledge Acquisition – Task 1.2 / 1.3 Research State of the Art and Industrial Practice (confidential)*. The NIMCube consortium, Stuttgart, 342-346.

Pfeifer, T. (1996). *Qualitätsmanagement*. Carl Hanser Verlag, München.

Phillips, E.M.; Pugh D.S. (2000). *How to get a PhD*. Open University Press, Buckingham.

Pinchot, G.; Pellman, R. (1999). *Intrapreneuring in Action, A Handbook for Business Innovation*. Berrett-Koehler, San Francisco.

Platz, J. (1996). Projektmanagement in Entwicklung und Konstruktion. In: *Erfolgreiche Produkte und Prozesse: Beispiele – Methoden – Werkzeuge*, edited by VDI Berichte 1305. VDI Verlag, Düsseldorf.

Pleschak, F.; Sabisch, H. (1996). *Innovationsmanagement*. Schäffer-Poeschel, Stuttgart.

Pór, G. (2000). *Knowledge – Intelligence – Wisdom: Essential Value Chain of the New Economy*. Minutes of the Consultation Meeting on the Future of Organizations and Knowledge Management of the European Commission's Directorate General "Information Management Technologies", Brussels, May 2000.

Pór, G. (2001). *Knowledge Ecology and Knowledge Management Compared* (WWW document). http://www.co-i-l.com/coil/index.shtml. (accessed 20th of August 2001).

Porter, M.; Stern, S. (2000). Measuring the "ideas" production function: evidence from international patent output, *National Bureau of Economic Research (NBER) Working paper No.W7891*, September 2000.

Poulin, J. (1997). *Measuring Software Reuse*. Addison-Wesley, Berkeley.

Prasad, B. (1996). *Concurrent Engineering Fundamentals Volume 1*. Prentice Hall, New Jersey.

Prenninger, J.; Polterauer, A.; Prieto, J.; Hauss, I.; Röhrborn, D. (1999). MaKe-IT SME: Managing of Knowledge using Integrated Tools. In: *Proceedings of the Second International .Conference on the Practical Application of Knowledge Management*; edited by A. Macintosh; R. Taylor. July 1999, Practical application Company, Blackpool, 221-228.

Prieto, J. (2001). *Ansätze zum Knowledge Function Deployment durch Entwicklung und Anwendung von Integrierten Wissenstrukturmodellen*. Dissertation (unveröffentlicht), Universität Stuttgart, Stuttgart.

© Cranfield University 2001. All rights reserved.
No part of this publication may be reproduced without the permission of the copyright holder

Prieto, J.; Roth, N.; Pilarek, D. (2001). A Methodology for Building and Implementing a Performance Management System from a Knowledge Reuse and Invention-oriented Perspective in New Product Development. In: Proceedings of the 7th International Conference on Concurrent Enterprising: 'Engineering the Knowledge Economy through Co-operation', edited by K.-D. Thoben; F. Weber; K. S. Pawar, Centre for Concurrent Enterprising University of Nottingham, Nottingham, June 2001, 195-203.

Pritchard, R.D. (1990). *Measuring and improving organisational productivity: a practical approach*. Praeger publishers, New York.

Probst, G.; Raub, S.; Romhardt, K. (1997). *Wissen managen*. Gabler Verlag, Frankfurt.

Pugh, D.S.; Hickson, D.J.; Hinings, C.R. (1983). *Writers on Organizations*. Penguin Books, Harmondsworth.

Rainbow, S.F. (1971). The use and planning of a research project planning and progressing system. *R&D Management*, 1(2), 101-106.

Rappaport, A. (1998). *Creating Shareholder Value: The new Standard for Business Performance*. Free Press, New York.

Reetz, U. (1997). Performance Measurements – A Key Method for a Guided Implementation of Concurrent Engineering Principles into Product Development Processes. In: *A Practical Approach to Concurrent Engineering. Proceedings of the European CE Workshop*, edited by R.A. Walker and F. Weber. Portugal, May 1997.

Reiß, M.; Rosenstiel von L.; Lanz, A. (1997). *Change Management – Programme, Projekte und Prozesse*. Schäffer-Poeschel Verlag, Stuttgart.

Rigas, J.; Fan, I.S. (2000). Devising improvement action plans out of performance measurement by an operational model of performance indicators. In: *Performance Measurement-Past, Present, Future, Conference proceedings*, edited by A.D. Neely. July 2000, Cambridge, 483-491.

Rigby, D. (1999). *Bain & Company On Management Tools that work* (WWW document). http://bain.com/bainweb/about/insights/pract_insights.asp. (accessed 1st of July 2001).

Robb, W.L. (1991). How good is our research?. *Research-Technology Management*, 4/5, 16-21.

Roberts, H. (1998). The bottom-line of competence-based management: management, accounting control and performance measurement. *Proceedings of the EAA Conference*, Antwerpen.

Robson, C. (1993). *Real World Research: A resource for social scientists and practitioner researchers*. Oxford, Blackwell.

Roehl, H.; Romhardt, K. (1997). Wissen über die Ressource <Wissen>. *Gablers Magazin*, 677, 44-45.

Roggatz, A.P.G. (1998). *Entscheidungsunterstützung für die frühen Phasen der integrierten Produkt- und Prozeßgestaltung*. Shaker Verlag GmbH, Aachen.

Röhrborn, D.; Hauß, I.; Prieto, J. (2000). MaKe-IT - Modellbasiertes Wissensmanagement im Intranet und Internet. In: *KnowTech 2000, Knowledge Engineering, Management, Consulting & Training*, edited by J. Becker. BDI, Berlin.

Romhardt, G. (1998). Die Organisation aus der Wissensperspektive. Gabler Verlag, Wiesbaden.

Roos, J.; Roos, G.; Edvinsson, L.; Dragonetti, N.C. (1997). *Intellectual Capital – Navigating in the New Business Landscape*. New York University Press, New York.

Roth, N.; Prieto J. (2000). Ein integriertes Wissensmanagement Konzept für die Produktentwicklung. *CADCAM Report*, 5, 100-110 .

Roth, N.; Prieto, J.; Dvir R. (2000). New-use and Innovation Measurement and Management Methodology for R&D (NIMCube). In: *Proceedings of 6th International Conference on Concurrent Enterprising: 'Enhancing Business Competitiveness through Sharing Experiences Between Research & Industry', Centre for Concurrent Enterprising University of Nottingham, Nottingham*, edited by F. Weber and K. Pawar. June 2000, Centre for Concurrent Enterprising University of Nottingham, Nottingham, 151-161.

Roth, N.; Prieto, J.; Pilarek D. (2001): Ein Performance Measurement System for wissensintensive Produktentwicklungsprozesse. *IO Management* , 3, 34-40.

Roussel, P.; Saad, K.; Erickson, T. (1991). *Third generation R&D,* Arthur D. Little, USA.

RSA (1995). *Tomorrow's company: the Role of Business in a Changing World*. Royal Society of Arts, Manufacturers and Commerce, London.

Rummler, G. A.; Brache, A. P. (1991) *Improving Performance. How to Manage the White Space on the Organisation Chart*. Jossey-Bass, San Francisco.

© Cranfield University 2001. All rights reserved.
No part of this publication may be reproduced without the permission of the copyright holder

Sarkis, J.; Bonnici, T.S. (2000). Market driven, activity based performance measurement: A telecommunications company case study. In: Performance Measurement-Past, Present, Future, Conference proceedings, edited by A.D. Neely. July 2000, Cambridge, 515-522.

Säubert, H.; Bürgel, H.D. (1998). Die Generierung von Steuerungsgrössen für die Erfolgsmessung von Wissensmanagement. *IOManagement*, 10, 52-57.

Schiuma, A. (2001). Measuring the value of Expatriates. *Newsletter of the Performance Management Association*, 1(3), 6-7.

Schneiderman, A.M. (2000). *Must your scorecard be balanced?* (WWW document). http://www.schneiderman.com/The_Art_of_PM/must_a_bsc_be_balanced.htm. (accessed 1st of June 2001).

Schott, G. (1991). *Kennzahlen – Instrument der Unternehmensführung*, 4. Auflage. Gabler Verlag, Wiesbaden.

Schulte, T. (1999). *Group Computing Workspace*. Dissertation, Universität St.Gallen, St.Gallen.

Sedecon Consulting (1999). *Strategic performance measurement*. Sedecon Consulting, Revontulentie 6, FIN-02100 Espoo, Finland.

Seemann, P.; Cohen, D. (1997): The Geography of Knowledge: From Knowledge Maps to the Knowledge Atlas. *Knowledge and Process Management*, 4(4), 247-260.

Simon, H.A. (1981). *The sciences of the Artificial,* 2nd ed. MIT press, Cambridge.

Simons, R. (1994). *Levers of control-How managers use innovative control systems to try strategic renewal.* Harvard Business School press, Boston.

Sink, D.S (1985). *Productivity Management: Planning, Measurement and Evaluation, Control and Improvement.* John Wiley & Sons, New York.

Sink, D.S.; Turtle, T.C. (1989). *Planning Measurement in your organisation of the future*, Industrial Engineering and Management Press, Norcross.

Skandia (1994). *Visualising Intellectual Capital in Skandia - supplement to Skandia's 1994 Annual Report.* Skandia, Stockholm.

Skandia (1996). *Supplement to Skandia's 1995 Annual Report.* Skandia, Stockholm.

Skandia (1999). *Human Capital in Transformation: Intellectual Capital Prototype Report.* Skandia, Stockholm.

Smith, D.K.; Alexander, R.C. (1999). *Fumbling The Future: How Xerox Invented, Then Ignored, The First Personal Computer.* Xerox Company, Palo Alto.

Smith, L. (2001). *Knowledge Management Metrics – A Learning Process* (WWW document). http://www.zigonperf.com/pmnews/knolwedge_metrics.html. (accessed 22nd of August 2001).

Spek, R. van der; Spijkervet, A. (1997). *Kennismanagement: Intelligent omgaan met kennis.* CIBIT, Utrecht.

Spur, G.; Krause, F.L. (1997), *Das virtuelle Produkt: Management der CAD-Technik.* Carl Hanser Verlag, München.

Steier, F. (1991). Introduction: research as self-relexity. In: *Self-Reflexity as Social Process. Research and Reflexity*, edited by F. Steier. Sage, New York.

Stewart, T.A. (1997). *Intellectual Capital: the new wealth of organisations.* Doubleday, New York.

Stewart, T.A. (1998). *Der vierte Produktionsfaktor – Wachstums- und Wettbewerbsvorteile durch Wissensmanagement.* Gabler Verlag, Wiesbaden.

Sveiby, K.E. (1997). *The New Organizational Wealth. Managing & Measuring Knowledge-Based Assets.* Berrett-Koehler, San Francisco.

Sveiby, K.-E. (2000). The great Gurus on New Use and Innovation. In: *Domain Knowledge Collection and Best Practice in New-use and Innovation Management: WP 1 Requirements Engineering & Knowledge Acquisition – Task 1.2 / 1.3 Research State of the Art and Industrial Practice*, the NIMCube consortium, Stuttgart, 350-352.

Sveiby, K.-E.; Lloyd, T. (1987). *Managing Knowhow: Add Value...By Valuing Creativity*, London.

Syan, C.S. (1994). Introduction to concurrent engineering. In: *Concurrent Engineering, Concepts, implementation and practice*, edited by C.S. Syan and U. Menon. Chapman & Hall, New Yersey.

Symoens, J. (1998). Site server is a fine set of tools for Web site building. *InfoWorld*, 4(1), 128.

Ten (2001). *Ten™ steps to performance management* (WWW document). http://www.tensoftware.com/tensteps.html. (accessed 1st of October 2001).

© Cranfield University 2001. All rights reserved.
No part of this publication may be reproduced without the permission of the copyright holder

Terwiesch, C., Loch, C.; de Meyer, A. (1998). *A Framework for Exchanging Preliminary Information in Concurrent Development Processes* (WWW document). http://www.opim.whartom.upenn.edu/~terwiesch. (accessed 10th of July 1999).

Thaller, G.E. (1998). *SPICE – ISO 9001 und Software in der Zukunft.* nhv Verlag, Kaarst.

The Enhance Consortium (2001). *European Project Enhance (Enhanced Aeronautical Concurrent Engineering), Deliverable D7.1-2 (confidential).* The Enhance consortium, Toulouse.

Tipping, J.W.; Zeffren, E.; Fusfeld, A. R. (1995). Assessing the value of your technology. *Research-Technology Management,* 38(5), 22-39.

Turney, P.B.; Anderson, B. (1989). Accounting for continuous improvement. *Sloan Management Review,* Winter, 37-47.

Ulrich, H. (1981). Die Betriebswirtschaftslehre als anwendungsorientierte Sozialwissenschaft. In: *Die Führung des Betriebes,* edited by M.N. Geist and R. Kohler. Beck Verlag, Stuttgart.

Ulrich, K.T.; Eppinger, S.D. (1995). *Product Design and Development.* McGraw-Hill Inc., New York.

VDI (1997). *Richtlinie 2222 Konstruktionsmethodik: Methodisches Entwickeln von Lösungsprinzipien.* Beuth Verlag GmbH, Berlin.

VDI (2001). *VDI Nachrichten: Wissensmanagement und CAD,* 10, 13.

Virginia Center of Excellence for Software Reuse (1993). *Reuse adoption guidebook, Software Productivity Consortium Services Corporation.* Herndon, Virginia.

Voss, C.A. (1992). A measurement of innovation and design performance in services. *Design Management Journal,* Winter, 40-46.

Vosselmann, E.G.J. (1996). *Ontwerp van management control-systeme.* Kluwer, Deventer.

Vreede, G.J. de (1995). *Facilitating Organisational Change. The Participative Application of Dynamic Modelling.* Delft University of Technology, Delft.

Wagner, K.; Hauss, I. (2000). Measurement Systems for the evaluation of R&D knowledge in the engineering sector. In: *Performance Measurement 2000 – Performance Measurement, Past, Present and Future proceedings,* edited by A.D. Neely. July 2000, Cambridge, 641-647.

Walker, R.A. (1997). The need for Industry to Improve Their Concurrent Engineer Practices. In: *A Practical Approach to Concurrent Engineering, Proceedings of the European Workshop held at Martinha Grande,* edited by R.A. Walker and F. Weber, May 1997, Portugal.

Ward, A. (1996). Measuring the Product Innovation Process. *Engineering Management Journal,* 10, 242-246.

Ward, A. (2000). The great Gurus on New Use and Innovation. In: *Domain Knowledge Collection and Best Practice in New-use and Innovation Management: WP 1 Requirements Engineering & Knowledge Acquisition – Task 1.2 / 1.3 Research State of the Art and Industrial Practice (confidential),* the NIMCube consortium, Stuttgart, 332-338.

Warnecke, H.J. (1995). *Aufbruch zum Fraktalen Unternehmen.* Springer Verlag, Heidelberg.

Warschat, J.; Wagner, F.; Roth N.; Prieto J. (2000a). Ein integriertes Konzept für die evolutionär-iterative Produktentwicklung. In: *Forschungs- und Entwicklungsmanagement 2000plus. Konzepte und Herausforderungen für die Zukunft,* edited by H.D. Bürgel. Springer Verlag, Berlin, 115-129.

Warschat, J.; Prieto, J.; Röhrborn, D.; Hauss, I.; Polterauer, A.; Prenninger, J. (2000b). Instrumente und Methoden des Wissensmanagements zur Umsetzung in die Praxis am Beispiel von MaKe-IT SME. In: *Wissens Wert!? Ökonomische Perspektiven der Wissensgesellschaft. 3. Freiburger Wirtschaftssymposium,* Nomos-Verl.-Ges, Baden-Baden, 287-314.

Weber F. (1999). *Concurrent Engineering – Die Reduzierung der Time-To-Market.* BIBA, Bremen.

Weber, J. (Hrsg.), (1995). *Kennzahlen für die Logistik.* Stuttgart.

Weber, J.; Schäffer, U. (1998). *Balanced Scorecard – Gedanken zur Einordnung des Konzepts in das bisherige Controlling Instrumentarium, Forschungspapier Nr. 60.* WHU Koblenz, Vallendar.

Weber, J.; Schäffer, U. (1999a). *Entwicklung von Kennzahlensystemen, Forschungspapier Nr. 62.* WHU Koblenz, Vallendar.

Weber, J.; Schäffer, U. (1999b). *Balanced Scorecard und Controlling - Implementierungsansätze und Erfahrungen.* Gabler Verlag, Wiesbaden.

Webster's (1998). *Merriam-Webster's Collegiate Dictionary,* 10th ed. Merriam Webster, UK.

Weggeman, M.C.D.P. (1999). *Wissensmanagement – Der richtige Umgang mit der wichtigsten Ressource des Unternehmens,* German ed. VMI, Bonn.

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No part of this publication may be reproduced without the permission of the copyright holder

Wenger, E. (1999). *Communities of Practice: Learning, Meaning, and Identity.* Cambridge University Press, Cambridge.

Werner, B.M.; Souder, W.E. (1997). R&D performance measurement: A state of the art review. *Research-Technology Management,* 40(2), 34-42.

