Cranfield University

School of Industrial and Manufacturing Science



PhD Thesis

ACADEMIC YEAR 2005-06

Markus Grüneisl

Dimensioning of an Automotive Final Assembly Shop Using a System of Key Performance Indicators

Supervisor: Professor John M. Kay

January 2006

This thesis is submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy

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"Strive for perfection in everything you do.
Take the best that exists and make it better.
When it does not exist, design it."

Sir Henry Royce
(1863-1933)

Abstract

All worldwide operating automobile manufacturers are on the constant search for the optimum between desirable flexibility on that one hand and required cost productivity on the other hand.

In particular, the planning of a new final assembly shop of a car manufacturer is a big challenge since a huge number of influencing factors must be taken into consideration, so that in the end a best-practice final assembly shop with the desired attributes is created. To minimise the risk of bad planning, the length of time for the planning process should be shortened and at the same time the planning exactness should be improved with the help of new tools.

This research project demonstrates that in the early stages of the planning process key performance indicators could be a proper instrument to achieve the the desired effects. Even if key performance indicators have been used in many areas of industry over several decades, this is the first research project which deals in this degree of accuracy with the dependencies between the different key performance indicators during the factory planning process for a new final assembly shop of a car manufacturer. Following the basic idea of 'System Thinking', numerous key performance indicators were linked to each other in an adaptable system of key performance indicators.

During this research project, the developed model was successfully evaluated with four locations of the research partner BMW Group. Since the results are all between ± 20%, which is a sufficient exactness for this planning stage, there is great confidence that this general system of key performance indicators could also be important to other automobile manufacturers. The findings of this research project should serve as a basis for other researchers in this field to enhance the scarce theories about the dependencies.

Besides, the software 'Powersim' and the chosen approach of 'System Thinking' doubtless can be transferred to other industrial areas with similar challenges.

Acknowledgements

First of all I would like to thank my supervisor Prof. John Kay. He has given me the opportunity to realise my dream of writing a doctoral thesis. During the past 3 ½ years he has always supported me with numerous helpful advice. Without his valuable support, his tips and suggestions this work would not have been possible.

I further would like to say thank you to the BMW Group and here especially to all planners and managers involved in this project. They were all very patient in answering my questions over and over again and supported me in recording the data required for this research project. I also thank the managers of the final assembly shops at the different locations for making the required resources available. Representing a gigantic circle of helpful persons within the BMW Group I may thank the following persons with all my heart: Mr. Jörg Bause, Mrs. Barbara Bergmeier, Mr. Olaf Cordts, Dr. Bernhard Eich, Mr. Manfred Erlacher, Mr. Jan Knau, Mr. Helmut Köhne, Dr. Jochen Lorenzen, Mr. Gerhard Menzel, Dr. Ulf Osmers, Mr. Erich Schwinge and Dr. Nils Tönshoff. They all gave me the opportunity to investigate the thrilling field of factory planning with an automobile manufacturer practically oriented and, besides that, were to me always open and honest counsellors.

A special thanks goes to Mr. and Mrs. Hollreiser as well as Mr. and Mrs. Mitchell who gave me a helpful hand to improve the spelling of my English written manuscript.

For the intensive support and the constructive discussion during the process of model building, I thank Dr. Kai Berendes of the Management Zentrum St. Gallen as well as Dirk Altmann, Michael Bihr, Michael Geisler, Manuel Günnewicht and Richard Kiank. Their helpful support was very meaningful for the success of this research project.

I also say thank you to Prof. Markus Petry and Prof. Andreas Jattke both of the University of Applied Sciences in Ingolstadt and Mr. Jörg Herkommer of Ingenics for the critical assessment of the chosen approach.

In my private setting I thank all my friends who have motivated me consciously or unconsciously over and over again to finish my thesis successfully.

I also thank my girlfriend Johanna for her patience and her understanding while I was working on this research project and writing the thesis. It is good to know that she is on my side.

Finally I thank my parents Regina and Ludwig Grüneisl for their affectionate support and their trust in me during the past 30 years. They have taught me the attributes necessary for finishing this research project successfully. Only with their support was it possible to write this thesis. Since I believe in the strength of the family, I dedicate this thesis to my parents and my grandparents.

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Table of Abbreviations

ABC	Activity Based Costing
ATO	Assemble to order
BMW	Bayerische Motorenwerke
BSC	Balanced Scorecard
DIN	Deutsche Industrie Norm
e	element
EFQM	European Foundation for Quality Management
e.g.	example gratia (Latin) = for example
et al.	et alii
etc.	et cetera
ETO	Engineer to order
EU	Europea Union
FA	Fully Automated
FIZ	Forschungs- und Innovationszentrum
HA	Hinterachse
i.e.	id est (Latin) = that is
KOPF	**K**ey Performance Indicators for an **O**ptimised **P**lanning of a **F**inal Assembly Shop
KPI	Key Performance Indicator
m	metres
MC	Managerial Control
MIT	Massachusetts Institute of Technology
MTO	Make to order

MTS	Make to stock
OEM	Original Equipment Manufacturer
OE	Optional Equipment
PA	Pre-Assembly
ROI	Return on Investment
s	system
SA	Semi-Automated
SD	System Dynamics
SOP	Start of Production
St	Station
TQM	Total Quality Management
USA	United States of America
VA	Vorderachse
VDA	Verband Deutscher Automobilindustrie
VDI	Verband Deutscher Ingenieure
VM	Vormontage
ZVEI	Zentralverband Elektrotechnik und Elektroindustrie

1 Introduction

1.1 Research Background

The changes in industry lead to the fact that "today's competitive manufacturing environment places tremendous pressures on manufacturing plants" (Higgins et al., 1996a, p. vii). That this applies especially to the automobile industry, is confirmed by a study of McKinsey&Company and Darmstadt University of Technology's Institute for Production Management (Kluge et al., 2003) as well as by the authors Ahmad and Benson (1999, p. 100), Maurer and Stark (2001) and Cunha et al. (2003).

Therefore, as in general described by Gunn (1992, p. 3), trends to shift certain volumes of a car or whole factories to lower cost countries in order to reduce costs can be identified. Nevertheless, such pretended potentials for cost reduction may not change the subject from the real problems like poor business processes or over-capacities.

With well organised processes, high-class quality standards and lower production costs in particular, the Japanese automobile industry puts more and more pressure on the European automobile manufacturers (Katzensteiner, 2004; Drucker, 1990, p. 95; Collis and Montgomery, 1995, p. 120; Womack et al., 1990, p. 7; Douglas, 1993, p. 3). As shown in the article 'Flexibility: The Next Competitive Battle' by De Meyer et al. (1989) Japanese companies also position themselves increasingly to the challenge of improved flexibility (Dixon et al. 1990, p. 150; Miller et al., 1992). This battle for satisfied customers and analougus sales figures is tough and leads to a more intensive predatory competition (Dillerup, 1998, p. 50), as shown in figure 1.

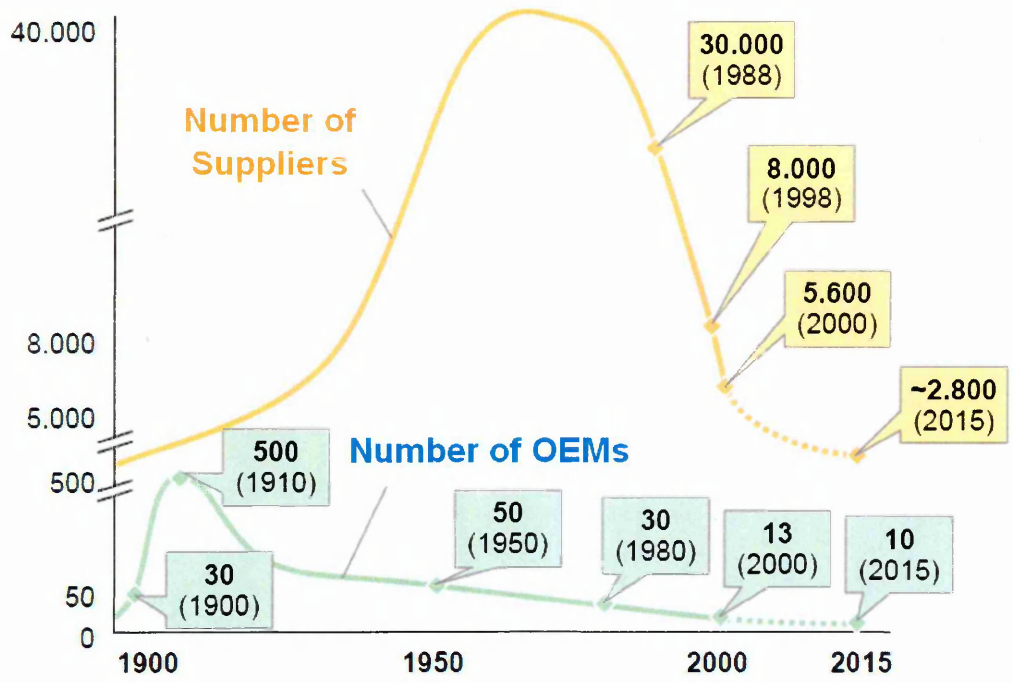


Figure 1 – Consolidation in Car Industry. Mercer Managament Consulting (2005)

Against the background of the following figures, changes in the automobile industry always have a big economic meaning for the single countries (Dillerup, 1998, p. 55) or as Wu (1992, p. 6) calls it, "manufacturing industries may be viewed as the backbone of the nation's economy". Maurer and Stark (2001, p. 8) for example quantify the investment for the 475 auto plants worldwide at around 100 $ billion. According to the annual report 'Auto 2005' of the VDA, in Germany every seventh job (= 5.3 million people) (Gottschalk, 2005) is linked with the automobile industry. Corresponding to this study, in Germany "764,000 employees generated revenues of euro 202 billion and an output of 5.5 million vehicles" in 2002 (Kluge et al., 2003).

Hence, the statement of Gunn (1992, p. 15) that "manufacturing's value added is vital to maintaining any nation's prosperity, competitiveness, and independence" can be agreed without additional comments.

1.2 Motivation

In a tumultuous, constantly changing competitive environment, the planning of a new final assembly shop for a car manufacturer is a big challenge for an enterprise and all responsible employees. Besides the high investments linked to it, the course for the future success or failure of the final assembly shop will be set during the planning process.

Hence, different scenarios for short-term, medium-term and long-term developments must be evaluated early, so that at the time of the opening of the new plant a best-practice final assembly shop can be presented. In doing so, a huge number of different partly changing planning parameters must be taken into consideration. To be able to meet the high requirements on the planning process, it must be the purpose of all experts involved to shorten the length of the planning process in spite of rising complexity and to improve at the same time the exactness of the planning results.

Against this background, all methods and tools which support the planning process must be used. Especially in the early stages of the planning process the use of key performance indicators (= KPIs) will often be recommended, since KPIs have shown their strengths in supporting the decision-making process in many areas of business.

Since an automobile manufacturer builds new plants only in intervals of decades and major rebuildings on existing final assembly shops will be done several years after the last conversion, the subject 'knowledge management' also offers potential. Having in mind the idea of a learning organisation the experiences of the past and the knowledge derived from it must be better used in future planning processes. Because of the numerous dependencies between the planning parameters and the economic meaning for an enterprise the resource knowledge may not be disregarded in the planning process.

All these facts and the problem described below gives a hint that there are still potential improvements working with key performance indicators in the area of planning a new final assembly shop of a car manufacturer. Some of these improvements should be realised at least partially with the present work.

1.3 The Original Problem

Within the planning for the new vehicle plant in Leipzig, the BMW Group already at the early planning stages wanted to make sure, following the Japanese idea of 'dantotsu' (= best of the best) (Camp, 1989, p.12) that the new final assembly shop at the start of production (= SOP) fulfils all criteria of a best-practice final assembly shop. Among the other tools, key performance indicators should be used at the beginning of the planning process to check the plausibility of the planning results and to optimise the final assembly shop as early as possible. However, it quickly became obvious that the few approaches offered in the literature contain plenty of shortcomings. Since the varied factors of influence on a final assembly shop are only illustrated insufficiently with simple key performance indicators, these key performance indicators could not be used as a reliable basis for the planning process. As a result of the complexity of a final assembly shop of a car manufacturer, the usage of reference values from internal or external benchmarks also was barely possible at this level of detail.

In the end, the following research question was derived from these problems:

How are the key performance indicators linked to each other and is it possible to better consider these interrelationships at the early stages of the greenfield planning process for a final assembly shop of a car manufacturer?

1.4 Basic Information about the BMW Group

As shown in the annual report 2004, the BMW Group consists of the three brands BMW, Mini and Rolls-Royce Motor Cars (BMW Group, 2005). "The BMW Group is the only manufacturer of automobiles and motorcycles worldwide that concentrates entirely on premium standards and outstanding quality for all its brands and across all relevant segments" (BMW HP, 2005).

Even though only the car segment is relevant for this research project, for reasons of completeness the other main business divisions are mentioned below:

- Motorcycles.
- Financial Services.

In the business year 2004, the BMW Group in sum generated revenues at euro 44,335 million (= 6.8% ahead of the previous year). The group net profit for 2004, at euro 2,222 million, was a new record, beating the previous year's figure by 14.1%. At the end of 2004, the BMW Group had a workforce of 105,972 employees, from which 99,043 are assigned to the automobile segment (BMW Group, 2005).
The BMW Group produced 1,250,345 cars (= BMW, Mini and Rolls-Royce) and delivered 1,208,732 cars to the customer. The breakdown of the delivered vehicles is shown below:

- 1,023,583 BMW.
- 184,357 Mini.
- 792 Rolls-Royce.

The fragmentation of the key automobile markets as a percentage of sales volume is illustrated in figure 2.

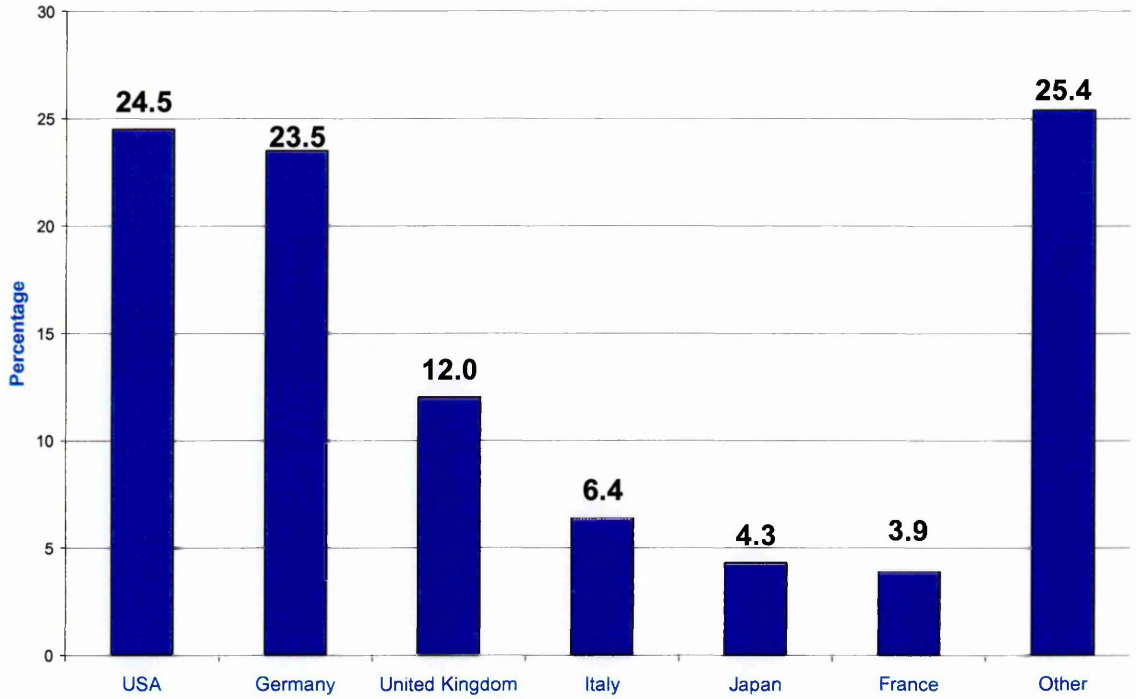


Figure 2 – Key Automobile Markets 2004 of the BMW Group. BMW Group (2005)

1.4.1 Mission / Vision of the Production-Division

As explained later, a system of key performance indicators should be oriented on overall values and strategies. This is the reason for the quotation of both the mission statement and the vision of the production division of the BMW Group. The premium philosophy of the BMW Group and the customer orientation linked with it will be unambiguously communicated with both basic principles.

Mission Statement

Outstanding individuals working together to produce fascinating products.

Vision

To be the best customer-oriented production network in the world.

The following two sections make clear that these basic principles will be kept in mind in daily business.

1.4.2 Product Portfolio of the BMW Group

The continuously growing model palette gives a hint for the necessity for this research project. On the basis of the 3 Series, the 5 Series and 7 Series the BMW portfolio was enlarged during the last few years, which is mapped in figure 3.

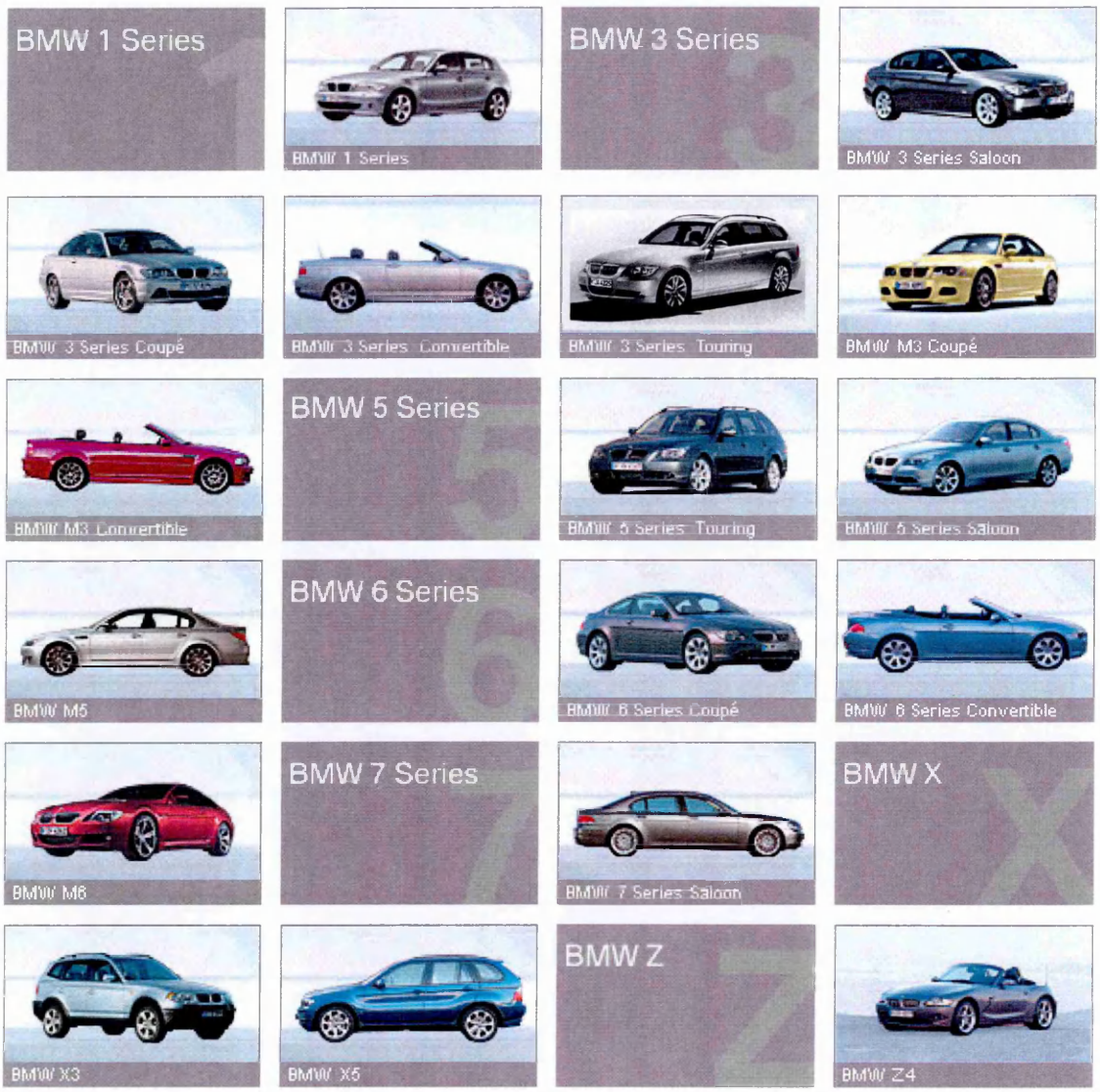


Figure 3 – Product Portfolio of BMW. BMW HP (2005)

This range of products can be expanded with the different models offered by the brands Mini and Rolls-Royce. In view of the complexity that has to be managed at every individual location, it has to be taken into consideration that there is almost no other OEM that offers more individualised products to its customers.

Considering the different models, colours, interior furnishing and accessories and engine types, the customer of the 3 Series can choose from 10^{17} (Reithofer, 2005) possible variations. This variation variety creates a huge number of different options for the planning process. In order to find the best solution for every individual location, these alternatives have to be evaluated against different criteria (e.g. cost effectiveness, flexibility, and so on).
In view of the challenges described at the beginning of this thesis and following to the idea from the "global village" (McLuhan as quoted in Maskell, 1991, p. 3) the optimum not only for one location has to be found, it is also a challenge to optimise the entire production network with its adaptable locations.

1.4.3 Production Network of the BMW Group

The production network of the BMW Group with its essential manufacturing plants illustrated in figure 4 distinguishes itself by its flexibility. Hence, the BMW Group calls its production locations "the backbone for growth in all global markets" (BMW, 2005). Since the final assembly shops are an essential component of this varied production network, the BMW Group seems to offer a good basis for representative research results. Although it has to be considered during this research project that in all locations exclusively high-quality premium vehicles are produced. Whether and how far the already mentioned premium mentality anchored within the enterprise influences the research results, must be observed critically during the research project.

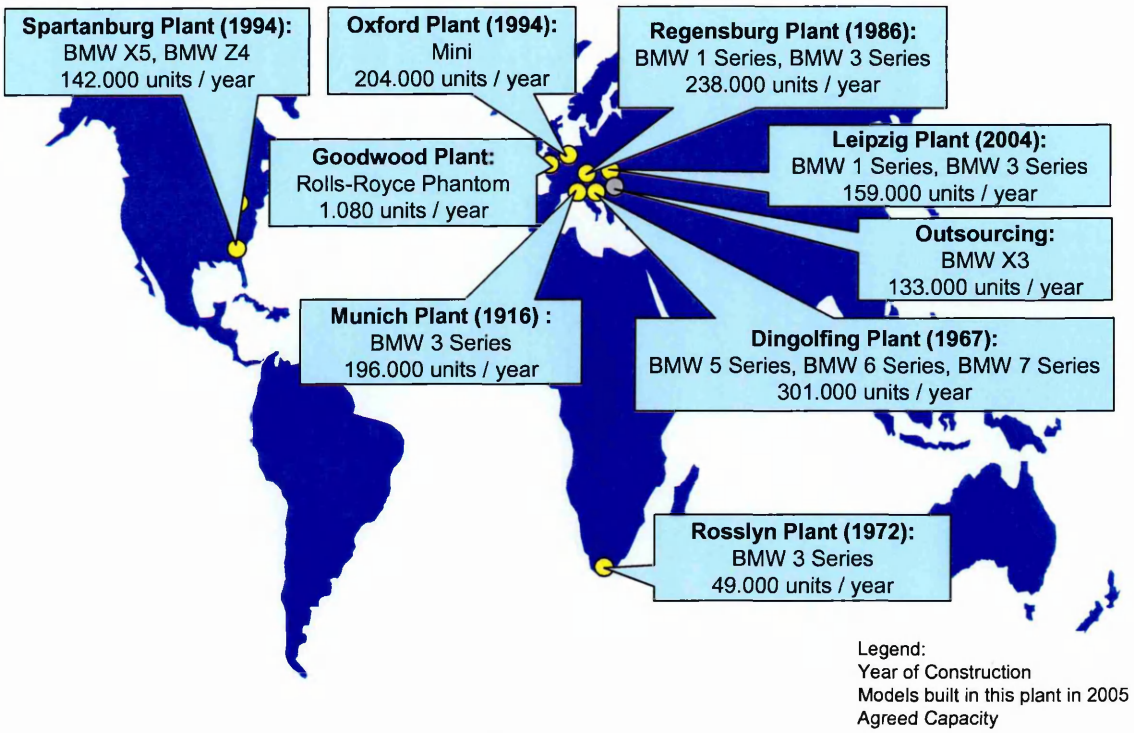


Figure 4 – Production Network of the BMW Group. BMW (2005)

The fact that the production capacity, as pictured in figure 5, is rather small in comparison to other automobile manufacturers should not have an impact on the research findings.

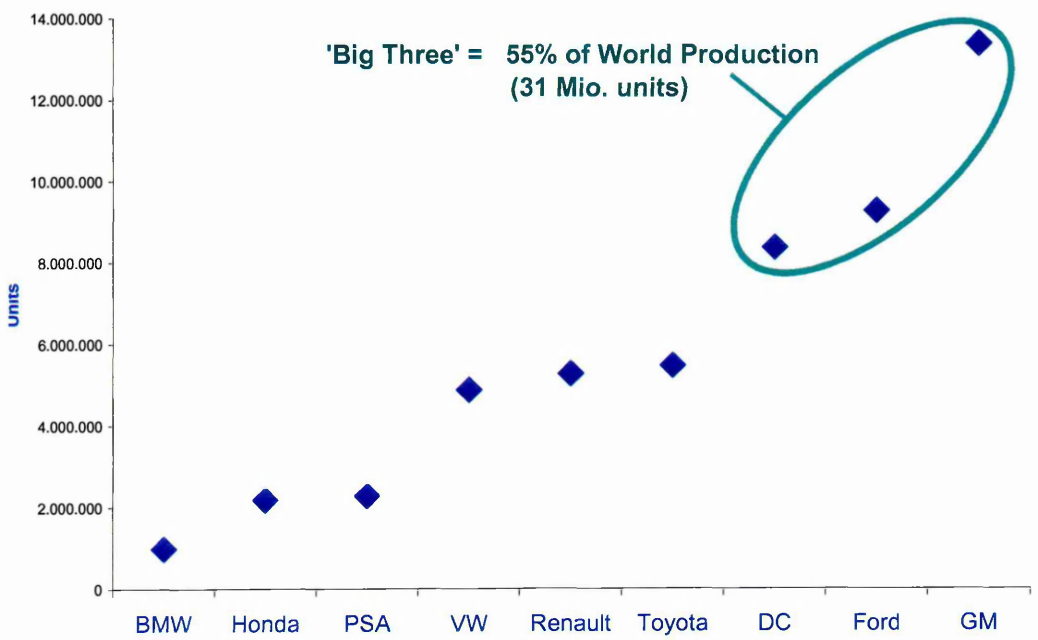


Figure 5 – Worldwide Production Capacity in the Automobile Industry. BMW (2005)

1.4.4 Organisational Structure of the BMW Group

Beside the production locations, the central planning office based in Munich called FIZ (= Forschungs- und Innovationszentrum) is of big importance for this research project. With its short ways this centre promotes the close collaboration of more than 8,500 employees from a wide range of different disciplines. Since a multiplicity of new / strategic ideas arises from the FIZ in Munich, it is known as the "technical brain of the BMW Group" (BMW, 2005).
For this research project, the teamwork of the departments involved in the planning process is relevant. At the beginning of the planning process of a final assembly shop, the planners in the FIZ are responsible for the planning results. Depending on the required degree of accuracy and the sensitivity of the questions, the affected locations will be integrated in the early planning stages. The closer the planning project moves to the SOP (= start of production), the stronger the planning capacities and the area of responsibility move away from the central planning departments to the individual locations (see figure 6).

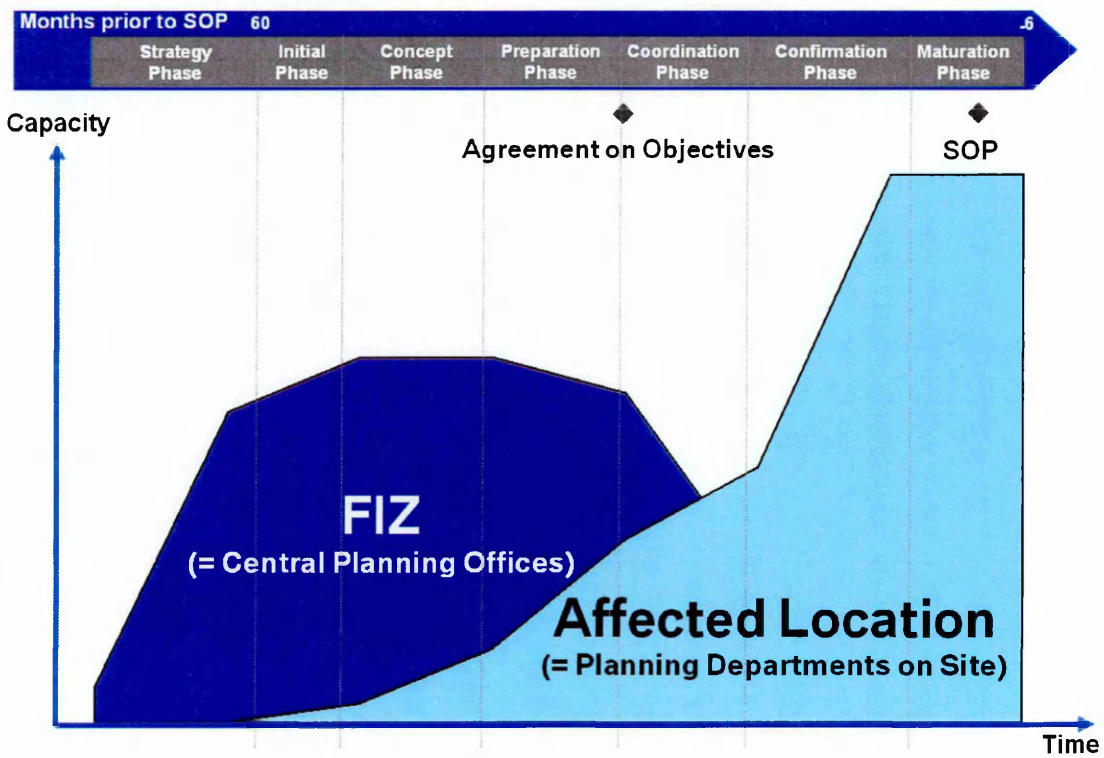


Figure 6 – Planning Capacity within the Planning Process.

This description shows how important it is that over all locations, all persons involved in the planning process basically have the same understanding about the dependencies between the numerous planning parameters. This is needed to ensure that the hand over between the different planning departments will be carried out without major problems. Taking into account the project character of a planning project for a final assembly shop, an essential challenge is recognisable in the know-how transfer. Considering the idea of 'continuous improvement', weak points detected within the planning process, which perhaps only become evident at the end of the planning, must be avoided in spite of changing persons for future planning projects.

1.5 Structure of the Thesis

The research question will be answered with the help of the following briefly described structure illustrated in figure 7.

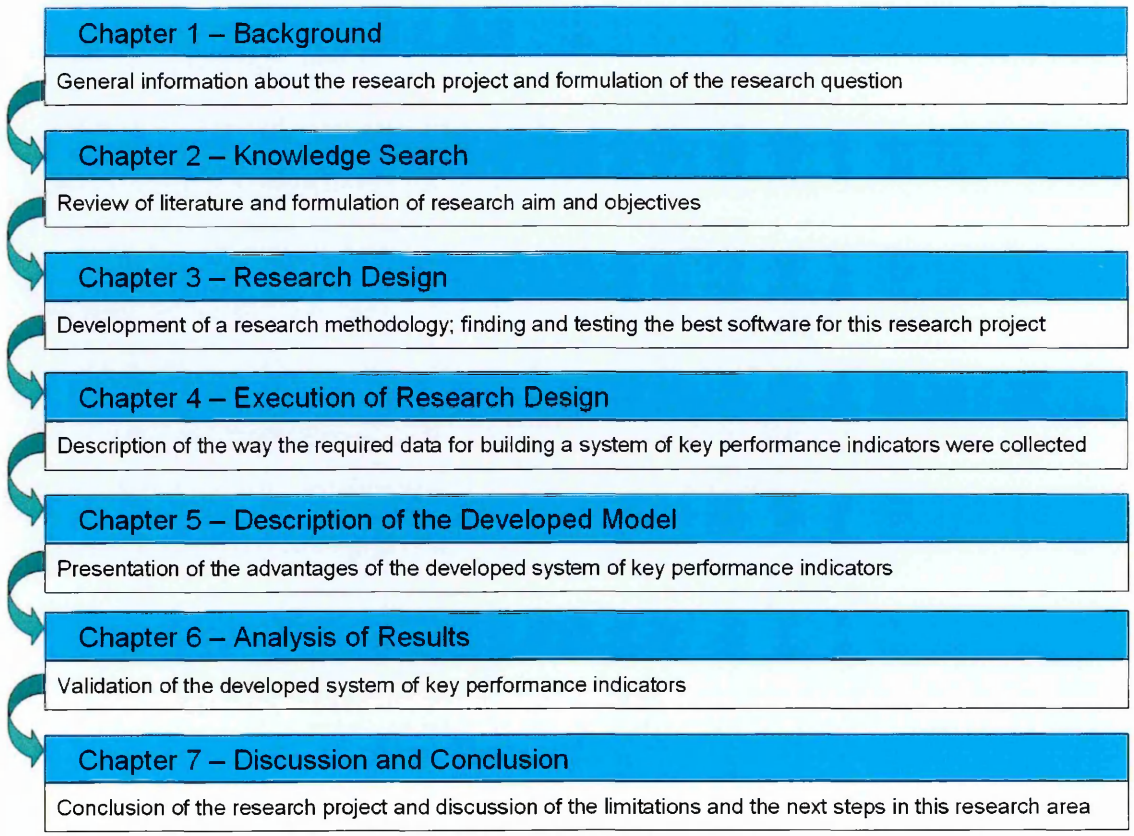


Figure 7 – Thesis Layout.

Chapter 2

After this short introduction, in chapter 2 the available literature will be analysed and assessed in detail.

A review of the thematic blocks 'factory planning' and 'key performance indicators' seems evident. In addition, the 'final assembly shop' with its specific targets will also be introduced in more detail. The analysis of the mentioned areas indicates that the research question could maybe be answered with the help of the idea of the 'System Theory', so that this field will also be reviewed in detail.

As a result of these investigations, the research aim and its matching objectives are fixed at the end of this chapter.

Chapter 3

In chapter 3 the basis for a successful research project should be established. Besides the naming of the research purpose and the fixing of the research process, a research strategy as well as a suitable data collection method will be defined. How this recorded information can be analysed and what explanatory power can be expected from the well-chosen research strategy will also be reviewed.

Since chapter 2 already gave a hint that 'System Dynamics' software could be the proper one for this research project, the process which has led to the usage of 'Powersim' is described at the end of this chapter. In addition, the basic elements of the software are introduced, so that later in the thesis a common understanding about the system can be assumed.

Chapter 4

In coherence with the research strategy described in chapter 3, the different options for collecting qualitative and quantitative information will be used in chapter 4. The way of prioritising the information that has to be recorded will be described right at the beginning of this section.

In order to guarantee the reliability of the results, both system boundaries of the investigated final assembly shop and definitions of individual key performance indicators will also be explained in detail.

Chapter 5

In chapter 5 the advantages of the selected software will be demonstrated with the help of some examples. In doing so it should be found out, whether at least some of the potentials indicated within the literature review done in chapter 2 can be realised with the chosen approach.

Chapter 6

Since in chapter 5 the developed model is judged only generally, a detailed validation of the model takes place in chapter 6. In doing so the results of the different levels of the developed system of key performance indicators are compared to the actual values of the four German BMW locations Munich, Dingolfing, Regensburg and Leipzig.

At the end of this chapter the consequences of changed planning premises on the result of the entire system are anlysed in order to detect the sensitivity of the individual key performance indicators.

Chapter 7

Based on the results of chapter 4, 5 and 6 the advantages and disadvantages as well as the limitations of the chosen approach will be discussed in chapter 7. This includes an examination of the research strategy, the methods of data collection and of course of the achieved research results. The results also will be valued in view of their contribution to knowledge. Based on the description of possible potential improvements, recommendations for future research projects in this subject area will be listed finally.

At the end of this thesis, is a list of the references used within the thesis. Also some interesting details about the research project, and here in specific to the definitions of the KPIs will be offered on the final pages (= appendices).

1.6 Classification of the Research Project

This thesis has its origins in a concrete problem industry is facing at the beginning of the process of planning a final assembly shop of a car manufacturer. As a result of the economic importance of the automobile industry, research results from this area often find attention in other industrial branches as well.

From a scientific view, this research project can be assigned both to the engineering faculty and the faculty of business and economics. On the one hand the technical understanding is necessary for the planning of facilities and processes of a new plant and on the other hand economic and personnel-political statements are of considerable meaning as well. Both facets will be regarded within this research project.

2 Literature Review

2.1 Introduction

After a comprehensive overview of the changes in industry, the targets of a manufacturing company are explained at the beginning of this chapter. Both sections should help to demonstrate how many aspects have to be taken into consideration during the process of planning a new final assembly shop and what is important for a successful manufacturing company.

Before the planning process can be introduced in detail, the final assembly shop of a car manufacturer is defined in general.

Afterwards the planning process with its different stages and the challenges related to it is analysed. Linked to the planning process the suitable tools and approaches significant for this research project are presented. Special attention should be paid on the mathematical calculation algorithms. They could be of major importance for the linking of the key performance indicators.

On account of the significance for this research project the key performance indicators and key performance indicator systems are reviewed in detail. By intention this is done very globally, because there are barely specific approaches for the factory planning process. In view of possible synergies the known methods and the available knowledge available from other areas should be taken into consideration in this research project.

Considering the formulated research question the literature analysed till then is evaluated critically in an intermediate conclusion.

Based on the introduced 'System Theory' and the potentials linked with it in connection with the original research problem a research aim and corresponding objectives will be formulated at the end of this chapter.

2.2 Changes in Industry

It is indisputable that in many industrial areas and in particular in manufacturing companies the competitive pressure has continuously risen during the last years. As shown below, different authors (Cunha et al., 2003; Wiendahl and Lutz, 2002; Zahn et al., 1998, p. 263; Kaplan and Norton, 1996, p. 3; Higgins et al., 1996a, p. vii; Gunn, 1992, p. 1; Zheng and Possel-Dölken, 2002, p. 1; Harrison and Petty, 2002, p. 69; Grundig, 2000, p. 10) name plenty of reasons for this development:

- Liberalisation of global markets.
- Shorter delivery times.
- Transformation of supply-driven markets into consumer-dominated markets.
- Customised products.
- Better quality.
- Shorter product life cycles.
- Lower prices.
- Increasing product variety.
- Utmost market volatility.
- Seasonal trends.
- Decentralisation.
- Innovation pressure.

These and many other factors lead to the fact that nowadays enterprises and factories must be above all 'agile' and must free themselves of thoughts of mass production. This is the only way to survive in this revolutionary and unpredictable change process (Kaplan and Norton, 1996, p. 2; Ahmad and Benson, 1999, p. 102; Maropoulos, 2003; Goldman et al., 1995, p. xv; Reindl, 2005; Wu, 1992). Agile Manufacturing, which is one of the main objectives of the BMW Group (BMW Group, 2002), can be defined as "the capability of reacting quickly to changing markets, to produce high quality products, to reduce lead times, and to provide superior service" (Halevi, 2001, p. 64).

These are achieved by improving enterprise communications among all disciplines engaged in the manufacturing process (Goldman et al., 1995, p. 64). It is a fact that many experts predict that the competitive pressure on plants will intensify over the next few years, because of the awakening of the sleeping giant China (Gunn, 1992, p. 2; Dillerup, 1998, p. 58) as well as the eastern extension of Europe (Dudenhöffer and Büttner, 2004). All these arguments underline the statements of Maurer and Stark (2001). With their comments they make clear how important present management decisions are for the future of an enterprise. "To remain competitive in 2020, companies need to follow a three-step process: first, achieve world-class performance in as many areas as possible; second, determine the structure and function of the plants they will need to operate in 2020; and third, develop year by year plans for transforming their current plants into the 2020 models" (Maurer and Stark, 2001). Maurer and Stark are supported by Tong et al., which also believe, that "manufacturing industry will need to redesign existing factories or design completely new factories more frequently" (Tong et al., 2003, p. 571).