Wheelwright, S.C.; Clark, K.B. (1992). *Revolutionising Product Development.* The Free Press, New York.

Whitehill, M. (1997). Knowledge-based Strategy to Deliver Sustained Competitive Advantage. *Long Range Planning Review*, 4, 621-627.

Wiig, K.M. (1997). Integrating Intellectual Capital and Knowledge Management. *Long Range Planning*, 4, 399-405.

Wolf, B. (2000). Embedding Knowledge sharing into work at Siemens SBS. *KM review*, 3/4, 22-25.

Wright, K. (2001). *Performance Management – beyond appraisals* (WWW document). http://ciras.iastate.edu/CIRASNews/summer97/performance.htm, (accessed 22nd July 2001)

Yeh, J.-H.; Chang, J.-Y.; Qyang, Y.J. (2000). Content and knowledge management in digital library and museum. *Journal of the American Society for Information Science*, 4, 371-379.

Yin, R. (1994). *Case Study research*, Sage, Thousand Oaks.

Zairi, M. (1993) *TQM based performance measurement: A methodical approach.* Technical Communication, Letchworth.

Zikmund, W.G. (1991). *Business Research Methods,* 3rd ed. Dryden Press, Orlando.

Zwaan, A.H. van der (1992). *Organisatie Onderzoek.* van Gorcum, Assen/Maastricht.

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Glossary

Framework	A structure, usually rigid, serving to hold the parts or something together or to support something constructed or sketched over or around it (Webster's, 1998).
Function	Mode of action or activity by which thing fulfils its purpose (ODCE, 1982).
Indicator	An indicator is a thing or an expression giving information about a fact or an event. It thus serves as a sign or signal (Oxford Advanced Learner's, 1989). It hence is the particularisation of a measure.
Infrastructure	A substructure or underlying foundation (Webster's, 1998).
Innovation	In a broadest sense, innovation is the implementation and realisation of an idea or solution (Hauser, 2000). These solutions can be of a technical, an economic, an organisational or social kind (Pleschak and Sabisch, 1996). In an enterprise, innovation comprises creativity and quality, as well as strategy and operations over time (Amidon, 1997). Innovation is implementing new ideas that create value (to the customers) (based on Amidon, 1997). Something newly introduced (Webster's, 1998).
Intellectual Capital	IC is (used as an umbrella term and further) defined as the applied knowledge in organisations, technology, relationships and skills, providing a competitive advantage (Edvinsson and Malone, 1997).
Invention	A main constituent element for creation of knowledge (Edvinsson, 2000). Something thought up or mentally fabricated (Webster's, 1998).
Knowledge	Knowledge is information that is relevant, actionable, partially based on experience and given meaning in the context for our working (Leonard and Sensiper, 1998) and (Saint-Onge, 2000). It is then the ability to take effective action (Sveiby, 2000). Likewise, knowledge evolves from *data, which is put in context and complemented with meaning* (Amidon, 1997). From an epistemological viewpoint, knowledge is considered a human process of justifying beliefs towards a truth (Nonaka and Takeuchi, 1995).
Knowledge Asset	An asset is a possession regarded having a certain value in meeting debts, commitments, etc. (ODCE, 1984). In the context of NPD and knowledge management, assets are considered the tangible or intangible products or byproducts of a development process (Lim, 1998).
Knowledge Management	KM is understood as the management of IC controlled by a company (Guthrie, 2000).
Management Control System	A management control system is a set of policies that ensures resources are procured, and effectively and efficiently, utilised from strategy development to implementation, while also ensuring that managers and engineers work together to achieve the organisation's goals (Lim, 1998).
Measure	A measure is the means for ascertaining the performance and abilities of an organisation by using quantitative and qualitative features (CBP, 2000). It thereby represents the essential tool for assessment and qualification of particular strengths and limitations. A [performance] measure is an indicator used to quantify the efficiency and/or effectiveness of purposeful action (Neely et al., 1996).
Measurement	Measurement is the guided process of associating numbers with phenomena (Webster's, 1998).
Method	A method is a defined and planned procedure and practice of attaining a particular purpose (ODCE, 1982).
Methodology	A methodology is the set of procedures and practices of attaining a purpose (Oxford Advanced Learner's, 1989).
Metric	The formula by which the value of an indicator is calculated is defined a metric (CBP, 2000). As a size or quantity of a measure it is typically of quantitative nature (Oxford Advanced Learner's, 1989).
Model	A model is a set of postulates, data and inferences presented as a description of an entity (Webster's 1998). It simplifies figuratively and / or mathematically structures, procedures and functionalities (Brockhaus, 2000). This thesis uses the term model to describe the complex arrangement of procedures, tools, structures and principles the author will develop and realise in the final achievement and proposal.
New	Of recent origin or arrival, made, invented, discovered, acquired or experienced recently or now for the first time (ODCE, 1982).
New Product Development	The sequence of steps or activities that an enterprise employs to conceive, design and commercialise a new product (Ulrich and Eppinger, 1995). The overall process of strategy, organization, concept generation, product and marketing plan creation and evaluation, and commercialization of a new product (PDMA, 2001).
Performance	The ability to achieve objectives in terms of parameters such as time, cost, quality and flexibility (Driva, 1997). Performance equates with purposeful action (Neely et al., 1996)

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Performance Management	Performance management is defined as the methods, processes, structures and behavioural patterns an organisation uses to improve the performance. Performance management may be used during the strategic and operative (tactical) planning, execution (or implementation) or communication stages activity.
Performance Measurement	As part of the communication activity, performance measurement is the process that gathers and records the effectiveness and efficiency of the execution (action) and planning stages.
Performance Measurement System	A performance measurement system is a set of indicators used to quantify the efficiency and effectiveness of action (Neely et al., 1996)
Procedure	A Set of logical steps (Neely et al., 1996)
Process	A process is a method of operation – the means by which inputs are converted into outputs (Neely et al., 1996).
Product	Thing or substance produced by natural process or manufacture (ODCE, 1982). Term used to describe all goods and services sold. Products are bundles of attributes (features, functions, benefits and uses) and can be either tangible as in the case of physical goods, or intangibles such as those associated with service benefits or a combination of the two (PDMA, 2001).
Purpose	To have as one's purpose, design, intend (ODCE, 1982).
Quality Function Deployment (QFD)	A structured method employing matrix analysis for linking what the market requires to how it will be accomplished in the development effort. This method is most valuable during the stage of development when a multifunctional team agrees on how customer needs relate to product specifications and features which deliver those By explicitly linking these aspects of product design, QFD limits the chance of omitting important design characteristics or interactions across design characteristics. QFD is also an important mechanism in promoting multifunctional teamwork (PDMA, 2001).
Requirement	Something that is needed for a particular purpose (MSN, 2001).
Reuse	Reuse is the utilisation of existing knowledge assets in the design, development and production of other assets (Lim, 1998).
System	The complex whole of connected parts and organised body of elements with distinct borders is defined a system. Distinct principles, classification and order usually characterise a system (ODCE, 1982).
Taxonomy	A systematic arrangement in groups or categories according to established criteria (Webster's, 1998).
To perform	To achieve one's goals (Neely et al., 1996).
Tool	Something used as a means of achieving something (MSN, 2001).

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Appendix A: Other Measurement Approaches at a glance

In the following, the author will introduce further approaches he considers relevant for the context of this research. Depending on the assumed importance for the research subject they vary in the granularity of description. The first three approaches (A1 - A3) origin from the KM and IC domain where measurement is currently a very emerging topic (Edvinsson, 2000). The approaches A4 - A7 represent some of the most important financial controlling oriented approaches. A8 highlights the benchmarking based approaches, while A9 discusses briefly the approaches of the big consulting companies. Again, the author does not claim completeness, however he thinks that he continues to provide a good overview on some further relevant approaches from different domains.

A1 Intangible Assets monitor

The roots of this measurement framework go back to the late 1980s when Karl-Erik Sveiby started to research on intellectual capital accounting (Sveiby and Lloyd, 1987; Öhman, 1996). The then so-called "Konrad Theory" was continuously refined resulting in the famous Intangible Assets Monitor (Sveiby, 1997):

A1.1 The rationale behind[76]

The Monitor builds on the assumption that the people's skills and knowledge are a key success factor in today's economy. However these resources are merely reflected in today's accounting practices. The measurement of intangibles requires specific procedures and measures tailored to the individual needs of companies and people. Sveiby himself explained his rationale as follows: "My purpose with the Intangible Assets Monitor is not to present a full picture of the intangible assets. It is not possible and this is why the all-comprehensive approaches have failed so far. The purpose is to be practical and to 'open a few windows' so managers can start experimenting."(Sveiby, 2000)

A1.2 The Invisible Balance Sheet

Sveiby has invented the Invisible Balance Sheet to outline and explain the often observed difference between a company's market value and book value, the stock market premium. He explains this discrepancy with the fact that the intangible assets, which can be very valuable for the company, are so far not reflected in traditional accounting systems (Figure 75). According to him, the intangible assets are divided into three categories:

- The external structure reflects on the external relationships of the company to customers, suppliers and other stakeholders.
- The internal structure refers to the facilities and processes applied within the organisation.
- Individual competence stands for the skills, abilities and knowledge of the employees.

[76] The discussion of the Intangible Assets Monitor is based on Sveiby (1997). Other references are explicitly indicated.

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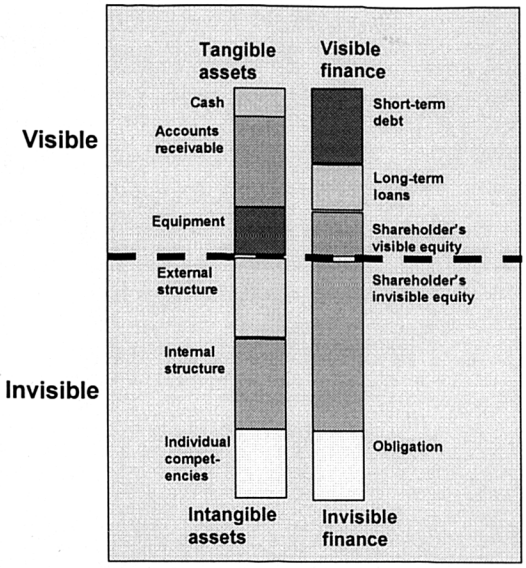


Figure 75: Invisible Balance Sheet (based on Sveiby, 1997)

A1.3 The Intangible Assets Monitor

Building on these thoughts, Sveiby proposes a classification scheme and indicators for reflecting and assessing the composition of an organisation's intellectual capital, the Intangible Assets Monitor (Figure 76).

	External structure	Internal structure	Individual competencies
Growth & renewal	•Profitability per customer •Organic growth •Image enhancing customers	•IT investments •Structure enhancing customers	•Training and education costs •Numbers of years in profession •Competence turnover •Competence enhancing customers
Efficiency	•Satisfied customers index •Sales per customer •Win / loss index	•Proportion of support staff •Values / attitudes index	•Proportion of profess-ionals •Leverage effect •Value added per employee •Profit per employee
Stability	•Proportion of big customers •Age structure •Devoted customers ratio •Frequency of repeat orders	•Age of organization •Support staff turnover •Rookie ratio •Seniority	•Professionals turnover •Relative pay •Seniority

Figure 76: Intangible Assets Monitor (based on Sveiby, 1997)

The matrix recaptures the above-mentioned classification into an external structure, internal structure and individual competence. These categories are horizontally divided into three dimensions: Growth and renewal indicate the potential development of the intangibles, efficiency is depicting the utilisation of the intangible assets and stability is measuring the risk of loosing the intangible asset. As shown in the figure above a set of reference measures is proposed for each area of the Monitor. These measures should serve as a guideline and starting point for customisation for organisations adapting the approach.

A1.4 A brief summary and assessment

The Intangible Assets Monitor offers a transparent taxonomy of an organisation's intangible assets thereby expanding the narrow focus of industrial management accounting. It proposes a holistic view on the internal, as well as on the external structures and is thereby explicitly committed to renewal, continuous development and utilisation of intellectual capital. On the other hand, the focus on intangibles comes along with the neglect of any financial figures and

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information. The process how the right measures for the right context can be identified is very implicit and does not provide a clear relation to the intangible assets. Thus, they are rather casual auxiliaries. Nevertheless, this perception is in line with Sveiby's original purpose of providing a starting point for further research and experimentation by raising awareness on the subject of intangibles.

A2 The Knowledge Balance Approach

North et al. (1998) propose a rather technical and financially-focused approach to intellectual capital management and measurement.

A2.1 The system of indicators

North et al. (1998) propose four indicator categories, which are supposed to elaborate on the impact of knowledge related activities and inventories to overall business results. The indicators are structured as follows:

- Organisational knowledge inventory describes the quantity and quality of the available knowledge stocks (e.g. number of subject experts).
- Interventions are the processes, activities and inputs changing these knowledge inventories (e.g. training expenses)
- Leverage effects measure the direct results and output of knowledge management activities (e.g. increased process efficiency)
- Business results reflect the impact of the above measures and levers on overall objectives (e.g. increased customer satisfaction).

The four indicator categories are the fundament for a process of knowledge measurement, management and transformation.

A2.3 The knowledge balance sheet

Causes and effect relationships between the objectives and measures allow for forming a reference measurement model. This combines the financial dimension with the knowledge-based dimension of business (Figure 77).

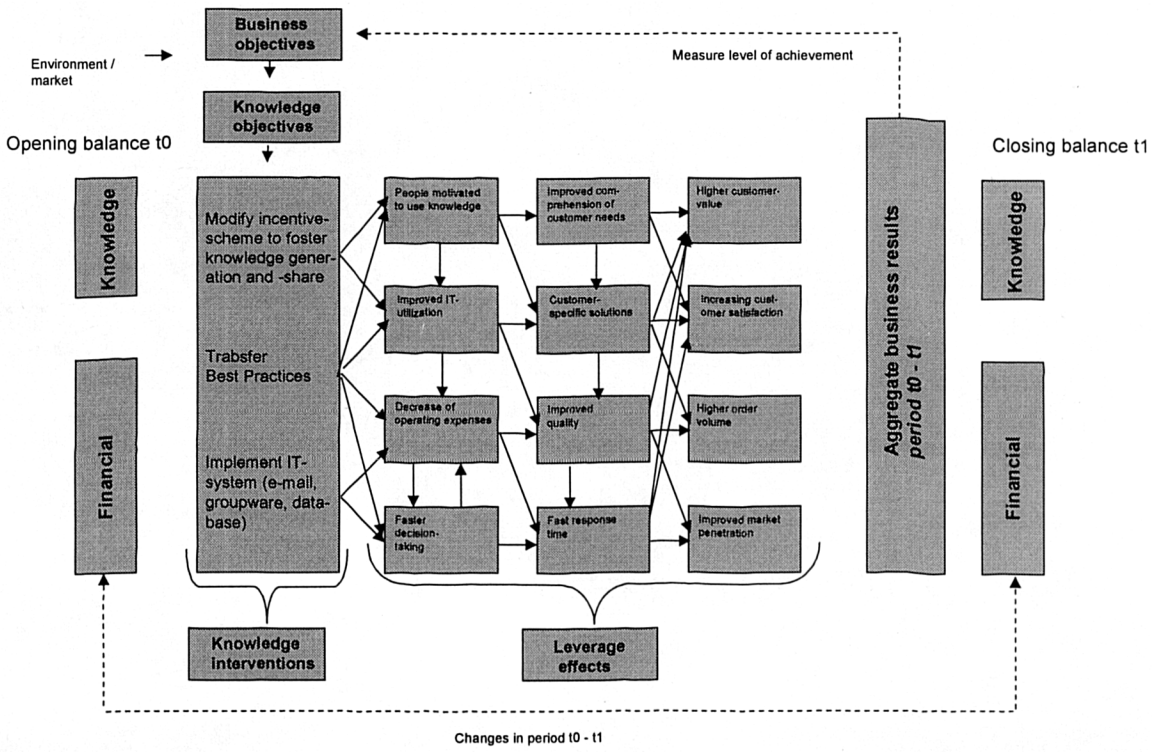


Figure 77: Reference model of knowledge-oriented enterprising (based on North, 1998)

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The model documents the interventions, processes and effects of knowledge-oriented management on an organisational knowledge market.

A2.4 A brief summary and assessment

The approach of North et al. (1998) provides a novel and business-oriented concept for the management and measurement of an organisation's intellectual capital. The means-end relations, described through an indicator taxonomy facilitate transparency and insight into assumed implications. Nevertheless, their proposal is so far considered to be incomplete, as it neither provides any focused set of measures nor does it indicate how to plan for appropriate interventions against defined goals.

A3 Stewart's approach

Stewart categorises intellectual capital into the three areas; human capital, structural capital and customer capital. His particular concern is a coherent representation and measurement based management of the components of intellectual capital.

A3.1 The rationale behind[77]

The general problem of non-financial measurement systems seems to the quality of indicators. Stewart observes a lack of consistency, as well as the absence of alignment and adjustment to company objectives and performance drivers. Building on this assumption, general rules for measure definition are suggested and a means for visualisation proposed.

A3.2 Definition of measures

According to Stewart an organisation should note the following key aspects when selecting non-financial measures:

- Intellectual capital should be structured in a simple and comprehensible manner (e.g. human-, structural- and customer capital).
- The single components should be described through few distinct indicators. An aggregate measure should thereby reflect the entire body of intellectual capital.
- Focus should be directed to those areas of strategic relevance.
- Measurement of intellectual capital should be linked to creation of "intellectual wealth"; i.e. be of significance relative to the competencies of the organisation.

Following that, Stewart proposes a system for representing an organisations current and desired state of intellectual wealth.

A3.3 The IC radar chart

A transparent visualisation of the company's IC performance is achieved through a well known radar chart diagram. Following Stewart's logic this graph divides the market-to-book ratio of an organisation into human capital, structural capital and customer capital. The three areas are then described by few distinct and meaningful measures. This allows for displaying the status quo and for representing the objective for each measure. Thus, one obtains a succinct overview of strengths and limitations and is, based on the measurement result, guided to initiate corrective action, if needed (see Figure 78).

[77] The discussion of the approach of Stewart is based on Stewart (1997) and Stewart (1998). Other references are indicated explicitly.

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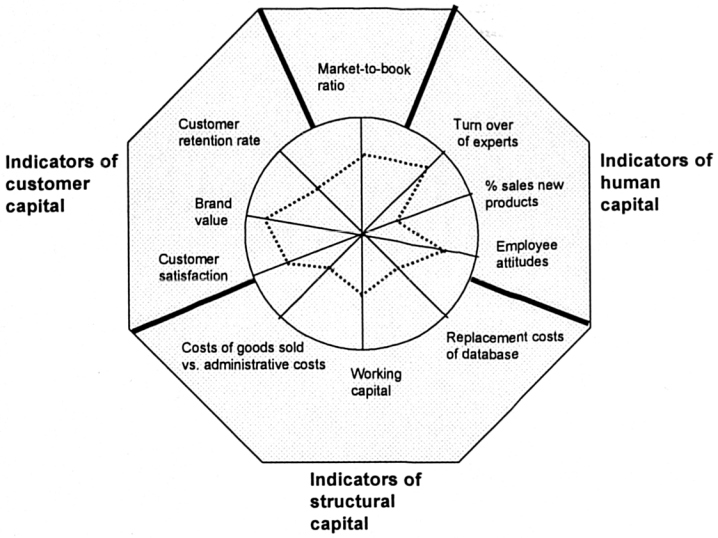


Figure 78: Intellectual capital navigator (based on Stewart, 1998)

A3.4 A brief summary and assessment

Stewart's approach rather describes means for powerful IC visualisation, than a comprehensive measurement concept. He underscores the importance of aligning indicators and metrics with organisation's specific requirements and objectives. The, not necessarily IC radar chart facilitates the determination of current strengths and deficits based on measurement. The strength of this concept is the simplicity and the focus on few strategically relevant constituent elements of intellectual capital.

A4-A7 The financial control oriented approaches

The sections A4-A6 provide a very short overview on well-known financial control oriented control systems. As the author sees in the elaboration only a small value add for the understanding of the research subject he will keep these sections rather short. The A7 approach is of higher interest, as it provides valuable insights in measurement aggregation and drill down of measures. Therefore this approach will be presented in more detail.

A4 The Shareholder Value Approach

Rappaport (1998) created the "Shareholder Value Approach" which states that the "only reliable measure of a business strategy is whether it creates and maximises economic value for shareholders". He shows that managers who take into account earnings as a main measurement tool, fool themselves as well as the shareholders because this kind of measure ignores completely the value of money in time (for example inflationary periods). He sustains that cash flows "are the foundations for shareholder returns from dividends and share price appreciation". In his opinion "cash is the king" representing the measurement tool that should be taken into account and not earnings increases which do not necessarily guarantee shareholder value.

A5 The Activity based costing (ABC) approach

According to Kaplan and Cooper (1998) an ABC model is an economic map of the organisation's expenses and profitability based on organisational activities. As opposed to traditional cost systems where overhead costs are allocated to production cost centres and then to products within the ABC approach resource expenses are traced to activities using activity cost drivers for tracing activity costs to objects. The approach is process oriented as its implementation starts with the analysing of the various value creation processes identifying the costs for each activity. Afterwards the various activities are brought into context using drill down and aggregation principles and attributed in a standardised way. The linkage between activities and cost object finally is accomplished by using activity cost drivers. The approach is purely financial oriented and very much end-product oriented. (based on Kaplan and Cooper, 1998)

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A6 The Economic Value Added (EVA) approach

Economic Value Added (EVA) measures are a corporation's true economic profit. EVA represents real profit versus paper profit. EVA is the after cash tax flow generated by a business minus the cost of the capital it has deployed to generate that cash flow. (Bielinsky, 1996)

The EVA formula is (Bielinsky, 1996):

EVA = (After Tax Operating Profits) – [(Cost of Capital%) * (Total Capital)]

- After Tax Operating Profits is a common profitability measure. (Bielinsky 1996)
- Total Capital represents a company's assets, adjusted to approximate their market value (Bielinsky, 1996).
- The Cost of Capital is the one that pays all the money. It is a weighted average of two rates of return:
  - the rate the company would have to pay for additional long term fixed rate debt
  - the cost of equity, the rate of return potential buyers would require for taking on the risk of owning a company (Bielinsky 1996).

When EVA is negative important changes should be taken into consideration. Using EVA to drive value creating change the next three steps should be carried out (Bielinsky, 1996):

1. Sensitivity analysis conducted to determine which factors have the greatest effect on EVA
2. EVA must be linked to key departments and processes within the business
3. Value-based incentives should be implemented using EVA

A7 The Selective Metrics System[78]

Beginning of the 1990s the WHU Koblenz initiated a research initiative focusing on logistics controlling. Various working groups were dedicated to focus and streamline conventional measurement concepts. The research outcome is the so-called Selective Metrics System (SMS). Even though, the system's roots can be found in the context of logistics, Weber himself underscores the general applicability of the concept (Weber, 1995).

A7.1 The Concept

The concept proposes to tailor and assign a set of metrics to a distinct corporate discipline of function (for example R&D). Thereby it reflects on the corporate and functional strategy, as well as on the operating systems, similar like in the famous Performance Pyramid approach as suggested by Lynch and Cross (1995). Implemented Metrics have to reflect and balance these two dimensions and provide the consistent link to an overriding business purpose. Thus, the framework essentially consists of three subsequent steps.

- Goal definition
- Metric selection
- Combination of the dimensions

A7.2 Goal Definition

An initial environmental analysis screens for required corporate performance goals from the customer's perspective. A profile of future customer requirements and potential trends of this profile is elaborated. Internally there have to be identified drivers for cost reduction against the attainment of the set performance goals. Such an external and internal screening allows for the definition of cost and performance-oriented strategic objectives. The global objectives are then

[78] The following discussion is based on Weber and Schäffer (1999a). Other references are explicitly indicated in the text.

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quantified and translated into the functional objectives of for example R&D. Eventually strategy is cascaded and communicated downwards and coherently operationalised.

A7.3 Metrics Selection

The Goal Definition allows for selecting few and meaningful referring metrics which are relevant to strategy implementation. Metrics have to refer to the defined objectives or to deliberately set milestones over time. The selection of relevant metrics is considered to be a key activity, in order to direct management's attention and efforts to the core issues (Simons, 1994). Above, research shows that data transformation and processing capabilities of man is limited (Simons, 1994).[79]

However, strategic metrics alone are not sufficient for management to ensure goal achievement. Thus, selected bottom-up driven operational metrics have to be put next to strategic metrics.[80] These operative measures are focused on the key drivers of the business system, which impact performance. A detailed analysis of the complexity and dynamism of the contributing work processes allows to filter the very critical and performance relevant success factors. Those operational metrics typically comprise input-, process- and output-related measures (for example man-months, number of re-designs and number of designs for manufacture).

A7.4 Combination of the two dimensions operations and strategy

The metrics system is value adding, if the resulting framework is operatively used for decision-making and action planning (Weber, 1995).

Thus the synthesis of the two dimensions allows to draw conclusions for practical management of the (R&D) function. Three cases are considerable:

- Strategic metrics are identical with operational metrics: the focus of strategic orientation is similar to the important metrics on operative levels. The operational metric would then directly indicate the degree of strategic stakeholder expectation fulfilment.
- Strategic metrics and operative metrics are not identical, but refer to the same subject matter: the operational metric provides logical or functional relation to strategy in the sense of cause-and-effect relationship. Consideration of the procedural bottleneck ultimately contributes to goal achievement.
- Strategic metrics and operative metrics are neither identical nor do they refer to the subject matter: the operational metric does not reflect a bottleneck for strategy and may therefore be neglected or it was initially overlooked on a strategic level and hence has to considered in the following strategy planning process.

A7.5 Brief summary and assessment

There is some evidence coming from practice, that the Selective Metrics System is first of all a tool for strategy formulation and goal definition and then, secondarily, for operationalising strategy through concrete metrics (Weber, 1995). The clear focus of this approach is an *advantage but in the same turn a major barrier to utilisation.*

After all, the structure and the potentials for management, strategy verification and operations are forward-thinking and valuable. Some instrumental shortcomings can be overcome by means of practical experience, refinement and incorporating well-known more comprehensive measurement concepts.

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79 Simons (1994): "..there is a limit to the organisation's energy and attention. Intensive focus on all systems simultaneously causes incredible stress, as employees are pushed to their limits to respond to the short-term information and action demands of superiors. Furthermore using multiple systems interactively diffuses senior management's signals of strategic uncertainties because attention is dispersed over several areas."

80 Weber (1995) states: "Strategy implementation does not fail because objectives are out of sight, but also because unexpected [operational] problems during implementation."

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A8 The benchmarking based approaches – CMM, PACE, RACE

The benchmarking based approaches which will be described below have all in common that the individual performance of a company is mapped against a pre-defined to-be standard. The assessment of the current performance of a company - in different domains – leads to a clustering into different levels of maturity, which allows the companies to go through a step-wise improvement process to achieve the highest level of maturity. All the approaches have in common that they are not set-up for day-to-day operative performance management. They pursue a very strategic set-up and facilitate improvement programs which are of long-term nature.

A8.1 CMM

Founder of the Capability Maturity Models is the Software Engineering Institute (SEI), a division of the Carnegie Mellon University (Eisner, 1997; Humphrey, 1989; Paulk et al. 1994; Thaller, 1998). This division started working on the idea of a process maturity framework in November 1986. This idea was developed in more detail in co-operation with the MITRE Corporation. The actual reason for starting this project was a request from the federal government to provide it with a method for assessing the capability of its software contractors. This project resulted in a book by Watts S. Humphrey which is called *Managing the Software Process* (1989). In the period between 1986 and 1989 two methods and a maturity questionnaire were developed to appraise software process maturity.

After years of experience with the software process maturity framework and the maturity questionnaire, the SEI evolved the maturity framework into the Capability Maturity Model for software engineering (SW-CMM). This SW-CMM is based on the actual practices and experiences from different kinds of industries. With the SW-CMM the SEI tries to reflect the state of the art on software development practices and tries to reflect the needs of individuals performing software process improvement and software process appraisals (Paulk et al., 1994; Humphrey, 1989).

In recent years the Software Engineering Institute developed, apart from the Capability Maturity Model for software engineering, some other capability models. These models all originate from the SW-CMM and are, in no particular order:

- the People CMM;
- the Systems Engineering CMM;
- the Software Acquisition CMM;
- the Integrated Product Development CMM.

All the CMMs are based on the structure of the SW-CMM which is very briefly outlined in the following section:

The road map in the SW-CMM has lead to a model which divides the capability of a company into five levels (Paulk et al., 1994): At the first level, the *Initial level,* the development processes are often ad hoc and chaotic. Just a few processes are defined and good performance depends on individual members of the organisation. At the *Repeatable level*, which is the second level, basic project management exists. Project management track the cost, functionality and schedule of the project. In this level some earlier successes can be repeated. The third level is the *Defined level.* At this level the management tasks and the development process are documented, standardised and integrated in the organisation. All projects use an approved and tailored version of the standard development process. The *Managed level* is the fourth level. At this level the quality of the product development process and the product are quantitatively understood. Data of the quality of the process and the product are collected. Finally the fifth level, the *Optimising level* can be characterised by continuous process improvement. This improvement is enabled by quantitative feedback from the process and implementing new ideas and technologies.

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Basic idea of these five levels is that each level is designed to lay the foundation for the next level. Goal for any organisation using the SW-CMM is to continuously improve towards a higher level, with the fifth level as end goal. This end goal is the reference state or the so-called 'soll' situation.

The capability levels in the SW-CMM consist of key process areas, common features and key practices (Paulk et al., 1994). Each *key process area* consists of a group of related activities which are identified as necessary for good performance in the software development. The key process areas are described in terms of *key practices*. These key practices describe the activities and infrastructure identified as being critical for effective implementation and institutionalisation of the key process areas. The key practices are grouped in *common features*. These common features describe the attributes which ensure that the key process areas can be implemented and institutionalised.

A8.2 PACE

PACE (Practical Approaches to Concurrent Engineering) is the name of a European Commission co-sponsored research project which consisted of eight partners from four European countries, namely Bremen Institute of Industrial Technology and Applied Work Science (BIBA), Black & Decker, Bremer Werzeug- und Maschinenbau (BWM), Creda, Danish Technological Institute, Fordesi, Simultaneous Engineering Technology and the University of Nottingham. The project ran from June 1994 to May 1997. "The main aim of PACE was to provide a sophisticated network of decision supporting tools, methods and techniques that could be used to implement or improve Concurrent Engineering practices. It was to be applicable to all organisations regardless of their state of CE awareness and without the need for consultants." (Walker, 1997)

To attain this objective the PACE consortium has identified three components: The first one is the Knowledge Platform. In this component general information on Concurrent Engineering, its tools and methodologies are given. This component should reveal an organisation the benefits to implement Concurrent Engineering. The Knowledge Platform relies on a computerised knowledge base. The second component is the workbench. In this component the tools, methodologies and techniques to help companies with self analysis are contained. The tools and methodologies which are covered are team building, tool selection, organisation structure modelling, optimisation of information exchange, cost benefit analysis, and performance measurement. The third component is the Implementation Framework. In this component a methodology is presented on how to change to a CE process by introducing a structured change process and a training handbook. Data from a pilot project carried out by the consortium are contained in this Framework as well.

The assessment model is part of the third component. The objective of the assessment is to serve as a basis for the change process towards Concurrent Engineering. As the Consortium had recognised that each company has different problems and objectives, it became obvious that it is impossible to build a common and uniform model that serves every company's real needs. Therefore the consortium has build a conceptual model with the covering the following areas: customer focus, goal sharing, strategy deployment, activities / processes, organisation, information and implementation (Reetz, 1997). For the assessment the company has two questionnaires. The first one is the CEO questionnaire in which the target profile is identified. This is attained by asking the management where they want to be relatively to every target area. After that the persons working on more operational levels are given the user questionnaires. This assessment reveals the actual as-is performance. The results of those two questionnaires can be mapped and improvement strategies can be defined.

A8.3 RACE

This model has been developed by the Concurrent Engineering Research Centre (CERC) from West Virginia University in the United States. This Centre was established with the goal to initiate and manage the development of the electronically processing of data to support product development and to promote the concept of Concurrent Engineering (Roggatz, 1998)

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The assessment model is part of an organisational concurrent engineering transformation strategy which has been proposed by the Research Centre. This strategy comprises four stages: awareness, readiness, deployment and improvement (Karandikar et al., 1993). "Awareness" consists of performing business cases and doing workshops to make the company aware of the possibilities of Concurrent Engineering. After this awareness the company is being checked for its "readiness". Part of this stage is the application of the RACE assessment tool. "Deployment" refers to the implementation of changes. Methods which can be used in this stage are process reengineering, change management strategies and the establishment of a team. "Improvement" analyses to the actual result of the deployment. These improvements should be mapped against the outcome readiness tool's application.

The Concurrent Engineering Research Centre believes that the readiness for concurrent engineering can best be conceptualised by two major components:

- The product development process and practices, and
- the technology being used.

To assess the two components and thus the readiness of a company CERC has identified critical clusters of elements for both components. The critical clusters of the *product development process and practices* are: discipline, leadership, CE enabling technology, product assurance, management systems, accommodation of teams, team development, team assignment, process focus and customer focus. The critical clusters of the *technology* are: integration, information sharing, co-ordination, communication and application tools (Anonymous, 1993; Karandikar et al. 1992). These critical clusters are in their turn specified by key criteria, maturity stage definitions, issues to be addressed, and metrics to be tracked (Karandikar et al., 1993).

A8.4 Brief summary and assessment

The concepts presented in the previous sections represent mature concepts for assessing organisational capabilities also suitable for product development contexts. All the approaches are set up as long range improvement tools. The remain on a rather generic level and do not support operative decision making. The reuse and invention perspective is addressed only implicitly.