2.3 *Targets of Manufacturing Systems*

Before the targets of manufacturing systems can be closer described as an entrance to the planning process, a uniform understanding must be generated to the term 'manufacturing'.

One understands by manufacturing 'in the broader sense' all areas linked with the production process (Dillerup, 1998, p. 30). So it encloses the following basic functions: "Procurement, transport, logistics and manufacturing as well as the management and control of these areas" (Staudt et al., 1985).

'In the narrower sense' manufacturing is only defined, as shown in figure 8, as "the transformation of raw materials into marketable goods" (Wu, 1992, p. 4; Zheng and Possel-Dölken, 2002, p. 251; Harrison and Petty, 2002, p. 5; Tong et al., 2003; Bunz, 1988). Within this system in general many 'value-adding manufacturing processes' will be performed (Wu, 1992, p. 4). As described later, the understanding of this work corresponds rather to the second definition.

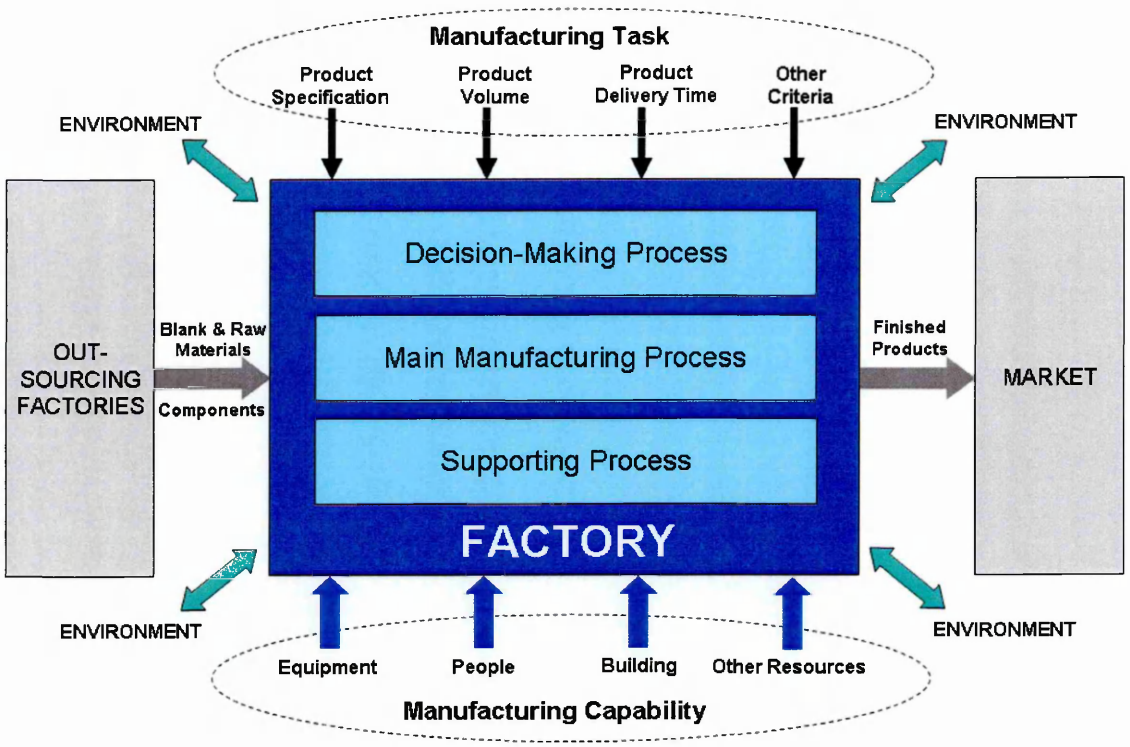


Figure 8 – Boundary of Factories. Tong et al. (2003)

In addition to the definition of the manufacturing system it is necessary to think about the position of the production unit within the entire enterprise (Bunz, 1988, p. 18; Schmigalla, 1995, p. 33). If it is possible to create long-term competitive advantage for the whole enterprise with the manufacturing area, because it is for example especially flexible, is much cheaper or reaches constantly an above-average high-class quality level in comparison to competitors, then "manufacturing can be used as a strategic weapon" (Higgins et al., 1996a, p. 60; Dixon et al., 1990, p. 4; Skinner, 1985, p. x). At the end of the day, it is primarily important to find an answer to the following question: "What do you have to do in your branch to differentiate between your direct competitors" (Brown, 1996, p. 159; Porter, 1980, p. 47)? "What are your core competences" (Halevi, 2001, p. 114; Prahalad and Hamel, 1990, p. 81)?

In search of competitive advantages, the early twentieth century was dominated by the birth of mass production but the 1960s saw the awakening of lean manufacturing (Womack, 1990). In the 1960s the increase of productivity was the only target for manufacturing companies (Dogramaci, 1981, p. 2).

However, during the last years, as a result of the rising competitive pressure and with the support of Japanese management methods such as TQM (= Total Quality Management), suitable awards such as the 'Deming Prize' as well as the 'Malcolm Baldridge National Quality Award' and models such as the 'EFQM Model for Business Excellence' or the 'Business Excellence Model', the subjects quality, time, flexibility and customer sattisfaction became more and more important (Bieri, 1995, p. 7; Kaplan and Norton, 1996, p. 100; Karreman, 2000, p. 13; Halevi, 2001, p. 284; Ahmad and Benson, 1999, p. 67; Eccles, 1991, p. 132; Drucker, 1990, p. 95; TCIOMA, 1993).

Even if in the automobile industry the above listed targets are monitored by all manufacturers, two basic philosophies can be distinguished.

On one side there are the volume suppliers such as GM, Ford, Honda, VW, and Toyota having the purpose to produce as many vehicles as possible at lowest costs (Higgins et al., 1996a, p. 56).

In contrast, premium priced brands such as BMW, Mercedes or Porsche try to differentiate from the competitors by innovative, customised products (Higgins et al., 1996a, p. 56).

Figure 9 demonstrates that basically both attempts can be successful, even if additional variations can cause more complicated manufacturing processes and rising coordination costs.

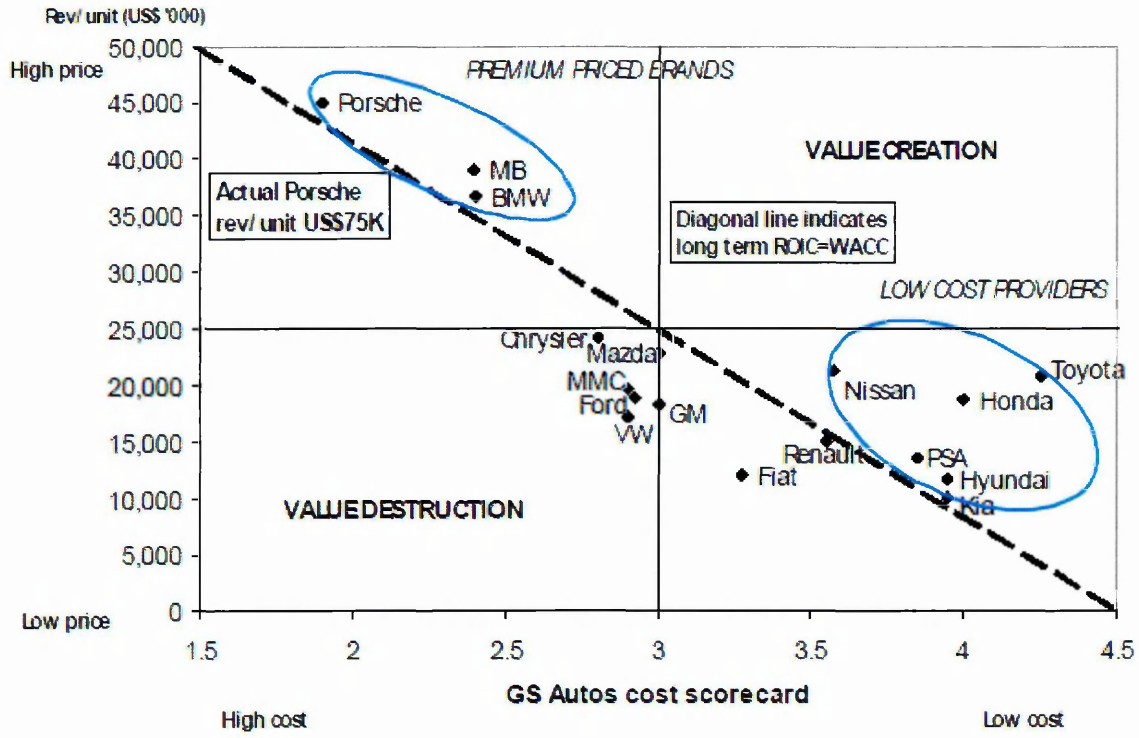


Figure 9 – Pricing Points vs. Cost Analysis. Warburton (2004)

To be able to achieve the desired differences in the production process later on, such aspects must be taken into consideration during the entire planning process.

In addition, the listed targets of course can be transferred to the planning process as well. This is done exemplary on the scarce resource 'time'. According to Stalk and Hout (1990, p. 149) in their book 'Competing Against Time' time should be examined as equally important for the assessment of the efficiency of an organisation as financial key performance indicators. Northey and Southway (1993) in their book 'Cycle Time Management' as well as Philip Thomas (1990) in his book 'Competitiveness Through Total Cycle Time' also attach great importance to the time.

For this research project, time plays an essential role, because of the time available for the planning process. On account of the tumultuous environment, e.g., in view of unpredictable retail volumes, more and more planning alternatives must be evaluated in shorter and shorter time (Reinhart et al., 2000).

Therefore, the planning departments may not only have the objective to plan fast production processes, but must also have the purpose to minimise the times required for the planning process. In view of topics such as 'time to market' a shortening of the planning time can lead to the creation of a competitive advantage.

2.4 Definition of a Final Assembly Shop of a Car Manufacturer

Before the planning process with its specific challenges can be reviewed in detail, the final assembly shop of a car manufacturer should be briefly introduced.

According to Womack et al. (1990, p. 76) automobile plants all over the world do almost exactly the same things, because practically all of today's cars and light trucks are built with very similar fabrication techniques. A plant for manufacturing cars in general consists of four shops, housing four basic operations:

- Press shop (= Stamping).
- Body shop.
- Paint shop.
- Final assembly shop.

The focus of this research project is on the final assembly shop. Again, at first view, there are no major differences between the final assembly shop producing cars for the mass-market and an assembly line manufacturing cars for the premium market. Based on a study of the Boston Consulting Group (Maurer and Stark, 2001), figure 10 shows a general schematic diagram of a final assembly shop. It illustrates that the layout follows the 'flow principle' (Harrison and Petty, 2002, pp. 12-23), with corresponding challenges, such as 'line balancing' or 'bottleneck-analysis' (Wiendahl and Hegenscheidt, 2002; Grundig, 2000, p. 119).

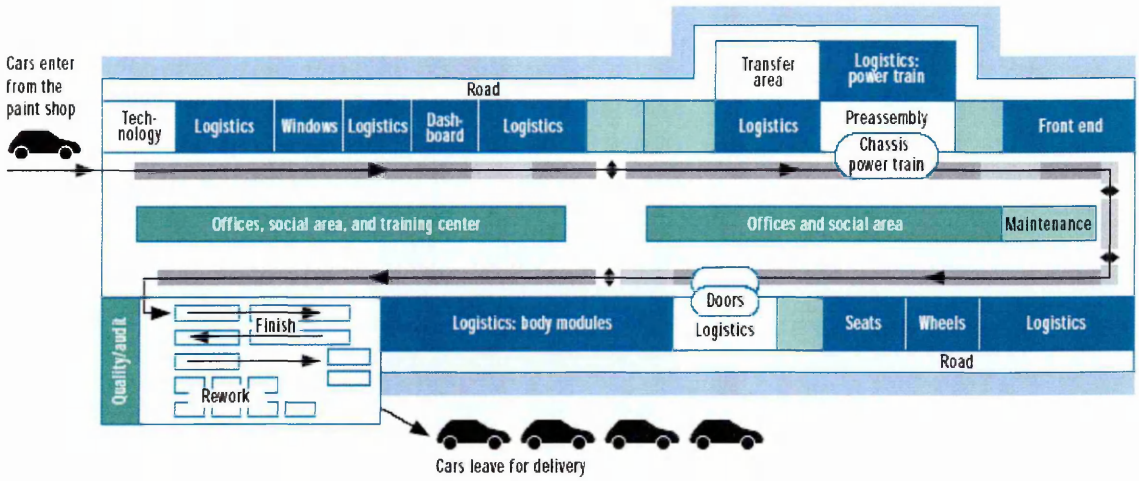


Figure 10 – The Final Assembly Shop. Maurer and Stark (2001)

Basically one can distinguish four types of manufacturing principles (Wemmerlov, 1984):

- Make to stock (= MTS).
- Assemble to order (= ATO).
- Make to order (= MTO).
- Engineer to order (= ETO).

While in the past, on account of the few product variants (Henry Ford: "People can have the Model T in any colour they want, as long as it is black!"), volume providers were considered to be the category MTS, today, as a reason of the introduced changes, an unequivocal movement of all manufacturers in the automotive industry is recognisable in the direction of ATO. Especially in the premium segment the manufacturers are forced, as a result of increasing customer wishes for individualisation, "to provide a wide range of products with short customer delivery lead times" (Higgins et al., 1996a, p. 13).

As pictured in figure 11, the main manufacturing process in a final assembly shop therefore is moving from the so-called 'transfer line' (Harrison and Petty, 2002, p. 12) to the 'flexible manufacturing system'. In doing so, the final assembly shop is of special interest, because it is the interface to the customer and disturbances in the process make it difficult to reach cost, quality and time targets (Bunz, 1988, p. 12).

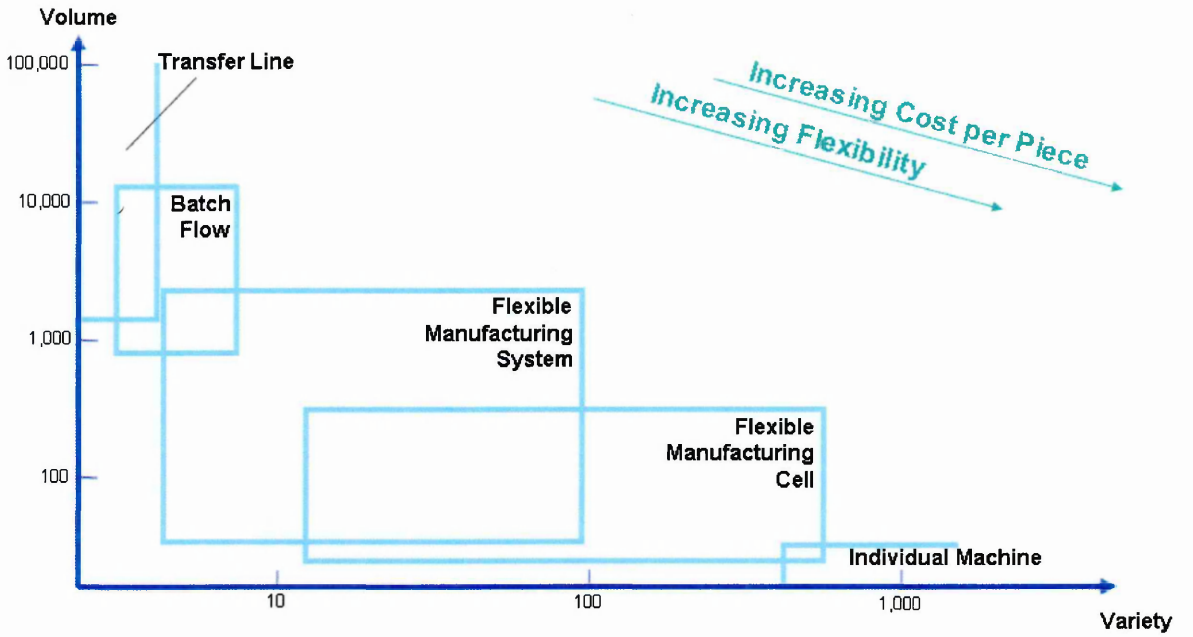


Figure 11 – Effect of Volume / Variety on Process Technology. Harrison and Petty (2002)

2.5 Planning a Final Assembly Shop of a Car Manufacturer

Since all basics necessary for a common understanding are introduced, in this section the planning process is reviewed in detail. To agree with Meyer and Stephens (2005, p. 1) in 'Manufacturing Facilities Design and Material Handling' and Gunn (1992, p. 34) in '21st Century Manufacturing' everyone reading this thesis should know that the planning process is of great importance. This high rating is also shared by Grundig (2000, p. vi), who adjudges it vital for a company. However, on account of the tumultuous environment, the long-term planning for a factory or their subunits is getting more and more arguable (= "decision making under uncertainty") (Harrison and Petty, 2002, p. 160; Dyson, 1990, p. 11; Grundig, 2000, p. 180; Skinner, 1985, p. 14).

This is another reason for the objective that means and ways have to be found to evaluate the different alternatives faster. New approaches for the planning process are the only chance to shorten the time between the initiative for planning and the start of production or at least to evaluate more alternatives at the same time.

However the planning process is not only about optimally planned facilities and factories, as the statement of Gunn (1992, p. 34) makes clear: "The real value of planning lies in its ability to facilitate learning and teamwork, especially among high-level executives, who often have a parochial concern and business understanding limited to their own function". The aspect of 'comprehensive planning' (Kettner et al., 1984, p. 4) and the work in teams will be taken into consideration in this thesis over and over again, because in these areas also potential improvements within the planning process are detected.
The thesis that the planning process altogether can be improved is supported by Bonney et al. (2000) with the help of the following statement: "Manufacturing systems design needs to be quicker, more efficient, adaptive and flexible".

2.5.1 Kinds of Planning Jobs

For this research project it is important to know that there are varying planning tasks, with different options within the planning process. According to Grundig (2000, pp. 14-16) five reasons for planning a final assembly shop are possible:

- New building of an industrial company (= greenfield).
- Transformation and reorganisation of existing industrial companies.
- Extension of existing industrial companies.
- Reduction of industrial companies.
- Revitalisation of industrial companies.

As already mentioned, the origin of the questions leading to this research project was the planning process for the new BMW plant in Leipzig. Therefore, it is obvious that this research project is primarily focused on greenfield projects. The main argument for this decision is that here almost no restrictions must be taken into consideration, so that the chosen solution should be closest to the ideal solution (Wiendahl et al., 2001; Reindl, 2005).

2.5.2 Expectations from the Planning Process

However, what may one expect from a planning process? Is there always an ideal solution at the end of the planning process? What is the outcome of a planning process? It could be helpful to better define the concept 'planning' more precisely.

Even if the term 'manufacturing planning' is used differently in literature (Schmigalla, 1995, p. 13; Kudlich, 2000, p. 11), in general it is the design and the implementation of physical facilities and organisational infrastructure for the product realisation process of different products that is understood by the expression 'factory planning' (Tong et al., 2003, p. 571).

For this research project also the definition of Vetter (1983, p. 32) matters, because he makes clear that complex processes must be analysed and planned with the objective of finding the optimum for the entire final assembly shop and not only for specific parts of the system.

In view of the future orientation of the planning, the idea of Kettner et al. (1984) is helpful. "Planning should be understood as a mental anticipation of future activities which wants to influence the development of the planning object actively" (Kettner et al., 1984, p. 2). Therefore, Grundig (2000, p. 1) calls the process of factory planning, "thought ahead production".

The linkage with the overall enterprise objectives will be highlighted by the statement of Schmigalla (1995, p. 14), who understands "factory planning as a bridge between the enterprise planning with the development of visions and strategies to the user".

Important for the judgement of planning results is the statement of Dolezalek and Warnecke stressing the aspect that planning results are never completely correct, since "it is impossible to forecast the hoped for developments safely" Dolezalek and Warnecke (1981).

Nevertheless, the expectations regarding the planning process already described by Vetter (1983, p. 1) in 1983 have not changed till this day. However, on account of the already described competitive situation, the pressure from management has increased (Grundig, 2000, p. 18; Reindl, 2005). The main points expected from an excellent planning process are as follows:

- Quick results.
- Reliable statements.
- Good basis for confident decisions.
- Transparency about the planning parameters.
- Manageability and updateability.

Facing these expectations, an essential challenge also is the economic efficiency of the planning process as described by Kettner et al. (1984, p. 7). As illustrated in figure 12, in spite of the many-sided questions during the planning process it has to be made sure that the relation between planning expenditure and planning result (= 'reduced planning versus excess planning' (Grundig, 2000, p. 23) comes close to the theoretical ideal value.

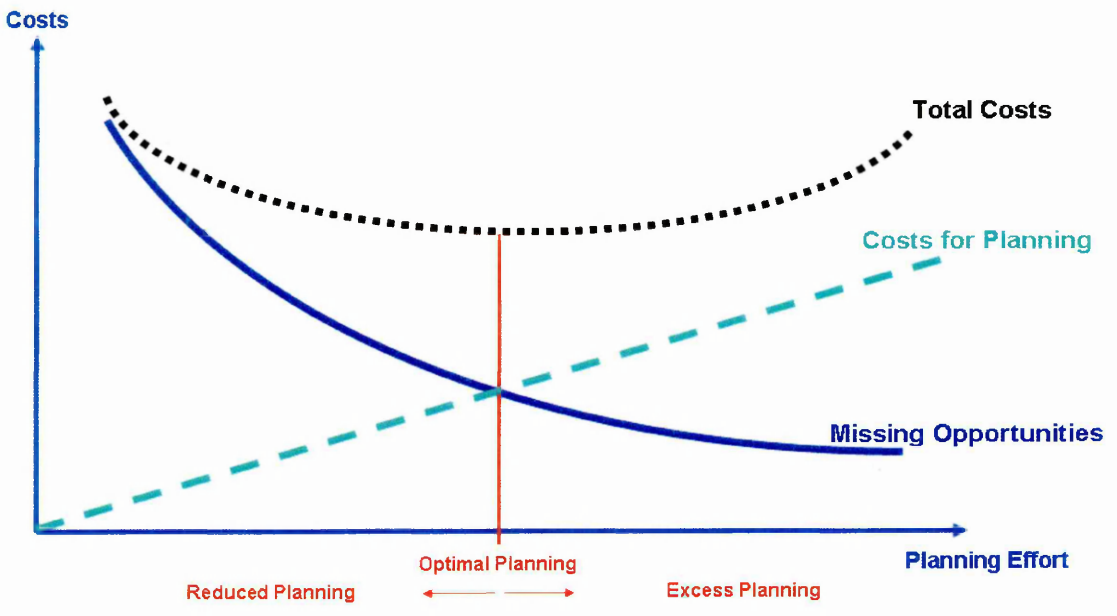


Figure 12 – Economics of the Planning Process. Kettner et al. (1984)

In order to meet the expectations in terms of costs for planning, it is necessary to adapt the degree of detail to the respective planning stage. In doing so, the challenge is that at a time when no detailed nor reliable information (e.g., product features) is available, first estimates about the required areas and investment costs are needed. Grundig (2000, p. 19) calls this "the dilemma of the factory planning".

Moreover, in many companies, the first figures are very important, since later divergences must be explained over and over again, leading to an increase of planning expenditures. Therefore, the purpose of all parties involved has to be, without question and despite only roughly available input data, to deliver high-quality planning results as soon as possible. Nevertheless, to stay within the tolerance of ± 20%, illustrated in figure 13, still is the first target at this planning stage.

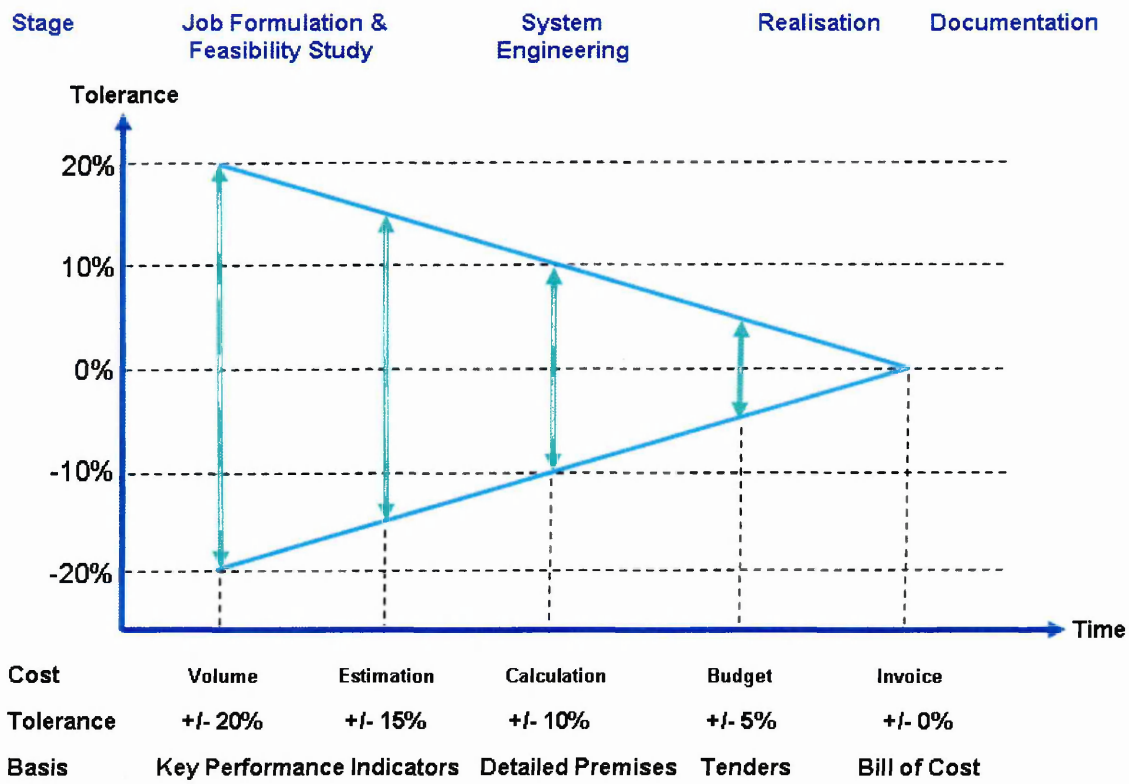


Figure 13 – Limits of Accuracy at the Different Stages of the Planning Process. Reindl (2005)

2.5.3 Planning Horizon / Stages for Planning a Factory

As indicated in figure 13, the accuracy level depends on the respective planning phase. Hence, in the following the relevant planning stages are described more precisely.

There are plenty of references (Meyer and Stephens, 2005, p. 11; Aggteleky, 1987, p. 31; Schulte, 2001, p. 45; Harms et al., 2003; Reinhart et al., 2000) illustrating the factory planning process. Tong et al. (2003, p. 571) offer the lowest level of detail. They differ between two stages during the design of factories:

- Pre-Design.
- Layout Planning.

The overview of Grundig (2000, p. 30), based on the '6-Phase Model' of Kettner et al. (1984), is much more detailed and will serve as a basic principle for this thesis (see figure 14).

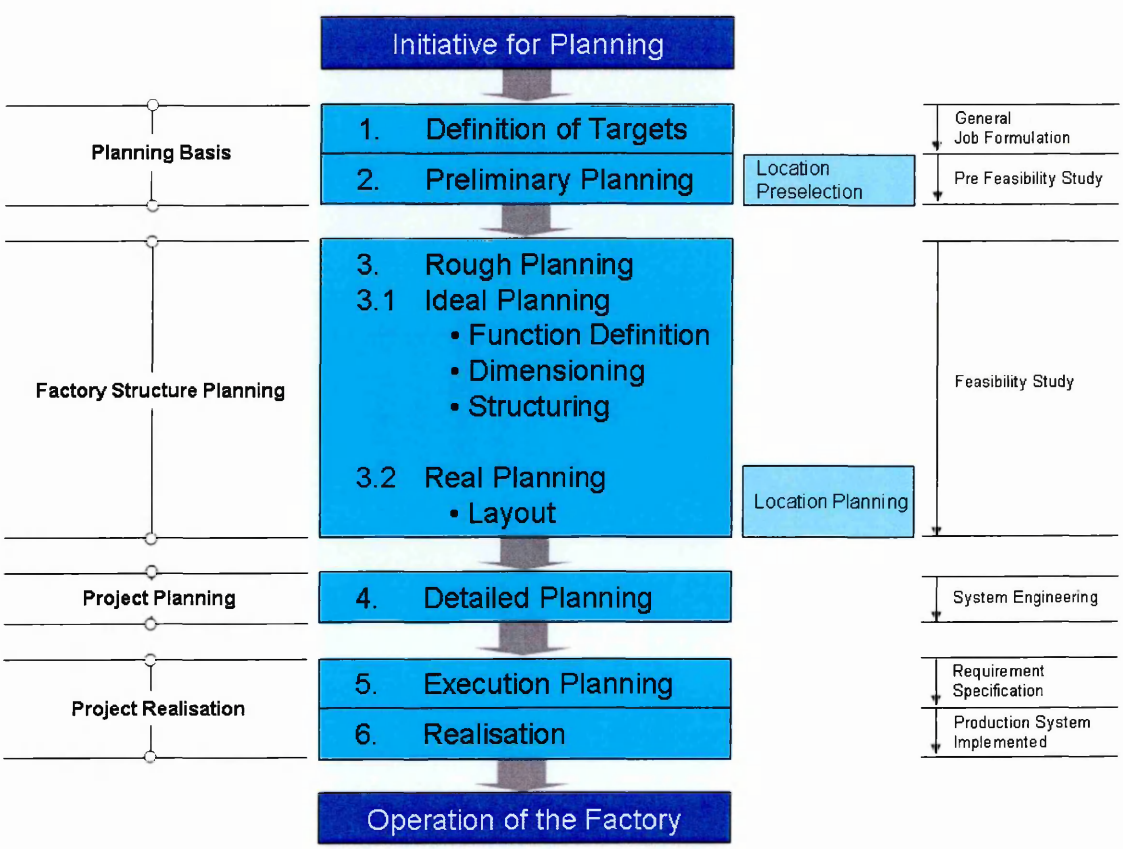


Figure 14 – 6-Phase Model of the Factory Planning Process. Grundig (2000)

This work concentrates upon the factory structure planning as a component of the rough planning. However, it must be stressed that the single planning stages often cannot be separated, because of the smooth transition between the different stages (Kettner et al., 1984, p. 5). From this point of view, aspects of the target planning (= strategic considerations) and the preliminary planning (= potential analysis) are important for this thesis as well, particularly since at the beginning of any planning process, strategic considerations should be carried out (Grundig, 2000, p. 43), even if no dependable data about volumes or product design features are available.

Since it is necessary for this thesis to have a common understanding, a formal definition of the factory structure planning still is helpful:

"Factory structure planning is the development, assessment and selection of alternative drafts (= variations) of factory structures including the different processes, e.g., assembly processes. It also includes, dimensioning, arrangement and coupling of functional unities (= ideal layout) and their integration into existing structures (= real layout)" (Grundig, 2000, p. 29). This research project is also focused on the 'dimensioning' (Schmigalla, 1995, p. 108), which according to Grundig (2000, p. 33) is defined as follows:

"Dimensioning is the determination of the type and number of elements required for the functional fulfilment. Here calculations occur, to determine the resources needed for equipment, areas, personal and other aspects" Grundig (2000).

As described by Vetter (1983, p. 32), at this stage it is not the objective to optimise the order of work routines but to define, for instance the areas required form a strategic point of view and to think about a further course of action.

Kettner et al. (1984, p. 4) also point out that in this "first planning stage the development of an overall optimum has unambiguously priority" where the planners should use "general methods and key performance indicators" (Schmigalla, 1995, p. 85). Kettner et al. (1984) and Aggteleky (1987) stress that, particularly in the early planning phase, the development and assessment of different variations is very important.

In view of the factors of influence listed below, the efficient realisation of the described planning tasks is a real challenge.

2.5.4 Challenges for the Planning Process

In the end one of the main objectives of this research project is the better support of the planners at the beginning of the planning process. However, for being able to succeed, it is necessary to know the relevant challenges. Therefore, the topics discussed in this segment should be kept in mind if a new tool will be developed within this research project.

2.5.4.1 Number of Variants

One of the biggest challenges for the planning process of a final assembly shop is given with the increasing number of variants. This trend, illustrated in figure 15, is especially observable in the car industry (Seemann, 2003; Schmigalla, 1995, p. 168). In particular for premium brands such as BMW no end of the steady rising number of versions can be recognised.

For the future, it must be assumed that more and more variations have to be manufactured in reduced quantities, leading to an increasing number of planning activities. According to Warnecke et al. (1991), the factory planning process has to make sure that these variants can be built in robust processes.

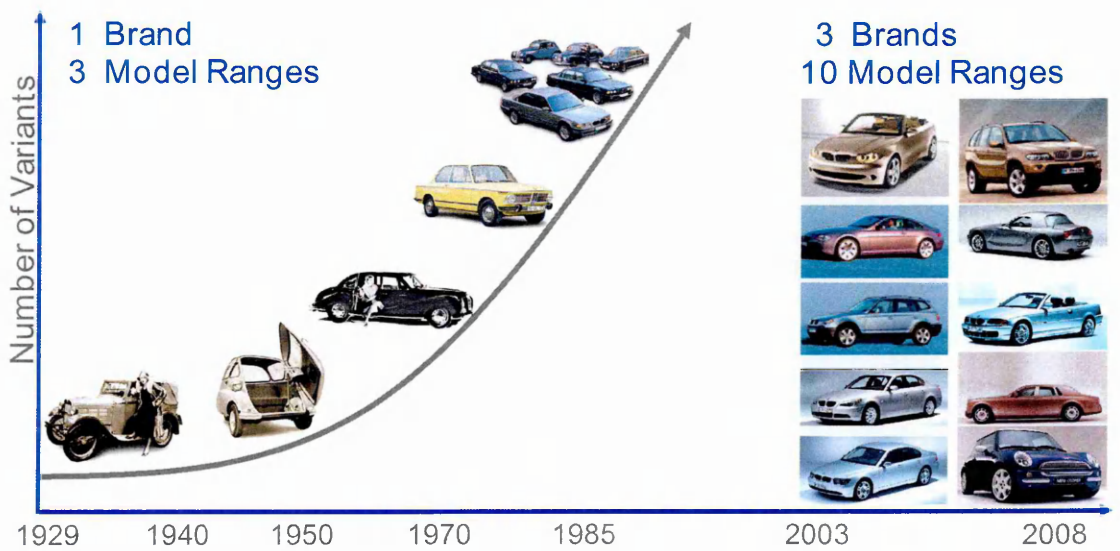


Figure 15 – Increasing Number of Variants on the Example of the BMW Group. BMW (2005)

2.5.4.2 Optimisation of the Production Network

An essential challenge for manufacturing enterprises and therefore also for the planning of final assembly shops of an automobile manufacturer is the optimisation of the production network (Wiendahl and Lutz, 2002; Angerhofer and Angelides, 2000; Dillerup, 1998, p. 232; Maurer and Stark, 2001; Winterkorn, 2003). On account of the required flexibility within a production network, the number of planning alternatives for every individual plant is continuously increasing, because theoretically it could be the best solution, to build every type of a car in every single location, following the principle of 'production follows the market'.

For the planning of a final assembly shop of a car manufacturer these network relationships play an essential role for the subjects 'vertical integration' (= make or buy decisions) and 'capacity planning' (Meyer and Stephens, 2005, p. 41).

Against the background of the stronger fluctuations of the sales figures of single products, the specification of the optimum capacity becomes more and more difficult (Reinhart et al., 2000). Since, however, costs, proceeds and profits are connected with the use of the capacities (Weber, 1999; Kettner et al., 1984) planning mistakes can cause serious and long-term consequences (Harrison and Petty, 2002, p. 9; Wiendahl and Hegenscheidt, 2002; Grundig, 2000, p. 77). Therefore, a plant can no longer be seen by it self. In a highly complex network, every individual plant has to fulfil a special role (Wiendahl, 2001; Drucker, 1990, p. 99/100; Dangelmaier, 1998; Martin, 1992).

Consequently, two possible solutions within a manufacturing company are available. On the one hand a manufacturer could have highly flexible final assembly shops in terms of volumes and products with a reduced dependency from other plants or on the other hand could have a final assembly shop optimised for one product with a specific volume. The second alternative could cause dependencies to other plants, since there is the question how a steady utilisation can be guaranteed in such a plant.

The example of Opel (= Vauxhall), where the strike in the Bochum plant also stopped the production in the plants in Antwerpen and Eisenach a couple of days later (Biskamp et al., 2004), shows the dependencies of such network partners.

A possible alternative to such networks within a company could be the outsourcing of essential volumes to reliable partners (Tong et al., 2003, p. 576; Wiendahl and Lutz, 2002; Jarillo, 1993, p. 11). More and more OEMs cooperate with external partners in order to use a huge number of possible advantages (Zheng and Possel-Dölken, 2002, p. 8; Goldman et al., 1995). On the example given by Karmann, one of the leading full-service-vehicle-supplier, figure 16 gives a hint, how many OEMs already work with external partners such as Karmann (2005), Valmet Automotive (2005) or Magna Steyr (2005).

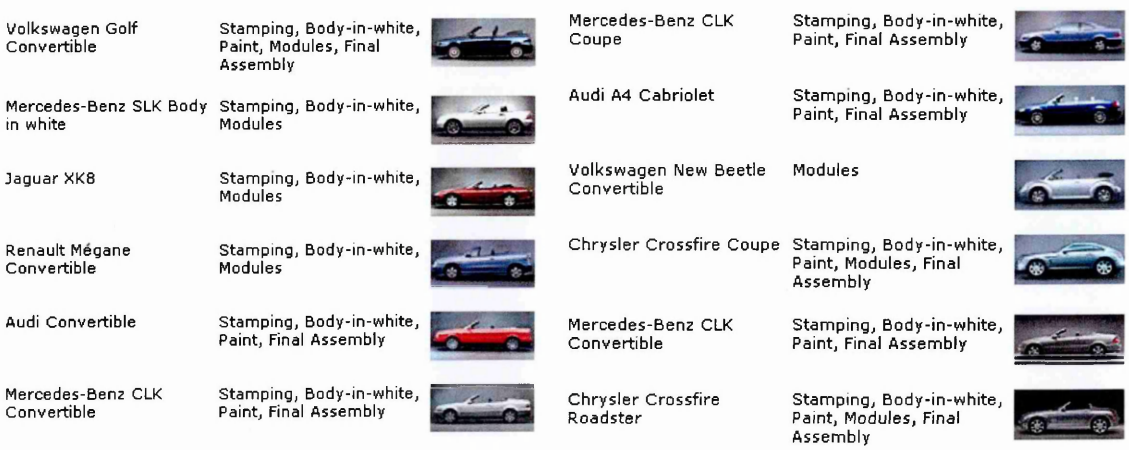


Figure 16 – References of Karmann since 2000. Karmann (2005)

Thus, Martin (1992, p. 14) recognises a new way of competition, moving from 'company versus company' to 'business network versus business network'. Harrison (1999) calls this "network competition, where the prizes will go to those organisations who can better structure, co-ordinate and manage the relationships with their partners in a network committed to better, closer and more agile relationships with their final customers".

As pointed out below, so far it is very difficult to compare different plants operated by different companies. For the development of a necessary trust culture between the involved partners (Zheng and Possel-Dölken, 2002, p. 12) as well as for the exchange of expertise (Cunha et al., 2003) and information (Wiendahl and Lutz, 2002), a higher degree of transparency about the final assembly shops could contribute to the aspired 'win-win-situation'.

2.5.4.3 Difficulties with the Comparability of the Plants

So far, the comparison of different final assembly shops of car manufacturers in search of 'best practice solutions' or the 'world-class-performance' has not really been successful. Even with reports like 'The Harbour Report – North America 2004' (Harbour, 2004) and competitive contests such as 'Factory of the Year' (A. T. Kearney, 2004) or 'Britain's Best Factory Awards' (Ahmad and Benson, 1999, p. 29), the comparability of the performance of different assembly plants is simply limited. This view is also supported by Maskell (1991, p.26). He recognises essential differences "from the products manufactured, the production processes required, the people employed within the plant, the age and suitability of the equipment, and the existing strengths and weaknesses of the plant" and, thus, comes to the conclusion that "the plants are different and comparing one plant with another does not make sense in this environment". However, it is precisely these differences that would be interesting for the planner of a final assembly shop of a car manufacturer to refer to in the planning process to performance benchmarks such as 'm² per unit' or 'investment per unit' gathered from other plants.

This leads to the question, how one can make sure in the early stages of a planning process for a final assembly shop that the structure for a world-class performance (see figure 17) will be developed? The importance of the decisions during the planning process becomes apparent with the statement of Harrison and Petty (2002, p. 11): "If the basic design of the manufacturing system is poor, no matter how well it is managed, the company will not be able to compete".