A9 The Consulting Companies' frameworks

All the approaches of the big consulting companies have in common that they represent generic performance management frameworks focused on the rather strategic aspect of performance management. Klingebiel (1999) provides a very good overview on those approaches. Especially with regard to those approaches originating from consulting companies it should be noted that there might be a discrepancy between the solutions the companies actually have developed and the solutions which are publicly available with regard to the level of detail. Often business interests prevail especially those companies to publish major parts of their knowledge. In the following sections three exemplary approaches are briefly described:

Accenture's PMS framework centres around their Quantum Performance Measurement Model relying on a classic top-down approach for indicator development incorporating a multi-stakeholder view on the considered system. Main performance indicators are output and process measures in combination with benchmarking measures. The output measures time, cost and quality can be further aggregated to value creation measures and service fulfilment measures. The overall system shows a tree tier architecture – organisational level, process level and employee level.

The **Booz, Allen & Hamilton** approach suggests nine key factors for a high performance organisation – strategy translation, business unit vs. corporate roles, business process design, organisation structure, staffing resources, planning processes, performance measures, reward and recognition, training and change management. The implementation of referring methods and tools should follow a four step process: Understanding of the potential of the key factors,

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Goal setting and responsibilities, implementation based on best practices and continuous improvement and finally recognition and incentives. The approach suggest three performance dimensions: Market factors, structural factors and management factors.

Coopers & Lybrand differentiate performance measures in two broad categories: efficiency and effectiveness measures. The efficiency oriented measures focus more on the internal perspective, while the effectiveness measures address the level of fulfilment of the stakeholder expectations. A four step process is provided for building and implementing a PMS: Definition of the mission, strategy and organisational structure of the company, identification of critical success factors, definition of performance measures and monitoring of the performance measures.

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Appendix B: The Measurement Catalogue measures

This section provides an overview on the list of measures which has been elaborated during this research. The list is subject of continuous validation and refinement. It can be accessed and downloaded on www.nimcube.com (accessed 5th of July 2001).

Further specific asset related measures are listed in section 6.4.3.

Some of the measures in the list below originally provided by other authors have been slightly modified for the purpose of this research, still the author recognised the original contribution through quoting them.

The various facets and subjects vary in terms of comprehensiveness. The author's main purpose was to elaborate more in depth on less well known subjects, like human resource or reuse related measures than on very well known time, cost and quality related NPD output measures.

Facet: Operating Context

Subject: Competitive Context

Measure	Metric	Description	Formula	References
Competition Quality Perception	Perception of competitors by the customers	Measures how the customers perceived the quality of competitors (reliability, innovativeness, responsiveness)	Results of customer satisfaction survey or marketing survey	
Competition Quality: Competitive Product Quality	Quality of competing products in a target market	Measures the quality, features and functionalities of products competing in the same market. Results possibly serve as benchmarks or models to own development.	Results of competitive products benchmarks	
Competitive Con-centration	Volume of competitors targeting the same customer group	Competitive concentration is relevant to NPD strategy. It allows companies to consider competitors when deciding on design, features, costs, etc. in early development phases.	# of direct competitors; # of indirect competitors	
Competitive Intelli-gence Exposure	Employee exposure level to competitive information	This indicator shows how deep the competitive intelligence is implemented in the NPD organisation. It is important that this information reaches many NPD staff, not only a marketing manager.	# of subscribers to the Competitive Intelligence Report	
Competitive Intelli-gence Investment	Investment in competitive intelligence	Knowing the competition is a critical element of good NPD process.	$ invested in competitive intelligence (staff, reports etc.)	
Market Activity	Growth of competitors Competition growth rate	Indicates how main competitors are growing. It is an indicator of market activity and it measures the size and the scope of the competition. It portrays also the intensity of the rivalry on the market. Indicates how an increasing competition shapes the company's strategy related to costs, prices and quality.	% of competition's growth	
Market Analysis	Competition activity	It is an indicator which provides the company with useful information regarding market potential. It measures competition activity (growth, decline, stagnant) and competition intelligence (competitors strategies and activities).		
Market Share	Market share owned by competitors	Presents the position on the market of the principal competitors targeting the same group of customers.	% of market share owned by each main competitor	Krogh et al. (1988)
Market Share: Competitive Product Concentration	Quantity of competing products in a target market	Measures the volume of competing products in the target market. It is an indicator of concentration and impacts strategic decision taking.	# of direct competitive products	
Market Share: Market Size	Potential volume of target market	Measures the size of an organisation's target market. It is an indicator of potential sales and share.	size of addressed market ($ or other relevant units)	

Subject: Human Resources

Measure	Metric	Description	Formula	References
Compensation Benchmarks	Compensation relative to industrial / regional benchmarks	Compares the compensation levels of an organisation to standards / references of the industry or region. The measure is important as compensation is a factor to employee satisfaction and retention.	# salary paid per position relative to industry average	Kennerley and Neely (2000)
Diversity Background	Employees background distribution	Indicates the employees' diversity by taking into account their profession / background. High diversity of employees' background leads to cross fertilisation, new perspective of thinking etc.	number of employees with an engineering, marketing, manufacturing, social, consulting background etc	
Diversity: Men / Women	Sex distribution	Sex diversity increases knowledge, ideas, attitudes, fertilisation.	% of male and female employees	

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Employee Age Diversity	Employees age distribution	Indicates the company's ability to maintain its current levels of energy and intensity, as well as its ability to move into the future without losing its character and operating philosophy.	% of employees in each age group (e.g. under 25, 25-35, 36-50, 51+)	Edvinsson and Malone (1997)
Employee *Empowerment*	Level of employee *empowerment*	It present the degree to which employees are involved in the decision making process. Shows the degree to which they have the freedom and responsibility to carry out projects without encountering a large management overhead.	# of employees involved in the decision making process	Tipping et al. (1995)
Employee Satisfaction	The level of employee morale and satisfaction	Indicates the degree to which the company concerns itself about things related to employee morale such as team environment, improving interpersonal skills, training.	# of surveys, regarding employees morale and satisfaction, with positive results	Tipping et al. (1995)
Fund Assets	Fund assets per employee	Measures the actual performance of the individual employee, contribution to the company, span of control, leverage of skills, customer service and the like.	# of fund assets per employee	Edvinsson and Malone (1997)
HR Development Spend	Training and development expenses of personnel	Measures the investment of the NPD organisation in development of its people abilities. Especially with respect to NPD the investment in furthering peoples' knowledge is an indicator of future success.	training costs per employee per unit of time	Kennerley and Neely (2000)
HR Effectiveness	Effectiveness of HR systems and operations	Measures whether HR Management is considered to contribute to NPD performance. It is a rather subjective measure, which builds on peoples' / managers' perception.	employee satisfaction survey	Kennerley and Neely (2000)
HR Efficiency	Efficiency of HR systems and operations	Measures whether HR Management performs its processes efficiently and is likely to add value.	e.g. lead time of processing job applications	Kennerley and Neely (2000)
Intuitive Skills	Intuitive ability of NPD personnel	Measures the level of tacit knowledge in an organisation and the company's ability to build and implement solutions in order to allow and favour the transfer of this intuitive knowledge throughout the company.	# of NPD employees who master intuitive skills	Glaser (1995)
Involvement and Empowerment	Employee awareness of innovation policies and values.	Measures the percentage of employees aware of, and sharing, the innovation policies and values.	% of employees aware of the innovation strategies, policies, and activities according to a survey	Chiesa et al. (1996)
Personnel Employment	NPD personnel employment	Measures the ability of a company to acquire NPD personnel when needed.	# of NPD personnel employed when needed per unit of time	Brown & Gobeli (1992)
Prizes and Awards	Innovation and reuse awards	Indicates the degree to which employees efforts in effective innovation and reuse are recognised and rewarded.	# of innovation / reuse awards granted per unit of time (this includes financial and non-financial awards)	
Project Team	Team unity	Indicates the level of unity within a team, if the members share a common goal in a project and if the working environment is a favourable and a friendly one.	# of complaints about team environment quality per unit of time	
Project team motivation	Project team satisfaction index	Measures the satisfaction of NPD team members	Measured through attitude surveys	Driva (1997)
Qualification Level	Proportion of staff with certain qualification	Measures the qualification levels within the NPD organisation. It is an indicator of capabilities and availability of skills.	e.g. # of employees with university degree to subject area x	Edvinsson and Malone (1997)
Recognition and Compensation	% of performance based compensation	Indicates the compensation levels of an organisation related to employees' performance. It is an improvement factor in raising the overall performance.	e.g. % of financial compensation (bonuses and incentives) for improved performance	
Recognition and Compensation	% of innovation based compensation	Innovation based compensation gives clear message from the management on the importance of innovation in the company's strategy.	% of employee financial compensation (bonuses and incentives) determined by his / her innovation performance (new ideas etc)	
Recognition and Compensation	% of functional and team-based compensations	Indicates the total pay programs designed to develop and improve cross-functional and cross-organisational potential. Team based compensation increases internal co-operation and reduces "knowledge is power" phenomena.	e.g. % of financial compensation (bonuses and incentives) determined on team based performance	
Recognition and Compensation	Non financial awards	Indicates the company's policy to award its employees in other way than financial. It can be an important stimulus for improving personal skills and / or team work performance.	e.g. # of gift certificates awarded per year	
Recruitment and Staffing Speed	Project staffing speed	Measures the speed of staffing NPD personnel (from internal to external sources).	Period of time from request to actual staffing	
Recruitment Policy	Recruitment Effectiveness	Identifies and measures sourcing techniques, recruitment policies and innovative strategies that can identify highly qualified candidates.	e.g. recruitment effectiveness evaluation survey	
Retention	Reasons for leaving	It can indicate low support and morale, poor quality of equipment, relatively low salaries etc.	e.g. complaint analysis	
Retention: Employee Turnover	Employee turnover – general	Presents the number of employees leaving. This is a need to balance between: the need to refresh the staff by certain degree of turnover and the need to maintain certain level of stability and organisational memory.	# of employees that leave the company per period of time (categorised by reasons and profession)	

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Retention: Management Renewal	Management turnover	Measures the level of organisational restructuring process. New managers bring new ideas and style. Thus refreshing the management layer is important.	e.g. average number of years in managerial position	
Retention: Employee Turnover	Employee turnover - first year	Presents the number of employees recruited in the last year who then leave.	# of recruited employees (last year) leaving / total number of recruited employee (last year)	
Retention: Costs of Employment	Costs of compensation and incentives of personnel	Measures the expenses of the NPD organisation for employment. The measure includes salaries, bonus pays, variable pays, etc.	e.g. employment costs per employee relative to profits	Kennerley and Neely (2000)
Retention: Employee loyalty	Loyalty of key employees	Measures the loyalty of staff to an organisation. The measure is especially important with respect to highly qualified experts.	Average length of employment of subject experts	Edvinsson and Malone (1997)
Skill Flexibility	Level of variability of skill application	Measures the ability of employees to apply their skills to diverse operations / tasks. Thus, it is an indicator of an organisation's flexibility to perform multi-faceted tasks.	# of internally available key skills supporting different tasks	Kennerley and Neely (2000)
Skill Management: Core Competencies	Usage of internal key skills	Measures how well the NPD organisation utilises internally available skills. The measure is important as it assesses whether the organisation is aware of the human capital available.	# of operations utilising critical key skills relative to all operations / routines	Kennerley and Neely (2000)
Skill Management: Skill Coverage Speed	Speed of coverage of skill gaps	Measures the ability of a NPD organisation to close skill and competence gaps quickly.	Average lead time to develop / acquire skills required	Kennerley and Neely (2000)
Skill Management: Key Skill Availability	Availability of internal key skills	Measures whether internal key skills are available for the NPD organisation when required.	# of occasions critical key skills are not available	Kennerley and Neely (2000)
Skill Management: Core Competence Availability	Key skill areas mastered by NPD personnel	Indicates the level of qualification of NPD department employees.	% of key skill areas mastered by NPD team	Brown & Gobeli (1992)
Skill Management: Employee Com-petence Expense	Competence development expense	Indicates those activities developed by the firm, designed to make the individual employee more productive in his or her area of expertise.	Total competence expense / employee	Edvinsson and Malone (1997)
Skill Management: Employee Flexibility	Level of employee flexibility	Presents the percentage of personnel who have worked in more than one function.	# of employees involved in more than one function	Chiesa et al. (1996)
Skill Management: Experience	Staff experience	Counts the total number of software personnel with experience in defined areas.	# of personnel, # of years of experience	
Skill Management: Qualification and Certification	Rating of technical capability	Measures the level of technical qualification in the organisation.	# of employees who possess a certain amount of technical skills, certification or professional / academic qualification	Tipping et al. (1995)
Skill Transferability	Level of inter-personal skill transfer	Measures the transfer of critical skills between employees. The measure is particularly important with respect to externalisation and dissemination of knowledge.	# of internally available key skills made transferable to colleagues	Kennerley and Neely (2000)
Training	Training Frequency	Indicates the number of trainings courses held by the company. The company should know how to balance "how much" and "how often" in order to get the best of performance out of its employees.	e.g. # of training courses per unit of time	
Training	Training Qualification	Indicates the training strategies created to meet current and future needs. Assesses the match between employees' needs and the training program resources and structures.	e.g. # of new training qualification programs for information system department	
Training Impact	Adoption / transfer of learning	Measures the impact of training programmes in terms of applying new skills and practices to operations.	e.g. # of practices applied before training relative to # of applied practices after training	Kennerley and Neely (2000)
Training Quality	Contribution of training to performance	Measures the alignment and support of training with / of performance targets. It indicates the purpose-orientation of training.	e.g. training evaluation survey	Kennerley and Neely (2000)
Training Take Up	Employee's participation in training programmes	Measures the readiness of employees to participate in training courses offered by the organisation. It is an indicator of commitment, receptiveness to teaching and curiosity of staff.	e.g. # of trainings fully subscribed	Kennerley and Neely (2000)

Subject: Information Technology

Measure	Metric	Description	Formula	References
Availability: Technology Inventory	Availability of technological infrastructure	Measures the provision of the NPD organisation with the required technology. It is an indicator of capability and management's commitment to NPD.	e.g. # of occasions required technology is not available	Kennerley and Neely (2000)
Availability: Technology Support	Internal support and service performance	Measures the performance of internal support and service providers.	e.g. average time to remedy defects	Kennerley and Neely (2000)
Availability: Down Time	Down time	Measures the number of computer system failures. It is an indicator of productivity and profit as a minute of down time makes impossible for the business to operate and to gain revenues.	e.g. # of system failures per period of time	
Employee Literacy	IT literacy of employees	Indicates how well the staff is using the organisation's IT investment.	# of employees who distinguish by IT competence / total employees	Edvinsson and Malone (1997)

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Functionality: KM Functions	Availability of KM functions	Measures how many KM functions are available to and actually used by employees.	# of KM functions actually used regularly by at least x % of employees (out of checklist)	
Functionality: Telecommuting	Employees working at home	Indicates the future of telecommuting. It also indicates how efficient that IT capacity is.	# of employees working at home / total employees (%)	Edvinsson and Malone (1997)
Information Flow: Extended Enterprise	Extended enterprise information flow	Measures the amount of information exchange with external "partners".	e.g. # of daily transaction with external partners, per employee	AIT (1998)
Information System	Enterprise information level	Measures the ability to access information only through the company intranet (e.g. enterprise business objectives, business strategic plan).	e.g. volume of enterprise information transfer level per unit of time	AIT (1998)
Information System	Change project information	Measures the ability to access information through a given company intranet or through an extranet , which is private to the change project team.	e.g. volume of change project information level per unit of time	AIT (1998)
IT Inventory	Change in IT inventory	Indicates the amount the company spent on new IT equipment over the course of a year.	amount of money spent on IT equipment	Edvinsson and Malone (1997)
Quality: User Satisfaction	User satisfaction level	Measures the satisfaction of the users from the IT they are using.	average satisfaction – results from a referring periodical survey	
Renewal. IT Future Expenses	IT expenses on devel-opment and training	Indicates the corporate IT department to determine whether it is properly investing in its own future.	IT development and training expense / IT expense (%)	Edvinsson and Malone (1997)
Renewal: IT Expense	IT expense	Indicates the level of technology penetration into the daily work lives of employees.	total IT expenses / employee (%)	Edvinsson and Malone (1997)
Renewal: Technology Age	Age of equipment	Measures the age of the IT-infrastructure. It indicates whether tools are still state-of-the-art and reliable.	e.g. average age of IT-tools in years of service	Kennerley and Neely (2000)
Renewal: Actual Use	Actual use of new functionalities	Measures the quality of implementation – do users actually use new systems / functions.	% of new functions provided in the last 12 months, which are actually used by at least X % of the intended population	
Renewal: Lead Time	New system / function lead time	Measures how effective the implementation of new required IT functions is. Measures the period of time necessary for the employees to get used to the changes made in the IT system. It is very important if the company desires smooth transitions.	e.g. pre-implementation and implementation period average time to implement a new system / function	
Schedule and Progress	Component status measure	Counts the number of software components that have completed a specific development activity. A comparison of planned and actual components is effective for assessing development progress.	# of units vs. # of units completed	
Sources of Information	Level of intra-departmental information transfer	Indicates the degree in which members from a project team seek out information from other teams, or from other people in the organisation.	# of new ideas used which derive from an intra-departmental information transfer	
Technological Innovativeness	Technological sophis-tication, orientation and innovativeness level	Portrays the degree to which firms utilise sophisticated and state-of-the-art development technologies.	e.g. # of new products that employ sophisticated development technology per unit of time	Cooper (1985)
Technology Audits	Frequency of technology audits	Measures the frequency of auditing and testing the technological infrastructure. It indicates awareness of providing reliable and state-of-the-art equipment.	# of audits per unit of time	Kennerley and Neely (2000)
Value Added	Value added per IT-employees	Indicates how the employees and the information technology of the firm work together to add value to the firm.	e.g. level of profit per unit of time	Edvinsson and Malone (1997)