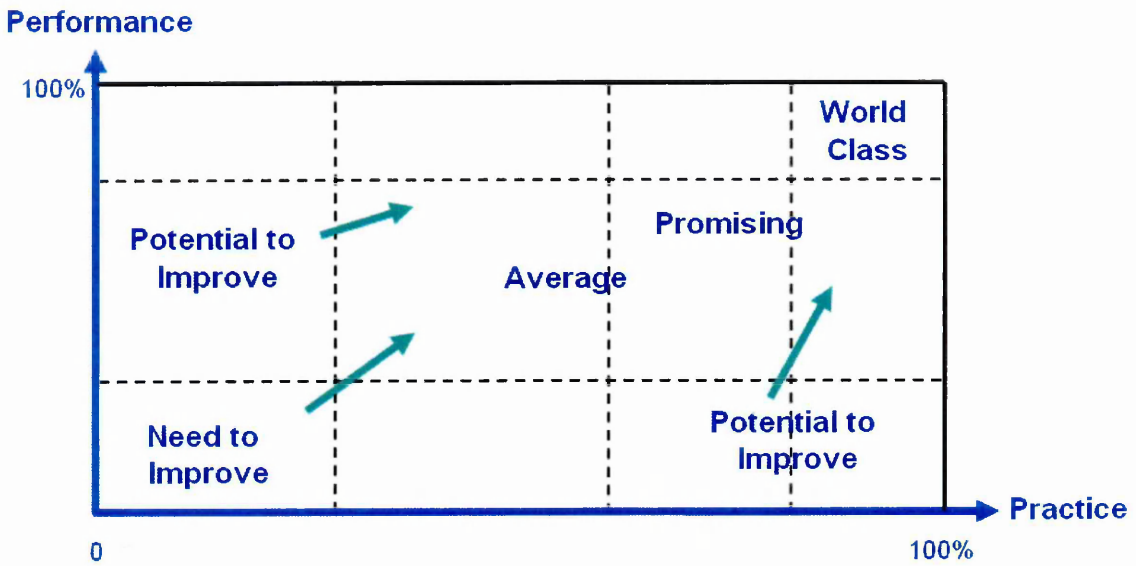


Figure 17 – Performance and Practice Benchmarks Plotted against World-Class. Ahmad and Benson (1999)

In addition to these evident differences, there is also the challenge, to compare key performance indicators based on the same definition. Even if this problem will be explained in detail later, an example will be given now, based on the key performance indicator 'percentage of units on schedule'. While for BMW a car is on schedule if it can be delivered to the customer within the forecasted day, the remaining German manufacturers accept a completion of the car within a time slot of one week (OEM-Benchmark, 2004). Therefore, a comparison of these percentages without knowing the definition could lead to wrong results. Hence, it is, as described by Kettner et al. (1984, p. 42) and Meyer and Stephens (2005, p. 11), always important to prove the quality of such data, because wrong key performance indicators could lead to wrong statements at the end of the planning process.

In consideration of these difficulties, it has to be said that it already would be a step in the right direction, if at least in one individual location the essential key performance indicators were unambiguously defined, because then at least trends could be indicated. Such trends can deliver helpful information during the planning process (Westkämper et al., 2001).

The challenges in connection with a lasting and general definition as well as with the opportunity to check the quality of key performance indicators will be described in detail later in this thesis.

2.5.4.4 Involvement of Multiple Departments

It is quite evident that during the planning stages of a project with such a high investment, many experts from different departments have to work together (Halevi, 2001, p. vii; Harms et al., 2003, p. 227; Kettner et al., 1984, p. 7; Grundig, 2000, p. 16; Meyer and Stephens, 2005, pp.1/25). Furthermore, these specialists have varying background and represent different interest groups (Tong et al., 2003).

Within the scope of his comments on the subject 'Master Production Scheduling', Gunn (1992, p. 168) describes impressively, the challenges such teams have to overcome during the planning process: "Everyone has his own set of numbers to defend his position and shift the blame to some other department or person, or even the customer or supplier. Tempers flare. Political considerations abound. Problems are hidden. Arguments abound in increasingly loud and insulting language" (Gunn, 1992, p. 168).

However, in spite of such conditions, it has to be made sure that the various groups do not solve the problems in isolation (Higgins et al., 1996a, p. 68). For the success of the planning process, it is essential that the cause and effect relationships are known between the single disciplines. In addition, Senge (1990, p. 10) argues that it could be seen as a chance for an organisation competing more successfully in the dynamic environment, if one can generate a climate of mutual learning.

2.5.4.5 Finding the Optimum

The challenges described so far, all have something in common. They make it more and more difficult to find the optimum for the whole final assembly shop. For example, what is the best mixture between flexibility and productivity? Do some planners still have some buffers, whereas others already have reduced investment costs to a minimum? Is there anybody looking for possible synergies?

To be able to answer such questions, a basic understanding of the dependencies of the single planning parameters must exist (Bunz, 1988, p. 54) and an isolated evaluation for specific partial solutions must be avoided (Grundig, 2000, p. 22; Wu, 1992, p. 28).

Therefore, the following statement of Higgins et al. can only be agreed upon. "An holistic view must be taken. [...] The planning process should examine the cumulative impact of the possible sequence of policy decisions. Modelling should be an integral part of the business planning process. The challenge for managers is to build up their understanding of how their business really operates and to use this knowledge to make more informed decisions" (Higgins et al., 1996a, p. 64).

2.5.4.6 Lack of Knowledge Management

Although knowledge management is recognised as one key issue in today's manufacturing systems (Thannhuber et al., 2001, p. 314; Wiendahl and Lutz, 2002; Zack, 1999, p. vii; Dixon et al., 1990, p. 8; Grant, 1996; Spender, 1994), a lack of knowledge management must be noticed in this context. According to Halevi (2001, p. 201) "knowledge management consists of the distribution, access and retrieval of human experience and relevant information between related individuals or workgroups". Young (2003) adds that "knowledge is information with added detail relating to how it may be used or applied".

As already described, during the planning process experts from different areas have to work together. Therefore, it is important for the quality of the planning results, to improve the mutual understanding about the dependencies within a final assembly shop. This is the only way of getting the chance to use possible synergies and to follow the principle that "the whole is being more than the sum of the parts" (Spender, 1994).

In some organisations, for instance the BMW Group, the master planning schedule has a milestone, where the planning results will be transferred from the central planning department to the specific location. Therefore, in a flexible production network with several locations, the same basic understanding about the dependencies within a final assembly shop should exist.

The final aspect is very important within a planning department. Even if the times between the planning activities for a new plant or for a major reconstruction of an existing plant have been shortened in the past (Harms et al., 2003), still some years can be in between (Meyer and Stephens, 2005, p. 14). Therefore, a better way of transferring knowledge between the planners has to be found, in order to have good fundamentals for the next planning projects (Thannhuber et al., 2001). Higgins et al. (1996a, p. 70) also argues in this direction, by stressing the point that "planning should be seen as the ongoing process of gathering more information for improved understanding of the manufacturing system rather than the one-time task of deriving a static representation of the system".

Every company should have the objective, as mapped in figure 18, "to move from one that exploits data through to one which uses the data to produce wisdom" (Ahmad and Benson, 1999, p. 106). The importance of a 'learning organisation' with regard to the competitiveness is also highlighted by Senge (1990, pp. 4/23). In view of the time intervals between the individual planning jobs, he argues that "it becomes impossible to learn from direct experience, when the actions have consequences beyond the learning horizon".

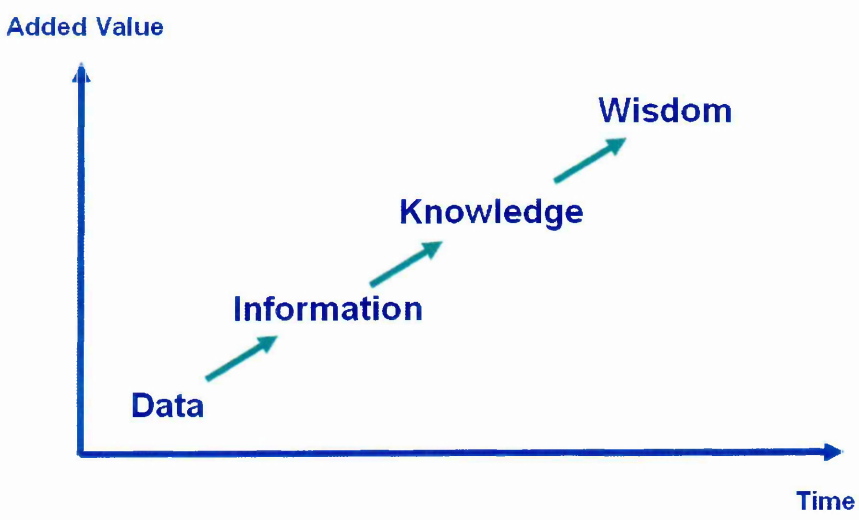


Figure 18 – Moving from Data to Wisdom. Ahmad and Benson (1999)

2.5.4.7 Proactive Cost Management

Perhaps, a more efficient 'knowledge management' can also serve to improve the 'proactive cost management'. Even if enterprises should not only pursue monetary objectives, the economic figures still play an essential role for the judgement of the competitiveness of a manufacturing company (Harrison and Petty, 2002, p. 37; Higgins et al., 1996a, p. 77).

As shown later, these kinds of information only allow ex post considerations, i.e. a problem must appear before management has the chance to solve it (Bieri, 1995, p. 39). However, product life cycles of several years, high investment costs and a lot of employees make a car manufacturer quite inflexible (Maurer and Stark, 2001, p. 6), so that in some areas several years can pass between the problem identification and the final recovery (Skinner, 1985, p. vii). Thus, it could be for instance that a reduction of the required resources in the first step only creates empty potentials in resources, but does not lead to lower costs (Kaplan and Norton, 1996, p. 31).

Today, vice versa cost problems can appear, although their origin dates far back in the past (Higgins et al., 1996a, p. 83; Kudlich, 2000, p. 14). Figure 19 should help to demonstrate that in this context the planner of a new final assembly shop has a very strong position, because in the early stages of the planning process he / she influnces most of the investment costs which have to be paid at the end of the planning process.

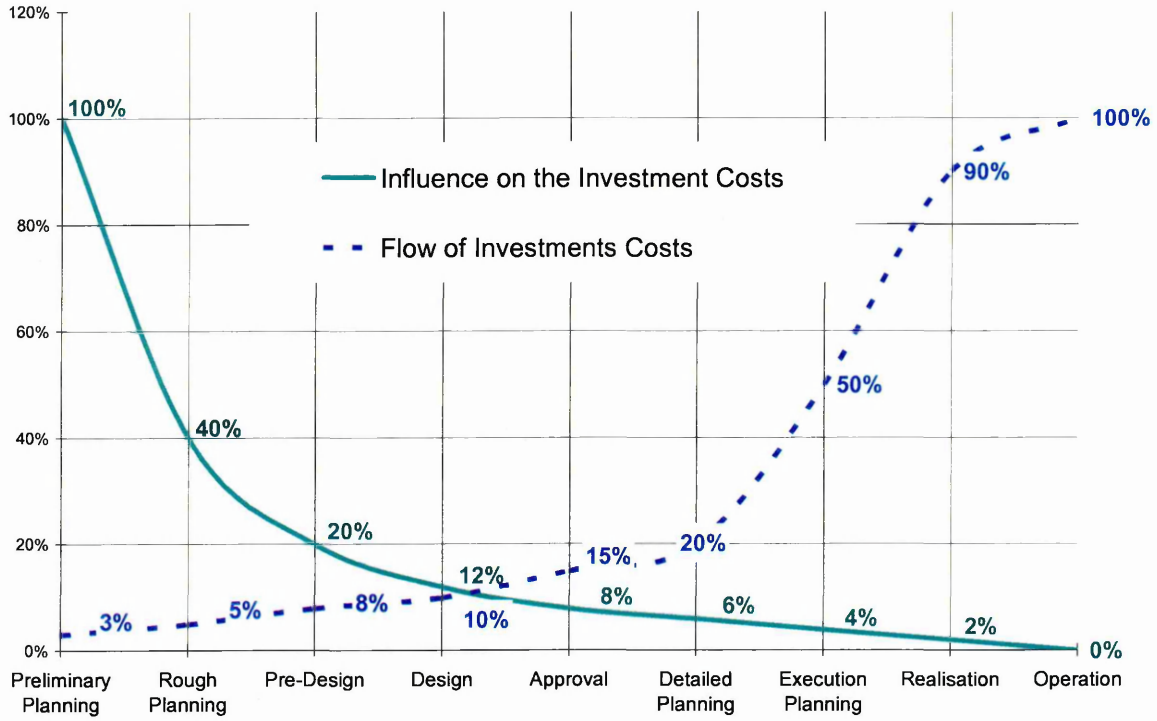


Figure 19 – Influence on the Investment Costs. Reindl (2005)

Hence, negative experiences in the recent past (e.g., Rover) and overcapacities in the automobile industry (Dillerup, 1998, p. 58) feed the fear that it often lacks of a dependable long-term planning culture. Also "uniform percentage cut in costs across all functions (or departments) indicate that management has not understood the complicated connections good enough or will not be supplied with the right information" (Higgins et al., 1996a, p. 77; Young, 2003; TCIOMA, 1993). Against the comment of Winchell (1989, p. 1) that "cost estimating is critical to the success of any company that competes in today's marketplace", such statements are very alarming.

For example in the automobile industry a comparison of the manufacturing costs is only purpose-leading, if some important influencing factors are taken into consideration (e.g., vertical integration, product complexity, average wage etc.).

The traditional instruments of cost / financial accounting in the following list cannot serve the new requirements or only insufficiently (Maskell, 1991, p. 41; Drucker, 1990, p. 97; Atkinson et al., 2001, p. 14; TCIOMA, 1993):

- Standard costing.
- Direct costing.
- Full costing.

Only slowly do new comprehensive ways of thinking, as for example the 'Activity-Based Costing (= ABC)', develop all around the concept of 'cost management' (Higgins et al., 1996a, p. 80; Halevi, 2001, p. 59; Chalos, 1992, p. 61). Higgins et al. (1996a, p. 84) point out that the complicated and dynamic enterprise processes must be illustrated in models, because only so can an early warning function be realised.

2.5.4.8 Shortening of the Planning Process

The previous challenges, confirm the statement of Sterman (1994, p. 291) that "the greatest constant of modern times is change", so that the available time for important decisions is getting shorter and shorter. Therefore, the planning departments have to speed up the planning processes without losing quality (Cunha et al., 2003; Milling, 2002; Stalk, 1988; Westkämper et al., 2001) or as described by Bunz (1988, p. 38) and Dillerup (1998, p. 1), to get more flexible while "the required changes will be anticipated".

The following example is valid only for greenfield projects, but hits the bull's eye to demonstrate this challenge. In the case of BMW, the planning departments at the beginning only knew that they had to start the planning activities for a new plant. A couple of months and several cutbacks later, the decision for the location of the new plant was made (Autoweb, 2004). At this stage, in all planning departments the planning activities already were running. For the critical observer the interesting question now is – would the new plant in Leipzig look different if it had been located elsewhere?

2.6 Tools and Methods to Support the Planning Process

The statement of Higgins et al. (1996a, p. 1) that "there has been much written about the many different manufacturing planning and control philosophies that are used in manufacturing" can be agreed without additional comments. In his book 'Handbook of Production Management Methods' Halevi (2001) describes 110 different manufacturing methods. At this point a description of the single approaches would not be helpful, so that in view of the original problem a first selection will be done with the help of the aspects consolidated by Halevi (2001, p. 3):

- *Production is very complex:* Therefore we need more and more complex computer programs and systems to regulate and control it.
- *Production is very complex:* Therefore THE only way to make such systems more effective is to simplify them.
- *Production is very complex:* Therefore there is no chance of building a system to solve the problems. Hence the role of computers should be limited to supplying data and humans should be left to make decisions.

This research project is mainly based on the third point. Just the aspect that in the early planning phase, human abilities like intuition, creativity and experience are needed, is an exclusion criterion for many support technologies. However, because of the numerous dependencies, the human brain cannot handle this complexity (Sterman, 1994, p. 309), so that in the planning and decision making process the experts should fall back on the support of computers (Bunz, 1988, p. 82; Young, 2003; Kudlich, 2000, p. 20; Morecroft, 1984).

According to these arguments and the statements of Kudlich (2000, p. 21), Bunz (1988, p. 88) and Wu (1992, p. 280), the planner at this stage could be supported with the following systems:

- Simulation techniques.
- Databases.
- CAD-systems.
- Mathematical calculation programmes.
- Systems for project management.
- Microsoft Office-family (e.g., Excel).
- Expert systems.

There are also some methodical approaches available (Grundig, 2000, pp. 49/107/176; Kettner et al., 1984, pp. 41/45). Essential methods are:

- Benchmarking.
- Key performance indicators.
- ABC-analysis.
- Value benefits analysis.
- Sankey-charts.

Taking into account the planning phase, the available level of detail of information and the desired results, some systems and methods will be described in detail below.

2.6.1 Simulation Techniques

Doubtless, these days simulation technology plays a major role while planning a factory (Grundig, 2000, p. 201; Meyer and Stephens, 2005, pp. 14/467; Thomson, 1995, p. xi; Wiendahl, 2002). The reasons for this development are linked with both the improved computer hardware and software programms offering a better way of programming and displaying the simulation models (Harrison and Petty, 2002, p. 166; Kudlich, 2000, p. 24; Eccles, 1991).

In the context of assembly, simulation can basically be divided into two categories. On the one hand, there is 'systems evaluation', having the objective to optimise existing processes. On the other hand, there is 'systems design', trying to recognise possible 'pitfalls' as early as possible during the planning process (Wu, 1992, p. 194).

In any case, simulation is defined as follows: "Simulation is the imitation of a real world system" (Harrison and Petty, 2002, p. 165) or in other words, "a laboratory replica of a company exists in the computer" (Forrester, 1998, p. 4). Like in all simulation models, input parameters will be converted into output parameters, in order to predict the response of the system (see figure 20).

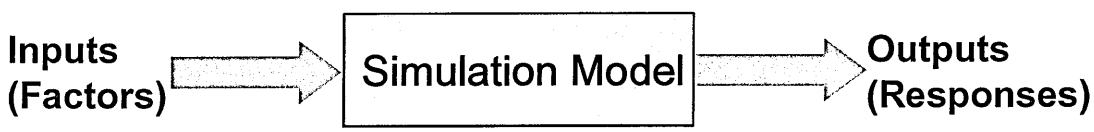


Figure 20 – Simulation Modelling. Robinson (1994)

Even if there are a huge number of simulation models, the probably best known examples are 'flight simulators' and 'business games' (Robinson, 1994, p. 3). In view of the original question, figure 21 shows some operational examples of simulation technologies in the area of factory planning.

Planning Level	Content	Simulation Model
Factory	• Manufacturing Principle • Logistic • Capacity Planning • Throughput Studies • Warehousing	• Material Flow Simulation (rough) • Business Process Simulation
Facility	• Layout Optimisation • Flow of Material • Performance • Operation Strategy • Breakdown Strategy	• Material Flow Simulation (middle)
Manufacturing Cell	• Cell Layout • Layout Optimisation • Operating Sequence • Collision	• Material Flow Simulation (detail) • 3D-Virtual Reality
Components	• Dynamic Load of Equipment • Joining Process • NC-Programme	• FEM • Graphical 3D-Simulation • Multibody Simulation

Figure 21 – Field of Application of the Simulation Technology. Reinhart et al. (1997); Trossin (1997)

After an analysis of different authors (Zheng and Possel-Dölken, 2002, p. 234; Harrison and Petty, 2002, p. 165; Wu, 1992, p. 196; Robinson, 1994, p. 4; Sterman, 1994, p. 317; Meyer and Stephens, 2005, p. 15; Reinhart et al., 1997), the following arguments for the use of simulation techniques can be summarised:

- Exact analysis of system states, leading to a better understanding of the systems.
- Analysis and evaluation of bottlenecks and weak points in a system.
- Analysis and selection of optimal alternatives or opportunities by influencing the system's behaviour, as well as optimisation of target parameters. Allows 'what-if' analysis.
- Simulation may allow a system to be tested under extreme conditions that could not be justified in the real world.
- Communication and animation (The user can play with a simulation model = training tool).
- Potential for group problem solving.

In comparison to direct experimentation, computer simulation offers the advantages "of lower costs, shorter time, greater flexibility and much smaller risk" (Wu, 1992, p. 193). For this research project, the advantages of simulation in contrast to mathematical modelling and for managers and planners, as given by Robinson (1994, pp. 7-9) in figure 22 are almost as important.

Reasons for Simulation	Advantages
Simulation Benefits	• Risk Reduction • Greater Understanding • Operating Cost Reduction • Lead Time Reduction • Faster Plant Changes • Capital Cost Reduction • Improved Customer Service
Benefits over Real Life Experimentation	• Cost • Repeatability • Control over the Time Base • Legality and Safty
Benefits over Mathematical Modelling	• Dynamic and Transient Effects • Non-Standard Distributions • Interaction of Random Events
Managerial Benefits	• Fosters Creative Attitudes • Promotes Total Solutions • Makes People Think • Communicating Good Ideas

Figure 22 – Advantages of Simulation. Robinson (1994)

For being able to transfer some of the listed advantages to this research project, a couple of rules should be followed. Therefore, the procedure for running a simulation as illustrated in figure 23 could be used as a guideline for this project.

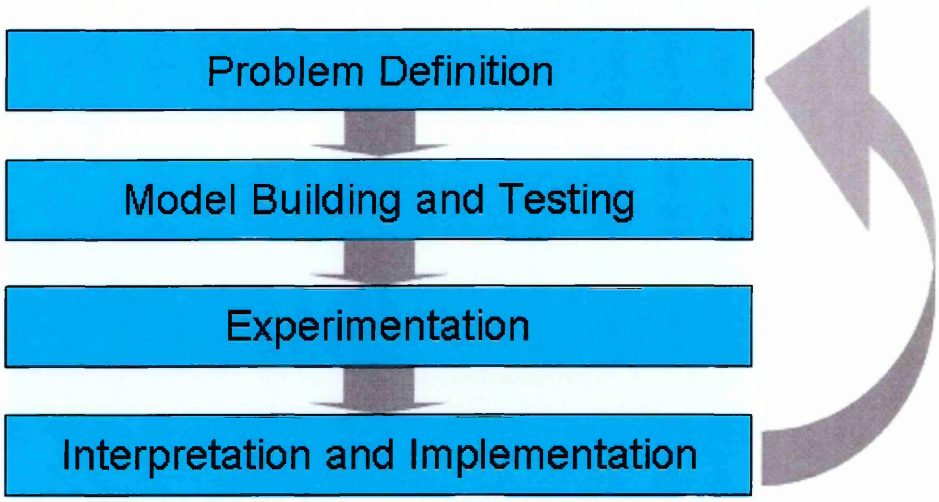


Figure 23 – Procedure for Running a Simulation. Kudlich (2000); Robinson (1994)

Even so, it should not be hidden at this point that some aspects such as 'data availability', 'requirement of expertise' and 'time required to construct a simulation model' produce risks and disadvantages associated with undertaking a simulation project (Wu, 1992, p. 200/201; Meyer and Stephens, 2005, p. 468). In spite of many advantages for example '3D-computer graphic environment' and 'virtual reality' offer for the improvement of the process of planning a factory (Cunha et al., 2003; Tong et al., 2003; Maropoulos, 2003; Maurer and Stark, 2001, p. 23; Wiendahl, 2002), the counter-arguments listed above are not easily to dismiss for the moment. However, on account of the necessary level of detail of the required data these two technologies cannot be used for this research project anyway.

Instead, two approaches are introduced below more precisely, since with respect to the planning stage and the required information they could matter to this research project.

2.6.2 Benchmarking

Before important decisions, and the planning of a new final assembly shop is one of them, enterprises often use the approach of benchmarking in order to evaluate the strengths and weaknesses of existing plants (Weber, 1999; Maskell, 1991, p. 308; Ahmad and Benson, 1999, p. 1; Grundig, 2000, p. 43). According to Camp (1989, p. 12), "benchmarking is the search for industry best practices that lead to superior performance". The opinion of Halevi (2001, p. 72) is interesting as well, since he points out that "to gain superiority it is dependent upon a detailed understanding of the company's own operations and those of others". Miller et al. (1992, p. 7) also argue in this direction, when they stress the aspect that "in-depth competitor analysis requires a great deal of data" and "the only way to obtain specific knowledge about another manufacturing company is to study it carefully as an entity".

With regard to the original problem leading to this research project, the question arises, how strong is the desire to analyse in detail a complex system such as a final assembly shop of a car manufacturer.

Doubts come up, since according to Luczak et al. (2000, p. 5) many enterprises just understand a comparison of 'key performance indicators' under the term 'benchmarking'. It seems to be difficult to explain the differences of such a complex system only with the help of some key performance indicators, or the so-called 'benchmarking gaps' (Ahmad and Benson, 1999, pp. 6/17). In his 'Framework for Competitor Analysis' Porter (1980, p. 48) supports this scepticism. As displayed in figure 24, key performance indicators are very important for the benchmarking process (Weber, 1999; Camp, 1989, p. 6), but there is still some additional information required to understand the differences. This should be kept in mind, for the evaluation of the results at the end of this research project.

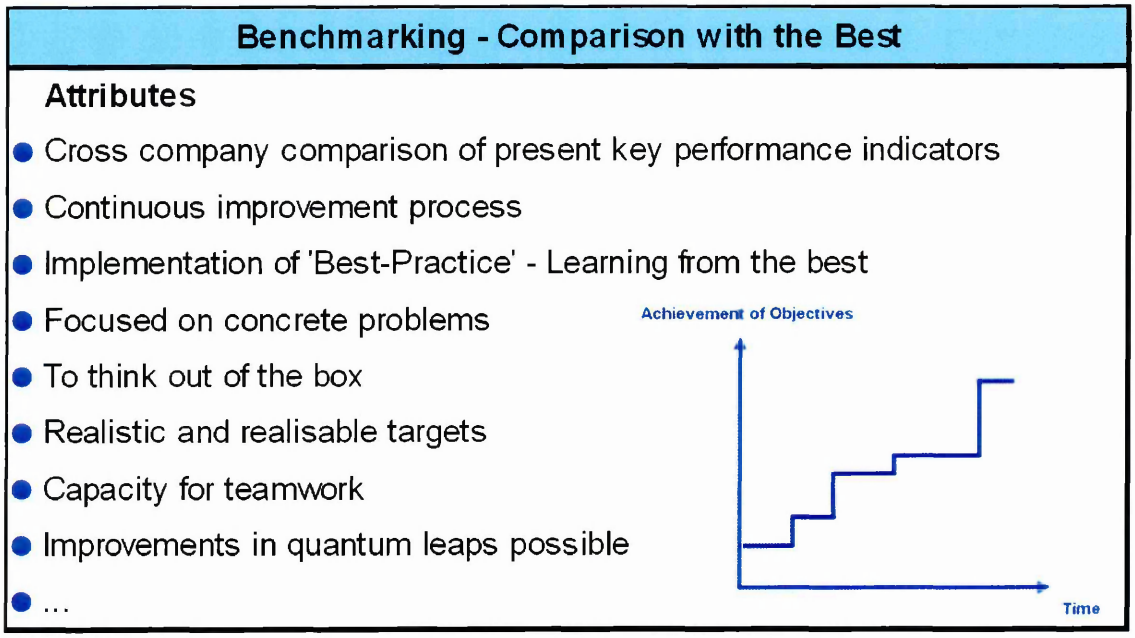


Figure 24 – Benchmarking – Comparison with the Best. Luczak et al. (2000)

For this research project, the following question has to be answered:
How much effort is necessary within the planning process of a final assembly shop to get information helpful for the improvement of the quality of the planning results?
Although the internal benchmark (= comparison within one company) (Halevi, 2001, p. 73) is classified as the kind asking for the lowest effort (Luczak et al., 2000, p. 9), within the BMW Group at least one important base for a successful benchmarking activity was missing at the beginning of this research project. Because of the lack of a definition of the collected key performance indicators, some of the figures could only be used with a lot of additional effort or could not be used at all. Due to the complexity of a final assembly shop it was also barely possible to derive some potential improvements using only the collected figures. In view of the terms 'comparability and learning potential' a continuous competitive benchmarking (= comparison with the direct competitors) should be the target. Besides some temporary and unique OEM benchmarks (e.g., the comparison of the final assembly shops of AUDI, BMW, DaimlerChrysler, Porsche and VW in 2004) (OEM-Benchmark, 2004), the only continuous comparison offered in automotive industry is the well known 'Harbour Report'.

Unfortunately, its results are insufficient for the planners of a final assembly shop, since highly summarised key performance indicators like 'hours per vehicle' may be helpful for top management and analysts, but do not give a hint about differences in the structures of the assembly plant. As described by Brown (1996, p. 19), the lack of exactness is a problem of the key performance indicators used by Harbour.

An important aspect for the comparison of competitors is a standardised classification of the benchmarking objects (Luczak et al., 2000, p. 23). An unique definition of the system boundaries is necessary, so that a discussion about the comparability of the key performance indicators can be avoided. Especially for complex systems like a final assembly shop of a car manufacturer, this is a big challenge, since such systems can differ in many points. Big variations in the vertical integration (Jarillo, 1993, p. 5) could significantly influence the value of a key performance indicator 'units per employee' (Maurer and Stark, 2001, p. 18; Kaplan and Norton, 1996, p. 126).

Hence, it is necessary to show cause and effect relationships (Kaplan, 2003), influencing such well defined key performance indicators, so that the figures get more comparable in the future and will become more helpful for the planners.

2.6.3 Mathematical Calculation Algorithm

Just with the development of the MS Office-family and here especially with the Excel-spreadsheets, many experts have developed their own mathematical calculation algorithms, which support them in daily business (Kudlich, 2000, p. 24). Such individual solutions are not very helpful for the enterprise, since they often do not contribute to the learning organisation, as the following examples show:

- The calculations are often not very transparent or simplify life too much.
- The calculations will not be tested and are a result of the mental models of the planner.
- The calculations are linked to the individual planner and get lost, after the project.

Since many specialists use such individual calculations, it is obvious that they play a major role during the planning process. As demonstrated later, this is a very important conclusion for this research project.

2.7 Key Performance Indicators for the Planning Process

On the basis of the original question and the relevance for this research project, in the following section, the key performance indicators will be analysed in detail. In doing so, it is helpful to know that different authors (Grundig, 2000, p. 59; Vetter, 1983, p. 3) rate the usage of key performance indicators as a classical tool within the factory planning process. Nevertheless, most of the information is very general because no specific key performance indicator systems for the task of planning a factory could be found.

2.7.1 Definition of Key Performance Indicators

Scheuing (1967, p. vi) already in 1966 realised that "key performance indicators are not a new management tool". Against this history, and because of the importance for this research project, it is absolutely necessary to generate the same understanding on the term 'key performance indicator'. Hence, it will be defined at the beginning of this section.

First of all, it has to be said that besides the expression 'key performance indicator' literature (Siegwart, 1990, p. 13; Weber, 1999; Geiss, 1986, p. 19) offers plenty of similar terms. They are all defined differently (Vetter, 1983, p. 17; Staudt et al., 1985; Ossola-Haring, 1999), but basically have the same intention. The terms 'ratios' (Tucker, 1961), 'key management ratios' (Walsh, 1996), 'performance indicators' (Chow et al., 1994), 'performance measures' (Karreman, 2000) or 'key performance ratio' (Gattorna, 1990) can be named synonymously.

According to Ahmad and Dhafr (2002), "a key performance indicator (= KPI) is a number or value which can be compared against an internal target or an external target 'benchmarking' to give an indication of performance".

In reference to the 'timeframe' the above mentioned definition can be completed by the definition of Nam (1997, p. i). "A key performance indicator should reflect and be focused on the most critical features of the current and future success of the organisation". Moreover, the "deliberate aggregation of the complex reality with the help of numbers" (Weber, 1993, p. 227) is important.
Besides these criteria, there are much more considerations (Ossola-Haring, 1999, p. 14; Geiss, 1986, p. 34) about the definition of a key performance indicator available.

2.7.2 Classification of Key Performance Indicators

Key performance indicators can be differentiated in many ways (Staudt et al., 1985; Schlegel, 2001). According to Weber and Schäffer (1999), for a long time many people tried to accept just monetary data from the past with relevance for balance sheet analysis (Mott, 1991, p. 116) as a key performance indicator. However, this one-sided view is based on past values only, so that it is correct that it will be criticised by different authors (Tucker, 1961, p. xi; Feggeler and Husmann, 2000, p. 15; TCIOMA, 1993). Hence, it is highly welcome that in recent years, by the distribution of Kaplan`s and Norton`s 'Balanced Scorecard', non-monetary figures became more important (Ossola-Haring, 1999, p. 20; Eccles, 1991, p. 131). For this research project both monetary and non-monetary figures will be relevant, since both aspects play a major role for the process of planning a final assembly shop.
Besides this differentiation, literature offers some more or less important ways of systematisation. A brief abstract is illustrated in figure 25.

Characteristics	Variants
Statistical Form	Absolute Relative
Content	Monetary Non monetary
User	Internal External
Reference Object	Total company Parts of a company
Timeline	Short-term Medium-term Long-term
Type	Normative Descriptive

Figure 25 – Differentiation of Key Performance Indicators. Geiss (1986); Weber (1993)

For this research project, also a very important classification is the subdivision of key performance indicators in absolute figures and ratio figures (Bieri, 1995, p. 38; Luczak et al., 2000, p. 25), which is shown in figure 26. Also this split just won recognition during recent years. For a long time experts discussed the question, if besides ratio figures also absolute figures can be key performance indicators (Siegwart, 1990, p. 13; Geiss, 1986, p. 23). In this context the definition was differentiated into a 'tight' one and a 'broad' one. The ambassador of the tight definition just accepted ratio figures as key performance indicators whereas the other side of experts also included absolute figures within their definition (Staudt et al., 1985, p. 22). For this research project both ratio figures and absolute figures will be accepted as key performance indicators. Even so, at this point it can be mentioned that in general the explanatory power from ratio figures is substantially higher compared to absolute figures (Weber 1993, p. 229; Ossola-Haring, 1999, p. 16).

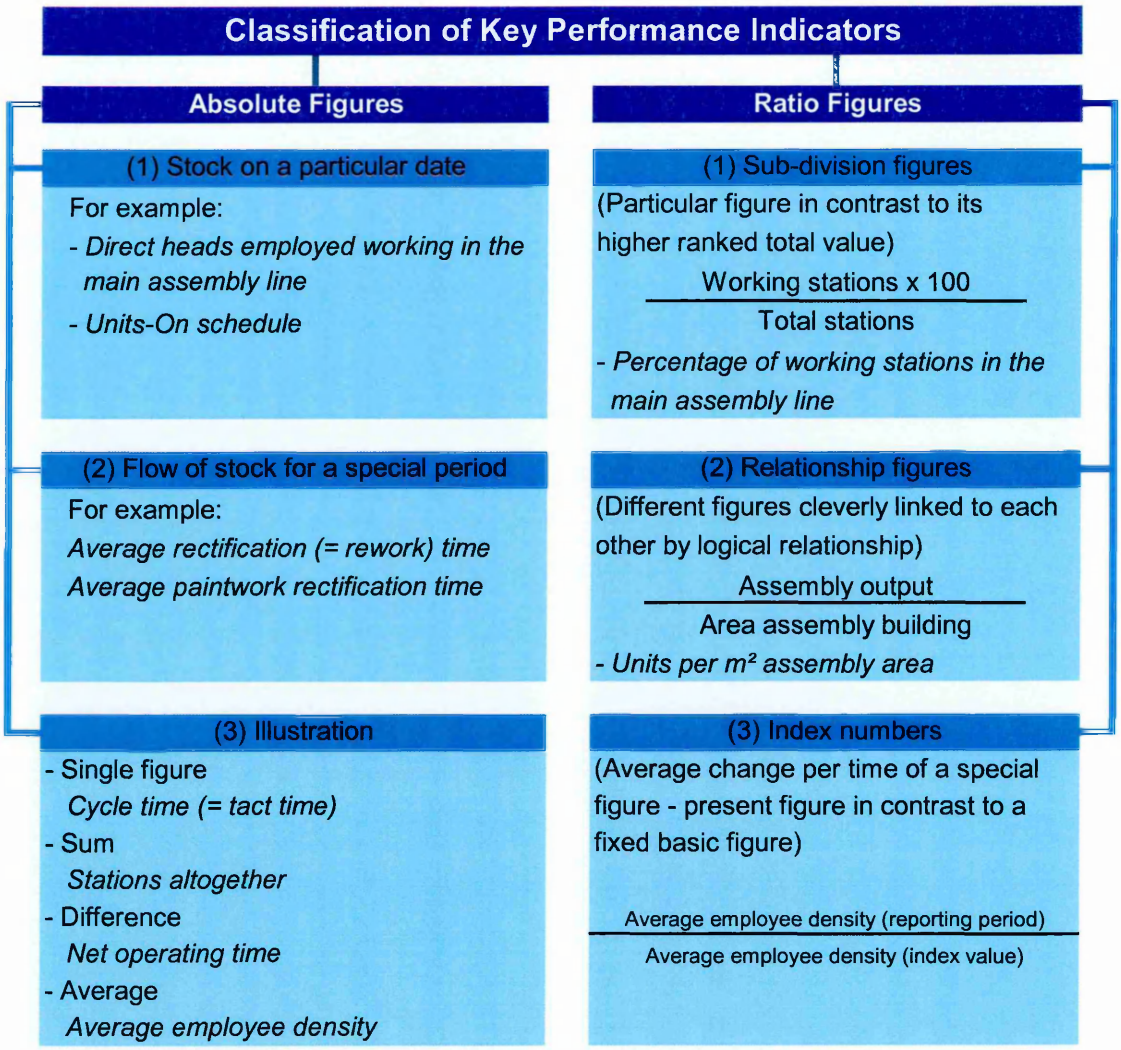


Figure 26 – Classification of Key Performance Indicators. Hopfenbeck (1997)

As shown above, the absolute figures – which can be measured – can be subdivided into a stock on a particular date or a flow of stock for a special period. Also a classification based on the illustration is possible.

Ratio figures just have to be calculated out of at least two absolute figures (Scheuing, 1967, p. 11). The observed figure is part of the numerator whereas the reference value is part of the denominator (Weber, 1999). Figure 26 also illustrates the further breakdown of ratio figures into sub-division figures, relationship figures and index numbers.

2.7.3 Operational Areas of Key Performance Indicators

As described by Weber (1993, p. 227), Vetter (1983, p. 56) and Staudt et al. (1985) and as displayed in figure 27, key performance indicators can support the processes of planning, regulation and control. Hence, they will be "used in every aspect of the modern organisation" (Karreman, 2000, p. 13).

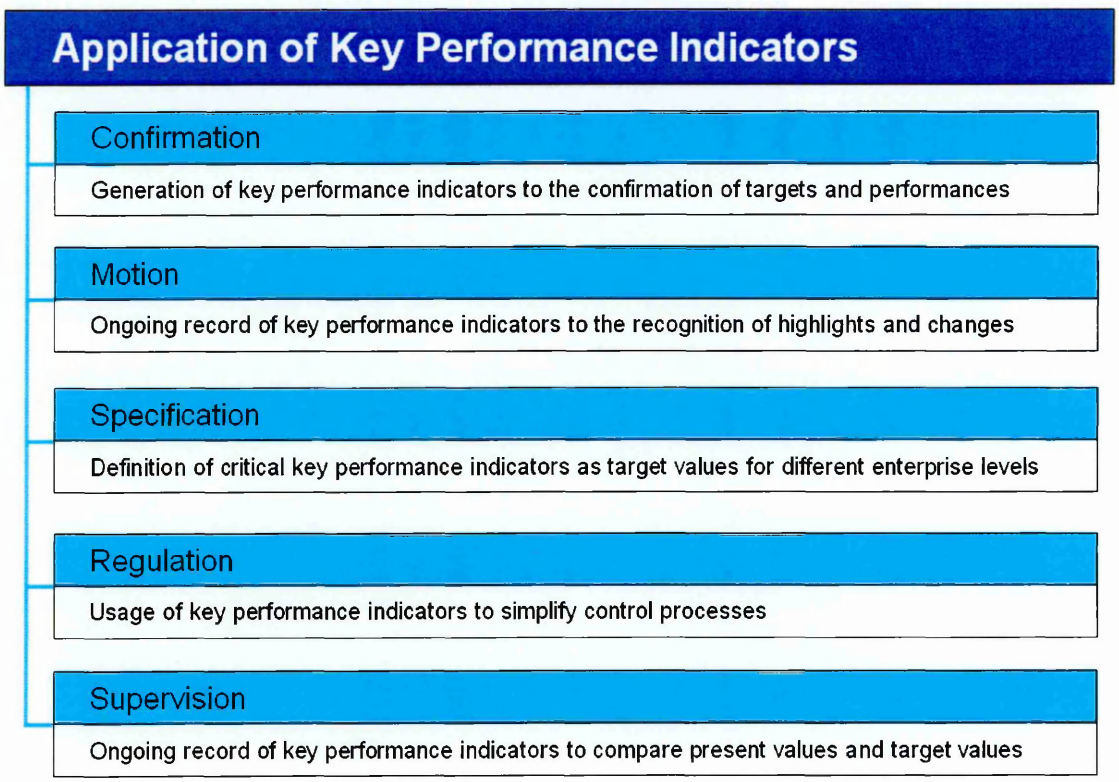


Figure 27 – Fields of Application of Key Performance Indicators. Weber (1993)

According to Vetter (1983, p. 2), Reindl (2005, p. 17) and Kettner et al. (1984, p. 22), for this research project the planning function is most significant, at the first view. Thereby, planning numbers from the specialists departments will be compared with the target values given by the controlling departments and the management (Weber, 2002).

2.7.4 Benefits of Key Performance Indicators

At this point it should be stressed once more that most of the articles found in literature about 'key performance indicators' are focused on KPIs as a management tool and the control of the already operating enterprise. However, it should be the purpose of all authors to make the advantages described below also usable for the planning process of a factory. In the end, these plannings often determine the future efficiency of a manufacturing company.
Many authors (Schlegel, 2001, p. 51; Nam, 1997, p. 15; Putnam, 1984, p. 56; Gattorna, 1990, pp. 283-286; Ossola-Haring, 1999, p. 14; Siegwart, 1990, p. 23; Harper, 1984, p. 6) agree that key performance indicators offer a huge number of advantages, if they are used correctly or as Walsh (1996, p. 4) calls it: "Business ratios are the guiding stars for the management of enterprises; they provide their targets and standards". In a little more detail, some of the benefits are:

- KPIs inform about the environment (= the market and the competitor) and the own position within the competition.
- KPIs offer an orientation for the enterprise objectives and the strategic concepts.
- KPIs allow users to keep track of core business activities easily.
- KPIs distil the information down into a few indicators that are easy to watch.

In addition, the four CPs of Neely (1998) can be mentioned, too.

- Check position.
- Communicate position.
- Confirm priorities.
- Compel progress.

For being able to use these benefits, key performance indicators have to be compared. In general, three kinds of comparisons are known (Siegwart, 1990, p. 20):

- Comparison over time.
- Target value – present value comparison.
- Standard value – present value comparison.

For the planning process of a final assembly shop, all three ways of comparison can be helpful (Grundig, 2000, p. 74).
Comparing individual key performance indicators over time, the positive or negative trends that could influence the planning process can be indicated.
Target values can be compared to present values. In this context present values can also be understood as planning values (Geiss, 1986).
Finally, certain norms (e.g., sanitary areas per employee) have to be kept in mind during the process of planning a final assembly shop. However, all these comparisons are only possible if suitable data are available in the right level of detail and at the right time.
To sum up, it can be said that at the different stages of the planning process all key performance indicators should help to minimise insecurity within decision-making (Siegwart, 1990, p. 23). Even if it is explained in detail below, it must be mentioned now that most of the time these advantages can not be realised with a single key performance indicator, because of the complexity of an enterprise (Luczak et al., 2000, p. 20; Kaplan, 2003). Rather, such advantages can only be used with the help of a balanced system of key performance indicators.

2.7.5 Key Performance Indicator Systems

In spite of the above listed benefits, individual key performance indicators will often be criticised that they only have low explanatory power by themselves (Weber, 1993, p. 230; Geiss, 1986, p. 39; Tucker, 1961, p. 30) and achieve, as already mentioned, their real value only in comparison to other key performance indicators (Scheuing, 1967, p. 31; Mott, 1991, p. 116).

Hence, the complex interaction of different key performance indicators will be displayed in a system of key performance indicators by which the explanatory power of the individual key performance indicators also will be increased (Siegwart, 1990, p. 123; Luczak, 2000, p. 26). A suitable definition for a key performance system is offered by Lachnit (1976, p. 216):

"A key performance indicator system consists of an ordered totality of key performance indicators, which are linked to each other in a factual reasonable way, complement each other and as a totality serve the purpose to grasp the observed object completely and as well balanced as possible".

According to Siegwart (1990, p. 33), key performance indicator systems try to illustrate the whole enterprise. The statement of Harper (1984, p. 8) that "a set of ratios chosen must reflect the fact that all industrial units are systems", shows that this understanding is tight-knit with 'System Theory', which will be described later.

The crosslinking of the parameters can be done mathematically (= arithmetic systems) and / or, on the other hand logically (= classification system) (Staudt et al., 1985, p. 32; Luczak et al., 2000, p. 26). Since Schott (1991, p. 29) comes to the conclusion that "key performance indicator systems are the most important management tools for information and control", both kinds will be explained below. In addition, both kinds of system are relevant for this research project.

2.7.5.1 Arithmetic Systems

Figure 28 pictures that arithmetic systems are shaped pyramidical. The elements (= key performance indicators) are linked to each other in a mathematical deductive structure (Geiss, 1986, p. 84). For the understanding of the complex system 'final assembly shop' as well as for the planning of it, these connections are very important.

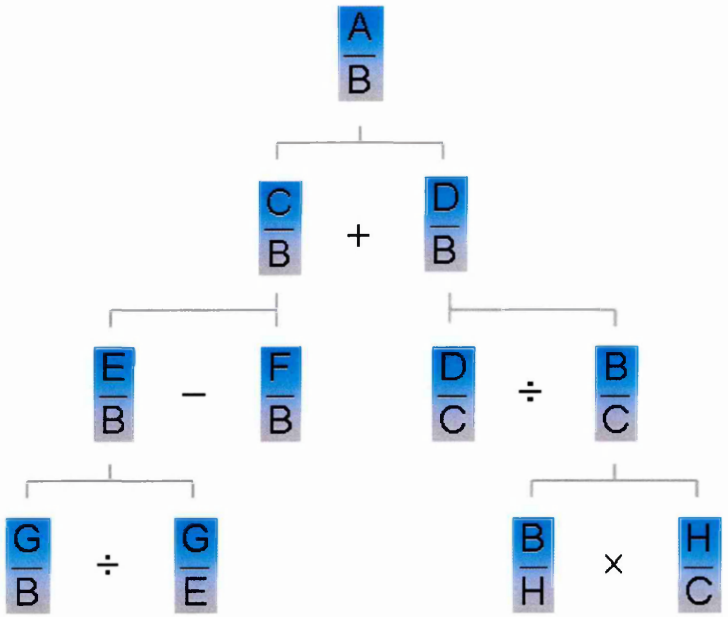


Figure 28 – Arithmetic Key Performance Indicator System. Siegwart (1990)

2.7.5.2 Classification Systems

As mapped in figure 29, in contrast to the 'arithmetic systems' the logical relationships come to the fore in 'classification systems' (Geiss, 1986, p. 84). Since there are a huge number of such connections within a final assembly shop of a car manufacturer, this way of structuring will also play a major role in this research project. In spite of the complexity of a final assembly shop, it should help to design a transparent key performance indicator system.

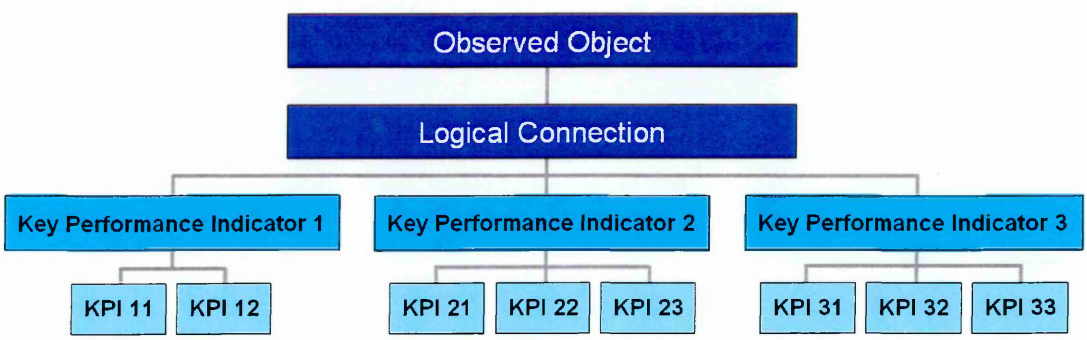


Figure 29 – Classification Key Performance Indicator System. Siegwart (1990)

2.7.5.3 Existing Key Performance Indicator Systems

At this point a short overview about probably the best known and, for the development of key performance indicator systems, the most important (Staudt et al., 1985) existing key performance indicator systems will be given. Even if the majority of the systems introduced below are aimed at optimising monetary figures, some aspects will still be important for this reseach project. Besides the systems introduced here, Staudt et al. (1985) and Geiss (1986, pp. 88/133) offer an overview about the development in the German-speaking literature. Since most of these show a modification or advancement of the 'DuPont-System', none of these will be described in more detail at this point.
In addition, it must be noted that there can be company specific developments, which are not documented in literature. For the car industry no such key performance indicator system is known, where a complete final assembly shop is mapped.

DuPont-System

Figure 30 shows the already mentioned 'DuPont-System of Financial Control', which is focused exclusively on the Return on Investment (= ROI), i.e. to the yield from the invested capital (Atkinson et al., 2001, p. 13; Hilton, 1994, p. 606; Siegwart, 1990, p. 36). For this research project the remark of Siegwart (1990, p. 38) is interesting, since he awards the system educational abilities on account of its construction and its ability to show the interesting interrelationships between the elements. He refers to the 'Management School St Gallen', where executives will be trained with this system. Hence, the learning effect which an accepted key performance indicator system can involve should not be underestimated.

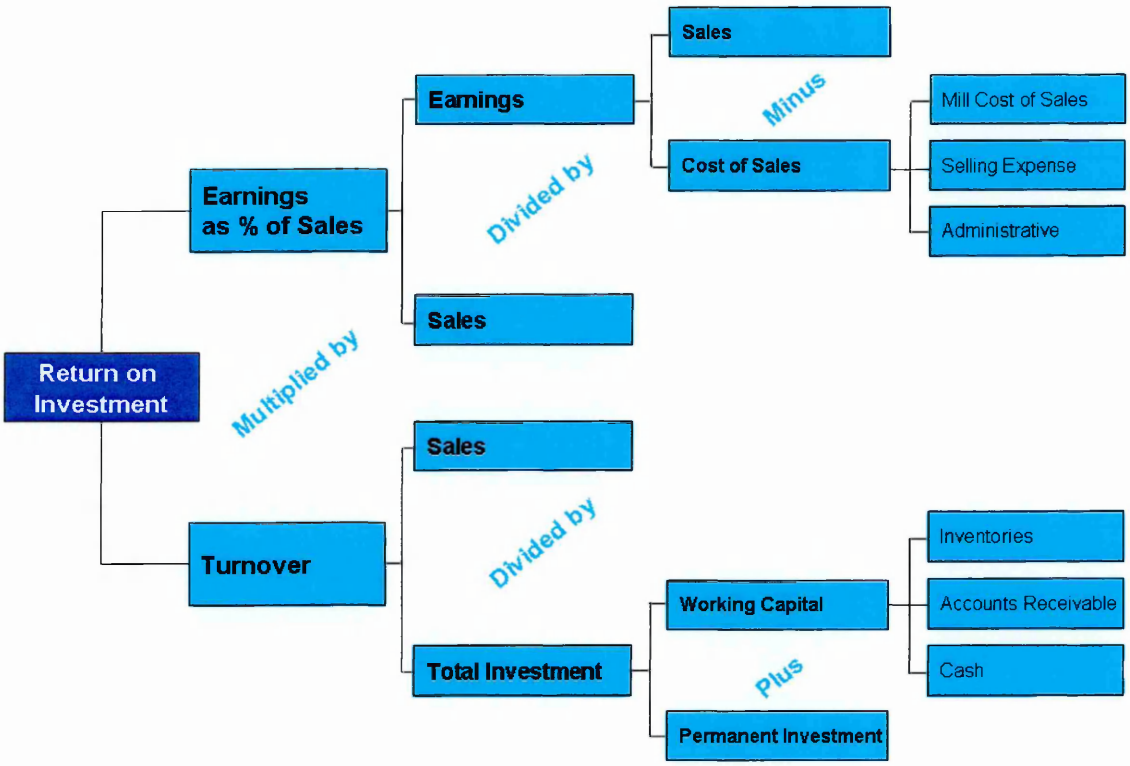


Figure 30 – DuPont-System. Geiss (1986)

Ratios au Tableau de Bord

The 'Ratios au Tableau de Bord' is also looking for the profitability of a system. In general it is based on the factors 'sales profitability' and 'capital turnover'. According to Staudt et al. (1985), the 'Ratios au Tableau de Bord' is a comprehensive system of information, which offers several views to solve the tasks from different enterprise levels (Weber, 1999). Reffering to this, a statement of Meyer is interesting, who will be quoted in Staudt et al. (1985) as follows: “For the analysis and knowledge production by means of extrapolation from present figures calculated future values will be used”. Especially the future oriented aspect for a key performance indicator system is of interest to this research project, since the planning of a final assembly shop of a car manufacturer likewise is directed in the future.

Pyramid Structure of Ratios

In 1956 the 'Pyramid Structure of Ratios' was developed at the 'British Institute of Management'. It is pyramidical shaped and as demonstrated in figure 31, consists of a sequence of logically linked questions and answers (Staehle, 1975). Once more, with the ROI (= Return on Investment) a so called primary key performance indicator is at the top of this system. The primary key performance indicators and the secondary key performance indicators are linked to each other both in a mathematical and in a logical way. In addition, it is mentionable that this key performance indicator system is especially focussed on the competitive comparison in order to obtain out of it the opportunity to evaluate the internal performance.

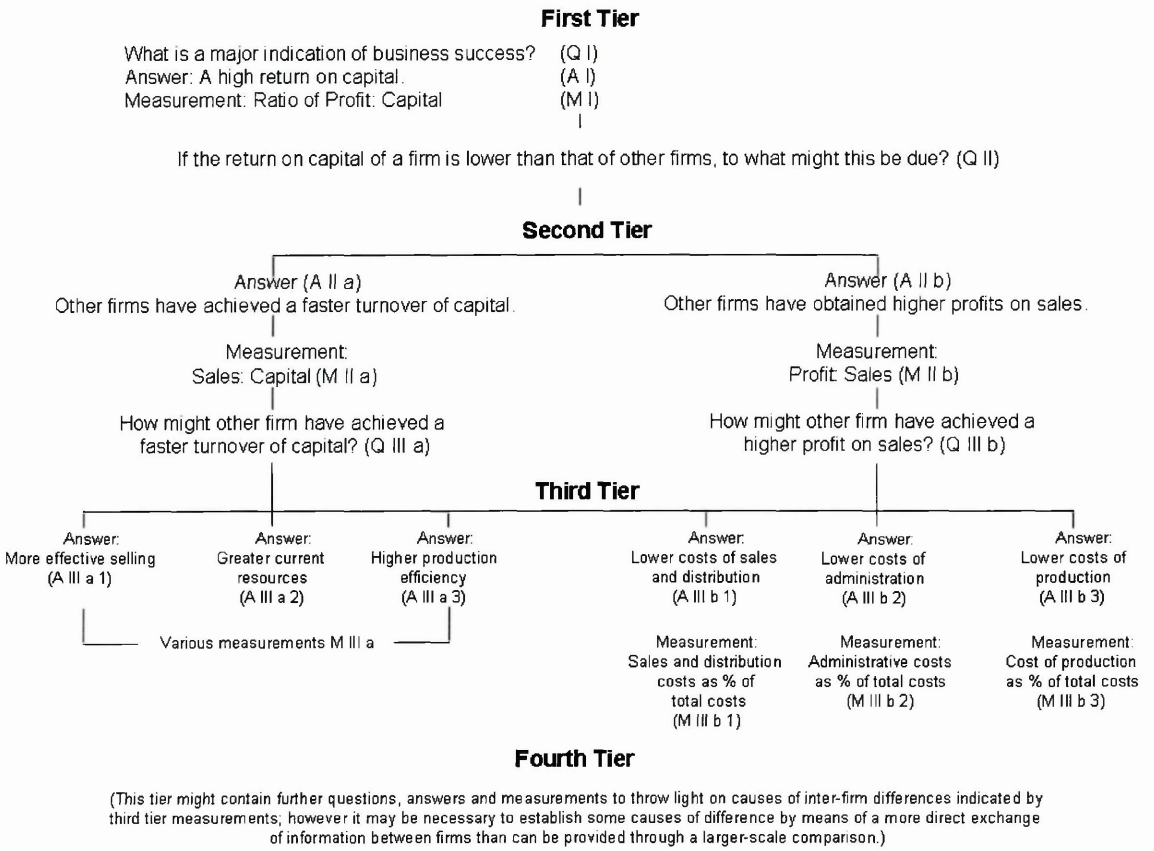


Figure 31 – Pyramid Structure of Ratios. Staudt et al. (1985)

ZVEI-Key Performance Indicator System

Following the 'DuPont-system', the 'ZVEI-Key Performance Indicator System' is also constructed pyramidically (Staudt et al., 1985; Geiss, 1986, p. 19; Staehle, 1975). It is exclusively focused on economic key performance indicators (Vetter, 1983, p. 17). In doing so, it consists of 60 main key performance indicators and 70 auxiliary key performance indicators, which are calculationally connected with each other (Siegwart, 1990, p. 42). The ZVEI-system permits both a growth analysis and a structural analysis, while it compares on the one hand the most important success factors to the previous period and examines on the other hand the top key performance indicator 'return on equity'. Since most of the required information only is available in internal management accounting, the ZVEI-system is not suitable for external analysts. This is one of the main criticism points regarding this system (Siegwart, 1990, p. 42).

Balanced Scorecard

The systems introduced so far were specially focused on economic figures. However, as already mentioned, today it is unquestioned that key performance indicator systems should be balanced (Weber, 1999; Dixon et al., 1990, p. 25). An essential contribution to the consolidation of this knowledge has performed by Robert Kaplan and David Norton (Dillerup, 1998, p. 139). In the article 'Putting the Balanced Scorecard to Work' Kaplan and Norton (1993) point out that only few organisations have a catalogue of well-balanced key performance indicators.

Figure 32 shows that the 'Balanced Scorecard' consists of four well-balanced perspectives. Besides the financial perspective, the customer perspective, the internal process perspective and the learning and growth perspective are important (Kaplan and Norton, 1996, p. 2). The consideration of the four success factors should help to minimise the risk that requirements of customers and employees will not be considered because of the importance of the financial results (Weber, 1999). In addition, the BSC connected, in a unique way, the key performance indicators with the business strategy (Brewer and Speh, 2001).

In view of the original problem of this research project it is important to keep in mind that a system of key performance indicators for the planning process of a new final assembly shop both should be able to handle different perspectives and should be linked to the higher enterprise objectives.

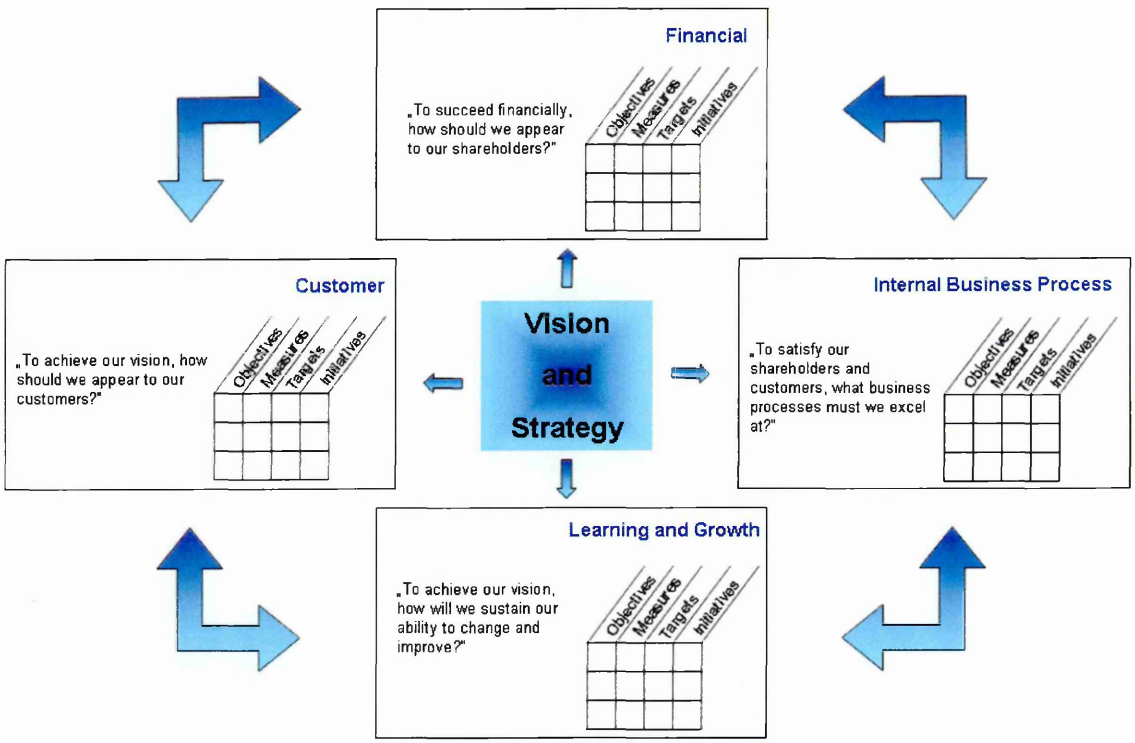


Figure 32 – Balanced Scorecard. Kaplan and Norton (1996)

Managerial Control System

The 'Managerial Control System' by Tucker (1961, p. x) is very interesting as well, because it differs from the systems introduced so far as follows. While a huge number of key performance indicator systems are formed Top-Down by the help of a super key performance indicator (= 'deductively derived key performance indicator system' (Luczak et al., 2000, p. 27)) Tucker develops key performance indicators Bottom-Up (= 'inductively derived key performance indicator system' (Luczak et al., 2000, p. 27)) by summarising various raw data. This approach ends in several top key performance indicators. Altogether, the system consists of 429 key performance indicators, which are organised in three levels (Tucker, 1961, p. xv).

According to Tucker (1961, pp. xii/71), the 'simple ratios', 'advanced ratios' and 'tertiary ratios', interrelate major areas and therefore are more convenient for higher management. He also stresses the mutal dependencies of single events as well as the interrelationship of data (Tucker, 1961, p. x). This comprehensive view supports management to recognise positive and negative trends and to evaluate these at an early stage in terms of the overall result. The MC-system also assists the idea that important decisions and the consequences linked with it can be tested ahead of the decision (Tucker, 1961, p. 12).
The listed aspects also play a major role during the process of planning a final assembly shop; hence they will be taken into consideration in this research project.

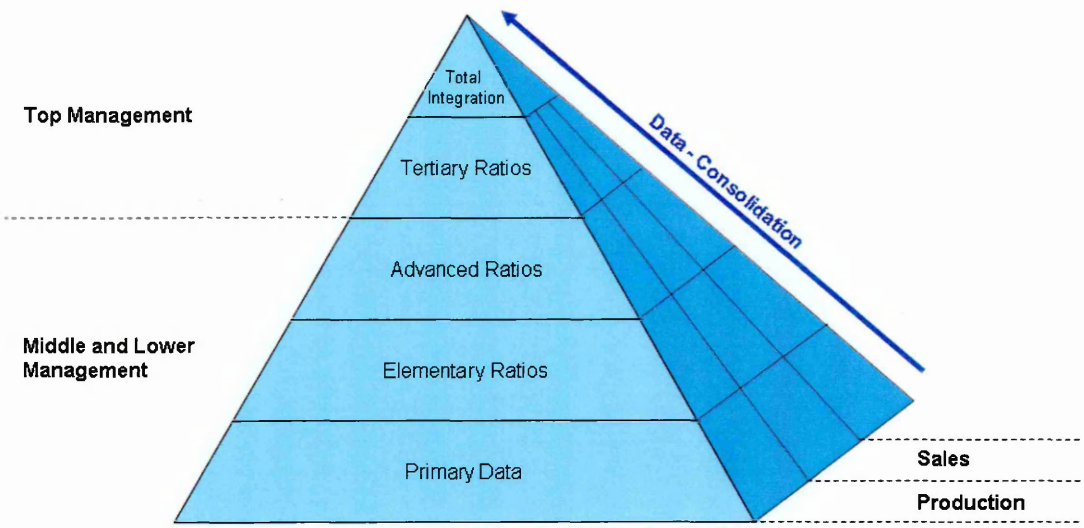


Figure 33 – Managerial Control Concept. Staudt et al. (1985)

However, it also must be mentioned that Tucker (1961, p. xii) is against the usage of 'general ratios'. In his eyes “ratios must be specific; designed and 'machined' to fit specific companies and situations” (Tucker, 1961, p. xi). Later in this thesis it should become obvious that it is not necessary to realise this demand completely.

In this context, it is very helpful for this research project that, as already mentioned, final assembly shops of car manufacturers are built up very similarly. Therefore, it should be possible to design a general key performance indicator system supporting the planning process for a new final assembly shop.

Key Performance Indicator Net

Although Staudt et al. (1985) call the key performance indicator net, developed by Caduff (1981), as contrary compared to the other key performance indicator systems, still some synergies to the 'MC-system' by Tucker can be recognised.

In this approach, key performance indicators are connected to a system, which Ebenda (quoted in Staudt et al., 1985) calls 'key performance indicator net'. This net consists of one or several key performance indicators (= situational dominant key performance indicators), net figures (= permanent given key performance indicators) and auxiliary key performance indicators which have the function of connectors (between the key performance indicators) (Staudt et al., 1985). The essential creation criteria are:

- Problem adequacy.
    - Completeness.
    - Sensitivity.
    - Robustness.
    - Multidimensionality.
- Flexibility.
    - Modular construction.
    - Switching on and off of key performance indicators in dependency on the problemspecific degree of summarisation.
    - Definition of the most important key performance indicator(s) dependent on the problem.
- Easy of use.
    - Participation of the users in the net creation.
    - Orientation towards the individual behaviour of the users.

- Profitability.
    - Adequate degree of abstraction.
    - Multiple uses of components of the key performance net for different decision problems.
    - Extensive usage of available internal data for the generation of the key performance indicators.

The key performance indicator net seems to be very interesting for investigations in a complex environment. Therefore, the basic idea introduced, could play a major role for this research project.

2.7.6 Characteristics of Good Key Performance Indicators

As described above, systems of key performance indicators consist of numerous key performance indicators, therefore, characteristics of a good key performance indicator are also the foundation of a good key performance indicator system. Hence, a strict separation of both terms is not purpose leading in this segment. Beside the criteria described below, in the technical literature (Ossola-Haring, 1999, p. 19; Weber, 1999; Maskell, 1991, p. 19; Kaplan, 2003) some more or less important attributes can be found.

2.7.6.1 Definition of the Key Performance Indicators

An essential quality criterion of a good key performance indicator is an unequivocal definition (Luczak et al., 2000, p. 57; Schott, 1991, p. 26; Harper, 1984, p. 11; Vetter, 1983, p. 55; Kettner et al., 1984, p. 42), so that compared subjects are really identical (Scheuing, 1967, p. 32).

There is a huge number of key performance indicators, which have at first sight the same meaning, however, imply absolutely different things, since definitions are missing or the definition components are different or can be interpreted (Bieri, 1995, p. 41; Geiss, 1986, p. 36). A good example is given with the country-specific definitions for the rates of unemployment (= 'economic key performance indicator' (Weber, 1999)), which considerably differ both with the recordal of the potential employees and with the capture of the unemployed persons.

For the planning process of a new final assembly shop it can be derived from this example that no doubts must arise about the content of a key performance indicator. Thus, it has to be unmistakably defined whether, e.g., a key performance indicator 'number of stations' contains only pure working stations or also testing and quality stations, technical stations and decoupling stations.
Independent of the location or the position within the company the content and the definition of a key performance indicator have to be known by anybody working with the key performance indicators as statement of Maskell should make clear: "In order to understand the importance of the ratio and to analyse changes in the ratio over time, the user is required to have a full grasp of the way the ratio has been constructed and weighted and to know precisely what the managers had in mind when the measure was devised" (Maskell, 1991, p. 30).

2.7.6.2 Topicality of the Key Performance Indicators

There is no doubt that key performance indicators have to be up-to-date (Siegwart, 1990, p. 31; Geiss, 1986, p. 38). A certain differentiation still seems necessary, particularly since the recording of the key performance indicators causes costs (Harper, 1984, p. 89).
In view of time horizon, the topicality of key performance indicators for a foreman responsible for the quality of a final assembly shop, which produces every 1.5 minutes a car, has unquestionably another meaning, than for the planner of a final assembly shop, who has to think about the long-term capacity requirements (Grundig, 2000, p. 74; Maskell, 1991). Against the statement made by Feggeler and Husmann (2000, p. 47) that primary data should be as exactly as necessary, not the topicality of the key performance indicators is most important for this research project rather the coherence of the collected data. As shown later, the data have to be collected from different sources and also variations, e.g., in the product life cycle must be taken into consideration (Kettner et al., 1984, p. 17).

2.7.6.3 Linking with Mission and Vision

For the success of the key performance indicators it is not only important that they are up-to-date, but that they also have, as already indicated the same superior objective. As mapped in figure 34, the key performance indicators should be in line with the critical success factors / the strategy of an enterprise (Brown, 1996, p. 5; Kaplan and Norton, 1993; Bieri, 1995, p. 41; Weber, 1999; Gunn, 1992, p. 196; Maskell, 1991, p. 21; Dixon et al., 1990, p. vii; Eccles, 1991, p. 132; TCIOMA, 1993; Weber, 2002).

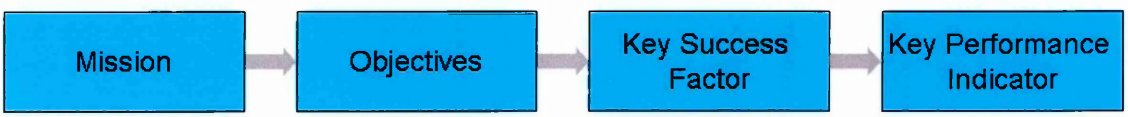


Figure 34 – Driving KPIs with the BSC. Nam (1997)

As already mentioned at the beginning of this chapter, a planner of a new final assembly shop of course must know whether top management is expecting a very flexible final assembly shop or rather a highly productive one. However, in the planning process numerous experts are involved; therefore no one in the enterprise should assume that all persons working on this project automatically have the same understanding about the superior objectives, even if the coherence of the individual key performance indicators over the various levels within an organisation is one of the essential success factors of a good system of key performance indicators (Feggeler and Husmann, 2000, p. 24). Hence, as already shown, key performance indicator systems often will be mapped like a pyramid (Weber, 1993, p. 250; Feggeler and Husmann, 2000, p. 24; Brown, 1996, p. 6), in order to demonstrate that all key performance indicators work in the same direction. Although this aspect is mentioned over and over again in literature, at this point a restriction seems to be necessary. For this research project, the hierarchical construction will be interpreted in this way that all key performance indicators should be adjusted on the strategy of the enterprise. However, this does not mean that a key performance indicator system must end for the purposes of compression in a single super key performance indicator, which is accessible only to the top management.

This research project understands a system of key performance indicators rather as a closed control circuit (Dillerup, 1998, p. 84), how it is illustrated in figure 35.

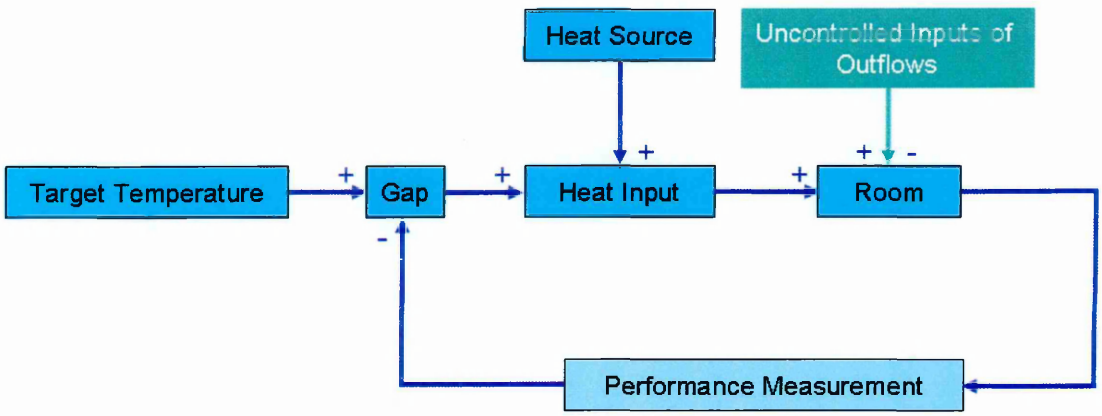


Figure 35 – A Simple Control System. Dyson (1990)

In dependence of the respective situation the user (= planning expert or top manager) has the opportunity (= 'applied subjectivity' (Geiss, 1986, p. 47) to inform him / herself about the state of the single elements of the control circuit. The hierarchical arrangement as a result of a ranking as decribed by Hunziker and Scheerer (1975) therefore has no meaning for this research project.

As a reason of the increasing dynamism of the markets and the necessary variability linked with it, such a key performance indicator system must be as adaptable as the enterprise must be (Feggeler and Husmann, 2000, pp. 24/49; Higgins et al., 1996a, p. 86; TCIOMA, 1993). Should important basic conditions change (e.g., uncontrolled inputs of outflows), it could be necessary to define new key performance indicators, to delete old ones and to define new targets for some divisions (Ossola-Haring, 1999, p. 18; Maskell, 1991, p. 29; Dixon et al., 1990, p. 4). For key performance indicators for the planning of a final assembly shop of a car manufacturer such adaptability is necessary, because, e.g., new technologies or processes can require a continuous modification at least at the more detailed planning levels.

2.7.6.4 Setting Targets

Figure 35 includes a 'target temperature' at the beginning of the control circuit. The question whether targets should be set will be discussed controversially in literature. Following the concept 'Management by Objectives' by George Odiorne (Odiorne, 1965; Brown, 1996, p. 10), it is important that for the various key performance indicators realistic and demanding targets exist (Camp, 1989, p. xi; Putnam, 1984, p. 56), which motivate the employees to reach them (Siegwart, 1990, p. 9; Humble, 1970, p. 18).

However, Brown (1996, p. 11) and Higgins et al. (1996a, p. 90) point out that many enterprises set targets arbitrarily and globally, without using background information for example gathered from benchmark studies. So the targets will not be traceable for the employees. Therefore, the statement of Neely (1998) has to be kept in mind: "One of the fundamental tenets of performance measurement is that it is not fair to measure people on something, over which they have no control".

Not everyone, as the statement of Dr. Edwards Deming (Voehl, 1995, p. 77) stresses, will support the idea of setting targets. He was quoted in Maskell (1991, p. 306) as follows: "Setting performance targets is fundamentally wrong". This criticism is not unjustified, so that in view of this research project at least the following questions must be answered.

In a large-scale enterprise, is there any transparency about the interrelationships of the planning parameters and therefore about the actually required investment available, e.g., during the process of planning a final assembly shop of a car manufacturer (Zahn et al., 1998, p. 263)? Is the target value in fact not often based on the most comparable values from the past? Does not a management committee set a target for the investment sum from which it hopes that it is demanding to reach, but does not cause any damages as a result of exorbitant savings? Does not the project manager agree vice versa to this target only when he or she is confident to reach it? How big is the buffer that is included in the plannings? In this constellation, is it still possible to look for the strategic optimum in terms of flexibility and productivity?

As a result of these questions doubts arise, whether the setting of targets in non-transparent areas is not more a psychological game than an honest search for the optimum.
However, as a result of lacking transparency in the complex planning process of a final assembly shop, there are often not enough alternatives, so that the setting of targets still is the lesser evil.
At the end of this thesis it will become clear that one of the objectives for this research project is to make the planning process more transparent, so that at the beginning of the planning process at least the plausibility of targets can be guaranteed. This should help to initiate a working atmosphere, in which the planners get the chance to develop the ideal final assembly shop and not to find arguments that the given targets are wrong.

2.7.6.5 Good Visualisation of the Key Performance Indicators

All these points give a hint that a key performance indicator system can be quite large, including plenty of elements. Therefore, an important aspect for the successful work with key performance indicators is the right visualisation of them (Feggeler and Husmann, 2000, p. 50; Harper, 1984, p. 76; Ahmad and Benson, 1999, p. 88). In view of the importance of a final assembly shop, it has to be made sure, as described by Young (2003) that during the planning process and for decision-making the relevant key performance indicators are available.
But also the criticism expressed by Maskell (1991, p. 30) that from highly complicated measures even more complex index and key performance indicators will be generated, which the employees do not understand and motivate anymore, has to be regarded for this research project. As argued later, many key performance indicators are important for the process of planning a final assembly shop of a car manufacturer. Therefore, an intelligent way of mapping the complex interactions of plenty of key performance indicators without losing transparency has to be found.

2.7.7 Problems of Existing Key Performance Indicators

After having described the most important success factors of good key performance indicators, now the field of the biggest challenges has to be entered as well. If anyhow possible, the problems listed below, should be knowingly avoided.

2.7.7.1 Data Availability for Generating Key Performance Indicators

Although we live in an information society, the subject 'data availability' must not be underestimated for this research project (Robinson, 1994, p. 87). Already when defining key performance indicators or when deciding which key performance indicators should be part of a system it has to be taken into consideration whether a key performance indicator is basically available (Vetter, 1983, p. 56) and with which efforts / costs it can be recorded?

Especially during the construction of complex and multi-layered key performance indicators systems this can be a challenge (Brown, 1996, p. 167). The effort for recording the figures, basically depends on whether the source is internal or external and if primary or secondary data will be collected (Staudt et al., 1985). However, the decisions about the source of the data also strongly influence the quality of the figures. Kettner et al. (1984, p. 17) adds to this aspect that "the goodness of every plan highly depends on the quality of the data source, so that special attention and care should be paid to the data gathering". Hence, already at this point it should be mentioned that in all stages of this research project high demands on the data quality will be made.

2.7.7.2 Right Number of Key Performance Indicators

A frequent problem at the work with key performance indicators is linked with the question about the right number of key performance indicators (Luczak et al., 2000, p. 27; Schott, 1991, p. 15; Siegwart, 1990, p. 55; Harper, 1984, p. 88). In spite of the above made remarks, it is less and less a problem to provide a huge number of key performance indicators as a result of the improved technical conditions (Eccles, 1991, p. 133; Feggeler and Husmann, 2000, p. 46).

However, such systems will often be criticised, since they generate 'cemeteries of figures' (Scheuing, 1967, p. 16) which demand too much of the users, because they do not flow into a few super key performance indicators (Siegwart, 1990, p. 9; Maskell, 1991). With the help of the following scenario Brown (1996, p. 164) strikingly describes the basic demand for few key performance indicators:

"You are the boss and you will be on vacation for three months. Every month you will have the chance to see four diagrams (= finances, customer satisfaction or another category) which inform you about the state of the company. What should be shown in these four diagrams?" This demand for only some key performance indicators will be supported by scientists who come to the conclusion that the human brain only can concentrate upon 7 to 20 key performance indicators (Miller, 1956; Brown, 1996, p. 4; Weber, 1999).

However, according to the above scenario the question raises whether it would be possible for the boss of a planning team to check the quality of the plannings for a new final assembly shop with only few key performance indicators. This question has to be answered against the background that many experts (Weber, 1999; Higgins et al., 1996a, p. 64; Gunn, 1992, p. 9; Zheng and Possel-Dölken, 2002, p. 254; Thannhuber et al., 2001; Young, 2003; Wiendahl et al., 1998; Sterman, 1994, p. 291) agree that an enterprise is a complex and dynamic system and the decision or planning processes linked with it are complex and multi-layered as well.

Doubtless, the experience of the planner and the knowledge about the system is very important. In figure 36 it is visualised that with rising model knowledge the degree of focussing can increase, too. As an example, Scully (1987) (as quoted in Weber and Schäffer (1999)) refers to the 'war' between 'Pepsi' and 'Coke'. The only key performance indicator that mattered was the comparison to the competitor (= "key Nielsen figures").