Subject: Organisation

Measure	Metric	Description	Formula	References
Control and Im-provement	TQM teams	Indicates the level of quality practices within the production, administration, procurement materials and other support groups. In other words it means the quality implementation level.	e.g. # of TQM teams within an organisation	
Control and Im-provement	PMS Implementation	It indicates the company's commitment to a performance measurement system, the degree to which the company develops the use of performance measurement for decision making.	e.g. # of performance measurement initiatives	
Control and Im-provement	Management reviews frequency	It indicates the effectiveness of quality and control system and the implementation of required improvements and the suitability of used procedures.	# of management reviews per unit of time	
Cross Boundary Co-operation: Early Cross Functional Involvement	Concurrency matrix	It determines the degree of early cross-functional involvement in new product development projects.	e.g. numerical calculation of % concurrent	Goldense (1993)
Cross Boundary Co-operation: Between Professional Disciplines	Percent of interdisciplinary teams	Indicates the overall commitment to the cross-functional team process. Shows the ability to bring greater knowledge and skill together at one time. Measures the ability and readiness of an organisation to co-operate across disciplines which is measure source for cross fertilisation.	# of projects using cross-functional teams	Tipping et al. (1995)

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Cross Boundary Co-operation: Matrix Organisation	Percent of "Matrix Organisation"	Matrix organisation work enables knowledge exchange between projects and intensive expertise development.	% of projects based on full matrix organisation work structure	
Cross Boundary Co-operation: Between Divisions	Percent of projects shared	Shared projects provide the most effective opportunity for mutual fertilisation between divisions.	% of projects which are shared between multiple divisions or SBUs	
Hierarchical Complexity	Set-up of management levels	Measures the internal organisational structure. The number of management layers is an indicator of efficiency and transparency.	e.g. # of management layers between board and shopfloor	Kennerley and Neely (2000)
Organisational Control	Level of self-organisation	Measures the degree to which an organisation is made up of self-contained entities.	e.g. # of self-organised NPD project teams	
Organisational Dynamics: Changes	Number of organisational changes	Appropriate number of organisational changes provides opportunities for renewal. But too many induce insecurity, chaos and shift attention from the work.	Average # of organisational changes each unit has experienced in the last 36 months	
Physical Arena: Feet for Purpose of Personal Work Area	User satisfaction	Portrays how well the physical environment meets user needs.	e.g. user satisfaction survey results	
Physical Arena: Shared Space / Private Area Availability	Private / Shared space ratio	Shared space can encourage knowledge and ideas sharing.	ratio of private offices space / shared space (including open space)	
Rotation: Internal Rotation	Percent of employees rotated to other departments	Internal rotation increases ideas and knowledge exchange.	% of employees rotated to other departments at least one time	
Rotation: External Rotation	Percent of employees "borrowed" to / from other organisations	External exchange of employees for limited time (several moths) increases ideas and knowledge exchange.	# of employees "borrowed" to / from other organisations in the last 12 months / total number of employees	
Multidisciplinarity	Multidisciplinary NPD project teams	Indicates whether product development projects are carried out in a multidisciplinary style	# of multidisciplinary teams versus one dimensional functional teams	Pawar (1994)

Facet: Exploitation

Subject: Customer Orientation

Measure	Metric	Description	Formula	References
Customer Attendance	Customer time per employee attendance	Measures the company's real commitment to customer related activities.	time spent (%) with customers' attendance	Edvinsson and Malone (1997)
Customer Base	Non-product-related-expense per customer	Measures the auxiliary customer-related investments, from bonuses and gifts to information gathering.	volume of non-product-related expenses per customer per year	Edvinsson and Malone (1997)
Customer Communication	Direct communications to customer	Measures how often the company actually communicates (newsletters, direct contact, magazines, press releases) with its customers per year.	# of direct contacts with the customers per year	Edvinsson and Malone (1997)
Customer Orientation	Market drive	It indicates the ability of a company to understand, attract and keep valuable customers.	e.g. market size	Bonsdorff and Andersin (1995)
Customer Relationship	Days spent visiting customers	Indicates the degree of direct personal interaction between customers and representatives of the company.	# of days spent visiting customers	Edvinsson and Malone (1997)
Customer Relationship	Policies without surrender	Indicates how many customers, after a long period of frustration, have finally given up.	% of company's policies, strategies, measures maintained although they are not in line anymore with customer requirements	Edvinsson and Malone (1997)
Customer Relationship	Telephone accessibility	It indicates the customer's daily interface with the firm. The company, the agent, the manager that is not there on the other end of the line is never going to be able to provide total customer service.	time spent (%) on line in order to provide customer full service	Edvinsson and Malone (1997)
Customer Requirements Fulfilment	Level of fulfilled requirements	Measures the number of test customers who perceive their requirements met to a certain percentage.	# of test customers "x %" satisfied	Kennerley and Neely (2000)
Fit for Purpose Volume	Volume of new products meeting customer requirements	Measures the volume of new products, which exactly meet requirements of the target group. It is an indicator of future success and of NPD being close to the market.	# of new products "x" % fit for purpose per unit of time	Kennerley and Neely (2000)
Product Variation	Range of product alternatives	Measures the possible / allowed for alternatives or versions of a new product considered in NPD. A high variability contributes to customisation and indicates a differentiated strategy, but increases development and manufacturing costs.	# of product versions provided for per unit of time	Kennerley and Neely (2000)

Subject: Exploitation Capability

Measure	Metric	Description	Formula	References
"Method and Technology" Hours	Share of "Method and Technology" hours	Shows the amount of time the company devotes to the development area which believes it is crucial to its continued competitiveness.	# of hours spent on development / total hours (%)	Edvinsson and Malone (1997)
Breakdown Costs	Costs incurred by equipment breakdown	Measures additional / avoidable expenses resulting from equipment breakdown. That ranges from costs of repair to penalties for delay.	e.g. total value of penalties due to breakdowns per unit of time	Kennerley and Neely (2000)
Development Hours	Share of development hours	This refers to the systematic packaging of experience for future sharing and recycling.	# of hours spent on "Method and Technology" / total hours (%)	Edvinsson and Malone (1997)

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New Products	Costs reductions	Indicates new products that provide similar performance at lower cost.	e.g. volume of sales per unit of time	Griffin and Page (1996)
New Products	Additions to existing product lines	Indicates new products that supplement a company's established product lines.	e.g. volume of profits achieved per unit of time;	Griffin and Page (1996)
New Products	Improvements in / additions to existing products lines	Indicates new products that provide improved performance or greater perceived value and replace existing products.	e.g. market share obtained by replacing the existing products	Griffin and Page (1996)
Platform of a Product Family	Platform efficiency	Indicates the degree to which a platform allows economical generation of derivative products.	e.g. volume of R&D costs for follow-on product per unit of time	Meyer (1994)
Platform of a Product Family	Platform effectiveness	Indicates the degree to which products based on a product platform produce revenue for the firm relative to the cost of developing those products.	e.g. accumulated profits per development costs	Meyer (1994)
Product Line Freshness	Proportion of sales from products introduced within last year	Measures how current a business unit's product line is and how fresh and up-to-date its products are.	% of sales from products introduced in the last 12 months	Loch et al. (1996)
Specific Tools Implementation	Use of specific tools like (FMEA, QFD, Rapid Prototyping)	Early development of FMEA, QFD, early use of prototypes and early involvement of marketing process.	% of projects in which specific tools are applied	Chiesa et al. (1996)
Technology Type	Technological maturity	Technologies characterised by their maturities (Embryonic, Growth, Mature, Aging).	Embryonic, Growth, Mature, Aging	Roussel et al. (1991)
Technology Utilisation	The number of different product types utilising a certain technical asset	It indicates the degree of usefulness of a certain technical asset.	# of different product types planning to utilise a certain technical asset	Bonsdorff and Andersin (1995)
Innovation Rate	New products normalised by life cycle	Expresses development speed and the capability to bring out products in rapid succession, relative to the business unit's competitors.	# of significant product line changes / innovation multiplied by product life cycles	Loch et al. (1996)
Knowledge exploitation	Knowledge reuse effectiveness	Measures the percentage of reused knowledge which is actually reused in the final product	Amount of reused knowledge which can be refound in the final product / the overall amount of reused knowledge in the development project	
Invention exploitation	Invention exploitation	Measures the number of inventions made which have been turned into innovations	Number of exploited inventions / number of overall inventions	
Reuse and Invention strategy fit	Strategy alignment of reuse and invention	Measures whether the reuse and invention activities are aligned to the corporate NPD strategic themes and vice versa	Mapping of strategic NPD themes with reuse and invention levels in NPD	
NPD strategy fit	Strategy alignment of NPD activities	Measures whether the stakeholder contributions are used in a way that they meet the NPD strategic themes	Mapping of strategic NPD themes with stakeholder contribution and NPD output performance	

Subject: Market Knowledge

Measure	Metric	Description	Formula	References
Market Feedback	Responses from markets to new products	Measures the response of customers, competitors, etc. to a new product. This serves as a foundation for marketing decision taking.	e.g. sales turnover of new product	Kennerley and Neely (2000)
Market Newness	Market need newness level	Describes whether the market needs, that the new product satisfies, are needs or functions, the firm has catered before.	# of new products that serve new needs for firm per unit of time	Cooper (1985)
Market Research Frequency	Volume of market research activities	Regular survey of market needs and trends allows a company to tailor products to the market. Furthermore it facilitates anticipated NPD activities.	# of market surveys per unit of time	
Market Research Quality	Sample size	Market research information regularly gains in quality relative to increasing sample sizes.	# of survey respondents	

Facet: Invention

Subject: Invention Organisation and Tools

Measure	Metric	Description	Formula	References
Invention Support IT tools	Access to invention support IT tools	IT tools can support invention , ideas pipelines, virtual brainstorming tools etc, are examples	e.g. % of NPD staff with access to Invention Support Infrastructure	
Use of creativity methodologies and tools	Use of creativity enhancement methodologies and tools	There are several formal creativity enhancement methodologies and tools used by NPD projects.	% of projects that actually use systematic, creative thinking methods and tools (e.g. TRIZ, SIT etc)	
Value creation	Number of pages in the annual report devoted to innovation and technology	It indicates the importance of the invention process in company's business strategy. Indicates how technology oriented the company is.	# of pages in the annual report devoted to innovation and technology per unit of time	Chiesa et al. (1996)
Invention environment: Communities of Practice (CoP)	CoP index	Measures the number of implemented communities of practice (CoP) in an organisation being a well-spring for inventions	# of communities implemented in a company	
CoP performance	CoP usage	Measures the number of CoP alive versus the overall number of implemented CoPs	# of CoPs alive / # of all CoPs	
Scientific Activity	Science oriented personnel	Certain degree of scientific activity in the organisation can encourage innovation.	% of employees with scientific tendencies / work	
Training for Invention	Participation of employees	How much does the company invest in systematic training for creativity ?	% of NPD staff that participated in an creativity training	

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Subject: Invention Portfolio

Measure	Metric	Description	Formula	References
Compensation for inventions	Compensation for inventions	Some companies compensate employees for inventions (e.g. in "Improvement ideas programmes).	cost of financial compensation for inventions	
Free Invention Time	Free invention time	Some companies allow their employees to spend X % percent of their time inventing new things not related to their ordinary responsibilities (e.g. 3M).	% for "free invention time allocated" to employees	
General Novelty	Inventions new to the world	Measures the volume of new ideas, which are entirely new to the "world". As information technology advances and companies gain access to sources globally, "world" is about to be taken literally.	# of inventions "new to the world" per unit of time	Griffin and Page (1996)
Innovation Categories	Innovation categories	Indicates the distribution of the products revenues according to the 4 innovation types according to Hamel (2000).	% of NPD investment in the following 4 product groups: new technology / new market, new technology / existing market, existing technology / new market, existing technology /existing market	
Internal Novelty	Inventions new to the company	Measures the volume of new ideas which are new from the perspective of the company. It is critical in terms of assessing the "re-invention of the wheel" phenomena.	# of new ideas new to the company per unit of time	Griffin and Page (1996)
Internal Venture Capital-Actual Use	Internal venture capital-actual use	Some companies allocate significant resources to internal venture capital which are never used due to lack of ideas and ineffective process.	% of "Internal Venture Capital" funds actually used	
Internal Venture Capital-Budget	Internal venture capital-budget	Internal venture capital is a good way to "bring silicon valley inside the organisation".	size of "Internal Venture Capital" funds	
Invention Dedicated Budgets	Invention dedicated budgets	Some companies find it important to allocate specific budgets and resources for invention.	volume of invention budget (e.g. budget for the Future Centre)	
Invention Dedicated Resources	Invention dedicated resources	Some companies appoint X% of the NPD personnel as "full time inventors".	% of NPD staff which have the task to invent new ideas (not necessarily related to current development projects)	
Invention Scope	Impact / scope of assets	Measures the volume of new assets, which are considered unique breakthroughs relative to rather incremental improvements. As such achievements are typically rare, an organisation has to be especially aware of them.	% of inventions considered breakthrough invention	
Market Novelty	New to the world products	Measures the degree to which new products are accepted by customers and satisfy them after use.	# of new products that create an entirely new market	Griffin and Page (1996)
Market Novelty	Assets new to the market	Indicates whether an invention is a novelty to the target market.	# of new assets introduced on the market completely new to the world per unit of time	Kerssens-van Drongelen (1999)
New Products	New to the company products	Indicates that new products that, for the first time, allow a company to enter an established market.	e.g. market share achieved by the new product	Griffin and Page (1996)
Product Differentiation	Product differentiation	Indicates the degree to which firm's new products are similar to its existing products, have a similar end use, are in the same product class, fit into existing product line, and are closely related to each other.	e.g. # of completely new products dissimilar to the existing products in the company's portfolio	Cooper (1985)
R&D Effectiveness	New products fit with business strategy	It indicates the number of new products developed accordingly to business strategy.	# of new products fit with business strategy per unit of time	Griffin and Page (1993)
Radical versus Sustainable Innovation	Radical versus sustainable innovation	Indicates how radical is the company's innovation.	% of R&D investment in the following 4 product groups: system level / radical innovation (business concept), system level / incremental innovation, component level / radical innovation, component level / incremental innovation	Hamel (2000)

Subject: Invention Process

Measure	Metric	Description	Formula	References
Assets Character	Nature of assets	Measures the proportion of tangible or intangible new assets relative to the sum of new assets generated over a period of time. It describes the strengths and focus of an organisation in asset generation.	% of tangible / intangible new assets relative to all assets stored	Kennerley and Neely (2000)
Classification of Internal Sources	Classification of internal sources	Ideas should be provided from all parts of the organisation.	% of new ideas from each employee group: engineers, marketing staff, manufacturing people, senior managers, middle managers, etc	
Company Renewal Orientation	R&D resources ratio	Measures how much commitment the company is making to its future renewal and development.	R&D resources / total resources (%)	Edvinsson and Malone (1997)
Customer Creativity	Creative input contributed by customers. Customers are a valuable source for the joint creation of new assets	Measures the degree to which customers are involved in creative processes. It indicates the comprehensiveness of innovation management.	# of new assets developed with customer support relative to all new assets	