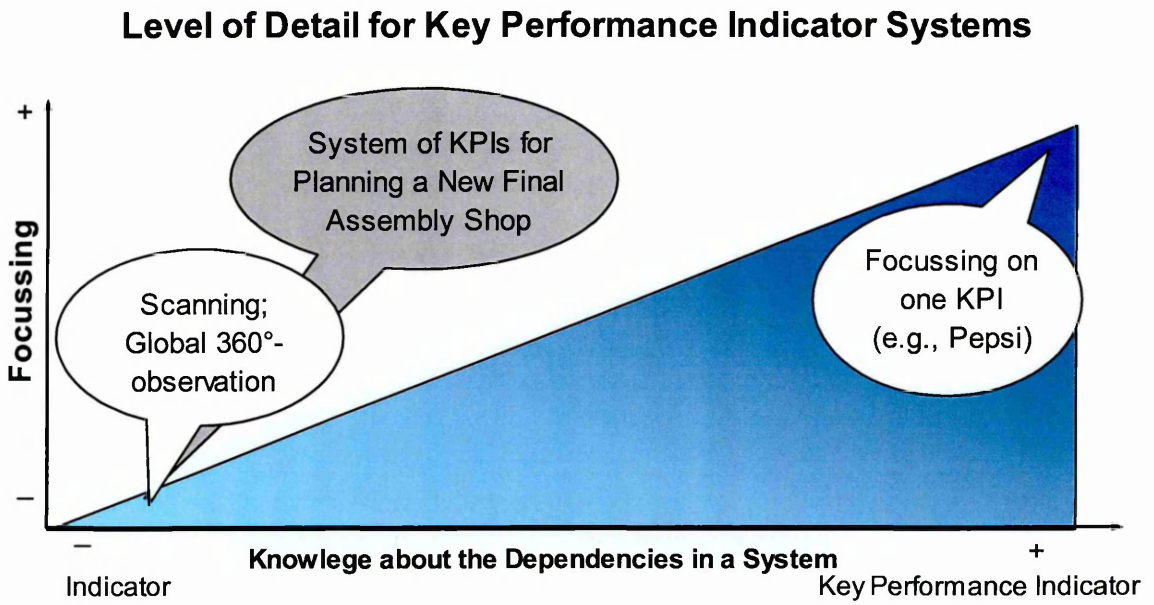


Figure 36 – Focussing of Key Performance Indicators. Weber and Schäffer (1999)

Altogether, the question still is unanswered, with how many key performance indicators a system of many dependent and independent elements should be illustrated? According to Grundig (2000, p. 11), the manufacturing planning process is characterised by a huge number of variable input data. This statement and the above mentioned unpredictable environment in the car industry give a hint that the intelligent linking of many individual key performance indicators will play a determining role for this research project.
Therefore, in the first step a system of key performance indicators for the process of planning a new final assembly shop will be found on the left side of figure 36, because the knowledge about the dependencies within the system still can be improved. This research project should help to develop a comprehensive understanding about the final assembly shop of a car manufacturer and to support the planning experts with the analysis of the sensitivity of the individual parameters (Harper, 1984, p. 16; Senge, 1990, p. 45; Milling, 2002, p. 74; Coyle, 1995, p. 347; Robinson, 1994, p. 146).

Based on these sensitivity analyses it is a desirable objective to move step by step from the left side of the diagram to the upper right area. There is no doubt that it would be great if in the early planning stages for a new final assembly shop of a car manufacturer only 7 to 20 key performance indicators would be necessary.

2.7.7.3 Reaction Instead of Action

In particular, monetary key performance indicators often face the problem that the data are based on decisions made in the past (Schott, 1991, p. 17; Kaplan and Norton, 1992, p. 77; Higgins et al., 1996a, p. 82). Therefore, critics like Tucker (1961, p. 7), Eccles (1991, p. 132) and Maskell (1991, p. 25) blame systems such as, the 'DuPont-system' (see 2.7.5.3) that a proactive cost control is not possible, since only the symptoms (= the cost elements) and not the underlying causes (= the factors that drove the need for the resource) are analysed. Thus, Dixon et al. (1990, p. 35) call the transition from purely financially oriented to a mix of financially and non-financially oriented measurement systems as "cutting the Gordian knot". Only with this new way of thinking, the demand of Brown (1996, pp. 3/52) and Weber (1999) can be followed, saying that "key performance indicators should include the past, the present and the future".

Such kind of thoughts are very important for this research project, since the planning of a final assembly shop always is future oriented (Grundig, 2000, p. 11) and will be based on present figures and experiences made in the past. For the various planning alternatives an optimised configuration for the future has to be developed. Possible undesired trends must be taken into consideration even at the early planning stages, so that they do not later become an unsolvable problem for the only slowly changeable final assembly shop of a car manufacturer (Ahmad and Benson, 1999, p. 27; Skinner, 1985, p. vii).

2.7.7.4 Short-Term Thinking

As indicated above, the planning of a final assembly shop is long-term oriented. However, 'Wall Street' and other stock markets promote short-term thinking (Brown, 1996, p. 19; Gunn, 1992, p. 195; Senge, 1990, p. 21), because short-term success achieved by radical saving measures will be rewarded with higher stock market quotations.

Because of the medium-term and long-term character of investments for a final assembly shop (Schmigalla, 1995, p. 13; Grundig, 2000, p. 180) and the cost pressure in the market, no automotive manufacturer can afford to plan a final assembly shop on the basis of short-term criteria. There are probably only a few industrial areas in which the planning horizon should be longer. For example, within the BMW Group there are already in 2005 first considerations for the year 2024. Therefore, a system of key performance indicators supporting the planning process of a new final assembly shop of a car manufacturer should offer the option to evaluate long term scenarios.

2.7.7.5 Lack of Acceptance

The financial key performance indicators used in the past had an elitist character (Feggeler and Husmann, 2000, p. 15). It seemed that only the management and few other experts were able to interpret the key performance indicators correctly. Such a structure stimulates the development of different key performance indicators at different organisational levels, which could lead in the worst case to a loss of acceptance at the lower organisation levels.

According to Feggeler and Husmann (2000, pp. 23/24), successful organisations distinguish themselves by the decentralisation of decisions even to the lowest possible levels. This is one of the arguments supporting the statement of Pümpin (as quoted in Bieri (1995, p. 50)), saying that it is very important that the employees know and live the strategy. Therefore, it is very helpful for the planners of a final assembly shop, to see what influence their decisions have on essential key performance indicators of the whole assembly system and indirectly to the entire enterprise. They must get the chance to see the 'big picture' (Senge, 1990, p. 18).

Bieri (1995, p. 37) calls this 'intersubjective traceability', i.e. the user of the key performance indicator system must have the chance to understand how the figures will be aggregated at the different levels. This aspect and the direct linking to the key performance indicators that also will be used by top management are a good fundamental for motivating the planners (Weber, 1999; Gunn, 1992, p. 191; Feggeler and Husmann, 2000, p. 59).

2.7.7.6 Lack of Knowledge Management

Both the planning of a final assembly shop and working with key performance indicators requires a certain degree of experience. The key performance indicator 'units per employee' seems to be easy to use, but actually is a good example of the hidden challenges arising while working with key performance indicators (Harper, 1984, p. 8; Schott, 1991, p. 61).

Harper (1984, p. 22) for instance, stresses the point that the output (= unit) of two equal systems does not have to be identical, even so exactly the same products will be manufactured, since for example the identical number of units can differ in the achieved level of quality. In terms of a proposition, figure 37 gives a hint, with help of the layout of the new final assembly shop of the BMW plant Leipzig, how many factors can influence the 'units per employee' of a final assembly shop. They all have to be kept in mind, if using this key performance indicator for planning a final assembly shop.

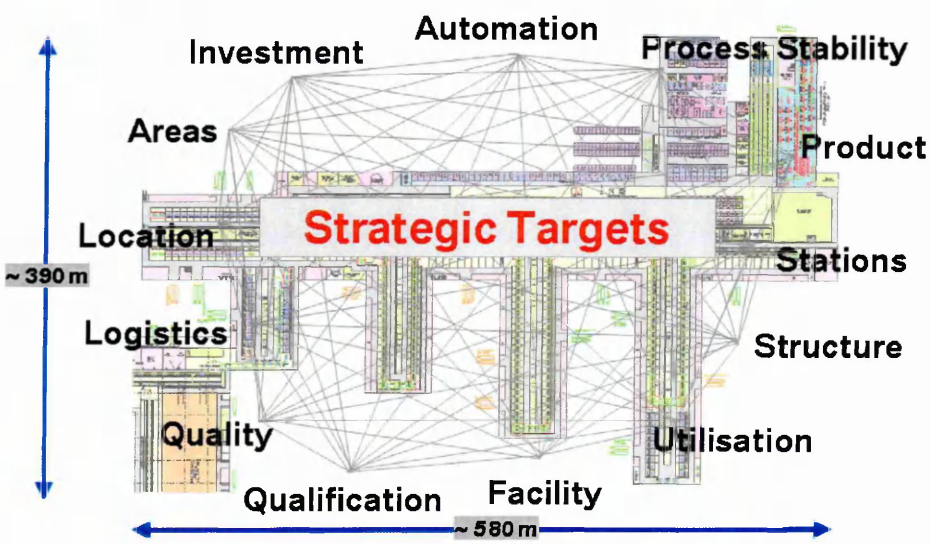


Figure 37 – Influencing Factors on the Dimensioning of a Final Assembly Shop.

If questions regarding the definition or the system boundaries of a key performance indicator cannot be answered without problems, changes over time can only be interpreted with difficulty (Schott, 1991, p. 25). Thence, Ossola-Haring (1999, p. 16) argues that "just the continuous work with key performance indicators makes them a useful tool".

However, practical experiences show that in particular historical key performance indicators as a result of poor knowledge management, poor defined interfaces, plenty of dependencies and unknown system boundaries will be questioned over and over again.

In addition, Schott (1991, p. 16) describes the fact that sometimes organisational units within a company only know their own key performance indicators and just try to optimise these. It often lacks the knowledge about the dependencies to other areas so that the finding of a common optimum is almost impossible. This is not only a challenge for the management of an enterprise, but also for the planning of a new final assembly shop of a car manufacturer.

2.7.7.7 Wrong Stimulation

With key performance indicators and the necessary support by the management, an incentive system can be created for the reaching of certain targets (Kaplan and Norton, 1992, p. 71; Higgins et al., 1996a, p. 86; Maskell, 1991, p. 21; Bieri, 1995, p. 41; Eccles, 1991, p. 131; Neely, 1998). However, with the help of several good examples about wrong stimulation Brown (1996, pp. 19-28) reveals that the overall system has to be kept in mind if setting targets for the lower levels. It has to be considered a good key performance indicator system, if single key performance indicators could only be reached at the expense of other important success factors (= 'divergent targets' (Feggeler and Husmann, 2000, p. 30)). For the planning of a final assembly shop this implies the need to critically examine which levers are the really important ones in view of the different targets and which dependencies exist between the diverse parameters. Thus, the consequent tracing of the key performance indicator 'units per employee' is sensible only, if no appreciable changes in the added value chain or the model mix can be registered (Kaplan and Norton, 1996, p. 125).

From an economic point of view, the assembly of a BMW 7 Series can be more interesting than the assembly of a BMW 1 Series, although the key performance indicator 'units per employee' sends a different signal.
Hence, the statement made by Brown (1996, p. 30) that "the selection of the wrong key performance indicators could result in a disaster" can be supported. As described by Staudt et al. (1985), Ahmad and Benson (1999, p. 95), Siegwart (1990, p. 124) and Scheuing (1967, p. 11), for the selection and interpretation of key performance indicators a lot of experience is necessary to avoid major mistakes.

2.7.7.8 Linearity of Key Performance Indicators

With the help of key performance indicators, alternative scenarios will often be calculated linearly. However, the later described 'System Theory' over and over again stresses the non-linear behaviour of many systems (Zheng and Possel-Dölken, 2002, p. 225; Senge, 1990, p. 73; Forrester, 1998, p. 4; Sterman, 1994, 297).
The statement of Tucker (1961, p. 29) also shows that this kind of simple calculation often leads to wrong conclusions. "Ratios should not be expected to move linearly: double the running time of the equipment does not necessarily equal double the maintenance expenses. Some ratios move faster than others".

2.8 Problem Definition

Even if many authors (Aggteleky, 1987, p. 31; Schulte, 2001, p. 45) in the field of factory planning recommend the usage of 'key performance indicators', it must be pointed out that so far the complex interactions within a final assembly shop of a car manufacturer are inadequately taken into consideration. Therefore, the criticism of Staudt et al. (1985) that in the field of the key performance indicator calculation, many single developments without theoretically based research exist can be supported.

Already by 1958, Antoine (1958, p. 166) had recognised the necessity of the practical research in the field of key performance indicators. However, in the car industry, no such research has taken place. There is no general-valid, theoretically derived key performance indicator system that supports the planning of a final assembly shop. As described by Geiss (1986, p. 13), up to now, key performance indicators are used on personal experiences of the user, which imply an intuitive control of plausibility.

As a result of the numerous dependencies of the individual parameters, reasonable targets cannot be set at the beginning of the planning process, nor is it possible to track the progress of the planning on the basis of key performance indicators.

Since several targets have to be considered (Staudt et al., 1985; Zheng and Possel-Dölken, 2002, p. 254), not just one exact optimum exists. Therefore, it is necessary to see the 'total picture'. However, the overall view will not be supported by planning systems, which was also criticised by Gunn (1992, p. 195).

At an early planning stage, there is no quantitative model in which the causes and effects of positive as well as negative factors of influence on the resource consumption of a final assembly shop of a car manufacturer can be evaluated. There are no general tools available that help in the early phase of planning a new final assembly shop to picture 'what-if?'-scenarios (Harper, 1984, p. 92; Robinson, 1994, p. 4) and which could help to weigh chances and risks at the early stages in the planning process (Higgins et al., 1996a, p. 86; Cunha et al., 2003, p. 605). Especially for more complicated problems, which occur during the planning process of a new final assembly shop, such an analysis of the interrelationships is necessary (Bieri, 1995, p. 40; Harper, 1984, p. 1).

Taking into consideration the statement of Tucker (1961, p. 1) that "industrial competition has steadily moved into the subtler areas of manufacturing structures to where the little things are important" a way has to be found, such that the complexity of a final assembly shop can be mapped in the right degree of detail and that the information is not too rough and still supports the planning process with significant information.

In doing so, the requirement of Zheng and Possel-Dölken (2002, p. 228) that new technologies should both improve quality of decisions and reduce 'decision-making time' has to be kept in mind.
At the moment, there is no planning system for the dimensioning of a new final assembly shop of a car manufacturer available, which fits to the requirements of Morecroft (1984). "A decision-support system provides reinforcement by storing relevant information, reworking and condensing it, indexing it and providing easy access" (Morecroft, 1984). All these problems lead to the fact that the research question asked at the beginning of this thesis is still unanswered.

How are the key performance indicators linked to each other and is it possible to better consider these interrelationships at the early stages of the greenfield planning process for a final assembly shop of a car manufacturer?

2.9 System Theory

Therefore, in this research project the dependencies on many different key performance indicators must be analysed, because these connections should have a considerable influence on the planning results. The question that has to be answered now is how the interconnections in such a complex sytem can be systematically grasped and explained?
The basic assumption that this question only can be answered with the help of a new approach is confirmed by a statement of Gunn:
"Effective solutions for today's business problems cannot be solved by old models that treat each function or even each business process separately and from a static viewpoint" (Gunn, 1992, p. 273).
This above sentence contains a possible answer for this problem. There must be an option to illustrate the entire system as a whole and not just to cover elements of the system using numerous separated key performance indicators.
The analysis of available methods supporting this idea highlighted the approach of 'System Theory'.

2.9.1 Basic Concept

At first glance, it seems to be contradictory to unite key performance indicators with the approach of 'System Theory'. On the one hand, as already described, key performance indicators should summarise complex interrelationships within a company and on the other hand 'System Theory' wants to avoid the fragmenting of problems into smaller pieces (Wu, 1992, p. 29). According to Senge (1990, p. 12) it is rather "the discipline that integrates the disciplines, fusing them into a coherent body of theory and practice".

Senge (1990, p. 14) and Forrester (1989, p. 10) argue that many of today's problems are a result of the lack of competence to analyse systems, which are getting more and more complex. This idea about system was shared by Wu (1992, p. 28), who highlights that "manufacturing industries are now leaving one technological age which is charcterised by machines, and are in transition to the age of systems". The objective of this approach is "to simplify the problematic situation through a systems perspective" (Wu, 1992, pp. 29/30).

As already argued, the idea of summarising the complexity of a final assembly shop of a car manufacturer with the help of top key performance indicators led into a dead end for the planning process. Therefore, this research project should help to better understand the "given logic" (Thannhuber et al., 2001) of a final assembly shop, so that the key performance indicators actually can be used during the planning process.

2.9.2 Definition of a System

According to Coyle (1995, p. 4) "a system is a collection of parts organised for a purpose". However, he immediately also makes clear that every system does not necessarily reach the desired target, which is often a result of a bad design of such systems. At the beginning of his presentation 'Designing the Future' Forrester (1998, p. 2) adds that it would be a false appraisal to believe that systems only exist in special areas, since "systems influence everything we do".

Figure 38 displays the basic structure of such a system, which consists of various elements, which are within the system boundaries linked to each other and therefore cause different system behaviour.

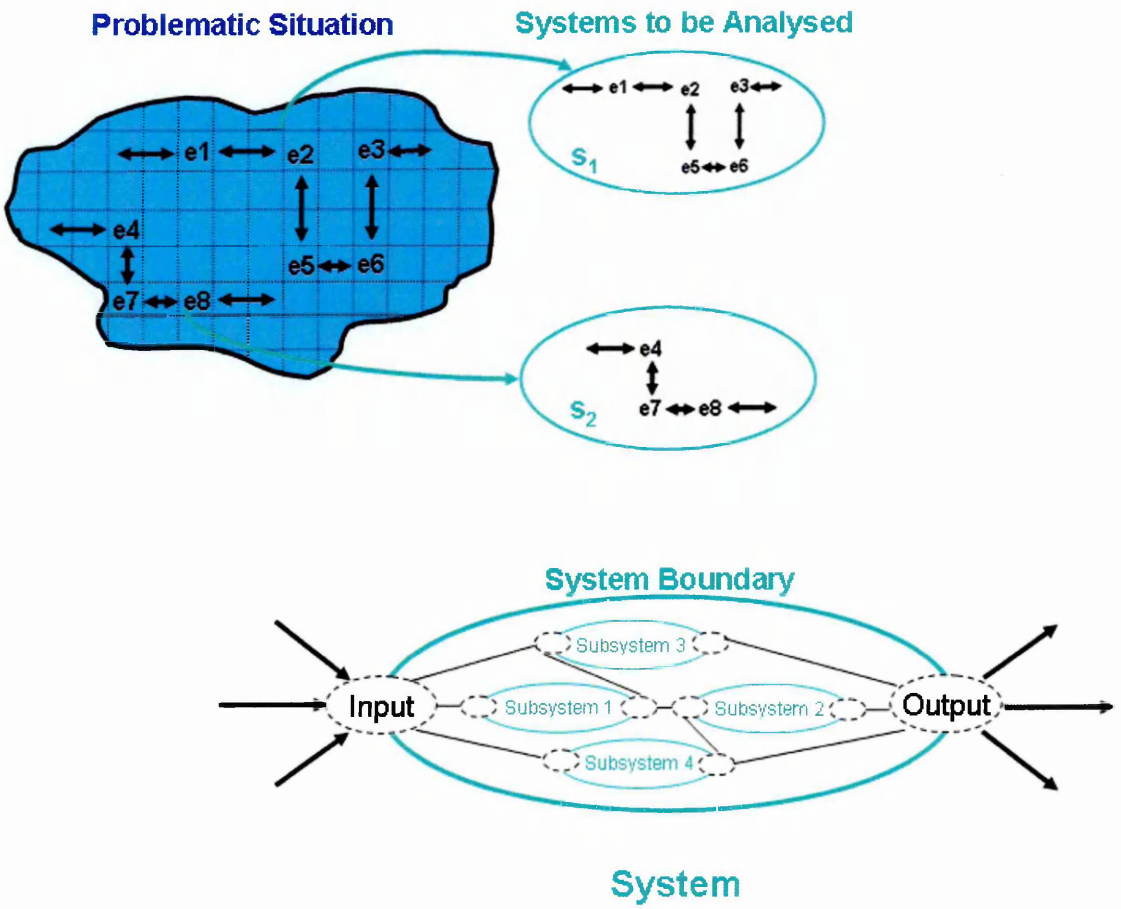


Figure 38 – Structure of a System. Wu (1992)

2.9.3 Models

Models are very important for mapping such systems, even if, at this point it has to be pointed out that a model can never illustrate reality in full scope (Homer and Oliva, 2001, p. 350). It is always only a simplified picture of the real system elements as well as of the relationships between the elements (Zheng and Possel-Dölken, 2002, p. 239; Dillerup, 1998, p. 11). This illustration should help, to better understand the total structure (Harper, 1984, pp. 3/4).

The process of modelling is transparently mapped by Naim and Towill (1994), as shown in figure 39. This view is helpful for this research project, since the dynamic analysis is placed at the end of the process. Later in this thesis it will become clear, with the dynamic perspective a certain border will be defined for this research project.

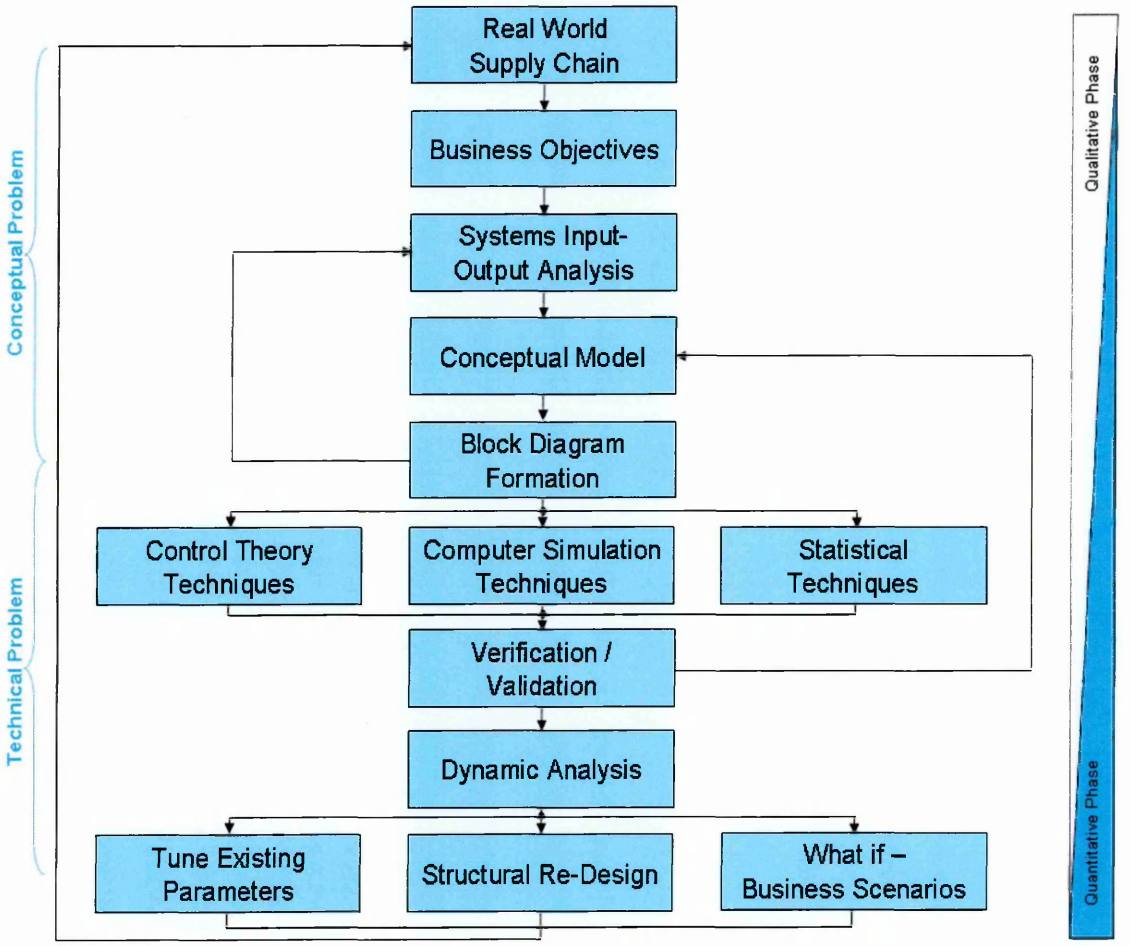


Figure 39 – Process of Modelling. Naim and Towill (1994)

Interesting as well is the difference between verbal and formal models, pictured in figure 40 (Dillerup, 1998, p. 11). The latter ones are based on mathematical rules and calculation methods and are of major importance for this research project (see figure 41).

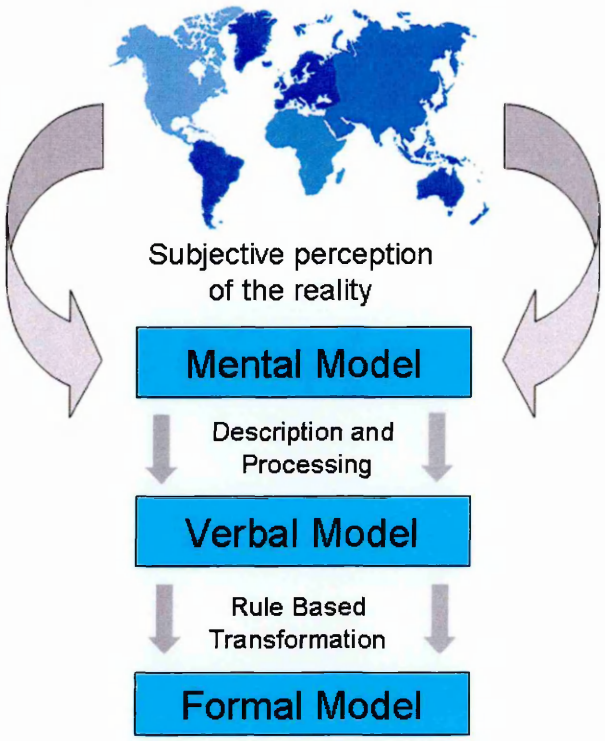


Figure 40 – Hierarchy of Model Categories. Bunz (1988)

As already described, during the interpretation of key performance indicators of complex systems, a certain learning process has to be run through. At the end of this process mental models about the dependencies within a final assembly shop of a car manufacturer have been formed. Up to now, these were described only verbally and therefore lead to unsatisfactory results, since a final assembly shop is very complex, so that it cannot be analysed exclusively in mental models (Forrester, 1998, p. 4; Dillerup, 1998, p. 11). In addition, as argued in figure 41, mental models are very subjective.

Thus, these mental models can cause problems as the statement of Argyris (1982), quoted in Senge (1990, p. 175) makes clear: "Although people do not (always) behave congruently with their espoused theories (= what they say), they do behave congruently with their theories-in-use (= their mental models)". Such behaviour significantly can falsify, e.g., the forecasts of elections (Gerwin, 2005, p. 62) but also the results of research projects (Argyris, 1992).

		Mental Models	Formal Models
Communication	Premises	• Subjective • Based on know-how and observations	• Transparent
	Decision Structure	• Vague • Sometimes irrational	• Obvious • Rule based
	Decision Making	• Almost irreproducible	• Logically • Transparent
Data Processing	Data Base	• Subjective know-how	• Systematic recorded information
	Data Volume	• Limits given by human mind	• Limits given by computer performance
	Data Selection	• Subjective • High risk of mistakes	• Objective, goal oriented
	Data Type	• Quantitative and qualitative	• Predominantly quantitative
Flexibilty	Model Configuration	• Any imaginable	• Few • Specific modeled
	Degree of Flexibilty	• Highly flexible	• Inflexible

Figure 41 – Mental Models versus Formal Models. Bunz (1988)

As argued by Senge (1990, pp. 9/174), it has to be the objective of this research project, "to bring the mental models to the surface and hold them rigorously to scrutiny". This should help to develop theories about the system 'final assembly shop', which on the other hand should support the process of planning the system (Angerhofer and Angelides, 2000, p. 344; Morecroft, 1984). Altogether, it seems that this is the only way to develop a common understanding about the multi-layered interrelationships. This transparency about the system structure enables the planners of a final assembly shop to recognise, how many elements are involved in the same system. This in turn, is fundamental for discussions about existing estimates and for the development of common visions.

One of the best known examples to demonstrate such complex interrelationships is the 'beer game' (Senge, 1990, pp. 27/51; Angerhofer and Angelides, 2000; Sterman, 1994, p. 303; SD-Society, 2003), which was developed at MIT. From it, three levels for the explanation of complex systems can be derived:

- Systemic structure (= generative).
- Patterns of behaviour (= responsive).
- Events (= reactive).

Senge (1990, p. 53) shows very well that it should be the aim to explain a system with the help of its structure, because this tries to analyse the underlying causes of behaviour and therefore tries to answer the question 'What causes the patterns of behaviour?'.

2.9.4 System Thinking Basics

The principle of 'System Thinking' requires an adjustment of the thinking process of the involved persons, as it can be demonstrated on the historical arms race, pictured in figure 42.

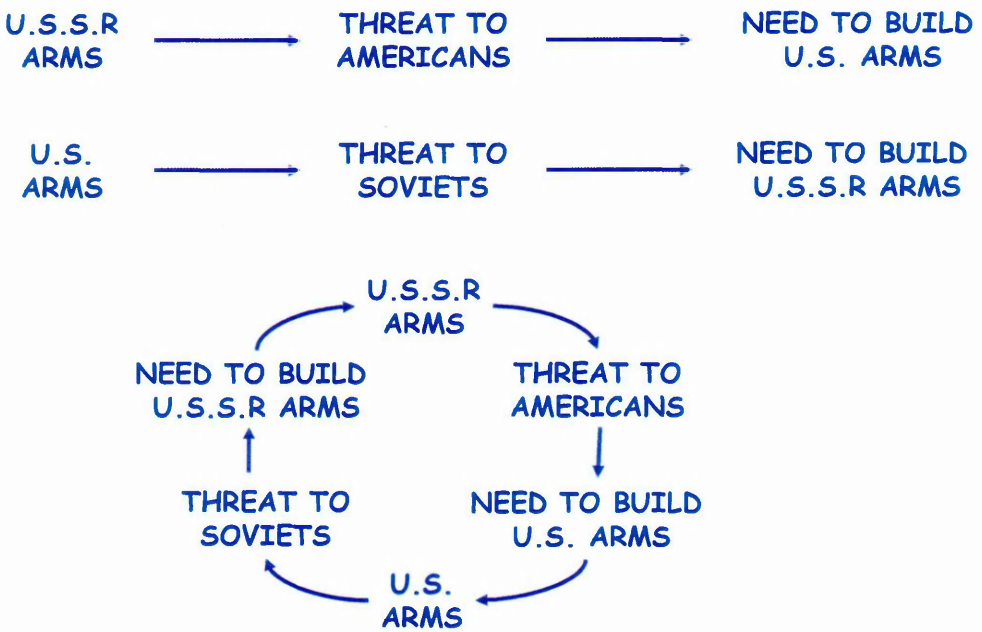


Figure 42 – System Thinking on the Example of the Historical Arms Race. Senge (1990)

Only the closer examinations from cause and effect chains (= influence diagrams, causal loop diagrams) and the analysis of processes and not from snapshots allow understanding complex systems. This example illustrates that both countries are connected in a system, which only becomes clear by analysing the situation in the new format. The 'peace race' started only by Mikhail Gorbachev's initiative to reduce arms (Senge, 1990, p. 72).

To illustrate 'circles' with corresponding 'feedback processes' (Senge, 1990, p. 74; Forrester, 1998, p. 2; Sterman, 1994, p. 293), special languages should be used. As described by Senge (1990, p. 79) and Coyle (1995, p. 6), this is the only way to map reinforcing (= amplifying, growth-producing, positive loops) and balancing (= stabilising, goal-seeking, negative loops) feedback loops. For the analysis of such processes it is also important to know that many active connections become evident only with 'delays' (Sterman, 1994, p. 297). Figure 43 shows the respective basic principle and also the process on the example of the work with key performance indicators. On the left side, there is the reinforcing process (= snowball effect, vicious circle), that is the engine of growth and can occur in both directions – for better and worse. On the right side, the balancing feedback, which can be caused by an explicit or an implicit goal and that sets the limits is shown. This happens, since every system is seeking stability (Senge, 1990, p. 84).

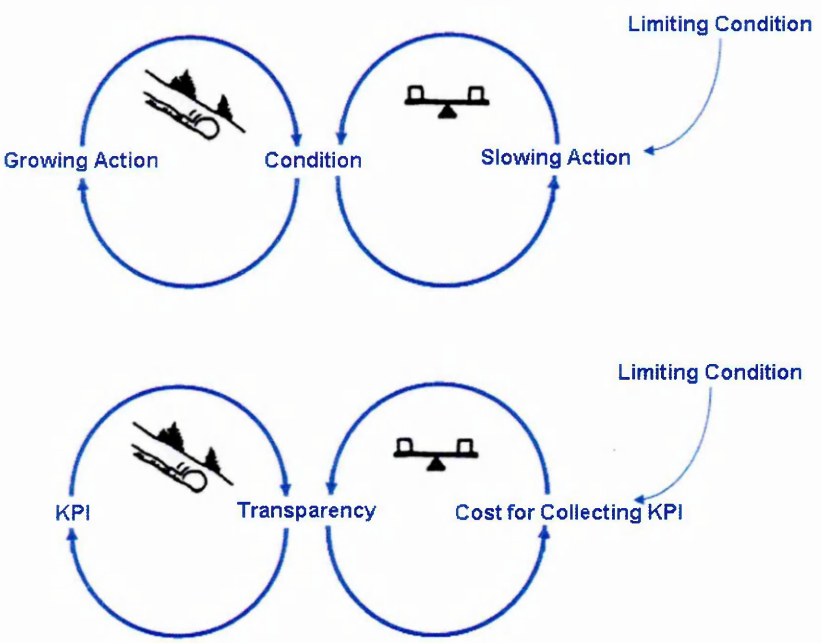


Figure 43 – Feedback Processes. Senge (1990)

2.9.5 System Dynamics Basics

At the beginning of the sixties, following the idea of 'System Theory', 'System Dynamics', at that time still 'Industrial Dynamics' (Forrester, 1958), was developed (Bunz, 1988, p. 103). According to Forrester (1998, p. 3), "System Dynamics uses concepts from the field of feedback control to organise information into a computer simulation model". Coyle (1995, p. 4) adds that "the 'System Dynamics' approach has the objective to walkthrough management systems in the same quality as an electrical engineer plans the central heating system". This is a very important comparison, since detailed drawings for electronic ciruits are available; however management decisions are often based on mental models. The mental models of the planners should be put on the test bench (Sterman, 1994, p. 312; Morecroft, 1984), so that the generated transparency about the dependencies between the different key performance indicators can be an essential success factor.

With the help of SD-models these mental models should become more transparent. Essential elements of SD-models are 'feedback loops' and 'delays' (Angerhofer and Angelides, 2000, p. 342; Dillerup, 1998, p. 19; Coyle, 1995, p. 4), since they determine the behaviour of a system (Richardson and Pugh, 1981).

2.9.5.1 Proceeding by the Generation of a SD-Model

As illustrated by Hopfmann (1989) in figure 44, five steps have to be run through for the generation of a SD-model. At this point, especially the missing aspect of the validation should be pointed out. Following the idea of Forrester (1969, p. 115), Dillerup (1998, p. 23) makes the statement that a model is validated, if it will be accepted. Therefore, a model as a result of this research project would have to illustrate the 'final assembly shop of a car manufacturer' system in such a way that it is accepted by the planners as well as by the management.

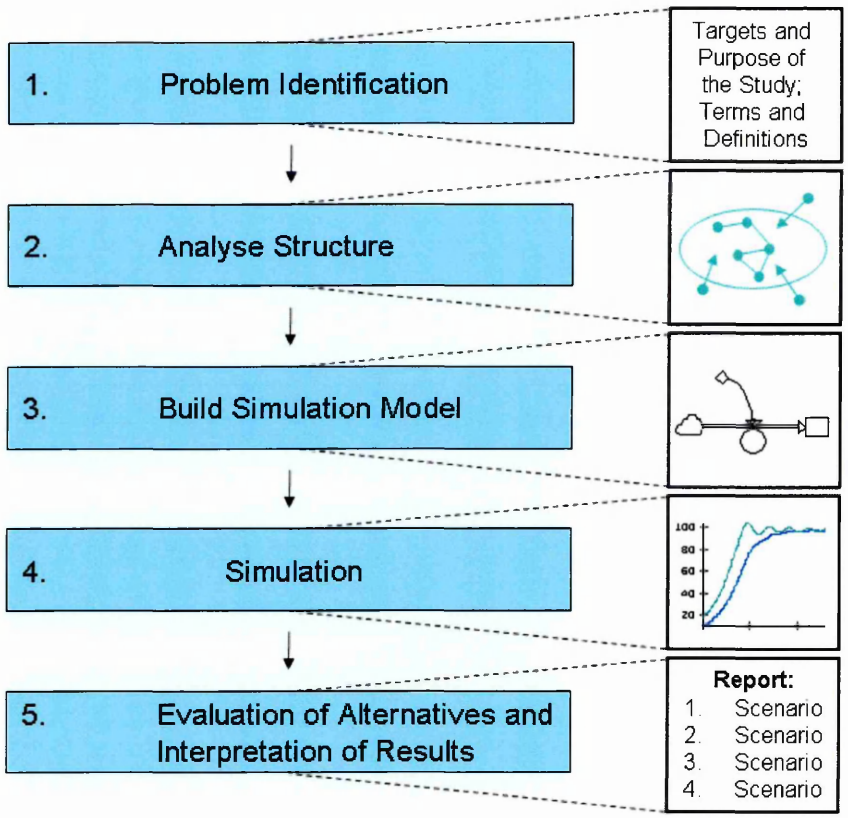


Figure 44 – Five Steps for the Generation of a SD-Model. Hopfmann (1989)

In addition, Bunz (1988, p. 97) and Coyle (1995, p. 353) offer an overview of possible performance characteristics, which can be used for the assessment of the developed model:

- Investigation of several alternatives.
- Improved understanding about the system.
- Quicker reaction to unexpected situations.
- Realisation of ad hoc analyses.
- Gain new insights and improvement of the learning ability.
- Facilitation of the communication.
- Improvement of supervision.
- Cost reduction.
- Improvement of decision making.
- Improvement of teamwork.
- Reduction of time.

If these formal (= measurable) and informal (= non quantifiable) criteria (Schwarz, 1987, p. 140) can be accomplished at the end of this research project, the chosen approach for the improvement of the planning of a final assembly shop of a car manufacturer can be evaluated positively.

2.9.5.2 Qualitative and Quantitative System Dynamics

The procedure described above is not indisputable, as the statements of Wolstenholme and Coyle (1983) make clear. Both support the 'qualitative SD-approach' which does SD-modelling without modelling in a simulation model (Homer and Oliva, 2001, p. 347). This separation is for this research project of determining meaning, because Homer and Oliva (2001, p. 348) argue that the major difference can be seen in the formulation of a 'dynamic hypothesis'.
For reasons of transparency, this research project will not consider the dynamic structures of a final assembly shop. The legitimacy of this proceeding becomes evident with the statement of Grundig (2000, p. 77), who points out that "dimensioning based on static values is sufficient for the first step".
Even if, as a reason of the missing dynamism of the model, neither a qualitative nor a quantitative SD-model can be developed, the fundament for this research project is adapted rather to the quantitative approach. As already described, at a certain point the human mind cannot handle the dynamic complexity of a final assembly shop, and therefore the support offered by computers should be used.

2.9.5.3 Advantages of System Dynamics

Forrester (1998, p. 9) also stresses that non-linear relationships can only be solved in the interaction of 'System Dynamics' and desktop computers. According to Roger and Menzies (1983, p. 52), 'System Dynamics' supports the mapping of complex dependencies and therefore it is helpful to find the best solution. During all planning phases of planning a final assembly shop of a car manufacturer, so-called scenarios play an important role.

As illustrated in figure 45, a scenario can be defined as "a hypothetical sequence of events, constructed for the purpose of focusing attention on causal processes and decision points" (Kahn and Wiener, 1967, p. 6). With it, the advantages and disadvantages of different and perhaps arguable alternatives can be judged. This offers the opportunity to derive consistent targets and strategies, since decisions based on mental models can be questioned (Dillerup, 1998, p. 53).

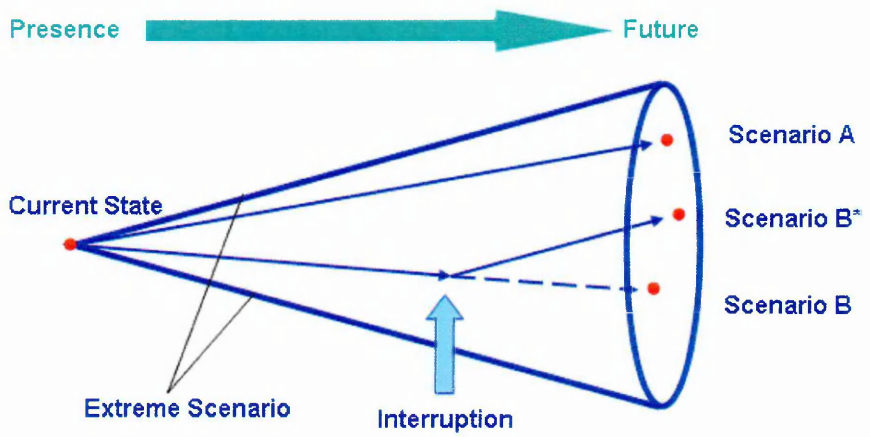


Figure 45 – Technique of Scenarios. Altmann (2004)

With the support of different authors (Zahn et al., 1998, p. 265; Angerhofer and Angelides, 2000, p. 342; Dillerup, 1998, p. 23; Morecroft, 1984), some additional arguments for the application of the System Dynamics method are listed below:

- Consideration of personnel and organisational influence determinants.
- Integration of qualitative target variables that are hard to quantify.
- Focus on the interdependencies between the considered target and decision variables, resulting in delayed and widely dispersed effects.
- Reference to strategic planning as part of the process throughout the whole of the planning period.
- Systematic analysis of delayed effects.
- Learn about modes of behaviour.
- System Dynamics models are well suited to investigate the long-term behaviour of complex systems.

2.9.5.4 Field of Application

The fact that there is a 'System Dynamics Community' (SD-Society) as well as the teaching in different institutes give a hint that the 'System Dynamics' approach may be used to answer many questions. Angerhofer and Angelides (2000, p. 342) as well as Bunz (1988, p. 105) offer an extensive overview about the different fields of application. With regard to the planning of a final assembly shop of a car manufacturer some well-chosen examples are listed below:

- Corporate planning and policy design (Forrester, 1961; Lyneis, 1980).
- Dynamic decision making (Sterman, 1989).
- Complex non-linear dynamics (Moskilde et al., 1991).
- Supply chain management (Akkermans et al., 1999).
- Manufacturing systems simulation using the principles of System Dynamics (Oyarbide-Zubillaga, 2003).

However, no model is known, supporting the dimensioning of a new final assembly shop at an early stage. Also the idea to use this approach in connection with key performance indicators is new.

2.10 Indicated Gaps in the Present Situation

As already described in chapter 2.8, with respect to planning a new final assembly shop, considerable gaps can be recognised in the literature concerning the subject 'system of key performance indicators'.
Even if many authors point out the importance of accurately described system boundaries and unequivocal definitions, in the automotive industry there is no literature which positions itself in sufficient detail to these challenges.
Moreover, nobody has analysed the mutual dependencies in a final assembly shop of a car manufacturer. So far, such interdependencies most of the time were closer described only for monetary systems of key performance indicators such as the 'DuPont-System of Financial Control'.

Anyway, it must be mentioned that the current systems of key performance indicators often focus very strongly on the short-term control of an enterprise. The long-term horizon, which is necessary for the planning of a final assembly shop, is theoretically described, indeed in practice is often neglected.
Perhaps one reason for many of these restrictions is founded in the almost unlimited monopoly position by 'Excel' from the 'Microsoft Office-family'. Hence, the discussion of alternative tools for the work with key performance indicators also seems to be necessary.

2.11 Research Aim and Objectives

The reviewed literature gives a hint that the planning process for a new final assembly shop of a car manufacturer in the early stages can be improved by a combination of the approach of 'System Theory' with the idea of the 'key performance indicator net'. Should one succeed in illustrating the mutual dependencies between the different key performance indicators in a formal model, the quality of the planning results could be improved and the time for the planning process could be reduced.

The following research aim is based on these considerations.

Development of a formal model
that considers the complex interdependencies
within a final assembly shop of a car manufacturer
in order to accelerate the planning process and
to increase the quality of planning results.

On the way to achieve this aim, the following objectives should be mastered successfully:

1. Definition of the system boundaries and breakdown of the final assembly shop in general valid and meaningful segments.

   Since the experts for the planning of a new final assembly shop come from many different departments, there must not be any doubts about the system boundaries, because otherwise the results of the system of key performance indicators would offer room for interpretations and could introduce uncertaintiy and errors.

2. Determination of the most important key performance indicators relevant for the planning processes of a final assembly shop of a car manufacturer both as input and output dimensions, taking into account the higher enterprise purposes for this selection.

   The orientation towards higher enterprise targets should help to guarantee the efficiency of the system of key performance indicators. Every key performance indicator which is used in the system and which does not improve the quality of the planning result slows down the planning process and therefore is not helpful to reach the aim of this research project.

3. Generally accepted definition of the most important key performance indicators.

   A system of key performance indicators using numbers which are not exactly defined, cannot achieve high explanatory power. If only one important key performance indicator raises questions regarding its definition, all results of the system of key performance indicators will be questioned.

4. Analysis of the dependencies between the individual key performance indicators.

   Following the idea of 'System Theory', the system of key performance indicators can only deliver reliable results if the most important connections between the different planning parameters are properly grasped.

5. Mapping of the formally described models in a user-friendly tool.

   Since the system of key performance indicators has to consider a huge number of elements, the 'user-friendliness' is an important objective too. The acceptance of a new tool strongly depends on this attribute. Only if one succeeds in illustrating the numerous dependencies within a final assembly shop in a way that gives the planner the chance to accelerate the planning process and to improve the exactness of the planning results, the aim of this research project can be achieved.

6. Validation of the tool with help of existing final assembly shops.

   As with every development process, at the end of such a research project it has to be tested, whether the developed object, in this case the new system of key performance indicators, generates reliable results in every situation.

3 Research Methodology

3.1 Introduction

In the previous chapter the challenges for the automotive industry in general and for the planning departments in particular were described. Having explained the most important terms relevant for this thesis and having reviewed the issue-related literature, at this point the 'research question' as well as 'aim and objectives' for this thesis are known.

In the present chapter, the approaches and techniques used for answering the research question will be explained, in order to achieve a reliable result of high quality with an efficient process.

Hence, right at the beginning the subjects 'research purpose' and 'research process' are described in detail. The section about the 'research strategy' that follows it, gives direction for the rest of the research project. For the purposes of a consistent planning of the research project the different options for 'data collection' and 'data analysis' will be introduced afterwards. In addition, the criteria to validate the chosen research methodology will be discussed.

Since proper software should help to achieve the objectives, the different options available are specified at the end of the research design process. During and after the decision-making process, the software finally used is tested and introduced. With a general example of use at the end of this chapter, the basics for an efficient research project are provided.

Before all these points are discussed, there is a need to explain the term 'methodology', since the relevant terms are used differently in various publications (Blaxter et al., 1996, p. 59; Higgins, 1996, p. 26; Arbnor and Bjerke, 1997, p. 8; Jankowicz, 1991, p. 158). As a result of its shortness and its clearness, the definition of Higgins (1996) is the basis for this research project:

"Under methodology, we describe how we propose to tackle the questions and topic we have defined".

For the success of a research project it is important "to have a sane and rational framework from which to operate" (Fitzpatrick, 1998, p. 15). Knowing the 'research purpose' is the foundation for building such a framework. According to Robson (1993), this should be the first step of a research project anyway.

3.2 Research Purpose

Popper (1959, p. 27) states that a scientist has "to put forward statements, or systems of statements, and test them step by step". Dominowski (1980, pp. 2/3) defines research as a "fact-finding activity" with the goal "of an organised understanding of the world around us". For this research project both definitions are valid, because at the end, knowledge that is useful and which extends human understanding in the field of key performance indicators for planning a final assembly shop of a car manufacturer should be produced. The attained results about the dependencies will be prepared in a traceable form, so that other scientists can evaluate the results critcally.
To achieve this purpose efficiently, a coherent research process is helpful. Some of the different options will be explained below.

3.3 Research Process

According to Walsh (2001, p. 2), a research process "is simply a planned, structured approach to inquiry that ensures that your investigation proceeds in a logical, coherent way". Based on this principle, literature offers numerous different, idealised and simplified research processes which can be helpful during a research project. Examples can be found in Blaxter et al. (1996), Bouma (1993), Drongelen (1999), Howard and Sharp (1983) and Checkland (2002).
The cyclical approach of Blaxter et al. (1996, p. 10) (see figure 46) seems to be especially interesting, since it is well structured but shows how everything is linked to each other and that there is no official starting line.

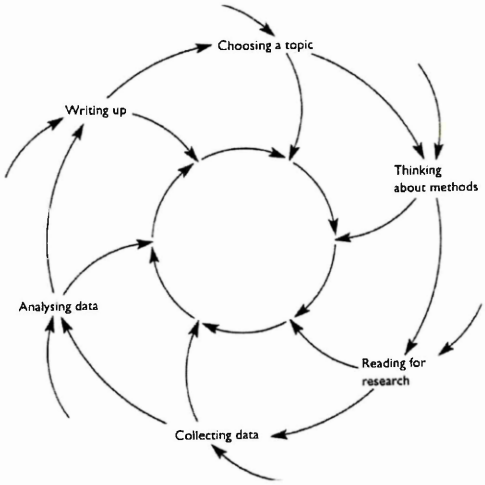


Figure 46 – Research Spiral. Blaxter et al. (2001)

On the other hand, literature offers plenty of linear processes (Bordens and Abbott, 1988, p. 22; Blaxter et al., 1996, p. 7; Bouma, 1993). They have the advantage of guiding the inexperienced scientist through the complex research process with clear instructions. If the recommended sequence is followed intelligently, the research project can proceed efficiently. Against this background, the flow illustrated in figure 47 according to Remenyi et al. (1998) seems to be very interesting.

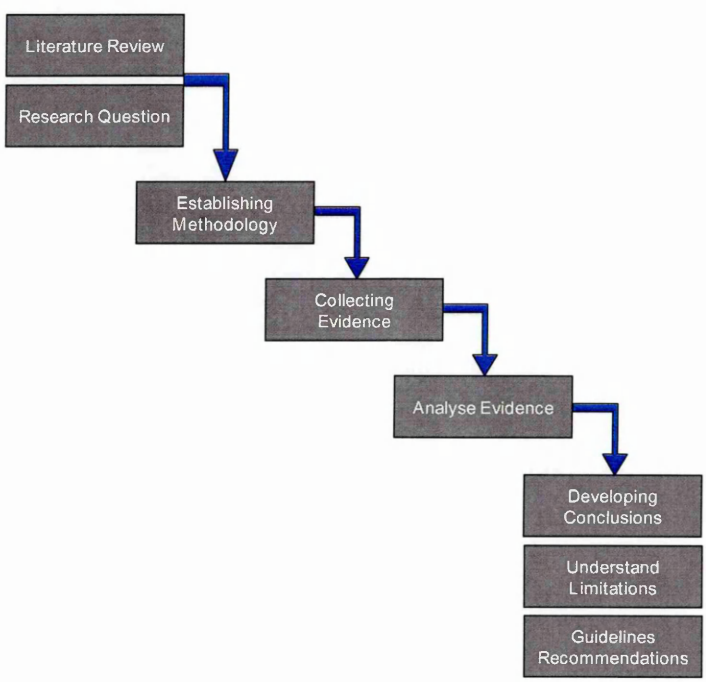


Figure 47 – Research Process. Remenyi et al. (1998)

In addition, the following flow chart, showing the critical rationalism of Popper, is very helpful, too. Figure 48 illustrates that after the step of building theory, every theory takes the risk of failure, since the empirical study only shows the reality within given conditions at that time.

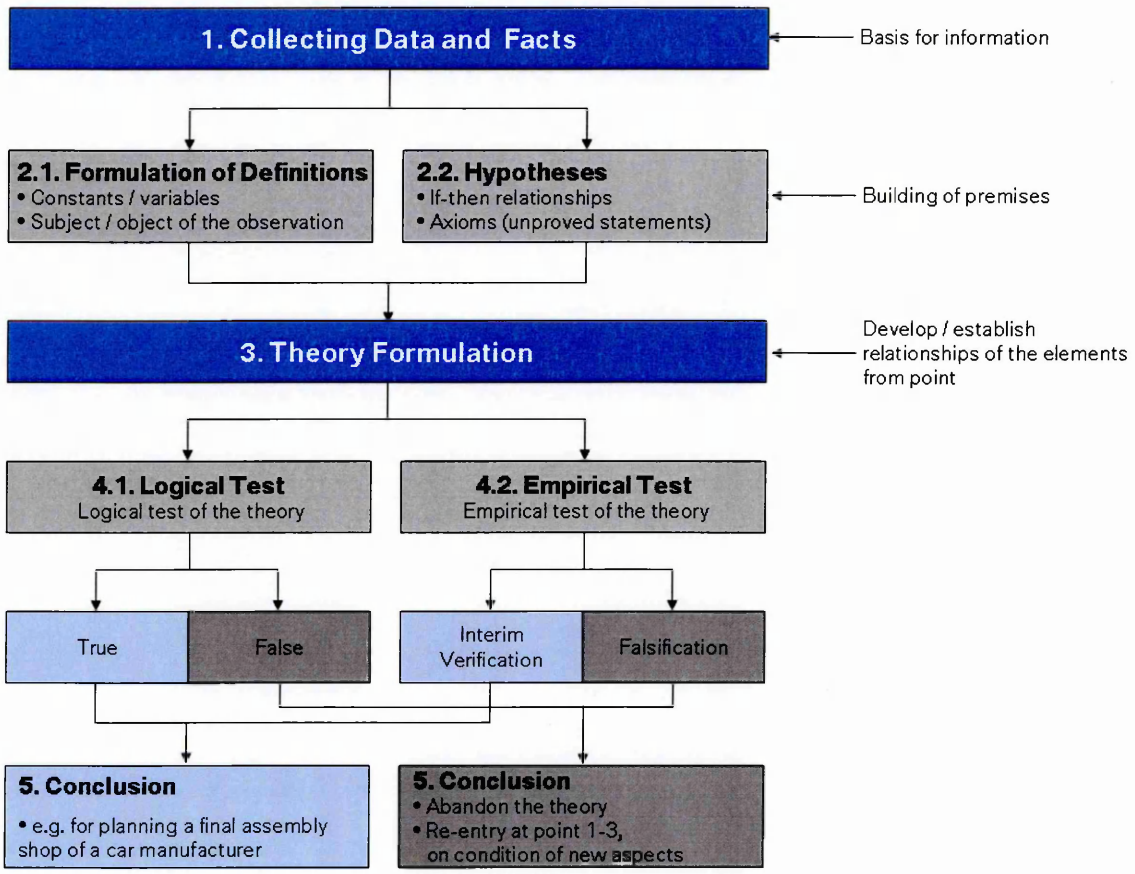


Figure 48 – Procedure of Building Theory. Methodiken der Volkswirtschaftslehre

3.4 Research Strategy

After introducing the research question in chapter 1, for an efficient research process it is important to choose the appropriate research strategy (Robson, 1993, p. 39; Bordens and Abbott, 1988, pp. 21/57). It has to be said that every research strategy has advantages and disadvantages (Yin, 2003, pp. 1/5) and no ideal strategy can be found (Wilkinson and Birmingham, 2003, p. 3).

Moreover, it can sometimes be helpful, to use more than only one strategy (Blaxter et al., 1996, p. 62; Yin, 2003, p. 9). In any case, the investigator should trade-off the "strengths and limitations of the different strategy options" (Walsh, 2001) in order to avoid "gross misfits" (Yin, 2003, pp. 1/5).

3.4.1 The Planning Factors of the Research Strategy

To ensure that the best available strategy is selected, the parameters having an influence on this decision have to be known. The following criteria summarise the opinions of different authors (Walsh, 2001, pp. 38/39; Fitzpatrick et al., 1998, p. 21; Blaxter et al., 1996, pp. 26/63; Higgins, 1996, pp. 16/64/65; Bordens and Abbott, 1988, p. 57). For this research project, these points are the influencing aspects for finding the best strategy, too.

- The type of research question.
- The control an investigator has over actual behavioural events.
- The focus on contemporary as opposed to historical phenomena.
- The personality / skills of the investigator.
- The aspect of deskwork or fieldwork.
- The time available.
- The financial resources.
- The other resources available.

3.4.2 Types of Research Strategies

After the influencing variables for a research strategy are defined, the most important strategies from which to choose should be introduced (see figure 49). According to Robson (1993, p. 40), "research strategies have been classified in many different ways". He further postulates that a widely used approach distinguishes between three main strategies.

Research Strategy	Characteristics / Features
Experiment	• Measuring the effects of manipulating one variable on another variable. • Selection of samples of individuals from known populations; allocation of samples to different experimental conditions; introduction of planned change on one or more variables; measurement on small number of variables; control of other variables; usually involves hypothesis testing.
Survey	• Collection of information in standardised form from groups of people. • Selection of samples of individuals from known populations; collection of relatively small amount of data in standardised form from each individual; usually employs questionnaire or structured interview.
Case Study	• Development of detailed, intensive knowledge about a single 'case', or of a small number of related 'cases'. • Selection of a single case (or a small number of related cases) of a situation, individual or group of interest or concern; study of the case in its context; collection of information via a range of data collection techniques including observation, interview and documentary analysis.

Figure 49 – Three Traditional Research Strategies. Robson (1993)

These strategies could be completed by a quasi experiment, action research, archivial analysis, field studies, history or ethnographic research (Blaikie, 2000, p. 39; McQueen and Knussen, 2002, p. 11; Wolcott, 1990, p. 65). Below, the three traditional strategies will be introduced in detail, since after a preselection none of the additional strategies seems to be the right one for this research project.

3.4.2.1 Experiment

Although the experiment tries to answer 'how' and 'why' questions (Robson, 1993, p. 43), it is not an appropriate strategy for this research investigation. This can be argued with the help of Walsh (2001, p. 49), who characterises an experiment as a strategy, where the investigator systematically has to manipulate specific input variables. Gill and Johnson (1997, p. 43) complete that the experimenter "must be able to identify and measure any subsequent changes in the dependent variable".

Doubtless, with this research project, the variables influencing a final assembly shop of a car manufacturer should be found out, but it is not possible to change some input variables easily. Therefore, a change of the dependent variables caused by the input variables cannot be measured directly.
Furthermore, literature asks for an isolation of the investigated variables. A condition, most of the time generated in a laboratory. Such an artificial environment is unrealistic for this research project, since for example, the investment for a final assembly shop is so high, that the findings never could be justified. In addition, the conclusions could be wrong, since the persons working in an assembly building could behave differently in an observed, manipulated and artificial environment. Altogether, the experiment definitely would be the wrong strategy for this research project.

3.4.2.2 Survey

According to Robson (1993, p. 49), "the term 'survey' commonly refers to the collection of standardised information from a specific population, or some sample from one, usually but not necessarily by means of questionnaire or interview. [...] Generally, a relatively small amount of information is collected from any one individual, contrasting with a case study, where a great deal of information might be obtained from a 'key informant'".
After the first part of the statement this strategy looks interesting, because for this research project information about the different final assembly shop is necessary. For example, some questions worth asking in the plants could be:

- How much area does the assembly building from plant A need?
- How many work stations does plant B have?

Yin (2003, p. 5) announces that questions asking 'how much?' and 'how many?' can be answered with a survey strategy, but he also points out that questions looking for the 'how' and 'why' cannot be answered with the survey strategy. This would fit to the above cited, second part of the statement of Robson, giving a hint that the case study is the best strategy for this research project, because of the huge number of information required for this investigation.

3.4.2.3 Case Study

In the previous section the case study strategy already indicated itself as the best strategy for this research investigation. To make sure, it is really the most suitable one for this research project, it now will be evaluated in depth.

Yin (1993, p. 59), probably the most quoted author in the field of case study research, defines it as follows:

"A case study is an empirical inquiry that

- investigates a contemporary phenomenon within its real-life context,
- addresses a situation in which the boundaries between phenomenon and context are not clearly evident, and
- uses multiple sources of evidence."

In his view a case study is the proper strategy, if "a 'how' or 'why' question is being asked about a contemporary set of events, over which the investigator has little or no control" (Yin, 2003, p. 9).

Advantages

Like no other strategy, the case study strategy offers the chance to have a detailed look to investigate the reality (Galliers, 1990, p. 334; Wisker, 2001, p. 190). For this research project this is a very strong argument, since in reality existing, complex final assembly shops with all their linked elements have to be analysed accurately.

According to Walsh (2001, p. 52), the case study research will be defined as 'holistic', because researchers are keen to understand how the various elements and relationships within the case study setting work together.
Based on the statement of Gassmann (1999, p. 11), it is also an advantage that the problem pictured in chapters 1 and 2 is a practical one. In his opinion, the case study research is well suited for practical issues.

Disadvantages

Doing a case study, one of the biggest challenges probably is, "to which extent findings can be generalised" (Walsh, 2001, p. 53; Klüver, 1995). Since this research project will be supported by the BMW Group, these concerns will be met in a special section (see section 3.7.3) within this chapter.
Gassmann (1999, p. 15) additionally mentions the high expenditure of time, the dependency on industry for cooperation, the possible lack of accuracy and the lack of objectivity as counter-arguments.
These potential disadvantages can be reduced with a good case study design. Furthermore, Göthlich (2003) offers plenty of logical arguments (e.g., lack of alternatives) to minimise such kind of arguments.

Types of Case Studies

A scientist can distinguish between three different basic types of cases, illustrated in figure 50. Figure 51 offers additional options, to duplicate the following alternatives.

Type of Case	Characteristics
Exploratory	• To find out what is happening. • To seek new insights. • To ask questions. • To assess phenomena in a new light. • Usually, but not necessarily, qualitative.
Descriptive	• To portray an accurate profile of persons, events or situations. • Requires extensive previous knowledge of the situation etc. to be researched or described, so that you know appropriate aspects on which to gather information. • May be qualitative and / or quantitative.
Explanatory	• Seeks an explanation of a situation or problems, usually in the form of causal relationships. • May be qualitative and / or quantitative.

Figure 50 – Types of Cases. Robson (1993)

As mentioned earlier, one of the objectives of this research project is to understand the interaction of the different elements (= key performance indicators) required for planning a new final assembly shop. According to Walsh (2001, p. 6), the explanatory case study would fit to this kind of research, because it might involve a study that examines the 'why' and 'how' questions. He adds that "explanatory research specifically seeks to look at the cause / effect relationships between two or more phenomena". Some of the questions that should be answered with this research project are listed below:

- Why do final assembly shops (e.g., areas, number of people, ...) in detail look different?
- How are the key performance indicators linked to each other?
- How are the results changeable under various circumstances?

Designing Case Studies

Göthlich (2003, p. 8) groups the process of doing a case study in the stages planning (= chapter 2 and 3), data collection (= chapter 4), data analysis (= chapter 5 and 6) and case report (= thesis).

According to Yin (2003, p. 21), the following five components are necessary for designing a case study:

1. A study's questions.
2. Its propositions, if any.
3. Its unit(s) of analysis.
4. The logic linking the data to the propositions.
5. The criteria for interpreting the findings.

In the previous section (see section 3.4) the coherence of the research question and the case study strategy were described. Now the question about possible propositions has to be answered.

For this research project the propostion is that the required space, the number of employees and the amount of investment for instance are dependent variables upon the complexity of the cars, the number of cars that have to be built, the degree of automation and the chosen logistical concept.

At the end of the planning stage, Yin (1993, p. 10) highlights the importance of the decision about the units of analysis. For example, the limitations for the generalisation of the research findings will often be argued with this decision. Since the BMW Group sponsors this research project, the definition of the units of analysis is mostly given. The BMW Group offers the opportunity for one single case with embedded units of analysis (see figure 51). Because of the confidential information and the complexity of the research project, a potential enlargement (e.g., Audi, DC, Ford) of the case study would not be realised within the available time and the financial resources.

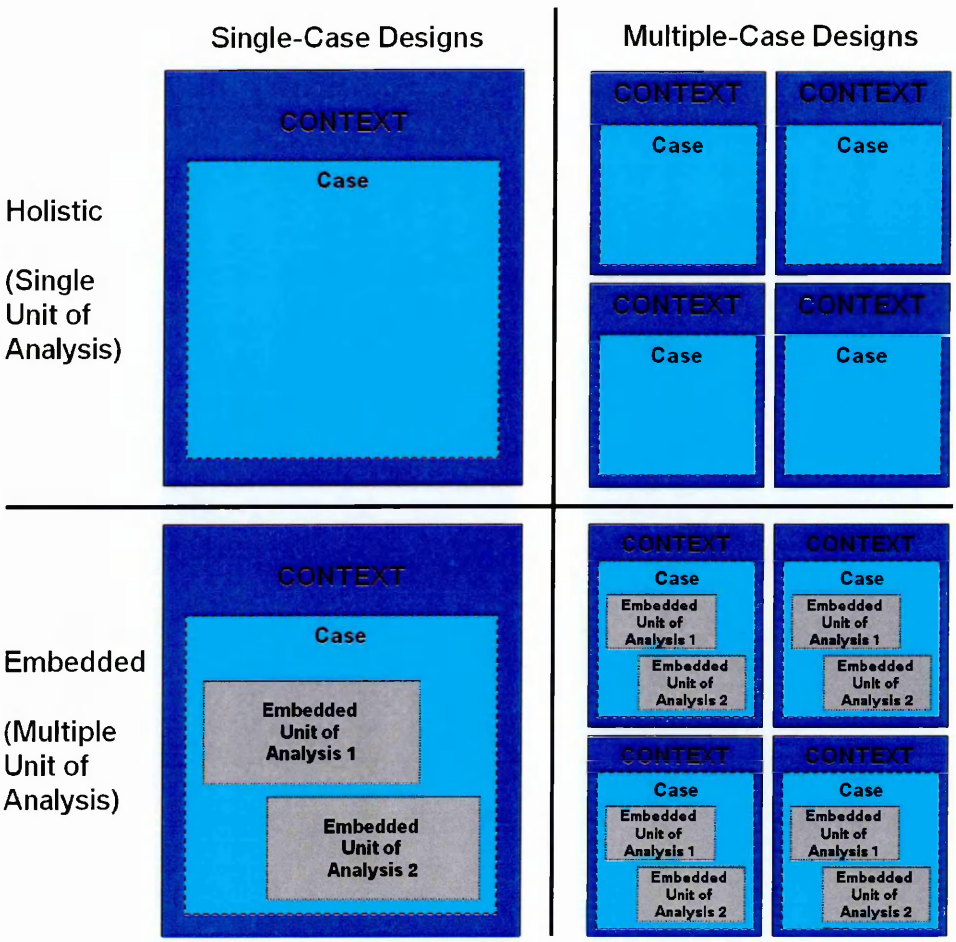


Figure 51 – Forms of Case Study Designs. Yin (2003)

The various plants will represent the embedded units of analysis. Because of the different influencing factors of every single plant, it is necessary to include as many final assembly shops as possible. For example some of the relevant distinguishing features are:

- Complexity of the products:
  Mini (Oxford) 7 Series (Dingolfing)
- Product variation at the assembly lines:
  3 Series (Rosslyn) 5, 6, 7 Series (Dingolfing)
- Location of the plant:
  Europe (Germany and Great Britain), USA and Africa
- Year of construction of the plant:
  Munich (1916) Leipzig (2004)

As the listed examples indicate, the production network of the BMW Group offers a multitude of typical distinguishing features for an automotive manufacturer. Therefore, this single-case can be classified as a 'representative or typical case' (Yin, 1993, p. 41).

3.5 Methodology Data Collection

After discussing the planning stage in detail, in this section the different facets of data collection will be generally explained. The advantages as well as the disadvantages of the different techniques for collecting qualitative or quantitative information will be illustrated. Also the influences on the subsequent quality of the research results will be discussed.

3.5.1 The Type of Information Source

The decision about the type of data can be made between quantitative and qualitative ones as illustrated in figure 52.

Type of Data	Characteristics / Features
Qualitative	• Based on meanings expressed through words. • Results in non-standardised data requiring categorisation into categories. • Analysis conducted through the use of conceptualisation.
Quantitative	• Based on meaning derived from numbers • Collection results in numerical and standardised data. • Analysis conducted through the use of diagrams and statistics.

Figure 52 – Qualitative and Quantitative Information. Saunders et al. (1997).

According to Yin (1993, p. 57), "qualitative research is characterised as being "'soft' social science, interested in 'mushy' processes and dealing with inadequate evidence, whereas quantitative research is considered hard-nosed, data-driven, outcome-oriented, and truly scientific". Such a separation can be found in Reichardt and Rallis (1994, p. 8) and Blaikie (2000, p. 244), too.

For this research project these kinds of definitions are irrelevant, since "it is possible for a single investigation to use both methods" (Best and Kahn (1989) quoted in Blaxter et al. (1996, p. 60)). Furthermore, often "the two poles in the spectrum complement each other" (Higgins, 1996, p. 28), so that Fitzpatrick et al. (1998) argue with the advantages of the 'mixed strategy'.

Quantitative Information

On the one hand, the final assembly shops at the different locations offer a lot of interesting elementary basic data and key performance indicators – quantitative information. This information offers an excellent starting point for a detailed analysis of the various final assembly shops.

Qualitative Information

On the other hand, many experts and departments are involved in planning future final assembly shops. Collecting the relevant qualitative information, has the objective to integrate the available planning know-how (= mental models) into the research project. This idea is supported by Walsh (2001, p. 7), saying, "a lot of research is conducted into people's experience. This produces non-numerical qualitative data". The definition of Denzin and Lincoln (2003, p. 5) about qualitative research also carries this objective:

"Qualitative researchers study things in their natural settings, attempting to make sense of, or to interpret, phenomena in terms of the meanings people bring to them."

Primary Data

Finally, it has to be mentioned that for this project all data has to be 'primary data' (Sacks, 2001, p. xiii; Blaikie, 2000, p. 28). Because of the complex interactions within a final assembly shop, it is important to collect data at the highest degree of quality, in order to minimise the risk of wrong conclusions during data analysis. Especially existing quantitative information (= secondary sources) are often based on different definitions or system boundaries and should be used with caution.

Since the availability of primary data for the author is only guaranteed within the BMW Group, for the moment this is an important limitation for this research project. After the coherences have been analysed with primary data, as a next step, existing secondary data of other OEMs could be used to evaluate the findings.

3.5.2 Data Collection Techniques

For the progress of the research project the next question that has to be answered is about the different techniques available to collect primary data. Again, it is necessary to weigh up the advantages and disadvantages of the different options, because the selected technique has a major influence on the quality of the research findings. Besides the approaches shown in figure 53, plenty of other techniques (Blaikie, 2000, p. 233) can be used, e.g., workshops, documents and ethnography.

Data Collection Techniques	Advantages	Limitations
Questionnaires	• They can be a cheap and efficient way of collecting data. • They can collect a large amount of data relatively quickly. • They are relatively reliable as a method of data collection. • A comparison of respondent`s answers is possible.	• It can be difficult to get people to complete. The response rate of postal questionnaires is particularly low. • Respondents often have limited choices of answers. They may not reveal or express their real views or attitudes if they do not match the 'forced choices'. Data collection possibilities are pre-limited by the researcher, as respondents can only provide responses to a restricted range of questions or scales. • Unless the questionnaire is conducted face-to-face, the researcher cannot be sure of the true identity of the respondent. • The respondents tend to be people who have stronger views or attitudes on the subject being surveyed. • If the questionnaire is posted, the researcher cannot be sure that respondents have understood the questions and cannot use follow-up questions to explore unusual answers.
Interviews	• It is possible to avoid too much pre-judgement where the questions are not predetermined. The researcher can obtain the interviewees 'real' views and beliefs. • Semi-structured interviews give the researcher an opportunity to 'probe' what the respondent says. The researcher can also discover and make use of unexpected and unforeseen information as it is revealed. • The depth of information is improved, because the interviewer can explore what the respondent 'really means' or 'really believes', as he or she talks more freely. • Response rates can be very good, as the interviewer is present to ensure completion of data collection. • The researcher can give help and guidance, explaining questions and giving additional information where it is needed.	• The validity of data is always suspect. It is never possible to be 100% sure that an interviewee is not either deliberately lying or that they can recall the 'truth' correctly. • Recording information can be difficult. Writing down what people say is difficult and can be intrusive. It is hard to keep up, and it interrupts the flow of an interview if you keep stopping to write. Tape recording the interview is much better, but introduces confidentiality issues and may cause the respondent to limit what he or she says. • People usually give too much information in semi- and unstructured interviews. Most of what they say isn`t useable and goes into too much depth. • Interviews take a long time to complete, and even longer to transcribe into a written record of what was said. • The reliability of 'data' is poor. It is very difficult to compare responses between respondents, because they may not have been asked exactly the same questions and, as a result, can produce very different data.
Participant observation	• Observation of 'real' life in natural settings give access to highly valid data. • Observation can produce data that`s 'rich' in meaning and may give access to otherwise 'hidden' data. • Participant observers can often obtain detailed data over a long period of time. • Covert participant observation may be the only way of accessing 'hidden' data or hostile groups. • Researchers do not have to decide what they are looking for in advance of beginning their study. They can make decisions about what is and is not significant behaviour as events occur and unfold naturally.	• Researchers may not be able to retain their objectivity or avoid becoming involved in the life of the group. This is sometimes referred to as 'going native'. Researchers may also influence behaviour or events in the research setting if they become too involved. • Participant observers may never really understand the group or setting if they are unable to appreciate the deep meaning and significance of behaviour from the standpoint of a detached outsider. • Participant observation studies tend to be small scale and the group being studied may also not be representative of any other social group (= therefore findings cannot be generalised). • Covert observation has serious ethical implications and problems associated with it. For example, informed consent is not obtained when covert observation is carried out. • The reliability of observational data collection methods is relatively low, because observations are often personal and non-repeatable.

Figure 53 – Data Collection Techniques. Walsh (2001)

3.5.2.1 Questionnaires

As illustrated in figure 53, it seems target oriented to use the technique of questionnaires for scanning the different final assembly shops. It is a cheap and efficient way to collect quantitative data.

Since different departments and persons are necessary for collecting all the relevant figures, it is required to define every single figure unambiguously in order to get comparable figures. At the beginning, the process of defining the figures can be very time-consuming, so that the argument of 'collecting the figures relatively quickly' only is partially valid.

Therefore, an essential aspect is the already mentioned quantity of information to be collected. For having the chance to use the technique of 'rival explanations' (see section 3.6.1), the researcher should be interested in collecting plenty of information. On the other hand, the costs for collecting the figures have to be kept in mind as well. Additionally, there is the danger that too many figures both reduce the response rate of the planners and reduce the support by the management.

Besides the clear question (= definition), the motivation of the planners to answer the questions is challenging as well. For this point Oppenheim (1992, p. 104) offers plenty of interesting tips. However, one additional aspect should be mentioned. Since the questionnaire will be sent within one company, management attention could be helpful too. The process of data gathering can be accelerated and the response rate can be increased, if management is interested in the figures.

In addition, it is also important to communicate the targets of the questionnaire right at the beginning. Also, a process for communicating the confidential information has to be defined, before sending the questionnaire. Both aspects will be explained in detail in chapter 4.

3.5.2.2 Interviews

The success of this research project is strongly linked to the planning experts. Only if their mental models can be explained, the interrelation of the different key performance indicators can be mapped. For collecting the required in-depth information, unstructured interviews will be used. This approach also fits to the 'naturalistic scientist' (Walsh, 2001, pp. 12/65). As already illustrated in figure 53, it is important to be aware that this is a very time consuming way of collecting information.

Furthermore, it is predictable that the planners will face the questions differently (Fitzpatrick et al., 1998, pp. 58/61), so that the strategy during interviews probably has to be changed. This is one of the reasons Oppenheim (1992, pp. 65) characterises an interview as a 'task of daunting complexity', which according to Wilkinson and Birmingham (2003, p. 43) requires "orchestrating, directing and controlling to varying degrees" from the interviewer. Therefore, plenty of helpful guidelines such as for example from McNiff et al. (2003, p. 124) are available.

One basic question in the context of an interview is the way of documenting it. Documentation with the help of an audio-recorder or a video camera would not be helpful for this research question. Since the relationships of different key performance indicators has to be mapped, it seems reasonable, to describe and record this information visually as maps, as suggested by Greenfield (1996).

3.5.2.3 Participant Observation

As explained by Walsh (2001, p. 67) "in a participant observation study, the researcher enters a group or situation that he or she is studying. Participant observers try to 'get to know' the group or situation from 'the inside'". Because of the sensibility of the data and the required information from plenty of planners, an external researcher would have great problems with getting deeper insights into the key performance indicators about the various final assembly shops of a car manufacturer.

Therefore for answering this research question, it is very helpful that the scientist is part of the planning department of the BMW Group. The support of the BMW Group offers the chance for a win-win situation, for the BMW Group, the scientist and the scientific world.

3.5.2.4 Triangulation

At the end of this chapter the technique of 'triangulation' will be introduced, since "it tries to counter the weaknesses that exist in different methods of data collection and analysis" (Walsh, 2001, p. 69). As described by Yin (1993, p. 69) and Fitzpatrick et al. (1998, p. 28), the usage of different techniques during both process stages should help to strengthen the research findings. Only if the outcome of the research has the same direction after a detailed oberservation from different angles, the data has been triangulated successfully. For this research question it would be careless if this technique were not used. Therefore, already during data collection the weaknesses of one technique should be compensated with the help of an appropriate different technique.

3.6 Methodology Data Analysis

Most researchers would start with the data analysis after the process of data collection. However, some authors (Blaxter et al., 1996, p. 173; Yin, 1993, p. 111) recommend an overlap of both activities. This could be helpful for improving the quality of the information or for collecting missing figures. For this research project, such an overlap is necessary to meet time restrictions and to motivate the people to collect some additional figures. These figures can help to analyse some topics in detail.

After finishing collecting information, "the process of making sense of the data" (Walsh, 2001, p. 79) starts. Since the collected information is available in different quality (= 'ordered vs. chaotic') and various forms (= 'qualitative vs. quantitative'), Yin (2003, p. 109) denotes the process of data analysis as the most difficult one during a case study, because there are no standardised approaches available.

Even so, from different analysing strategies and techniques can be chosen. They will be introduced in this chapter.
It is important to know, that the options described below, are especially suitable for case studies. Other available strategies / techniques (Blaikie, 2000, p. 237; Walsh, 2001, p. 79; Dominowski, 1980, p. 123; Kreyszig, 1999; Bird, 2003; McDonald, 1974) are more general.

3.6.1 Analysing Strategy

Yin (1993, p. 115) points out that it would be at least difficult to analyse a case study without a proper strategy. Therefore he recommends picking one of the following alternatives:

- Relying on theoretical propositions.
- Thinking about rival explanations.
- Developing a case description.

Not only in this context, Yin (1993) favours the usage of propositions (see section 3.4.2.3). At this stage, they help to stay focused and to separate important information from unimportant. As specified in chapter 4, the theoretical propositions can be helpful for the great number of interviews with the planning experts. Without having such propositions, it could be difficult to stay on the level of the case without getting lost in the details of the experts. Therefore, "the first and most preferred strategy is to follow the theoretical propositions that lead to your case study" Yin (1993, p. 111).
Closely linked with the above described strategy, is the approach of 'rival explanations'. For this research project one of the direct rival explanations is that the target for the investment given by the management has a bigger influence on the size of a final assembly shop than the cars that have to be built within it. Such kinds of statements are helpful, for worming the beliefs out of the experts. They animate the specialists to talk about their mental models, since they provoke a clarification. In the style of Yin (1993, p. 113), figure 54 gives an overview about the rival explanations available.

Type of Rival	Description or Examples
Craft Rivals:	
1. The Null Hypothesis	The observation is the result of chance circumstances only
2. Threats to Validity	e.g., history, maturation, instability, testing, instrumentation, regression, selection, experimental mortality, and selection-maturation interaction
3. Investigator Bias	e.g., 'experimenter effect', reactivity in field research
Real-Life Rivals:	
4. Direct Rival (Practice or Policy)	An intervention ('suspect 2') other than the target intervention ('suspect 1') accounts for the results ('the butler did it')
5. Commingled Rival (Practice or Policy)	Other interventions and the target intervention both contributed to the results ('it was not only me')
6. Implementation Rival	The implementation process, not the substantive intervention, accounts for the results ('did we do it right?')
7. Rival Theory	A theory different from the original theory explains the results better ('it is elementary, my dear Watson')
8. Super Rival	A force larger than but including the intervention accounts for the results ('it`s bigger than both of us')
9. Societal Rival	Social trends, not any particular force or intervention, account for the results ('the times they are a-changin')

Figure 54 – Different Kinds of Rival Explanations. Yin (2003)

Even if Yin prefers the two strategies introduced above, the third strategy for data analysis (= developing a case description) could be used for more than a descriptive case study. For example, this approach may help to identify the appropriate causal links to be analysed – even quantitatively.