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External Idea Generation Rate	Volume of external inventions	The measure describes the rate of newly introduced ideas to the organisation from an external source. It measures contribution of external stakeholders to invention.	# of (product) ideas introduced per unit of time from diverse stakeholders (customers, suppliers, academy etc)	Kennerley and Neely (2000)
Internal Communications of Inventions	Internal communications of inventions	An effective way to enhance awareness to creative is to publish throughout the organisation all new inventions.	# or % of inventions widely published throughout organisation	
Internal Idea Generation Rate	Volume of internal inventions	The measure describes the rate of newly introduced ideas to the organisation. It is an indicator of creativity and innovativeness.	# of (product) ideas introduced per unit of time from / within the organisation	Kennerley and Neely (2000)
Invention Effectiveness	Idea transformation	Measures the number of ideas acquired / generated evaluated and implemented / stored in a given period. It is a measure of quality and value of new ideas as well as of awareness of potentially valuable ideas; i.e. it describes the conversion of ideas into asset	# of new ideas assessed and implemented / stored per unit of time	Kennerley and Neely (2000)
Invention Effectiveness	Degree of innovation	Measures the volume of new ideas implemented. It shows also the degree of creativity.	# of new ideas implemented per unit of time	Brown & Gobeli (1992)
Invention Protection	Number of patents	Measures the inventive capabilities of an organisation and the far-sighted management of new assets.	# of patent applications successfully registered per unit of time	Kennerley and Neely (2000)
Invention Rate	Idea generation rate	Measures the degree of creativity. It is an indicator of the organisation's ability to explore new lines of thought.	# of ideas generated per unit of time	Kennerley and Neely (2000)
Managers and Employees Attitude	Managers and Employees attitude towards invention	The importance of creativity and invention should be clearly communicated.	survey results regarding how do managers and employees perceive the importance of creativity and invention	
New Ideas Types	Categories of new ideas	Shows how new ideas are distributed among different categories.	% of distribution of new ideas of each type: marketing, technology, features, cost reduction, quality related etc.	
New Methods	Invention rate of tools and methods for a new project	Measures the rate of newly introduced tools and methods into the new products.	# of new tools and methods created per new project developed	
New Product Ideas	New product ideas and product enhancement ideas	Indicates the proficiency and creativity of R&D department. Indicates the effectiveness and speed of evaluating ideas.	# of new product ideas evaluated per unit of time	Chiesa et al. (1996)
New Technology Implementation	Speed of getting new technology into new products	It describes the rate of newly introduced technology into the new products.	# of new technologies into new products per unit of time	Hauser and Zettelmeyer (1997)
Output of Invention Programmes	Yield of invention programmes	This metric measures how effective various invention supporting programmes are (i.e. do they impact the commercial development work).	# of ideas that impacts the NPD work (processes or products) generated by the invention programme. Invention programmes are: "Future Centre", "Invention Fairs", "Invention Clubs", "Creative Thinking Workshops" etc.	
Product Modification	Products significantly changed	The rating of changes or corrective actions that affect a product.	% of products significantly changed in the past x years	Loch et al. (1996)
Publications	Scientific publications by the professional staff	Measures the degree of creativity and the invention capabilities of the professional staff in an organisation over a time period.	# of publications by the professional staff per unit of time	Tipping et al. (1995)

Facet: Performance

Subject: Customer

Measure	Metric	Description	Formula	References
Adherence to Contract	Achievement of contractual agreements	Measures the ability of the NPD organisation to fulfil agreements as provided by contract.	# of occasions the organisation adheres to agreements	Kennerley and Neely (2000)
Customer Complaints	Frequency of customers complaints	Measures the frequency of customer complaints. Complaints are a valuable opportunity for improvement and a source of feedback.	# of registered customer complaints per unit of time	Kennerley and Neely (2000)
Customer Relationship	Customer lost	It represents the loss of years of time and money in developing the customer relationship and even more years of lost revenues.	# of customers lost per unit of time	Edvinsson and Malone (1997)
Customer Retention	Loyalty of existing customers	Measures the loyalty of existing customers to the NPD organisation and its products. A high score suggests superior NPD performance.	# of existing customers purchasing new products per unit of time	Kennerley and Neely (2000)
Customer Satisfaction	General customer satisfaction	It indicates positive responses to new products.	# of positive answers from the customers	Bonsdorff and Andersin (1995)
Delivery Reliability	NPD delivery on time in full	Measures the ability of the NPD organisation to complete a project entirely on time. It is an indicator of reliability.	# of NPD projects completed on time in full relative to all NPD projects	Kennerley and Neely (2000)
Design Quality	Products for which the first design fully met the customer's specification	Indicates the effectiveness of R&D Management regarding the quality of the design and the fulfilment of customer requirements.	# of products which met customer's requirements per unit of time	Kaplan & Norton (1996b)
NPD Failure Recurrence	Repetition of NPD defects and causes for complaint	Measures the frequency of recurring problems resulting from insufficient NPD activities.	# of identical defects occurred until root cause is solved	Kennerley and Neely (2000)

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Perception of Value for Money	Financial value assigned to a product by customers	Measures the customer's perception of financial value of a product. This perception eventually impacts the buying decision. It can be obtained by customer feedback, market survey, etc.	Perceived value for money as % of selling price	Kennerley and Neely (2000)
Preferred Supplier	Occasions selected first choice supplier	Measures the preference assigned to the NPD organisation by customers. A high score indicates most satisfied customers and thus superior NPD performance.	# of customers preferring the organisation as supplier of first choice per unit of time	Kennerley and Neely (2000)
Quality	Achievement of quality requirements	Measures the ability of the NPD organisation to deliver new products meeting all relevant quality criteria.	# of new products delivered 100% defect free	Kennerley and Neely (2000)
Quality	Output quality	Indicates the quality of products marketed compared to the companies which target the same group of customers.	% of product which meet quality standards	
Sales Price	Sales price compared to benchmarks	Measures the selling price of a new product compared to competitive products. The measure should be used to evaluate a possible premium to be charged for superior features.	Selling price per product relative to competitive products	Kennerley and Neely (2000)

Subject: Management

Measure	Metric	Description	Formula	References
Contribution to Revenue	Financial contribution of new products to total revenues	Measures the quantifiable (financial) contribution of new products relative to total revenues.	% revenues of new products relative to total revenues	
Cost Error	Cost for administrative error / management revenues	Measures the efficiency of the company's performance by looking at the ratio of the cost of errors.	Total cost for administrative revenue / management revenues (%)	Edvinsson and Malone (1997)
Cost of Quality	Cost incurred by quality failures	Measures expenses originating in failure impacting quality. The measure displays critical quality-related NPD activities and underscores impact on business performance.	e.g. total costs incurred by non-conformance to quality standards	Kennerley and Neely (2000)
Cost Planning Accuracy	Comparison of actual costs at completion to target costs at planning	Measures the accuracy and reliability of cost planning. It warrants that costs do not spin out of control and perhaps highlights areas for planning improvement.	Actual costs vs. target costs of NPD project at gate review	Kennerley and Neely (2000)
Costs of Delay	Cost incurred by NPD project delay	Monitors / reviews additional costs resulting from delayed progress / conclusion of NPD project. It assesses cost awareness and responsibility of NPD.	e.g. total penalties resulting from late completion	Kennerley and Neely (2000)
Customer Acceptance	Economic value of a new product feature	It indicates volume of sales and profits generated by a new product.	(price premium due to the feature-extra cost)*sales volume	Tipping et al. (1995)
Degree of Commitment	R&D spending	Indicates the impact of the firms' new product programme in terms of the firms' total operations.	% of corporate sales spent on new products	Cooper (1985)
Design Quality	Technical product performance	Measures product performance as perceived by marketing, R&D and top management. It is widely considered to be an important aspect of development output.	# of technical improvements per unit of time	Loch et al. (1996)
Development Performance	Capability maturity model level	Reports the rating (1-5) of a software development organisations software development process, as defined by the SEI.	CMM rating	
Focus and Structure of R&D	Project duration	Measures the "ambition", technical content of the project.	Average duration in months	Loch et al. (1996)
Innovation Efficiency	Profitable patents	Indicates how many of the company's patents bring real profit to the firm.	Profit rate per patent	
Investment Return	Return of investment in terms of development costs	Indicates the period of time necessary for a company to get a return on investment in terms of development costs.	# of months required to get a return of investment in terms of development costs	
New Product Prof-itability	Profits generated by a new product or programme / investments	It indicates cumulative profits generated by a specific new product or programme. Indicates how profitable the new developed products proved to be.	Volume of profits generated by new products or programmes / total profits (%)	Griffin and Page (1996)
New Product Prof-itability	Level of profit from projects launched x years ago	Indicates the level of performance of new projects seen by the level of profit acquired.	Total profits resulted from new products launched per unit of time	
NPD Break-Even	Time to equal profits from new product and development cost	Measures the time period to equal development costs and profits generated by the new product. It is an indicator of market-oriented performance.	Time elapsed when cumulative profits from new product equal cost of development	Kennerley and Neely (2000)
NPD Effectiveness	Number of new products launched in the last x years	Measures the proficiency of NPD department. The ability to apply new ideas and to successfully develop and bring new products to the market.	# of new products launched in the last x years	
NPD Efficiency	Quality of the product specifications	Measures the number of products which fulfil quality specifications.	# of products which fulfil quality specifications	
Overall Orientation	Programme focus	Indicates how closely related the new products are to each other in terms of production methods and development technologies.	# of new products that employ related production methods and development technologies per unit of time	Cooper (1985)
Overall Performance Score	Fulfilment of strategic objectives	It indicates the degree to which product met revenue goals.	% of sales due to products introduced in the last x years	
Premium Income	Premium income resulting from a new business operation	Measures how the company is likely to perform in the years to come.	Total income resulting from a new business operation	Edvinsson and Malone (1997)

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Productivity	NPD output relative to contributions	Measures productivity of NPD projects by relating a reasonable unit of output to a reasonable unit of input.	e.g. new assets generated per engineer	
Profitability	Present value of investments	It indicates the present value of estimated cash flows due to a product or programme.	% technical improvement expressed in technical units	Brown & Svensson (1988)
Profitability	Return on NPD investment	Measures the return on Senior Management's investment in NPD projects. Financial profitability is usually management's prior concern.	Revenue generated by new product divided by NPD investment	
Project Abandon	Timing project cancellation	Measures the duration of a project started until the management decides to abandon it.	# of months spent with a project until it is cancelled	
Project Delays	Non-technical factors which may delay the project	Assessment of non-technical factors which may cause delay in the project.	# of non-technical factors which may delay the project per unit of time	Rainbow (1971)
Project Duration	Months completed per project stage	Indicates the duration of a project started.	# of months per completed project stage	Chiesa et al. (1996)
Project Novelty	New projects created out of business plan	Measures the ability of a company to develop projects that are not stipulated in the business plan or project plan.	# of new projects developed that are not mentioned in the business plan per unit of time	
Project Planning	Project staffing speed	It measures the number of resources needed by a project and time for each task to perform their work.	# of resources required per unit of time and project task	Goldense (1993)
Projects Effectiveness	Projects, ultimately considered commercial successes	Projects fully completed, that fulfil their initial goal.	% of projects successfully completed	Cooper and Kleinschmidt (1995);Griffin and Page (1996)
Projects in Process	Static time-to-market	It measures schedule forecast accuracy, examines the variation in predicted and actual phase times across projects and identifies the places where the development processes typically break down all with the same set of data.	e.g. # of months between milestones	Goldense (1993)
Quality	Number of defects	Measures the ratio of the number of defects identified against a component relative to the size of the component.	# of defects / Number of lines of codes	
Quality	Problem reports	Quantifies the number, status, and priority of problems reported.	Number, Average age, severity, status of problem reports	
R&D Effectiveness	R&D effectiveness index	Measures the percent of revenues generated by new products.	% of revenues from new products*(net profit% +R&D%) / R&D%	McGrath & Romeri (1994)
R&D Focus	R&D focus	Measures the ability of the R&D department to develop a number of parallel projects in the department.	# of parallel projects in the department per unit of time	Loch et al. (1996)
R&D Productivity	Net Present Value of a project or programme	It indicates present value of estimated cash and flows due to a product or programme.	Total income due per project or programme	Griffin and Page (1993)
Resource and Costs	Earned value	Comparison between the cost of work performed and the budget, based on dollars budgeted per WBS element.	BCWS, BCWP,ACWP ,EAC, BACK	
Resource and Costs	Effort	Counts the number of hours or personnel applied to a specific NPD task.	# of labour hours	
Sales	Sales profile of a new product	Measures the volume of sales along the life cycle of an innovative product.	% of sales profile of a new product	Kaplan & Norton (1996b)
Sales	Percent of sales due to products introduced in the last x years	Measures the volume of cash flows due to products introduced in the market in the last x years. Indicates the level of success of the projects and products developed by the company.	Volume of sales due to products introduced in the last x years / total sales (%)	Griffin and Page (1993)
Schedule and Progress	Change requests written	Counts the number of written change requests, enhancements, or corrective action reports that affect a product.	# of change requests written	
Schedule and Progress	Change request resolved	Counts the number of resolved change requests, enhancements, or corrective actions.	# of change requests resolved	
Strategic Alignment	Correspondence of structures with strategy	Measures whether the organisational set-up is a qualified reflection of business strategy. It indicates how strategy is implemented.	e.g. scope of action (effectiveness) of development teams	
Target Project	Target project size	It measures project sizes and attributes that makes projects successful.	# of projects estimated as successful in a company per unit of time	Goldense (1993)
Timeliness	Timeliness Index	Measures the effectiveness and the efficiency of project development process.	# of projects completed on time during some representative periods / number of projects started	Werner & Souder (1997)
Total product development time	Lead time	Measures the overall lead time of a new product from idea generation to production ramp-up.		Driva (1997)
Total Yield	Total yield compared with overall industry	Measures how well the company's asset measurement programme compares to the industry wide index.	Total company's results / total industry wide results (%)	Edvinsson and Malone (1997)
Value Creation	Innovation effectiveness	Overall effectiveness of the innovation process.	# of projects finishing development / # of projects started development	

Subject: Marketing

Measure	Metric	Description	Formula	References
Costs of Marketability Deficiency	Additional cost to Marketing Management incurred by NPD	Measures marketing costs resulting from deficient design.	e.g. total marketing costs to correct design deficiencies	Kennerley and Neely (2000)

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Degree of Commitment	Market research spending	Captures the firms' degree of commitment to its new product programme.	% of corporate sales spent on market research for new products	Cooper (1985)
Design to Cost	Unit cost reduction	Reflects whether an industry is driven by product performance and innovation or by cost and price. Measures development capability of designing manufacturable and cost efficient products.	unit cost reduction (%) normalised by industrial average	Loch et al. (1996)
Market Leadership	Products first to market	Indicates the ability to tackle new needs that are not yet satisfied in the market and can not be copied and to successfully launch them before other competitors.	% of product innovation first to the market	Loch et al. (1996)
Market Novelty	Product innovations first on the market	Measures the ability of NPD organisation to deliver product innovations faster than the competition.	# of significant product innovations that were first to the market per unit of time	Loch et al. (1996)
Market Novelty	New major products compared to industry average	Measures the ability of NPD organisation to deliver a larger number of new major products than the industry average.	# of new major products per unit of time	Loch et al. (1996)
Market Share	Market coverage	It is kind of an opportunity index. Indicates the degree to which a company reaches its potential customer base.	% of target market completely covered	Edvinsson and Malone (1997)
Market Share	Share of the relevant market taken by a new product	Measures the market share taken as a result of introducing a new product. It is an indicator of potential profitability of a new product.	% of target market captured by a new product	Kennerley and Neely (2000)
Marketability Level	Proportion of developments considered marketable	Indicates the proportion of NPD output which is considered to be built into marketable products; i.e. products in pipeline.	# of potentially marketable developments relative to all developments	
Marketability Specification Fulfilment	Level of deviation of marketing specifications	Measures the rate of deviations of defined marketing parameters per new product. It indicates additional costs, probability of success, necessary marketing efforts, etc.	# of deviations of marketability parameters per product	Kennerley and Neely (2000)
Marketing Expense	Marketing expense level per customer	Captures the company's commitment to marketing by using customer satisfaction.	total marketing expense per customer per unit of time	Edvinsson and Malone (1997)
Product Life Cycle	Average product life cycle	Indicates the ability of a company to develop long standing products instead of short standing ones.	e.g. average of product lifecycle length	Chiesa et al. (1996)
Projects in Process	Dynamic time-to-market	It provides a framework for identifying problem projects and for getting a "second-opinion" on the most realistic prediction of actual development time and launch dates.	e.g. # of months necessary to complete a project	Goldense (1993)
Realisation Level	Proportion of developments realised in marketable products	Measures the proportion of NPD output realised in marketable products.	# of realised developments relative to all developments	Kennerley and Neely (2000)
Value Creation	Product differential advantage level	Measures the degree to which a new product makes the company a major entity in the market. The ability of a company to create products which cannot be copied.	# of products not similar to competition offerings per unit of time	Cooper and de Brentani (1984)

Subject: Production

Measure	Metric	Description	Formula	References
Cost of Manufacture	Production costs incurred by NPD	Measures the financial impact of NPD on manufacturing costs. Complexity of design regularly determines a large proportion of production costs.	Total production costs as incurred by NPD	Kennerley and Neely (2000)
Cost of Re-Design	Cost incurred by deviation of production specifications	Measures additional costs resulting from design failing to address production requirements. Highlights opportunities for earlier integration of Production Management.	Total costs incurred by re-design	
Cost Savings	Savings in the cost of goods sold	Cost savings due to process development of product changes.	% of savings generated by product changes	Tipping et al. (1995)
Maintenance Costs	Costs for maintaining equipment	Measures the ongoing expenses for service and support of existing tools. High maintenance costs suggest need of investment in more reliable technology and / or more reasonable utilisation.	e.g. costs of repair per unit of time	Kennerley and Neely (2000)
Production Specification Fulfilment	Level of deviation of production specifications	Measures the degree and volume of deviations from production requirements (e.g. technological constraints).	# of deviations of production parameters per product	
Production Synergy	Production and technological synergy	Describes the degree of fit between the requirements of products the firms develops and the firm's technological resource base.	# of new products fit firms production skills and resources per unit of time	Cooper (1985)
Project Duration	Project management cycle time	Indicates the elapsed time from project start until commercial sales commerce.	# of months from the beginning of a project till the commercialisation of the final results	Tipping et al. (1995)
Quality	Rework effort	The amount of work effort to find and fix defects.	Labour hours due to rework	
Quality of Design	Design changes before release	Measures the number of changes in design, identified before product release.	# of design changes before release per unit of time	Brown & Gobeli (1992)
Quality of Design	Design changes after release	Measures the number of changes in design after release.	# of design changes after release per unit of time	Brown & Gobeli (1992)
Technology Impact	Quantified impact of implemented equipment	Measures the effects of newly implemented tools on NPD performance. It is an indicator of effective selection and use of technology.	e.g. change to development costs after implementation	Kennerley and Neely (2000)
Technology Implementation	Time to implement / replace equipment	Measures the elapsed time to implement new equipment and / or replace obsolete tools.	e.g. average lead time to put new tool into operation	Kennerley and Neely (2000)