3.6.2 Analysing Techniques

Based on the chosen strategy, five techniques for analysing the data are available. Only four of them – cross-case synthesis applies specifically to the analysis of multiple cases – can be used for a single case (Yin, 2003, p. 139). For this research project the time-series analysis and logic models can also be excluded, since both techniques are focused on developments over a given period of time. However, significant changes of a final assembly shop could be analysed after one or two decades, since high investments in rebuildings often are linked to the product life cycle. At this point, it has to be said that these kinds of long-term analyses could be interesting for the future.

Pattern Matching

The technique of pattern matching seems to be interesting, since every single expert has his / her own mental pattern. According to Trochim (as quoted in Yin (1993, p. 116)) "this logic compares an empirically based pattern with a predicted one (or with several alternative predictions)". For this topic a predicted pattern is that the assembly time needed for one car as well as the average employee density are changing the amount of investment and the space required for a new final assembly shop. Such a kind of predicted pattern can be reviewed with the help of the quantitiative data collected from the different plants (= embedded units of analysis).

Explanation Building

The last available analysis technique therefore is the 'explanation building', which is mainly relevant to the explanatory case studies" (Yin, 2003, p. 120). This technique has the objective "to analyse the case study data by building an explanation about the case" (Yin, 2003, p. 120). In an iterative process, the following steps have to be done:

- Making an initial theoretical statement or an initial proposition about policy or social behaviour.
- Comparing the findings of an initial case against such a statement or proposition.
- Revising the statement or proposition.
- Comparing other details of the case against the revision.
- Comparing the revision to the facts of a second, third, or more cases.
- Repeating this process as many times as is needed.

The above mentioned iterative process allows a complete analysis of the complex connections within a final assembly shop. In cooperation with the quantitative data from the different plants (= embedded units of analysis), the causal links can be analysed, explained and documented step by step.

3.6.3 Quality of the Analysis

According to Yin (1993, p. 137), the quality of an analysis is linked to the following four points:

- Attend to all the evidence.
- Address all major rival hypotheses.
- Address the most significant aspect of the case study.
- Use your own prior, expert knowledge.

These criteria will be kept in mind during the whole research project. A conclusive statement about the quality of the analysis can be made at the end of the research project.

3.7 Research Methodology Evaluation Criteria

Many sources introducing the research process contain a chapter about the evaluation of the chosen methodology. Empirical social research in general and qualitative research in specific, have to consider such kinds of quality criteria in particular. The most important ones for this research project will be judged below.

3.7.1 Reliability

Reliability in general stands for the reproducibility of the research findings (Wisker, 2001, p. 253; Walsh, 2001, p. 15). It is strongly linked with the transparency within the research process. As shown later in the thesis, this will be one of the most important criteria while recording the quantitiative data. The definitions of the most important key performance indicators, agreed to by all plants, are the basis for any research finding. They also make it possible that the researcher does not have to collect the figures. Since independent planners from the different locations measure the figures, the researcher does not have the chance to influence the values. Any other researcher would collect the same information by using the same definitions.

For the process of recording the qualitative data, a similar degree of reliability is difficult to achieve. Blaxter et al. (1996, p. 76) for example state that "researchers themselves are powerful". Despite the fact that the most important quality criteria will be taken into account, it is still possible, that another investigator in some areas would come to other research findings. Coefficients like 'beliefs, values or preconceptions' (Walsh, 2001, p. 15) should not be underestimated in this context.

3.7.2 Validity

According to Higgins (1996, p. 83), "the word 'valid' (= from the Latin 'valere': to be strong) carries at its core the idea of strength, soundness, and efficacy". Yin (1993, p. 40) defines this as 'construct validity'. For Blaxter et al. (1996, p. 200), the research project is valid, if the methods, approaches and techniques actually relate to, or measure, the issue the investigator is exploring. The tools described in the present chapter 3 provide a good foundation for a valid research project.

Nevertheless, during interviews or any other data collection technique, there are some influencing factors, which could lead to a wrong picture of the situation. The matter of fact that it is one single case within the BMW Group and the investigator is part of the company are strong arguments for valid research findings. It probably would be much more difficult to achieve validity, if the researcher was an external consultant. This statement can be well founded, because there is already an identifiable difference whether the figures will be communicated within one location or if they have to be communicated to a central planning department (= want of confidence).

Furthermore, a misunderstanding on both sides of the communication channel could lead to wrong data or a misguided data analysis. Some control mechanisms have to be found, for evaluating the data quality within the project.

Some examples are listed below:

- Designing plausibility checks for some sections.
- Using secondary data (= layouts, historical data etc.) for plausibility checks.
- Interviewing different experts about the same topic.
- Building of rival theories.
- Collecting / comparing data from different locations.

3.7.3 Representativeness

As quoted in Walsh (2001, p. 16), McNeil (1990) says "that representativeness refers to the question of whether the group or the situation being studied are typical of others". Such a categorisation is helpful for the survey strategy, but it should not be the critical point of interest for a case study strategy. This opinion is supported by Yin (2003, pp. 10/11), who stresses the point that for a case study it is important "to expand and generalise theories (= analytic generalisation) and not to enumerate frequencies (= statistical generalisation)". This kind of differentiation is essential for the evaluation of this research project. After only one single case, a statistical generalisation doubtless is not possible. Since the production network of the BMW group offers a wide spectrum of relevant influencing aspects (see section 1.4), but still looks comparable to other car manufacturers, at the end an analytic generalisation can be made. In terms of following the logic of replication, such an analytic generalisation is acceptable, if the most important influencing variables can be explained.

3.7.4 Objectivity

During a research project, it has to be the objective of a researcher to face the topic and its findings neutrally. According to Blaxter et al. (1996, pp. 15/16) this is a difficult target, since "research is a social activity powerfully affected by the researcher's own motivations and values.

It also takes place within a broader social context, within which politics and power relations influence what research is undertaken, how it is carried out, and whether and how it is reported and acted upon".

After such a statement it seems not to be possible for the researcher himself to determine the objectivity of his research methodology. Due to the fact that the environment of the case study was set by the BMW Group, a question towards the objectivity is legitimate.

However, there are some indications that the research process is objective within its possibilities. Without question, it is a big advantage that the research is conducted by an investigator without any specific previous knowledge in terms of planning a final assembly shop. Since the work with key performance indicators demands a high level of neutrality, it is also helpful that the author is not assigned to one of the plants. The central planning division (= FIZ) supports the project and the internal control mechanisms would stop the research project, if either the researcher would not be objective or the way of collecting or analysing the data would be intransparent.

In addition, the findings will be presented to external project works in order to ask for rival theories. According to Yin (1993, p. 112), this is a good procedure for avoiding any kind of bias.

3.7.5 Significance

A final statement about the significance of this research project can be made at the end of this project. Nevertheless, at this stage it can be said that the significance of the research project will not be evaluated with the help of statistical tools, it will rather be done in reference to a more general aspect. Against this background, "significance has to do with how important a particular finding is judged to be" (Blaxter et al., 1996, p. 201).

From this point of view, some arguments can be listed, indicating that the findings of the research project could be significant. For instance, the sponsorship of the BMW Group is evidence for the practical relevance. The fact that this research project is about dimensioning a final assembly shop of a car manufacturer includes two additional aspects.

First of all, in many nations the car industry is important for the economic wealth as well as it is a booster for technical innovations. The example of 'virtual reality' shows that an improvement in the planning process could be relevant to other industries, too.

In any industry the building of a new factory is linked with a major investment, leading to the second argument that every industry will be interested in improving the accuracy of the planning in the early stages.

Since this chapter should conclude the planning phase of this research project, still one important decision has to be made.

As a result of the literature review about 'System Theory' and 'System Dynamics' the available SD-software seems to be the proper one for this research project. It is supposed that it can support the planning process of a new final assembly shop, if it is used intelligently. Therefore, below a SD-software must be defined and introduced which fits best to the varied requirements.

3.8 System Dynamics Software

The complexity of a final assembly shop and the number of expected key performance indicators suggest that the often used Excel-spreadsheets for calculating key performance indicators will not be enough for running this project successfully. Moreover, the investigation about mental models pointed out that a suitable tool should be used to map the dependencies between different key performance indicators used by the numerous experts. Therefore, an instrument for supporting the process has to fulfil the following criteria:

- Holistic mapping of qualitative and quantitative information.
- Traceable illustration of complicated connections.
- Supporting the interpretation of the information.

Since SD-software can fulfil these criteria, a suitable package had to be selected for this research project.

3.8.1 Available SD-Software

An excellent overview (see figure 55) about the development of the available 'System Dynamics' software is offered by Coyle (1995, p. 362).

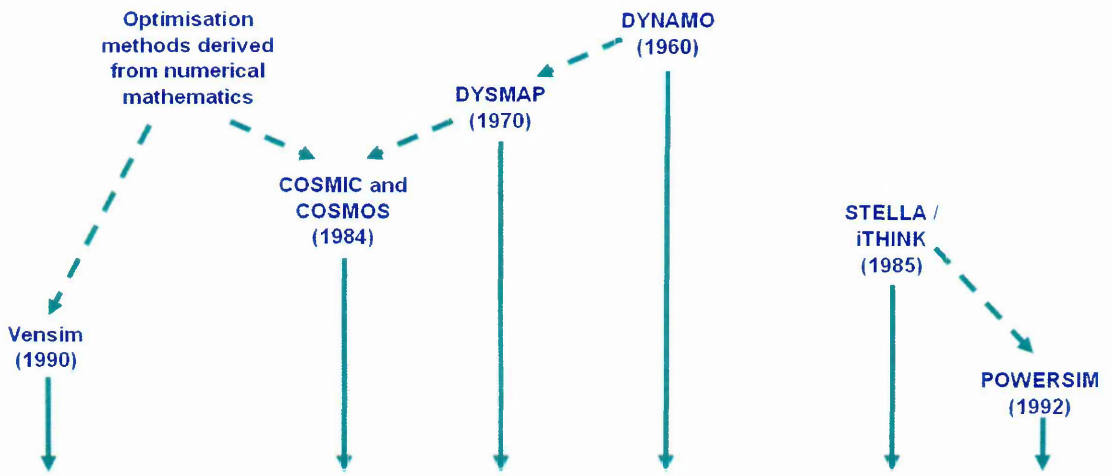


Figure 55 – The Evolutionary Lines of System Dynamics Software. Coyle (1995)

'DYNAMO', 'DYSMAP' and 'COSMIC' should not be considered for this research project, because they are based on the concept of 'writing equations' and use a 'text editor' (Coyle, 1995, p. 362). These aspects were an exclusion criterion, because they do not support the visual communication of the interrelationships.

Since 'Vensim' only uses two out of three core elements for mapping SD-models (= levels and auxilliarys and no flows – see figure 57), this software was rated low as well, in order to keep all options for any further developments after this research project.

Therefore, 'Stella/ithink' (ISEE Systems, 2002) and 'Powersim' (Powersim, 2002) are left for this research project. Both make use of Forrester's flow diagrams which are drawn with help of symbolic icons as illustrated in figure 56.

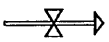
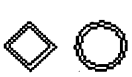
Name	Symbol	Description
Constant		A variable that contains a fixed (initial) value.
Auxiliary		A variable that contains calculations based on other variables.
Level		A variable that accumulates changes. Influenced by flows.
Information link		A connector that provides information to auxiliaries about the value of other variables.
Continuous flow		A connector that influences levels. A flow is controlled by a variable connected by an information link (or attached directly) to the valve.
Submodel		A variable that contains child variables. A submodel variable has no definition (value), data type, or unit.
Cloud		A symbol illustrating an undefined source or outlet for a flow to or from a level. The cloud symbol, also referred to as the source or sink or a flow, indicates the model's outer limits.
Permanent variables		A variable symbol with a pin in the upper left corner indicates that the variable is a permanent variable. Permanent variables keep their value when the simulation is reset. The permanent symbol can appear on constants and levels.
Public variables		A public variable inside a submodel is indicated by a cross in the upper right corner. A public variable can be included in the diagram of the parent variable, can be referred to by variables outside the submodel, and itself refer to variables outside the submodel.
Snapshot		A variable symbol with an extra set of corners represents an alias for another variable on the same diagram. Snapshots are useful for linking variables located in different parts of a model.
Variable with diagrams		A document indicator indicates that the variable has diagrams. Any variable can have its own diagrams and child variables.
Array variables		A variable symbol with double frames indicates that the variable it represents is an array.

Figure 56 – Symbols Offered in Powersim.

A comparison with the general criteria for the assessment of simulation software offered by Robinson (1994, p. 14) and the below described, special criteria for the evaluation of SD-software given by Coyle (1995, p. 367), does not highlight any advantages or disadvantages of one of the two options.

- "Its basis in fundamental system dynamics theory.
- The ease with which it can be used.
- The support it gives to model building.
- The extent to which models can be documented and explained to a sponsor.
- The facilities it has to debug a model.
- The ease of making experiments and producing output.
- The scope of its facilities for policy design" (Coyle, 1995, p. 367).

Since the BMW Group, DaimlerChrysler and Ford use the software package 'Powersim' in other areas, this criterion was the final argument to use 'Powersim', in this research project as well.

3.8.2 Applicability of the Chosen Software Powersim

After the basic decision was made in favour of 'Powersim', the specific applicability has to be checked in another step. First of all, it should be mentioned that there are various software packages of 'Powersim' (Powersim, 2002) available, which differ considerably in the price as well as in their performance. The price for the software package 'Powersim Studio Enterprise 2003' acquired in 2002 was 4,500 euros. In the period of this research project some advancements of the software took place, so that the following details are based on the software 'Powersim Studio Enterprise 2005'. Even so, most of the aspects listed below, were tested over a period of two months with help of a free test version.

The all-embracing software package 'Powersim Studio Enterprise' allows the building and analysing of models and furthermore to distribute models in a special presentation mode. In particular, the second point is important for this research project. As described in detail later, every planner within the production network has the opportunity to download the free of charge 'Powersim Studio Player' onto his / her computer. This option makes it possible to send a centrally built model to an unlimited circle of experts to check it and also to use it in a special presentation mode.
The usage of the model in only one host system would not have been acceptable for this research project, because the proposed system of key performance indicators must be accessible to all planners within the BMW Group.

3.8.3 Easy-of-Use of Powersim

In parallel with the verification of the basic applicability of the software 'Powersim' it also had to be checked that the software would be easy to use. In doing so, two groups of users had to be considered. On the one hand, the author had to be able to illustrate the mental models of the interviewed experts. On the other hand, in the end everyone within the company should be able to use the new system of key performance indicators without spending much time in learning the basics of the tool.
The tests made clear that the latter point could easily be fulfilled with the already mentioned 'Powersim Studio Player'. The exact realisation within this research project is specified in chapters 5 and 6.
The main aspects required to learn how to build a model in 'Powersim' are briefly explained below.
Right at the beginning it is important to stress that 'Powersim' is designed to build SD-models including 'feedback loops' and to simulate dynamic dependencies (= including 'delays'). However, both criteria are irrelevant for this research project. As shown in figure 57, a huge number of key performance indicators should be processed transparently but with little or no dynamic modelling.

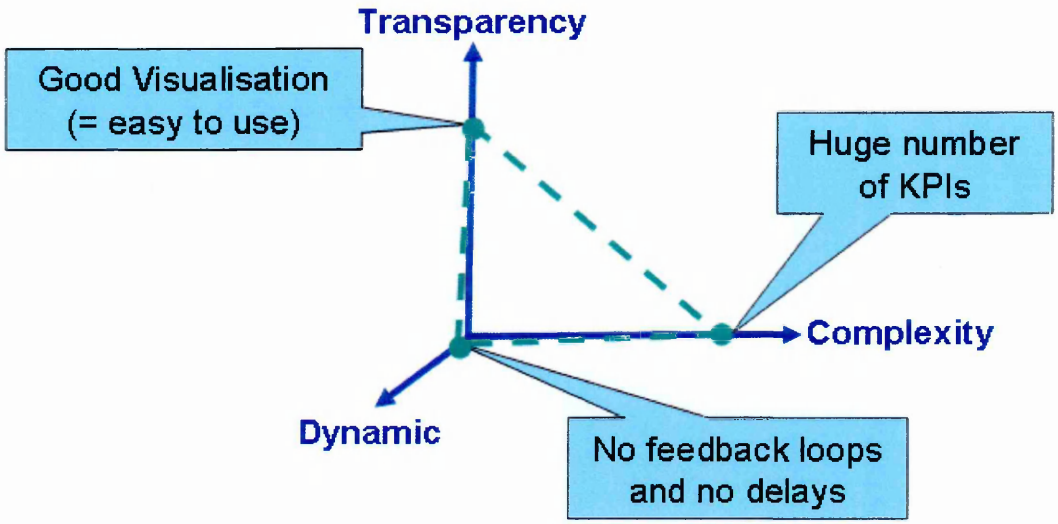


Figure 57 – Objectives of the New System of Key Performance Indicators.

Nevertheless, within the test stage the basic function of all elements had to be understood, even if some of the elements explained in figure 58 are unimportant for this research project. Therefore, at the end of this practice different general models were built, in order to learn modelling in 'Powersim' and even more important, to make sure that the basic idea really helps to solve the original problem.

These models are based on suggestions as they can be found in 'Road Maps – A Guide to Learning System Dynamics' (Forrester, 1992). For an unskilled user approximately four hours should be scheduled for building such a model (see figure 58/59).

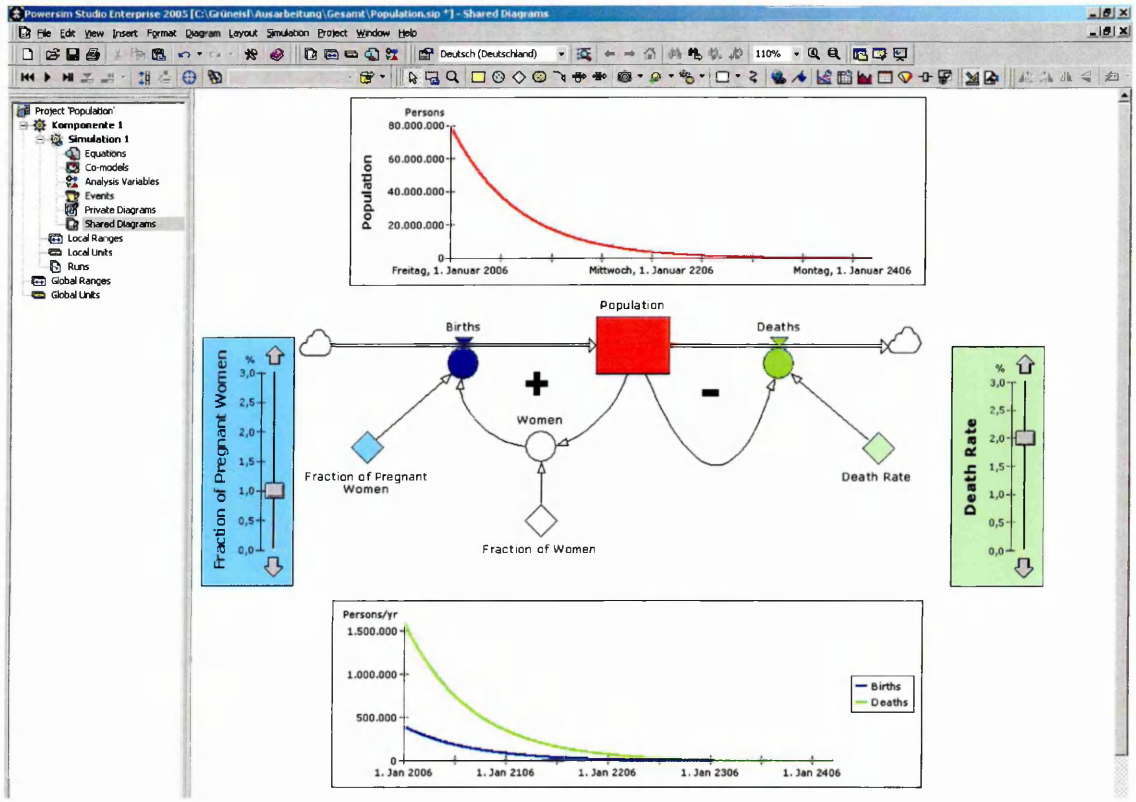


Figure 58 – Change of Population Figures as a Result of a High Death Rate.

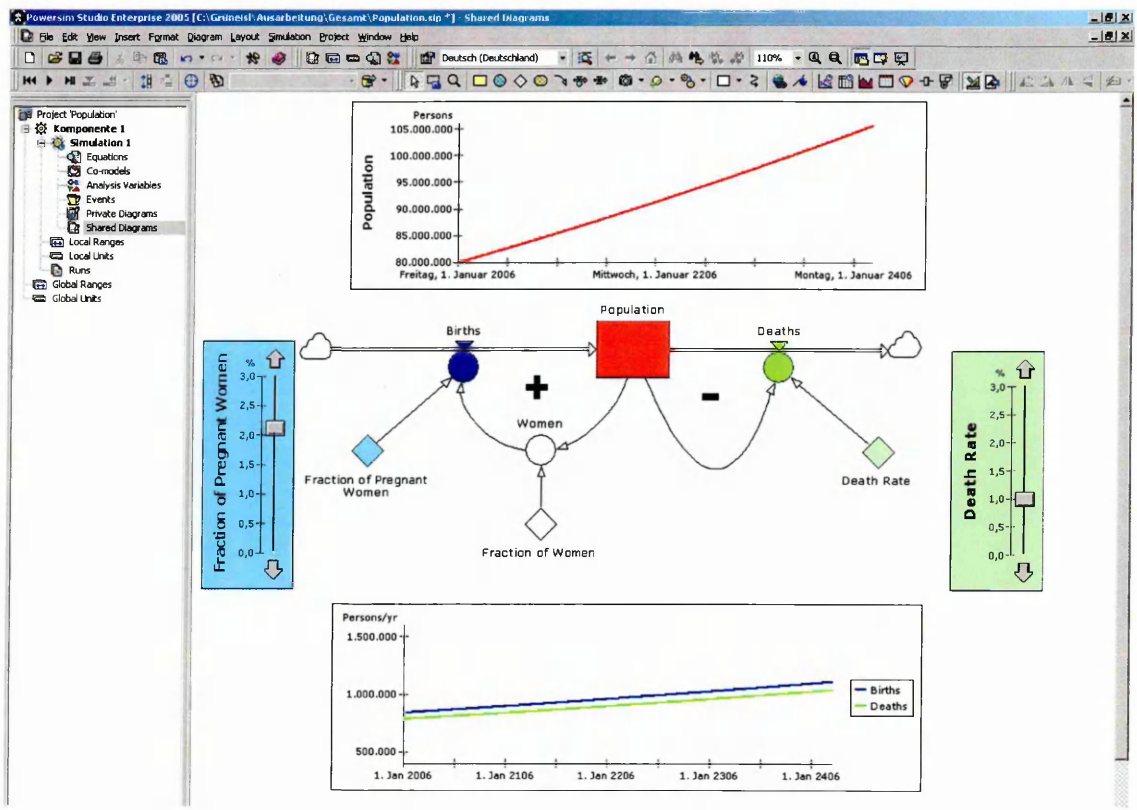


Figure 59 – Change of Population Figures as a Result of a High Rate of Pregnant Women.

With the chosen model the long-term population figures of a nation can be simulated. The positive feedback loop (+) can be described as follows: The larger the population, the greater the number of births. The more the birth rate increases, the faster the population increases. However, if the population figures decline as a result of a high death rate, the effect could be even boosted, because the births would drop at the same time.
The effects caused by the negative feedback loop (-), work against these tendencies. If the population figures rise and nothing else changes, the number of deaths will increase. As the population decreases, the death rate becomes less drastic, causing a reduced decrease of the population.
The consequences of both loops are also visualised in figures 58 and 59. For the moment, these charts of this apparently easy example confirm the idea that a SD-software can support the process of planning a new final assembly shop of a car manufacturer. However, it has to be mentioned again that neither 'feedback loops' nor 'delays' will be used in this research project.

3.9 Summary

At the end of this chapter, the readers should be aware of the strengths and limitations of the different methodical options available for this research project.
Based on the shown differences the decision was made that within a case study both qualititative and quantitative data should be recorded. Besides, in view of the aimed high data quality different techniques should be used to collect the information.
Figure 60 maps how the selected building blocks lead to an efficient process to an increased knowledge about the planning of a new final assembly shop of a car manufacturer using a system of key performance indicators.

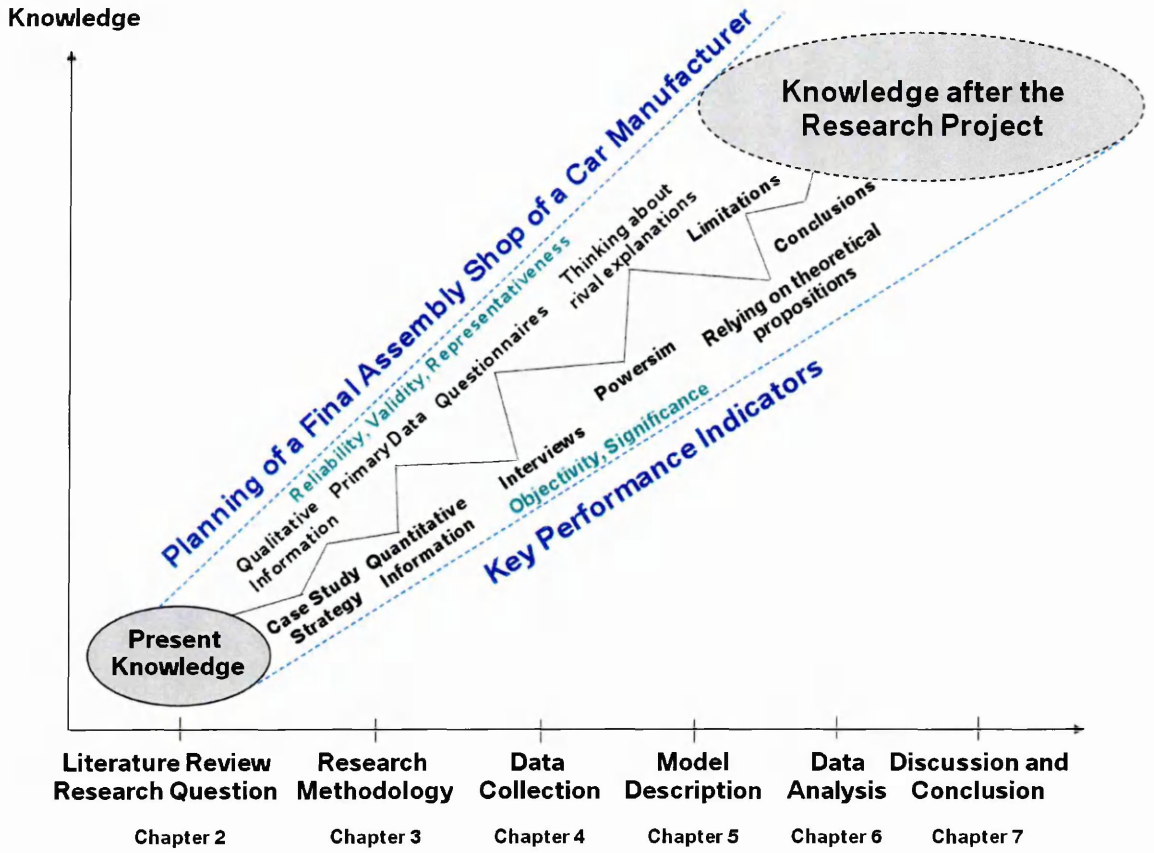


Figure 60 – Summary of the Research Methodology.

For the success of this research project also very important was the definition of the best suitable SD-software. Hence, at the beginning of this section the decision-making process leading to 'Powersim' was described. In doing so, the essential elements of 'Powersim' have been introduced. The training phase was concluded with the modelling of general models for practice purposes and to make sure that the software really helps to improve the planning process for a new final assembly shop. Since all tests were finished successfully, the research design process for this research project is completed.

As illustrated on the x-axis of figure 60, in the next chapter the required data for this case study will be collected. In view of the aim and the objectives formulated in chapter 2, this point of the research programme is important, because at this stage the system boundaries of the new system of key performance indicators will be defined and least significant and more significant key performance indicators will be separated from each other. In addition, the most important key performance indicators have to be accurately defined at the beginning of the data collection in order to make sure that there are no misunderstandings later in the planning process.

Afterwards, the gathered information must be transferred into a computer model using the software 'Powersim'. For this step it is important that the huge number of key performance indicators can be processed simply and fast. Only if the tool meets these criteria will a high acceptance of the new system of key performance indicators be feasible.

As illustrated in figure 60 on the x-axis and as forumulated in the objectives, finally the quality of the results achieved with the system of key performance indicators will be compared to existing final assembly shops. If these tests can be finished successfully, the aim of this research project will be achieved. This would demonstrate that the complex interdependencies within a final assembly shop of a car manufacturer are properly illustrated within the new model.

All these building blocks of this research programme should help to improve the planning process in terms of quickness and accuracy and to make the knowledge about the interrelationships accessible to everybody interested in this topic.

4 Data Collection for Model Building

4.1 Introduction

Since the planning process of this research project was completed with the end of chapter 3, with this chapter the description of the case study begins.
As already explained, quantitative as well as qualitative information was required for a successful research project. Therefore, in this chapter the proceeding of collecting both kinds of data will be explained more precisely. In doing so, the challenges will be reviewed and the formula for success to master possible barriers will be introduced. The details should point out that for this stage of the research project it was one of the main objectives to gather data of the highest quality.
Hence, the next segment will make clear that for this reason it was barely possible to use available secondary information.

4.2 Analysis of Available Secondary Information

Based on the original problem, in a first step all quantitative information used in the past for the early planning process were brought together. This analysis uncovered that more than 300 different figures were used at least once. However, most of them confirmed the problems described in chapter 2 by the following attributes:

- Lack of definition.
- Non specific system boundaries.
- No continuous usage.
- Concentration on single sections.
- No transparency about the dependencies between different key performance indicators.
- No obvious connection to the overall enterprise objectives.

Therefore, only some of the available historical figures could be used for supporting the planning process of a new final assembly shop and thus for this research project.
However, the areas of interest for this research project were highlighted by this analysis. The necessity for an unambiguous definition of the system boundaries and for the definition of the key performance indicators became even more evident.

4.3 Determination of the Success Factors

Even if in chapter 2 the basic success factors of a final assembly shop of a car manufacturer were explained in general, at the beginning of this case study it was necessary to determine the most important key performance indicators for a final assembly shop of the BMW Group.
Thus, in a closed collaboration with top management of the final assembly shops of the different locations and in consideration of the higher enterprise objectives (see figure 61), the so called 'strategic key performance indicators for the final assembly shops' were developed at the beginning of this research project and are described below.

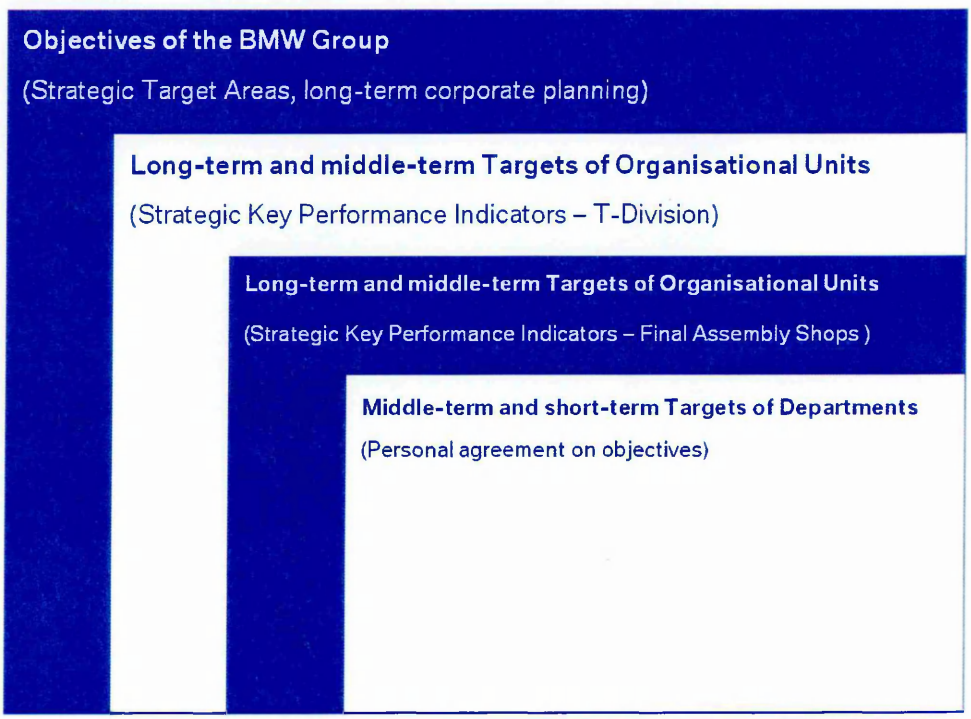


Figure 61 – Structure of Objectives within the BMW Group.

Based on a suggestion of the author, which was derived from the target areas (e.g., customer orientation, shareholder orientation and so on), top management of the final assembly shops identified different strategic key performance indicators. Interestingly, the discussions described in chapter 2 regarding the right number of key performance indicators, its changeability and its relative importance, really occurred in the meetings with the BMW managers. In the end, after a process of several weeks, 16 strategic key performance indicators were agreed. As illustrated in figure 62, some of them have informative character (e.g., units per year), because they only can be influenced partly by the managers of the final assembly shops and others can be understood as real result- / target key performance indicators (e.g., first run quota).

Also the already described divergence between productiveness (e.g., units per employee and year) and flexibility (e.g., number of variants) can be demonstrated with help of the selected key performance indicators.

		2006	2007	2008	2009	2010	2011	2012
Customer Orientation								
Quality - Index	Value							
Costs for Warranty and Goodwill	€ / unit							
F2-On Schedule	%							
Competitive Orientation								
Units per Year	Mio. units							
Employee and Public Orientation								
Employees employed, annual average	Heads							
Employee satisfaction - Index	Value							
Time and Value Added Orientation								
Number of variants	Value							
Number of development - codes	Value							
First run quota	%							
Rework time as part of assembly time	%							
Rework time per unit	Min / unit							
Shareholder Orientation								
Total assembly time per year	hours / unit							
Direct costs per unit	€ / unit							
Total costs per unit	€ / unit							
Units per employee and year	units / H/a							
Investment per year	Mio. EUR							

Figure 62 – Strategic Key Performance Indicators of the Final Assembly Shops.

Even if the strategic key performance indicators illustrated above are well balanced the monetary key performance indicators are still very important (Walsh, 1996). Hence, in closed collaboration with the plants and here in specific with the controlling departments (Grundig, 2000, p. 78) an economic benchmarking had to be carried out, in order to define the most important "cost drivers" (Hilton, 1994, p. 33; Chalos, 1992, p. 62) within a final assembly shop, so that they can be taken into consideration at the early stages of the planning process. For the collection and analysis of the numerous data, the so called 'Economic Business Cube' pictured in figure 63 was developed within this research project.

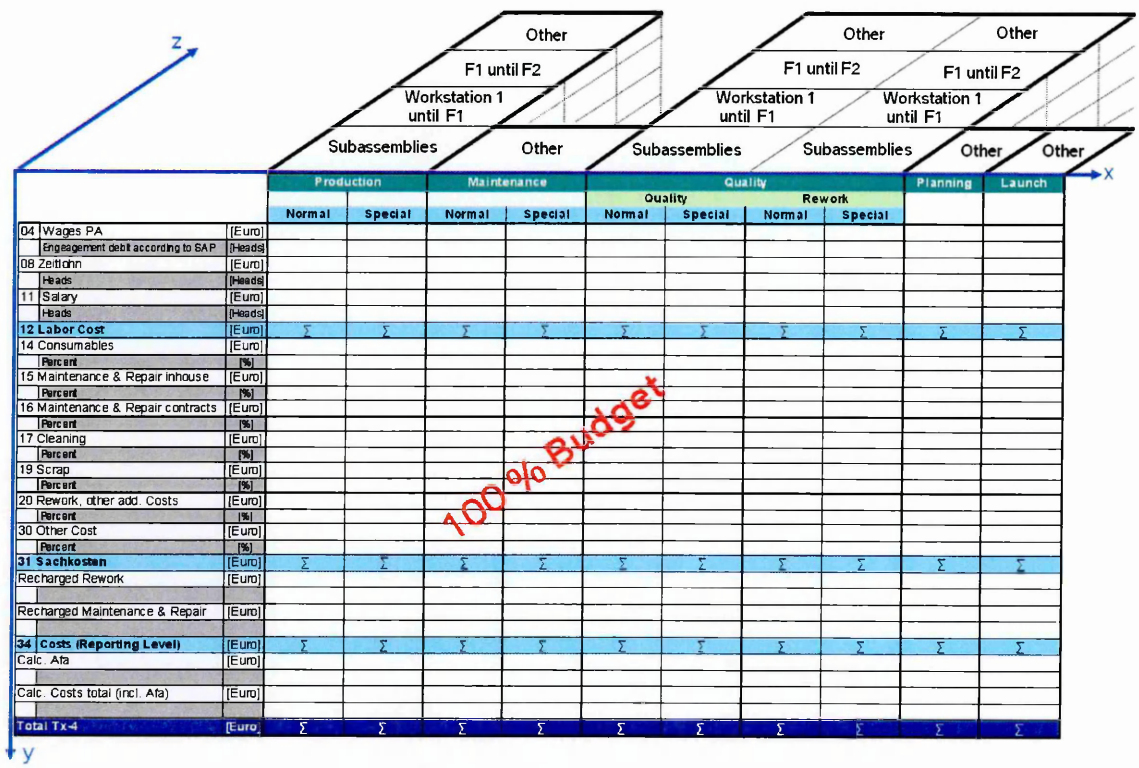


Figure 63 – Economic Business Cube.

It consists of three axes, described below:

- x-axis
  Fragmentation of the final assembly shop in the main areas of operation.
- y-axis
  Fragmentation of the cost categories following the cost accounting systems used at BMW.
- z-axis
  Fragmentation of the final assembly shop in the essential segments.

With the help of this cube both the employees and the cost categories planned at the beginning of the year (= "budgeted activities" (Mott, 1991, p. 5)) could be recorded and analysed. For the success of this overview it was necessary that 100% of the respective direct and indirect budget of the final assembly shop was mapped in this cube. So at least, the sum of all cells could be checked against the figures from the official economic systems.
This was the only way to make sure that the figures could not be manipulated knowingly or unknowingly. It further should be highlighted at this point that all figures are without costs for purchased raw materials / parts.
In addition, organisational differences had to be taken into consideration for comparing the numerous final assembly shops. In the end, these figures provided essential basic knowledge for this research project.
Just the aspect that on account of the employee's intensity in a final assembly shop of a car manufacturer about 75% (see figure 64) of the annual costs (= only operation of the final assembly shop – without purchased parts) are caused by the direct employees (= "direct cost" (Mott, 1991, p. 6)) has to be kept in mind for the long-term planning for a new final assembly shop (Winchell, 1989, p. 6; Drucker, 1990, p. 97).

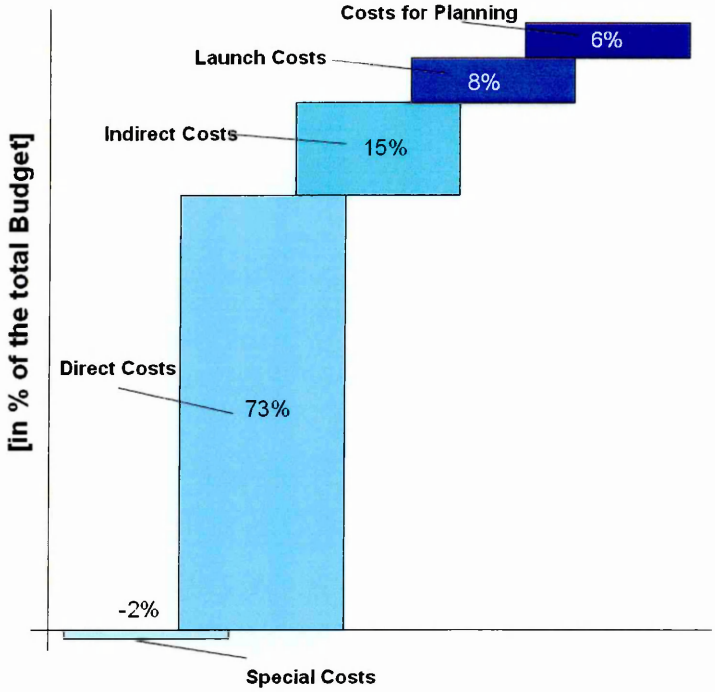


Figure 64 – Cost Structure of the Final Assembly Shops.