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Technology Planning Accuracy	Comparison of actual utilisation at completion to target utilisation at planning	Measures the accuracy of planning and allocating technological resources to an NPD project. The measure indicates responsible/far-sighted handling of equipment.	e.g. deviations of planned utilisation per NPD project	
Time Management	Time Slack	It measures the potential of the company to reduce a project's delivery time by diminishing the number of tasks dependencies or slack time.	slack time = compute time – deadline time	

Subject: Regulators

Measure	Metric	Description	Formula	References
Licensing	License agreement usage	New / reusable assets may be leveraged by licensing them to other organisations. Thus, they generate additional income. The company needs to assess realisation of these opportunities.	# of organisations using a licensing agreement	Kennerley and Neely (2000)
Partners Satisfaction	Partners satisfaction	Having satisfied partners enhances knowledge exchange and productivity.	results of a survey measuring partners satisfaction from the work with the organisation.	
Value Creation	Patent ratio	Patents and copyrights amount spent on sales.	# of patents and copyrights per million dollars of sales	
Value Creation	Protected sales	Sales protected by intellectual property rights.	Sales protected by intellectual property rights / total sales	

Subject: Supplier

Measure	Metric	Description	Formula	References
Engineering Change Orders	Engineering change orders due to change specifications in NPD	Measures the amount of changes in orders before product release due to some change in existing specifications.	# of engineering change orders due to specification changes before product release per unit of time	Bonsdorff & Ander-sin (1995)
Communication efficiency	Quality of request orders	Measures the quality of the requests received by the supplier	Quality level of requests received	
Payment behaviour of customer	Timeliness of payments received	Measures the timeliness of payments received	# payments received in time / # of overall payments	

Facet: Reuse

Subject: Knowledge Assets

Measure	Metric	Description	Formula	References
Existing Products	Repositioning	Indicates the existing products targeted to new markets or market segments.	e.g. # of new satisfied customers	Griffin and Page (1996)
External Asset Acquisition	External input to reuse store	A measure of ingenuousness and readiness to obtain knowledge from outside the organisation. However, an unusual high level of external acquisition suggests dependency on external sources and lack of internal creativity.	# of acquired reusable assets from external sources per unit of time	Lim (1998)
Reuse of Historical Data	Level of historical data recurred	Measures the degree to which the company applies consequences and lessons learnt to different products and projects. It also shows the use of historical data from past projects for project planning and estimating.	volume of historical data reused in future projects	
Reuse of Patents	Granted patents maintained	Indicates the maintenance of granted patents in an organisation.	% of granted patents in an organisation	Tipping et al. (1995)
Reused Assets	Use of standard templates	Indicates the frequency of use of standard templates for test and design specifications in order to get the desired results.	e.g. # of standard templates used per project	
Reused Assets	New project documentation	Measures the degree to which the company uses past projects records relevant to the new developed ones in order to get efficient results.	e.g. # of processes readopted for the development of the new project	

Please note that section 6.4.3 provides further asset related performance measures.

Subject: Reuse Library Use

Measure	Metric	Description	Formula	References
Reuse Search Efficiency	Efficiency of hits	Measures the efficiency of a reuse store search scheme. A high score indicates mature search algorithms and user friendly data entry.	# of qualified assets presented relative to # of requests per unit of time	Lim (1998)
Reuse Search Response Time	Time to presentation	Measures the speed with which a reuse store is screened for qualified assets. Fast response is a measure of efficiency and indicates clear categorisation as well as data processing power.	elapsed time to present required assets	
Reuse Storage Cycle-Time	Time to store	Indicates the cycle-time until acquired assets are available in a reuse store. The measure depends on filter- and storage mechanisms, but also on readiness to and immediateness of submission by engineers.	elapsed time until acquired assets are stored	Lim (1998)
Reuse Store Review	Review frequency	A measure of maintenance and diligence with respect to reuse assets. A high frequency underscores that an organisation is aware of the short knowledge shelf-life and endeavours for actuality of assets.	e.g. # of reviews and assessments of reuse store per unit of time	

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Reuse Store Utilisation	Search volume	Measures the frequency of searches and requests to a reuse store for reusable assets. A high score indicates the awareness of the organisation of reusability and suggests an user-friendly design of the search and retrieval mechanisms.	# of requests to reuse store over unit of time	Lim (1998)

Subject: Reuse Organisation

Measure	Metric	Description	Formula	References
"Reinventing the wheel" Phenomena	Level of re-invented parts used in a new project or product	Indicates the degree in which a company feels that some parts such as, (software, engineering, hardware) were invented again instead of taking them from previous work.	# of re-invented parts (software, engineering, hardware) per unit of time	
Active Range of Reusable Assets	Applied volume of reuse store	The indicator describes the proportion of stored assets, which are actually reused. A high score indicates the quality of assets, the precise selection of assets and the reuse awareness in an organisation.	# of stored assets reused more than once at a certain measurement point	Lim (1998)
Existing Processes Maintained	Reuse frequency of existing processes and components	Indicates the level to which a company applies consequences and lessons learnt to different products and projects. It also shows how often a company chooses to use radically new processes each time it develops a new product or project.	# of new processes and components used per unit of time	
Marketability of Reusable Assets	Qualification for leverage	Measures the qualification of reusable assets for exploitation outside the organisation. Such assets can for instance be sold, leased, licensed, etc.	# of assets qualified for market leverage (sell / lease / license) per unit of time	
Passive Range of Reusable Assets	Idle volume of reuse store	Measures the volume and scope of reusable assets in a reuse store. It indicates the capability and readiness of an organisation to store potential assets. It describes a prerequisite for reuse, but neither quality of assets, nor actual reuse.	# of stored assets not reused at measurement point	Lim (1998)
Post Project Reviews	Frequency of post project reviews	Indicates the level to which a company adds value to new projects by organising post projects reviews by reusing parts that will bring benefit for the project and loosing all the negative ones.	# of post project reviews per unit of time	
Reusability of Asset	Qualification for reuse	Measures the quality and variability of a particular reusable asset. A high score suggests the object being a valuable core asset.	e.g. # of times an asset is reused per unit of time	Lim (1998)
Reuse Assessment	Reuse costs, benefits, risk assessment level	Indicates the importance of cost / benefits / risk assessment in reuse process decision making.	# of reuse assessments conducted per unit of time	
Reuse Retrieval Cycle-Time	Time to reuse	Indicates the cycle-time until a request is processed by the system; i.e. until potential assets are presented to the inquiring user and retrieved (physically / virtually).	elapsed time until requested assets are available for reuse	
Variety of Reuse	Qualification for variability	Measures the variety of different possible applications of a reusable asset. A high variety indicates creativity in identifying new applications and suggests that a reusable asset is available in a standardised version.	# of different applications of a particular asset per unit of time	Lim (1998)

Subject: Reuse Process

Measure	Metric	Description	Formula	References
Black-Box Reusability of Assets	Qualification for unmodified reuse	Measures the qualification of a particular reusable asset for reuse without modification. Such an asset is highly adaptive and a considerable core asset.	# of times a particular asset is reused without modification per unit of time	Lim (1998)
Black-Box Reuse Level	Level of unmodified reuse	Measures the ability of an organisation to apply reusable assets to new products without modification. It indicates highly efficient reuse. Nevertheless, it might narrow the scope of applications.	# of assets reused without modification per unit of time	Lim (1998)
Carryover Reusability	Qualification for sequential reuse	Measures the qualification of a particular reusable asset for reuse within follow-up versions of a product (e.g. upgrades). It indicates a level of development standardisation and modular design / production.	# of times a particular asset is reused within subsequent versions of the same product	Lim (1998)
Carryover Reuse Level	Level of sequential reuse	Measures the ability of an organisation to apply their reusable assets to follow-up versions of product (e.g. upgrades). It is an indicator of cost-effective and far-sighted development efforts.	# of assets reused within subsequent versions of same products per unit of time	Lim (1998)
External Information	Availability of external information	Indicates the degree to which the company is scanning the external environment for new ideas and information in general.	# of new ideas used which are derived from another source outside the organisation	
External Reuse Level	Volume of reused assets from external source	Indicates the percentage of reused assets which originate from external sources. A high score is a measure of open-mindedness and readiness to incorporate external knowledge.	# of reused assets from external sources per unit of time	Lim (1998)
Internal Reuse Acquisition	Internal input to reuse store	An indicator of creativity and readiness to make knowledge available to the organisation. However, an unusual high level of internal acquisition suggests neglect of external sources and the "not-invented-here-syndrome".	# of acquired reusable assets from internal sources per unit of time	Lim (1998)

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Internal Reuse Level	Volume of reused assets from internal source	Indicates the percentage of reused assets which originate from internal sources. A high score is a measure of creativity. It also describes the mechanisms installed for storage and retrieval of reusable assets.	# of reused assets from internal sources per unit of time	Lim (1998)
Knowledge Sharing Channels: After Action Reviews	Number of after action reviews	After action reviews provide good opportunity to learn from previous failures and successes, and to share this learning.	# of after action reviews per year	
Knowledge Sharing Channels: CoP	Activity of communities of practice (CoP)	Measures how well this learning and knowledge sharing tool is implemented.	# of active CoPs	
Knowledge Sharing Channels: Design Reviews	Effectiveness of design review	Good design reviews provide opportunity for project related ideas and knowledge exchange between all stakeholders.	results (rating) of periodical audits, checking regularity, openness, actual results, scope, participants lists etc	
Knowledge Sharing Channels: Knowledge Sharing Events	Number of knowledge sharing events	Knowledge sharing events increase knowledge sharing. For example: seminars, lectures, knowledge fairs etc.	e.g. average # of knowledge sharing events per month, each employee participate in.	
Knowledge Sharing Channels: After Action Reviews	Number of after action reviews	After action reviews provide good opportunity to learn from previous failures and successes, and to share this learning.	# of after action reviews per year	
Knowledge Sharing Channels: CoP	Activity of communities of practice (CoP)	Measures how well this learning and knowledge sharing tool is implemented.	# of active CoP	
Knowledge Sharing Channels: Design Reviews	Effectiveness of design review	Good design reviews provide opportunity for project related ideas and knowledge exchange between all stakeholders.	results (rating) of periodical audits, checking regularity, openness, actual results, scope, participants lists etc	
Knowledge Sharing Channels: Knowledge Sharing Events	Number of knowledge sharing events	Knowledge sharing events increase knowledge sharing. For example: seminars, lectures, knowledge fairs etc.	e.g. average # of knowledge sharing events per month, each employee participate in.	
Reuse Acceptance Rate	Volume of acceptance of reusability	Indicates the quality and potential reusability of submitted assets. The measure is two-edged: a high score might result from highly qualitative asset generation or from insufficient assessment and catalysation of submitted assets.	# of assets accepted for reuse per unit of time	Lim (1998)
Reuse and / or Invention	Balance between product maintenance, related and unrelated to new product efforts	Measures the ability of an organisation to balance between reuse and invention, to weigh the risks, costs and the alternatives.	# of products maintained rated to the # of new products per unit of time	Krogh et al. (1988)
Reuse Deletion Rate	Renewal frequency	Indicates the turnover of reuse assets. A high deletion rate might on the one hand point to an actual and frequently updated reuse store. On the other hand it perhaps suggests unqualified assets as well as negligent and superficial handling of assets.	e.g. # of obsolete assets deleted from reuse store per unit of time	
Reuse Search Effectiveness	Volume of hits	Measures the precision of a reuse store search scheme. A high score indicates a diligent categorisation and classification of assets.	# of qualified assets presented relative to all assets in store	Lim (1998)
Reuse Store Actuality	Age of assets	Measures the actuality of reusable assets stored. A high volume of young assets indicates frequent review and update, but implies the danger of deletion and neglect of mature assets.	e.g. # of assets in reuse store younger than x years	
Reuse Submission Rate	Volume of proposals for reusability	Indicates the ability to create potentially reusable assets and the readiness to share these assets across the organisation. Thus, it is a measure of creativity and awareness of knowledge reuse.	# of assets submitted for reuse verification per unit of time	Lim (1998)
Virtual Information Flow: Cross-Departmental Communication Level	Frequency of formal IT supported cross-de-partmental exchange	Measures the frequency of formalised communication mechanisms between NPD and Production Management. Early consideration of manufacturing constraints and abilities is vital to avoid re-design.	e.g. # of IT supported cross-departmental meetings per unit of time	
Virtual Information Flow: Internal Information Flow	Virtual internal information flow	Measures the volume of internal computerised information flow.	e.g. volume of daily transactions on the intranet per employee	
Virtual Information Flow: External Information Flow	Virtual external information flow	Measures the ability of a company to collect information which is available world wide.	e.g. volume of general information transfer flow per unit of time per employee	AIT (1998)
Virtual Information Flow: Discussion Groups	Activity level of virtual discussion groups	Discussion groups provide the opportunity for effective knowledge sharing which is not dependant on shared time and space.	# of monthly transactions in discussions groups per employee	
White-Box Reusability	Qualification for modified reuse	Measures the general qualification of reusable asset for reuse, even though it needs modification. A high score suggests that an organisation is actively reusing assets and puts efforts in adapting (standardised) assets to new applications.	# of times a particular asset is reused with modification per unit of time	Lim (1998)

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White-Box Reuse Level	Level of modified reuse	Measures the ability of an organisation to apply reusable assets at the cost of modification. A high level signals creativity in reuse, but also implies time and financial efforts required for adaptation.	# of assets reused with modification per unit of time	Lim (1998)

Facet: Stakeholder Contribution

Subject: Customer

Measure	Metric	Description	Formula	References
Customer Base	Customer purchases	It shows the success of company's investments in R&D process and to every process related to this.	Volume of average customer purchases per year	Edvinsson and Malone (1997)
Customer Involvement	NPD-Customer communication level	Indicates the ability of a company to set and develop a real communication channel with its customers. Intensive interaction between NPD personnel and the customers improve the understanding of the real needs and enhances mutual fertilisation.	# of hours spent by NPD unit with the customers	
Customer Relationship	Frequency of formal communication with external customers	Measures the frequency of formalised communication with customers. It indicates closeness to the market.	e.g. # of meetings with key customers per unit of time	Kennerley and Neely (2000)
Customer Support	Customer IT literacy	It indicates IT customers' competence threshold in order to remain successful customers.	# of customers who have a certain IT competence / total customers (%)	Edvinsson and Malone (1997)
External Customer Involvement	Level of involvement of external customers in NPD	Measures the active involvement of external customers (end-users) in NPD. It is crucial for meeting customer requirements. High customer involvement improves NPD outputs (fit for purpose).	# of NPD projects actively involving external customers relative to all NPD projects	
Internal Customer Involvement	Level of involvement of internal customers in NPD	Measures the active involvement of internal customers in NPD projects. It is crucial for meeting requirements.	# of NPD projects actively involving internal customers relative to all NPD projects	

Subject: Management

Measure	Metric	Description	Formula	References
Industry-Wide Efforts	Industry development investment	It looks at the company's participation in industry-wide efforts such as trade organisations. Includes such things as salaries of executives on loan to associations, and comparable contributions.	volume of investments on industry development / total investments	Edvinsson and Malone (1997)
Investment Process	R&D investment level	Indicates how much of a company's profits are invested in an R&D development. Indicates the company's technology orientation.	% of profits spent on R&D	
Management Intervenience	Frequency of management intervenience	Indicates how often Senior Management interferes with project work.	# of interferences from senior management with project work per unit of time	
New Product Business Areas	New product based business areas / ventures started	Counts the number of business areas or ventures set up for new product development.	# of new product based business areas / ventures started per unit of time	Chiesa et al. (1996)
NPD Board Involvement	Members from product development on the corporate and subsidiary board	Measures the number of NPD employees involved in decision making process.	# of members from product development on the corporate and subsidiary board	Chiesa et al. (1996)
NPD Budget Level	Absolute level of (annual) NPD budget	Measures the financial commitment of Senior Management to NPD in absolute figures. Quality and quantity of NPD efforts are likely to increase relative to budget.	amount of nominal capital provided to NPD over unit of time	
NPD Budget Level Change	Development of (annual) NPD budget	Measures changes (increase / decrease) of financial commitment of Senior Management to NPD.	% change to NPD budget over unit of time	
Personnel	Staffing ratios	It provides for a scalability as an organisation grows and shrinks over time. It measures the human capability in an organisation.	total engineers / # dedicated to NPD	Goldense (1993)
R&D Personnel	R&D sufficient number of personnel	It indicates the optimum number of R&D personnel considered to be sufficient for a proper activity.	# of sufficient R&D personnel for a proper activity	Brown & Gobeli (1992)
R&D Programme	Business development expense	Measures the company's commitment to building structural capital for the future.	business development expense / administrative expense (%)	Edvinsson and Malone (1997)
Risk Evaluation	Market Risk	Indicates the uncertainty of earnings from changes in market conditions such as the asset prices, interest rates, volatility and market liquidity.	e.g. a potential total loss expressed in currency terms	Longerstaey and More (1995)
Risk Evaluation	Liquidity Risk	Indicates the ability of a firm to fund illiquid assets.	e.g. the length of time an institution can survive without liquid money	Longerstaey and More (1995)
Risk Evaluation	Operational Risk	Measures the number of errors that can be made in instructing payments or settling transactions.	e.g. estimated time for tracking errors	Longerstaey and More (1995)
Risk Evaluation	Credit Risk	Indicates potential losses due to the inability of a counterpart to meet its obligations.	e.g. total loss due to non-fulfilment of the obligations of a counterpart expressed in currency terms	Longerstaey and More (1995)
Security Requirements	Securities required for funding NPD projects	Measures the value / content of securities Senior Management requires from NPD managers for funding a project. It is an indicator of capital accessibility.	e.g. value of security as % of funding	Kennerley and Neely (2000)

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Senior Management Involvement	The degree of co-operation between the management and the NPD team	Indicates the time and effort spent by the management personnel with the NPD team in order to understand the plans and objectives of their activity.	e.g. number of meetings between the management and product development team having like main topic NPD activities	
Uncertainty	Probability of overall success	The product of technical and commercial probabilities.	Probability units, 0.1-0.9	Roussel et al. (1991)
Uncertainty	Probability of commercial success	The probability of commercial success if the project is technically successful.	Probability units, 0.1-0.9	Roussel et al. (1991)
Uncertainty	Probability of technical success	Indicates the probability that the objective will be achieved as defined.	Probability units, 0.1-0.9	Roussel et al. (1991)
Value Creation	R&D expenditure segmentation	Presents the percentage of R&D expenditure that is issued on projects that is aimed at the development of future product lines or future technologies.	future products R&D budget / total R&D budget	

Subject: Marketing

Measure	Metric	Description	Formula	References
Market Strategy	Market competitiveness	Describes whether or not the firm enters highly competitive new product markets featuring intense price competition and a high level of customer satisfaction with competitors products.	# of markets which have customers satisfied with competitors' products per unit of time	Cooper (1985)
Market Strategy	Competitive loyalty	Describes the firms tendency to enter new product markets featuring a high degree of customer loyalty to a competitor.	# of new product markets which have customers loyal to competitors per unit of time	Cooper (1985)
Marketing Synergy	Marketing synergy level	Indicates the degree of fit between the firm's new product markets and its marketing resource base (channels and sales force, advertising and promotion skills and market research resources).	# of new products fit firms' marketing resource base per unit of time	Cooper (1985)
New Markets Development	New markets development investment	Indicates the company's investment in developing new markets for its products and services.	volume of investments on new market development / total investments	Edvinsson and Malone (1997)
Overall Orientation	Marketing orientation and domination	Indicates a new product programme dominated by a marketing group and strongly market oriented, proactive on market need identification, and relying on market-derived new-product ideas.	# of new product ideas which are product derived per unit of time	Cooper (1985)
Overall Orientation	Market need and offensive orientation	Describes the ability of an organisation to develop an offensive programme aimed at increasing market share (as opposed to defensive), with an active idea search effort relying heavily on market research.	# of active new product ideas aimed at gaining market share per unit of time	Cooper (1985)
Type of Markets	Export orientation	Portrays the international scope of the firm's new product markets.	# of products which are aimed at world markets per unit of time	Cooper (1985)

Subject: Production

Measure	Metric	Description	Formula	References
Production Specification	Production requirements available to NPD	Measures the availability of production specifications to NPD. Early knowledge of these requirements is vital to design for manufacturability.	# of production requirements communicated relative to all production requirements	Kennerley and Neely (2000)
Production Involvement in NPD	Production staff involved in NPD	Measures the number of production employees who are involved in product development	# of production staff involved involved in NPD / # of production staff	

Subject: Regulators

Measure	Metric	Description	Formula	References
Public Reputation	Image to relevant public	Measures the reputation of an organisation in its relevant environment. It is an indicator of attractiveness as supplier, as employer and as partner / sponsor.	e.g. # of positive press coverage per unit of time	
Regulator Relations	Quality of relationships with regulators	Measures the quality and maturity of an organisation's interaction with relevant regulators. It is an indicator of responsibility, adherence to law, reputation, etc.	e.g. # of meetings with community representatives per unit of time	Kennerley and Neely (2000)
Relationships: Community Involvement	Employee involvement in the wider community activities	Involvement of the employees in the wider community enhances the organisation spirit, and is a source of unexpected ideas and insights.	# of hours spent in activities with the wider community (schools etc.)	
Relationships: Other NPD Organisations	Intensity of interactions	Learning from other NPD organisations is a major source of ideas, reuse opportunities, and skill enhancement.	# of knowledge sharing events with other NPD organisations (mutual visits, meetings etc.)	
Relationships: Partners Interactions	Intensity of interactions of NPD personnel with NPD partners	Intensive interaction between NPD personnel and NPD partners (join ventures, design subcontractors, suppliers) enhances mutual fertilisation, knowledge and ideas flow.	Average # of hours spent by each NPD employee with business partners (visits, meetings etc.)	
Relationships: Scientific Activity	Intensity of the academy – organisation project based relationships	Co-operating on projects can benefit both commercial NPD organisation and scientific institutions.	# of projects in which academy is involved as full partner, major supplier or similar capacity	
Standardisation: "Green" Certifications	Certification to environmental standards	Awareness of environmental issues is critical in sustainable NPD processes.	% of units certified to a relevant environmental standard (e.g. ISO 14000)	
Standardisation: CMM	CMM certification level	System CMM,SW CMM, people CMM levels indicates the maturity of the processes in the organisation.	% of units that reach a certain level of CMM	

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Standardisation: Quality Awards	Quality awards	Self or external assessment based on criteria of Baldridge awards or similar awards, is a detailed measure of the organisation's quality.	Ranking in quality competitions e.g. the Baldridge award (external or self assessment)	
Value Creation	R&D co-operation metric	Presents quantitative figures on co-operation agreements of different nature aimed at supporting R&D "time-to-market", risk reduction or vital know-how.	# of alliance, small alliance, merge or acquisition, joint venture	
Value Creation	Product announcements	Product announcements in trade journal.	# of product announcements weighted by importance	

Subject: Suppliers

Measure	Metric	Description	Formula	References
Supplier Contribution	Supplier involvement level	Indicates the ability of a company to involve a supplier into the design process and to make him understand the requirements he needs to fulfil.	# of hours spent on getting the supplier to understand the requirements and the design process	
Supplier Involvement	Creative input contributed by suppliers.	Measures the degree to which suppliers are involved in creative processes. It indicates the comprehensiveness of innovation management. Co-development with suppliers frequently enhance NPD quality and quantity and is therefore to be assessed.	# of new assets developed with suppliers relative to all new assets	Kennerley and Neely (2000)
Supplier Involvement	Level of resources spent on clarifying the requirements and design process with the supplier	Indicates the level of interest the company has in making its process and design requirements clear to the supplier. It indicates the degree of involvement the supplier has in the manufacturing process. It will bring quality to the NPD process.	e.g. the length of time spent on making the supplier understand the process and design requirements	
Internal Supplier Involvement	Internal Suppliers Focus	Measures the degree in which a company concentrates on internal supplier relationship in order to provide intra-departmental communication, delivery and responsiveness quality.	e.g. # of quality in time delivered products to the internal customers	

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Appendix C: The semi structured interview questionnaire

Reuse and Invention Performance Management in New Product Development

The objective of this semi structured interview is to verify recent research findings of the European Project "NIMCube (New-use and innovation measurement and management methodology for R&D)" at industrial users sites. You may find more information on the project at www.nimcube.com. All interview results will be considered strictly confidential.

A. Organisation			
Name of company:			
Country:			
Sector:	❑ industry	❑ services	❑ public institution
Please specify:			
Main product(s) / service(s):			
Total turnover in the last year:			Euro
R&D budget (% of turnover, if applicable):			%
Number of employees:			Number

B. Your details
Your department name?
Your role & position?
Your name (optional)?

C. Design of the PMS: General strengths, weaknesses, opportunities and threats of the PMS

C.1. What are the general strengths of the PMS solution implemented at your company?

C.2. What are the general weaknesses of the PMS solution implemented at your company?

C.3. What are the general opportunities of the PMS solution implemented at your company?

C.4. What are the general threats of the PMS solution implemented at your company?

D. Building and implementing the PMS: General strengths, weaknesses, opportunities and threats of the PMS

D.1. What are the general strengths of the PMS build and implementation concept?

D.2. What are the general weaknesses of the PMS build and implementation concept?

D.3. What are the general opportunities of the PMS build and implementation concept?

D.4. What are the general threads of the PMS build and implementation concept?

E. Meeting of needs and fulfilment of functional specification

E.1. Do you think that the implemented PMS solution meets your needs identified during the requirements engineering phase through the functions identified within the QFD conducted at your company?

NEEDS (see also QFD)	Complete fulfilment	Good fulfilment	Fair fulfilment	No fulfilment
Decision support regarding reuse[81]	❑	❑	❑	❑
Communication of reuse and invention strategy throughout the organisation	❑	❑	❑	❑
Store for reuse and invention assets to become more efficient	❑	❑	❑	❑
Explicit measurement of customer contribution to	❑	❑	❑	❑

81 The needs are company specific, the above needs are an example.

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NPD success				
Specific measures for efficient reuse of knowledge	❑	❑	❑	❑
User friendliness of the solution	❑	❑	❑	❑
Minimal additional effort in maintaining, migrating, processing data	❑	❑	❑	❑
Involvement of all stakeholders	❑	❑	❑	❑
Solutions should be based and rely on proven standards	❑	❑	❑	❑
Easy and cost effective implementation of the PMS	❑	❑	❑	❑
Fulfilment of the "80-20" rule	❑	❑	❑	❑
Improving the quality of the offer process through a controlled management of knowledge	❑	❑	❑	❑

E.2. In your opinion which of the 9 PMS functional clusters have been addressed to which level of satisfaction?

Functions	Complete Satisfaction	Good Satisfaction	Fair Satisfaction	Unsatisfactory
Standardisation	❑	❑	❑	❑
Data processing mechanism	❑	❑	❑	❑
Transparency	❑	❑	❑	❑
Participation	❑	❑	❑	❑
Alignment	❑	❑	❑	❑
Comprehensiveness	❑	❑	❑	❑
Effectiveness	❑	❑	❑	❑
Operability	❑	❑	❑	❑

E.3. What additional needs, requirements and potential functions did you determine during the PMS project and to which degree does the current PMS solution address those issues?

F. Meeting of purposes

F.1. Did the provided functions help your company to support awareness, understanding, management of reuse and invention to improve NPD performance on strategic as well as on operational level.

F.2. Did the provided functions help your company understand and support the improvement of the balance between reuse and invention.

G. Lessons learned from the use of the system

F.1. What are your major lessons learned after working with the PMS for more than 5 months?

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Appendix D: Expert interview questionnaire

The following list below summarises the main questions which were posted to the experts mentioned in section 2.2.2.

- What effect, do you think, does measurement have on the reuse of existing knowledge?
- What effect, do you think, does the reuse of existing knowledge have on measurement?
- What effect, do you think, does Innovation management have on measurement?
- What effect, do you think, does measurement have on Innovation management?
- What is your personal definition of measurement / metric?
- As you know , this project is seeking to 'balance the reuse of existing knowledge with the need to be innovative in an NPD context. From your experience, could you foresee any critical success factors, essential to create an effective measurement system, which would support this methodology?
- Which, in your opinion, are the main challenges for performance measurement systems within an NPD context for the 2000's?
- What effect, do you think, does the reuse of existing knowledge have on Innovation management?

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Appendix E: The survey questionnaire

Reuse and Invention Performance Management in New Product Development

The objective of this survey is to evaluate and justify recent research findings of the European Project "NIMCube (New-use and innovation measurement and management methodology for R&D)". You may find more information on the project at www.nimcube.com. All survey results will be considered strictly confidential.

A. Organisation

Name of company:			
Country:			
Sector:	❑ industry	❑ services	❑ public institution
Please specify:			
Main product(s) / service(s):			
Total turnover in the last year:			Euro
R&D budget (% of turnover, if applicable):			%
Number of employees:			Number

B. Your details

Your department name?
Your role & position?
Your name (optional)?

C. Innovation, Invention and Reuse

C.1. How would you rate your company's innovation performance, relative to your competitors or to your expectations?

Our definition: Innovation = (invention + reuse) X exploitation

❑	❑	❑	❑
very good	good	moderate	not sufficient

C.2. How would you rate your company's invention performance, relative to your competitors?

Our definition: Invention = generation of new knowledge and its novel application. Knowledge comprises tangible and intangible assets, such as ideas, modules, documents, etc.

❑	❑	❑	❑
very good	good	moderate	not sufficient

C.3. How would you rate your reuse performance, relative to your competitors?

Our definition: Reuse = recurring application of existing knowledge in diverse contexts. Knowledge comprises tangible and intangible assets, such as ideas, modules, documents, etc.

❑	❑	❑	❑
very good	good	moderate	not sufficient

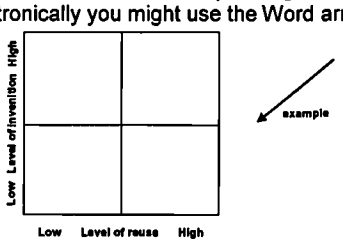
C.4. How would you rate your company's balance between reuse and invention?

❑	❑	❑	❑
very good	good	moderate	not sufficient

C.5. How important is it for you to maintain a sound balance between reuse and invention in your company?

❑	❑	❑	❑
very important	important	fairly important	not important

C.6. What is the typical relation between reuse and invention in your organisation? (please indicate below; if you should fill out the questionnaire electronically you might use the Word arrow function)



C.5. Do you agree with the following definition of innovation?

Our definition: Innovation = (invention + reuse) X exploitation;
exploitation = the ability to commercially exploit ideas, via new products, and turn them into profits (or value in a non-profit organisation).

❑	❑	❑	❑
strongly agree	agree	fairly agree	disagree

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D. The NIMCube Invention and Reuse Performance Management Method

D.1. In your opinion, can the explicit management and measurement of reuse and invention performance have a positive impact on New Product Development performance?

Our definition: Measurement is part of a management process which collects and interprets data and information about actual performance.

	strong impact	Impact	weak impact	no impact
Product quality	❑	❑	❑	❑
Product performance	❑	❑	❑	❑
Time to market	❑	❑	❑	❑
Development cost	❑	❑	❑	❑
Product cost	❑	❑	❑	❑
Profitability	❑	❑	❑	❑
Competitiveness	❑	❑	❑	❑

D.2. In your opinion, does such measurement of reuse and invention require metrics that are unique to your organisation?

❑	❑	❑	❑
very necessary	Necessary	fairly necessary	not necessary

D.3. In your opinion, does the measurement of reuse and invention require alignment to a company's R&D strategy?

❑	❑	❑	❑
very necessary	Necessary	fairly necessary	not necessary

D.4. In your opinion, does the management and measurement of reuse and invention require a process-oriented performance measurement infrastructure?

❑	❑	❑	❑
very necessary	Necessary	fairly necessary	not necessary

D.5. In your opinion, are the following six measurement perspectives useful to measure NPD performance:

- ❑ **Reuse** – describing factors and processes in reuse of knowledge
- ❑ **Invention** – describing factors and processes in generation of new knowledge
- ❑ **Performance** – describing the outcome of NPD efforts measured against stakeholder expectations
- ❑ **Exploitation** – describing the ability to exploit new products and turn them into products
- ❑ **Ecology** – describing the impact and quality of the working environment and organisational factors on NPD
- ❑ **Stakeholder Contributions** – describing the input of diverse stakeholders (management, suppliers, customers, ...) in NPD

	very useful	Useful	fairly useful	not useful
Reuse	❑	❑	❑	❑
Invention	❑	❑	❑	❑
Performance	❑	❑	❑	❑
Commercialisation	❑	❑	❑	❑
Ecology	❑	❑	❑	❑
Stakeholder Contributions	❑	❑	❑	❑

D.6. In your opinion, how important is an appropriate environment (infrastructure, culture, leadership human resource (HR) management and physical environment) for reuse and invention?

	very important	important	fairly important	not important
IT infrastructure	❑	❑	❑	❑
Culture	❑	❑	❑	❑
Leadership	❑	❑	❑	❑
HR management	❑	❑	❑	❑
Physical environment	❑	❑	❑	❑

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