In addition to these important economic figures recorded from all final assembly shops of the BMW Group worldwide, a huge number of additional information / key performance indicators are important for the dimensioning of a new final assembly shop.

Having the purpose to positively influence the higher ranked strategic key performance indicators, below the key performance indicators essential for the planning of a final assembly shop will be described in detail.

4.4 Recording of the Quantitative Information

As described in chapter 3, qualitative as well as quantitative information should be used in this research project. It was assumed that the quantitative data would deliver both an impression of the present situation at the different locations and an essential input for the gathering of the qualitative data, so that the collection of the most important quantitative key performance indicators was done first. However, ahead of the recording, some basic conditions had to be created in order to ensure reliable data.

4.4.1 Set the Stage for Collecting the Quantitiative Information

Since a huge amount of data had to be collected by the plants for both the strategic key performance indicators and for the business cube, it was not easy to persuade management of the fact that some additional information had to be continuously recorded for dimensioning a new final assembly shop. The argument for this additional data gathering was complicated, since top management of the final assembly shop was highly pleased with the new information provided so far. Furthermore, they did not see the necessity for collecting figures supporting the dimensioning of a new final assembly shop anymore, since the planning for the new plant in Leipzig was in the next stage already and nobody could imagine building another new final assembly shop within this decade. Based on a first suggestion of 75 key performance indicators and an argument about the upcoming challenges also for the existing final assembly shops, in the end management were persuaded into gathering the additional planning parameters. As a result of the required data quality of the primary figures, once more it was necessary to guarantee the support of every single location.

In order to achieve credibility for the recorded data, it was essential that the general defined key performance indicators would be collected by experts from the different plants, without any support by the headquarters. After every location had named a contact for the support of this research project, in the new team the following points were discussed in several meetings:

- Definition of the system boundaries.
- Determination of the relevant KPIs.
- General definition of the important KPIs (incl. the strategic KPIs).
- Rules for collecting and communicating the KPIs.
- Point / period of time for data collection.
- Sheet for collecting the figures.

4.4.1.1 Definition of the System Boundaries

For the analysis of a complex system the unambiguous definition of the system boundaries is an essential success factor. This can be demonstrated on the example of the areas required for a final assembly shop.

Figure 65 illustrates that in the ideal layout all assembly areas are in one individual main building (I, green), however, there also can be assembly areas on the factory site (II, yellow) or in old factories, like for example in Munich, even beyond the factory (III, blue). Therefore, it must be well-defined whether the green areas (I) are part of the key performance indicator 'areas assembly building', or whether to the green areas also the yellow (II) or, perhaps, even the blue (III) areas must be added.

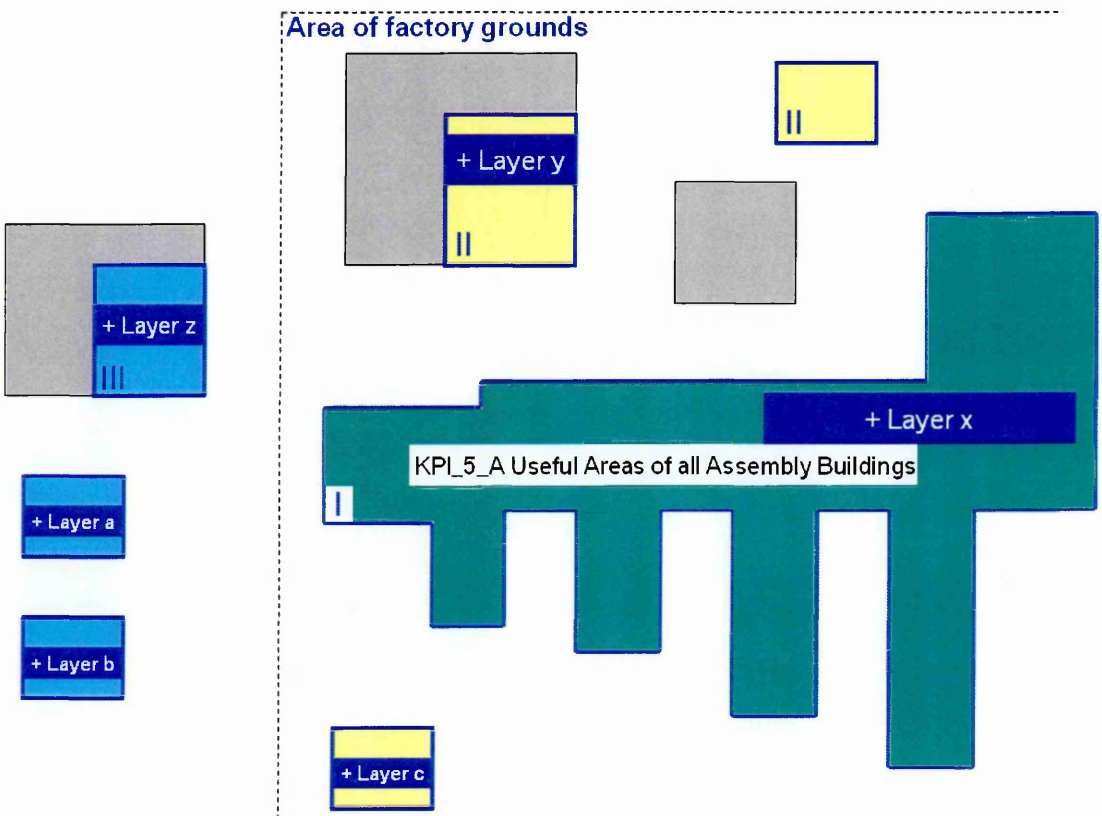


Figure 65 – Definition of Useful Areas of a Final Assembly Shop.

However, it also has to be made sure that the areas within the specific manufacturing buildings are only used by the final assembly shop. Within one well defined production building it could happen that other technologies or functions, such as the 'plant fire brigade', use areas within this building.
In addition, it should be asked, whether in a building several levels exist, e.g., under the floor (= basements) or overhead. Meyer and Stephens (2005, p. 8) call this "utilising the building cube". With the help of an unambiguous system boundary, such objects must be included or excluded consciously for any comparisons or plannings.
Nevertheless, even the well defined assembly areas can still be used differently, because of various logistic concepts or other influencing factors. Therefore, during the comparison of the values of several locations and the search for best practice solutions, many influencing factors can lead to a distorted picture or even wrong conclusions.
Similar definitions of the system boundaries become necessary, for instance, in case of personnel key performance indicators, e.g., by organisational differences as well as differences in the vertical integration (Jarillo, 1993, p. 5) (see figure 66).

	Plant A	Plant B	Plant C	Plant D	Plant E	Plant F	Plant G	Plant H	Plant I	Plant J
VM Türen PA Doors	X	X	X	X	X	X	X	X	X	X
VM Frontend PA Frontend	X	X	X				X	X	X	
VM Cockpit PA Cockpit	X	X	X	X			X			X
VM Motor PA Engine	X	X	X	X	X	X	X	X	X	X
VM Räder PA Wheels		X	X			X				
VM Achsen VA PA Front axle	X	X	X	X					X	
VM Achsen HA PA Rear axle	X			X					X	

Figure 66 – Vertical Integration at the BMW Group.

Since one of the premises for this research project is the planning of a new final assembly shop, this project concentrates upon the processes of a painted car body from the entrance in the final assembly shop up to the exit of it (= see manufacturing in the 'narrower sense', section 2.3). It will further be assumed that the calculated areas (= without work fire brigade, canteen, etc.) are all in one building.

In doing so, the car body, as is standard in the automobile industry, runs through three major sections:

- Main assembly line (= entrance in the final assembly shop until first start of the engine).
  The car body is following the synchronised flow principle.
- First start of the engine until exit of the final assembly shop.
  The almost finished car has to pass different test benches and if necessary also some rework areas.
- Major pre-assemblies.
  Outside of the main assembly line, bigger parts of a car will be pre-assemblied.

Later in this thesis, the three sections illustrated in figure 67 will be further specified.

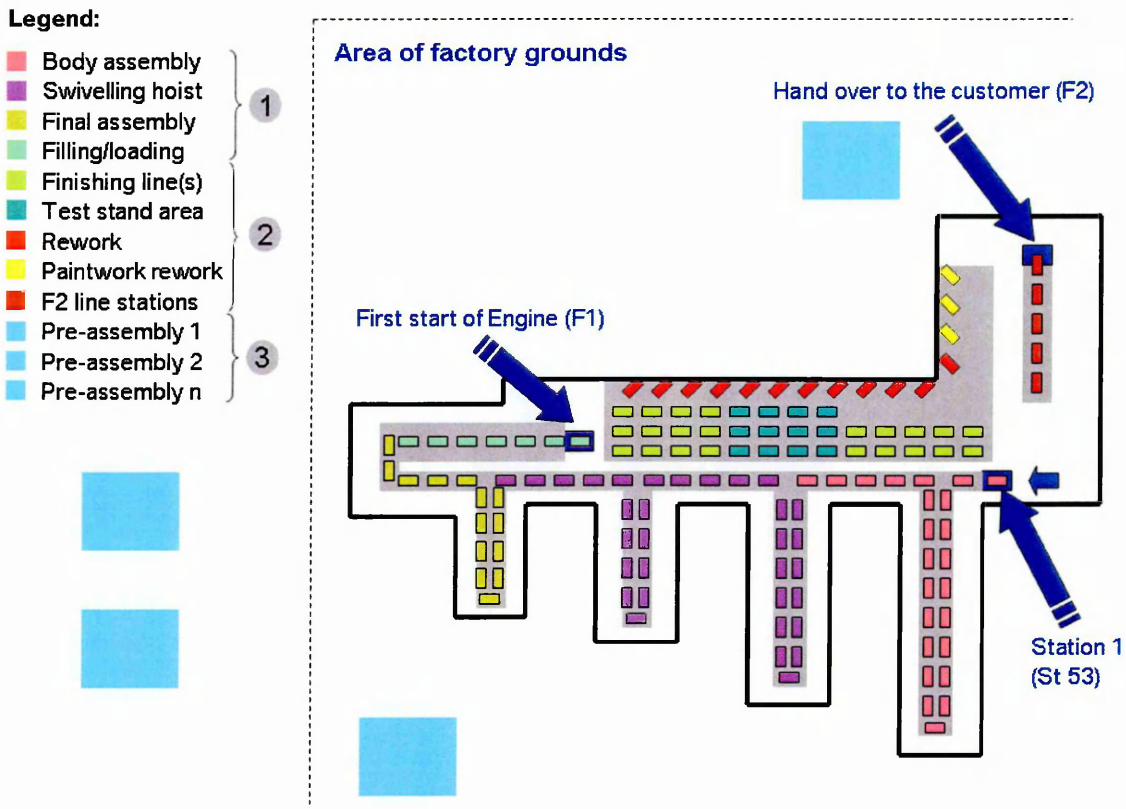


Figure 67 – Areas within a Final Assembly Shop on the Example of Plant Leipzig.

4.4.1.2 Determination of the Relevant KPIs

In terms of the number of key performance indicators that would have to be recorded by the experts, it was necessary to convince them, as well as the management, of the advantages of a system of key performance indicators based on the idea of 'System Thinking'. In the end, the team agreed on the recording of 75 key performance indicators. Nevertheless, the high number of key performance indicators caused a certain degree of uncertainty, because this idea was absolutely atypical to the approaches known so far. Over and over again, different arguments were necessary (e.g., figure 36) to convince the sceptics of this idea.

On purpose, just absolute key performance indicators were collected. This made it easier to evaluate the quality of the data and therefore was helpful for the transparency within the research project.

The selection of the 75 key performance indicators is based on the following aspects:

- Explanatory power in view of strategic questions.
- Availability of data.
- Experiences of the different planners.
- Opinions found in literature (Vetter, 1983, pp. 1/34; Grundig, 2000, pp. 73/78/84; Meyer and Stephens, 2005, pp. 7/27; Winchell, 1989, p. 2; Productivity Development Team, 1999)
    - Areas.
    - Production plan, capacity planning, takt time.
    - Assembly times.
    - Manpower.
    - Investment and costs.
    - Availability.
    - Shift model.

4.4.1.3 General Definition of the Important KPIs

After the relevant key performance indicators were determined, in the next step the single dimensions had to be generally defined in two languages (= German and English). Even if this aspect would become one of the success factors for this research project, the process was protracted and difficult. In particular, the strategic key performance indicators (see section 4.3) which are at the highest management levels on the agenda of the target management process, e.g., first run quota, proved to be a big challenge. It was difficult to convince the individual location representatives to adapt existing definitions specified for one location for the benefit of a general definition, because this led to a change of the value, implicating in the end a unique transition from the old figures to the new ones.

In addition, the definitions should also be suitable for benchmarks with external competitors, so that not only internal figures and sources for definitions could be used, but also external norms had to be considered. For example, the norms for the 'areas' offered by the 'German Institute for Standardisation' (= DIN 227) or the definition for the 'availability' according to the 'Association of German Engineers' (= VDI 3649) can be mentioned. However, on account of the special conditions of a final assembly shop of a car manufacturer some of these official definitions still had to be partially adapted.

Hence, it can be valued as a big success of this research project that the most important key performance indicators could be defined in the so-called KOPF (= **K**ey performance indicators for an **O**ptimised **P**lanning of **F**inal assembly shops) in the form mapped below (see figure 68), and as illustrated in the appendix A.

KPI_053_D	Work stations in the main assembly line (Work station 1 to F1)	Quantity
Definition Key Term	**Work station** Station at which the vehicle body is actually worked on or which is necessary for the assembly process of a vehicle. The assembly work may be performed either manually (by a person), semi-automatically or automatically (by a robot). **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point. **Body assembly** Vehicle is on skid or conveyor Possible tasks: wiring harness, plugs, hinges, fitting of vehicle interior. **Tilt line** Vehicle on Tilt line, adjustable angle of rotation. Possible tasks: underbody paneling on body, engine compartment interior panels, wiring package, fuel system, wheel arch lining, fitting to underbody and sill areas. **Final assembly** Vehicle on gantry hanger Core component: marriage, underbody, fitting of wheels, fitting of front and rear ends, engine compartment connections **Filling/loading** Vehicle is on conveyor (standing on its own 4 wheels) Possible tasks: filling with fluids (fuel, air con refrigerant, washer fluid, brake fluid), loading of data, etc...	
Content	Number of pure work stations in the main assembly line The following areas are to be explicitly itemized: • Body assembly • Tilt line • Final assembly • Filling/loading Availability stations, testing and quality stations, and decoupling stations are not included in this figure.	
Significance	Degree of automation; cycle ratio	
Definition source		
Figure source		Plant

Figure 68 – Example of a Definition in the KOPF.

During this research project the 'KOPF' in a contionuous improvement process became a catalogue of 108 generally defined key performance indicators (appendix A). In support of the already described 'classification system' (see section 2.7.5.2) the key performance indicators are split as follows:

- A Area Key Performance Indicators. (30 KPIs)
- B Productivity Key Performance Indicators. (2)
- C General Plant Key Performance Indicators. (16)
- D Station Key Performance Indicators. (19)
- E Automation Key Performance Indicators. (2)
- F Conveyor System Key Performance Indicators. (4)
- G Personnel Key Performance Indicators. (1)
- H Product Key Performance Indicators. (1)
- I Quality Key Performance Indicators. (7)
- J Logistic Key Performance Indicators. (15)
- K Assembly Financial Key Performance Indicators. (4)
- L Plan / Unscheduled Time Key Performance Indicators. (7)

The key performance indicators are numbered continuously from 1 to 108 and according to the 'classification system' (see section 2.7.5.2) are divided in the categories A (= areas) to L (= plan / unscheduled time).
At this point it should be mentioned that some definitions have become stable only with the third version of the KOPF-catalogue. During the interpretation of the first data a certain learning process was run through but also data unavailability from some locations made few adjustments necessary. This is important to know in view of the temporal comparison of individual key performance indicators (e.g., analysis of trends).

4.4.1.4 Rules for Collecting and Communicating the KPIs

During the preparation for collecting key performance indicators by the experts from the different locations, some rules for gathering and communicating the key performance indicators had to be defined.
Right at the beginning a culture of trust in dealing with key performance indicators should be generated with this research project, because this was regarded as an essential success factor.

Following the idea of the 'DELPHI-method' (SME, 1979) a process was defined (see figure 69), which gave to all locations the opportunity to interpret the key performance indicators in the team ahead of the communication to the upper management level.

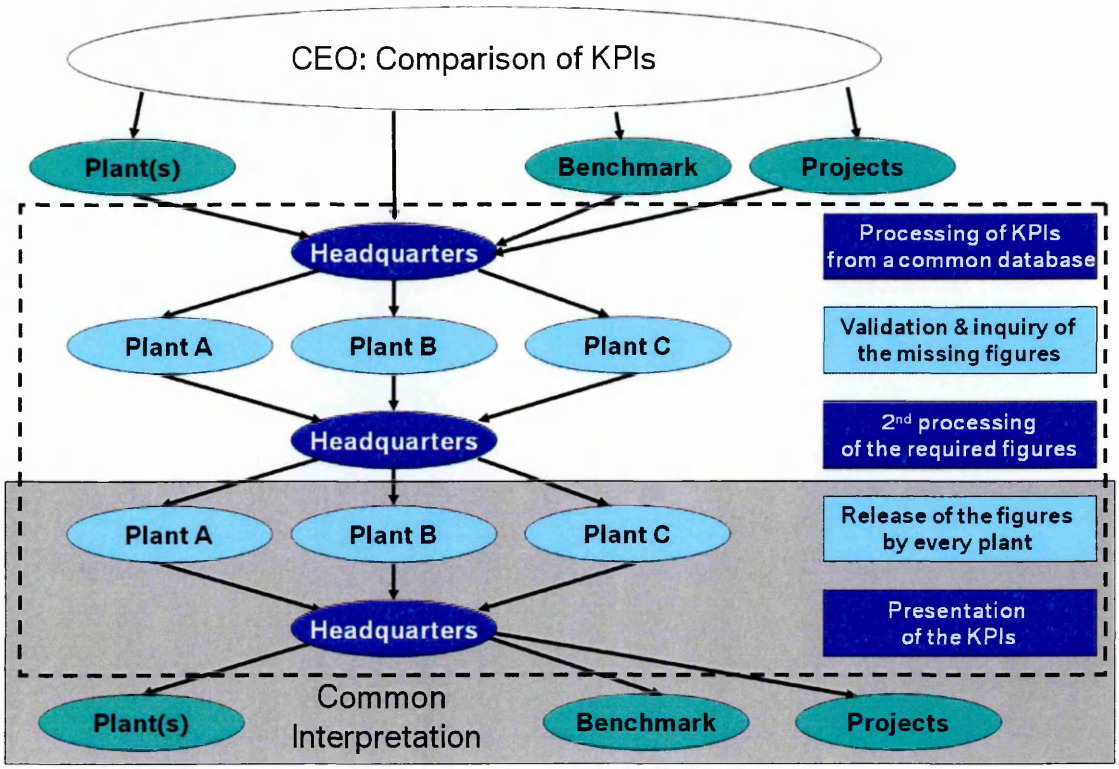


Figure 69 – Process for Communicating Key Performance Indicators.

In any case it had to be avoided that uncoordinated key performance indicators of the location 'A' would be used for comparisons in the location 'B', without the location 'A' having agreed to these figures / this interpretation. This rule was harmonised in the management circles in front of the data gathering process and was communicated with help of a detailed preface in the 'KOPF' to all process partners. As described in appendix A, many other aspects, as for example the objectives of this data collection were closer described in this preface as well. The huge number of experts involved from the different locations should have the possibility to be able to read up the relevant information any time.

Therefore, one of these significant messages was about the handling of the confidential data. It was important to clear this aspect ahead of the recording, because especially in the early phase of the research project a failure of one process partner could have strongly endangered the willingness of all locations to be compared to the other final assembly shops. Under some circumstances a premature interpretation could have led to overhasty conclusions and, perhaps, even unnecessary reproaches. In addition, for the development of the mutual trustfulness two other points were especially important.

On the one hand, it was important that the research project was supervised from the FIZ (= headquarters) in Munich. The basic idea was that the neutrality and unprepossession of a person not directly affected by the results could promote an open exchange of the data between the single locations at any time.

On the other hand, all key performance indicators always should have been collected by the locations themselves. Since the figures were unambiguously defined, the risk of doubts regarding the quality of the figures should be minimised, if the figures would have been recorded on site by the experts. If an employee from the headquarters would record the data by her/himself, this substantially would complicate the interpretation of the key performance indicators, because some managers probably would challenge the correctness of the data.

As a result of the varied data sources, the coherence to other figures could not have been guaranteed in this way anyway. This aspect also leads to the next point including a special challenge.

4.4.1.5 Point / Period of Time for Data Collection

In view of the stage of the planning process and the required level of detail to answer the more strategic questions, the team decided that many of the variations within one year would not have a significant influence on the results. Hence, it was fixed that an annual collection / update of the key performance indicators would be enough.

However, ahead of the recording the definition of the point / period of time for collecting the data caused unexpected problems. The theoretically optimal scenario that all locations would collect the data to the same deadline was difficult to fulfil. Different SOPs (= start of production) of new vehicle models or building work in any of the locations would have led to unrepresentative data. Besides, the planners do not have time to collect key performance indicators during a building work. As a result of the complexity of a final assembly shop, several departments were necessary in one location to record all the required data. In particular at the beginning of this research project a not unimportant additional expenditure had to be included in the schedule for collecting the figures according to the new definitions. Hence, a period of several weeks for recording the figures had to be defined. Within this time slot it was up to the individual locations to deliver key performance indicators for one month or one year. Since most of the building work is done at the turn of the year, the team decided to collect the figures from the previous year or from November of the previous year. That is in other words that in between January and March 2006 the annual average figures of 2005 or just the November figures of 2005 are collected.

The disadvantage of this time slot is that consequences of any modernisation done between December 2005 and January 2006 will be quantitatively grasped only in 2007.

On the other hand the data gathering at the beginning of the year made it easier to stick to a very important premise for collecting the figures. The most important criteria was that the data was in the individual locations consistent and representative in themselves. It had to be avoided that, e.g., key performance indicators about the areas would be grasped before a building work and key performance indicators about the stations after such a project.

4.4.1.6 Sheet for Collecting the Figures

To be able to guarantee the already described advantages of an easier analysis of the quantitative data, still a standardised format for collecting the information was fixed at the end of the preparation phase. As illustrated in figure 70, all locations had to enter their figures in a common Excel-file. For supporting the different experts, the old figures from the previous year were listed once more. In a comment column helpful additional information can be put down. In addition, for every key performance indicator a field with the contact person, the telephone number and the entry date of the figure had to be entered. With this information automatically a list of experts for each subject was generated. This was very helpful if questions during the interpretation had to be answered quickly. Also no figure could hide behind anonymity or use a statement like "We do not know where the figure comes from".

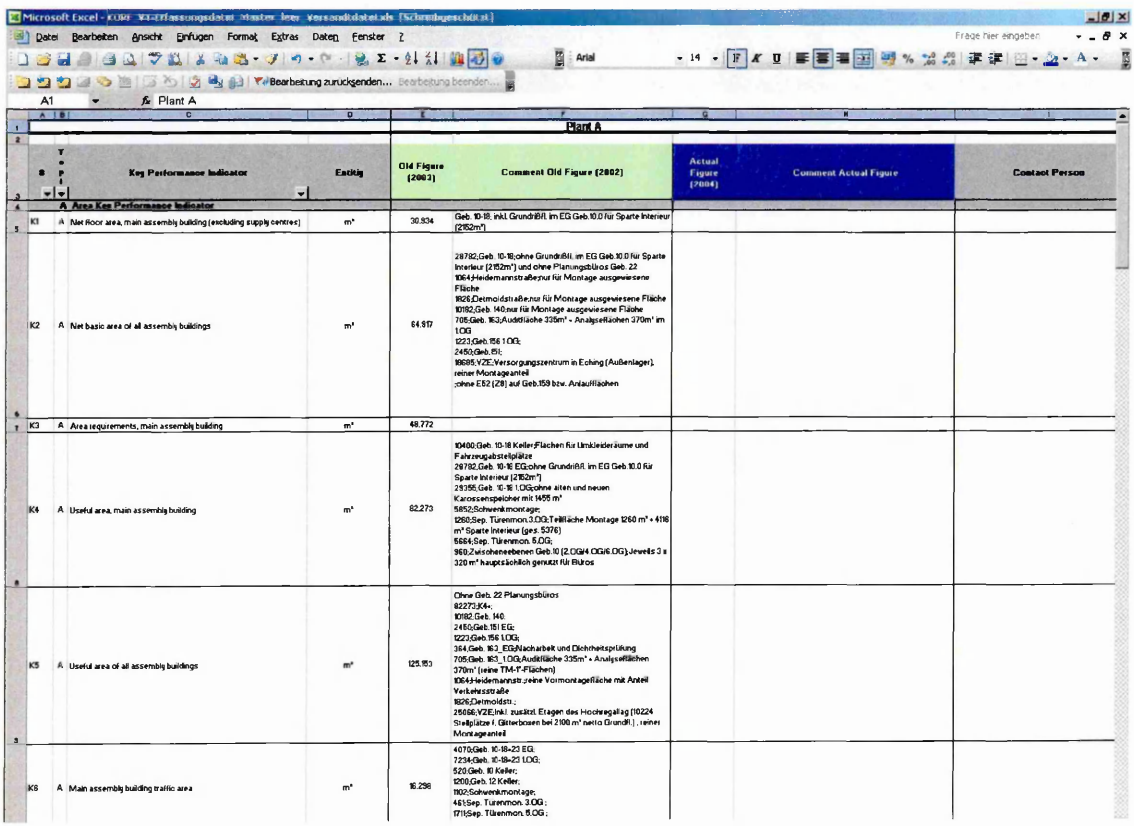
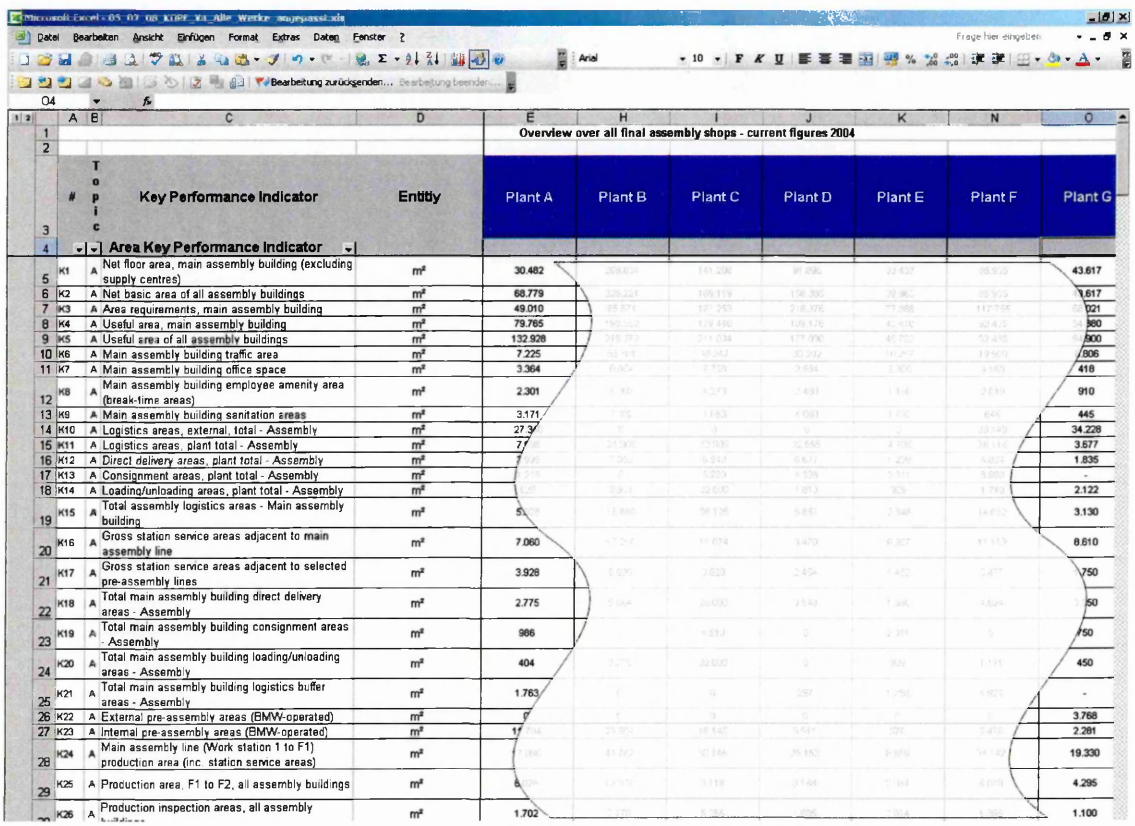


Figure 70 – Sheet for Collecting the Quantitative Information.

4.4.2 Results

Figure 71 indicates that at the end of the data collection process of several weeks comparable absolute key performance indicators (= primary data) were available of all locations. The response rate for the 108 key performance indicators varied between 90% and 100%. Most of the time, it was not possible to collect the missing figures, because of problems with the availability of data at the individual locations.



Overview over all final assembly shops - current figures 2004

#	Topic	Key Performance Indicator	Entity	Plant A	Plant B	Plant C	Plant D	Plant E	Plant F	Plant G
		Area Key Performance Indicator								
K1	A	Net floor area, main assembly building (excluding supply centres)	m²	30.482						43.617
K2	A	Net basic area of all assembly buildings	m²	68.779						1.617
K3	A	Area requirements, main assembly building	m²	49.010						021
K4	A	Useful area, main assembly building	m²	79.765						980
K5	A	Useful area of all assembly buildings	m²	132.928						900
K6	A	Main assembly building traffic area	m²	7.225						806
K7	A	Main assembly building office space	m²	3.364						418
K8	A	Main assembly building employee amenity area (break-time areas)	m²	2.301						910
K9	A	Main assembly building sanitation areas	m²	3.171						445
K10	A	Logistics areas, external, total - Assembly	m²	27.3						34.228
K11	A	Logistics areas, plant total - Assembly	m²	7						3.677
K12	A	Direct delivery areas, plant total - Assembly	m²							1.835
K13	A	Consignment areas, plant total - Assembly	m²							-
K14	A	Loading/unloading areas, plant total - Assembly	m²							2.122
K15	A	Total assembly logistics areas - Main assembly building	m²	5						3.130
K16	A	Gross station service areas adjacent to main assembly line	m²	7.060						8.610
K17	A	Gross station service areas adjacent to selected pre-assembly lines	m²	3.928						750
K18	A	Total main assembly building direct delivery areas - Assembly	m²	2.775						50
K19	A	Total main assembly building consignment areas - Assembly	m²	986						450
K20	A	Total main assembly building loading/unloading areas - Assembly	m²	404						450
K21	A	Total main assembly building logistics buffer areas - Assembly	m²	1.763						-
K22	A	External pre-assembly areas (BMW-operated)	m²							3.768
K23	A	Internal pre-assembly areas (BMW-operated)	m²	17						2.281
K24	A	Main assembly line (Work station 1 to F1) production area (inc. station service areas)	m²							19.330
K25	A	Production area, F1 to F2, all assembly buildings	m²	8						4.295
K26	A	Production inspection areas, all assembly	m²	1.702						1.100

Figure 71 – Result of the Quantitative Data Collection.

Having summarised all the figures, the quality of every individual figure had to be checked as good as practicable. Some control mechanisms for evaluating the data quality are listed below.

- Designing sheets of plausibility for some sections.
- Using secondary data (= layouts, historical data etc.) for plausibility check.
- Comparing the data from different locations.
- Building of rival theories.

After the correctness / comparability of the data was finally confirmed by the author and the experts in the company internal intranet, the key performance indicators could be made available to management as well as the specialist departments (see figure 72). In doing so, the reference to the definitions as well as the reference to the agreed rules for communicating the data was very important.

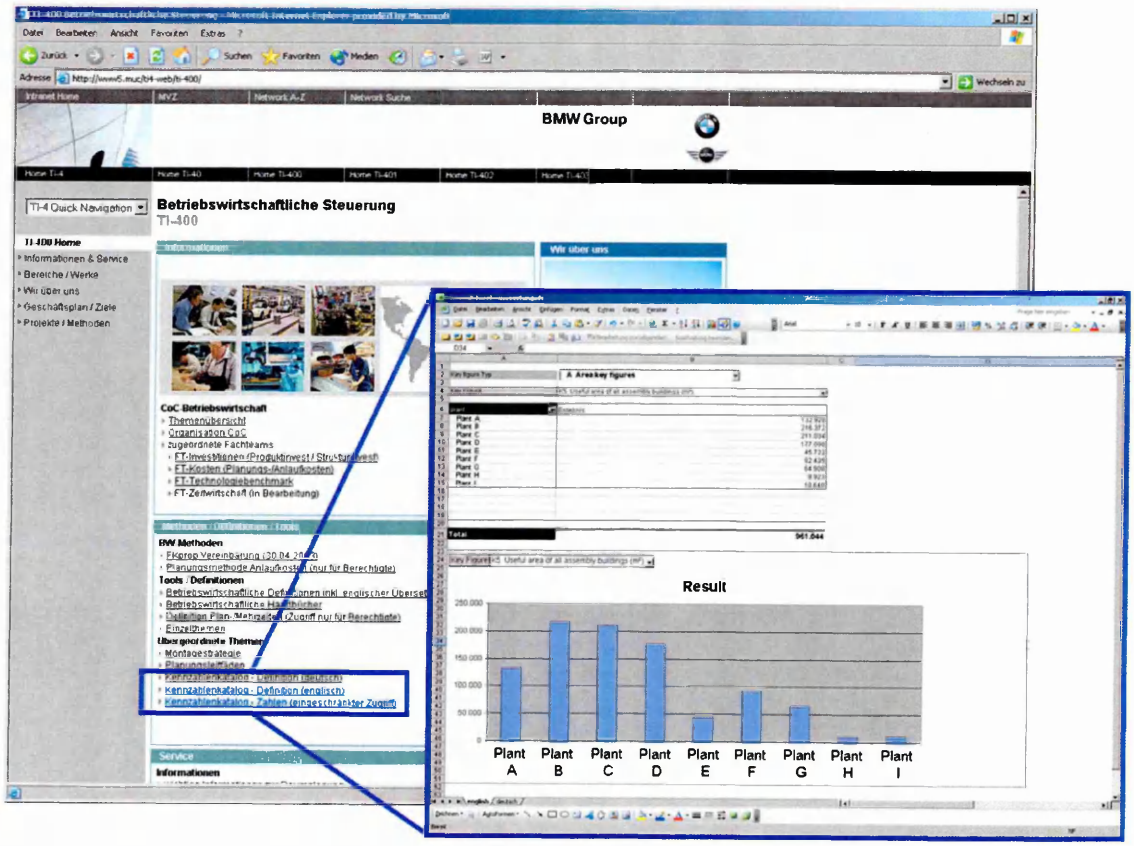


Figure 72 – KPIs in the Intranet of the BMW Group.

Even if this transparency would be already a significant step for the improvement of the planning quality, it also had to be kept in mind that the analysis of the simple absolute key performance indicators is just limited helpful, because of the complex interrelationships within a final assembly shop.
Since some of the figures change only marginally over several years, trends can also be recognised after only a few years. Hence, in order to better support the planning process, a system of key performance indicators was still necessary.

4.5 Recording of the Qualitative Information

As mentioned above, besides the collected quantitative data, qualititve information was also important for the success of this research project. Primarily, the mental models of the individual experts had to be challenged at this stage. It was assumed that the many opinions about the connections of the different key performance indicators are a result of such mental models.

4.5.1 Generation of Simple Ratio Key Performance Indicators

As pictured in figure 73, based on the available absolute figures, different ratio figures were generated at the beginning of the collection of the qualitative information.

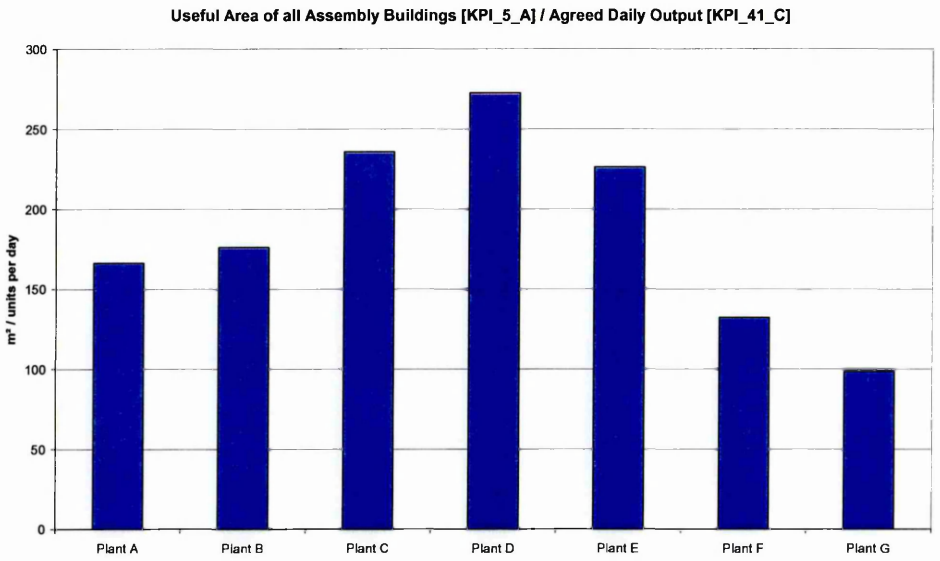


Figure 73 – Simple Ratio Figures – 'm² / units per day'.

Charts like the ones shown above, supported the project in two respects. On the one hand, during the interpretation of the diagrams the author himself developed independent mental models about the possible interrelationships between the key performance indicators. On the other hand, such analyses were most of the time the starting point for the interviews with the real experts. Differences in 'm² per unit per day' immediately were explained with help of the product complexity or a different degree of vertical integration. Such aspects have a considerable influence on the areas required by a final assembly shop and therefore on the variations between the key performance indicators collected from different locations. The explanations for the differences are based on mental models of the numerous specialists and now had to be transferred into formal models. The success of this research project was closely connected with the process of transformation.

4.5.2 Unstructured Interviews

As already described and as a result of the complexity of a final assembly shop, many experts are involved in the planning process. Depending on the planning phase, the BMW Group has specialists in the FIZ (= central planning departments) and in the different locations (see section 1.4.4). In view of their neutral position, the planners from the headquarters were of prime importance for the recording of the qualitative information. These experts plan facilities and processes for several locations, so that they can normally fall back on a big fund of experience.

In the run up to the interviews, a standardised final assembly shop had to be fragmented and assigned to the numerous experts. A basis for this allocation was information from the organisation chart or conversations with suitable managers. At the end, there was a list of about 45 experts who had to be interviewed in order to illustrate the mental models of an entire final assembly shop. As a rule, up to three meetings with every planner were required to record the qualitative information about his / her area of activity. It would turn out later that the sections of a final assembly shop for which several contacts were available were especially challenging in terms of the standardisation of the mental models.

Since with 'Powersim' the tool for the documentation of the qualitative (and also the quantitative) data was defined and successfully tested (see section 3.8), the author could start to question the mental models of the planners and to transfer these models into formal models.

At the beginning of the first meeting, the problem and the objectives of this research project were introduced and the field of responsibility of the planner had to be confirmed. Only now in one-to-one conversations and with the help of 'MindMap' drawings (see Appendix B) both the factors of influence could be determined and the dependencies between the different key performance indicators could be defined.

Sometimes there were, for one field of application, several experts whose mental models were not identical right away. In these cases the experts had to explain the advantages and disadvantages of the single approaches in a common meeting and come with the help of a neutral presentation by the author to an agreed solution.

During all discussions, the system boundaries were kept in mind. Also the definitions for the most important key performance indicators already established during the gathering of the quantitative information were considered within the scope of these interviews.

As expected, as a result of a huge number of influencing factors (e.g., crowded schedules of the experts, motivation of the specialists, required additional meetings etc.), this part of the research project was very time-consuming. Some of the points which significantly influenced the progress of such meetings are listed below:

- Experience of the planner.
  The greater the experience of the planner, the more self-confident he or she was that their own mental model would produce correct results, and it therefore would not be necessary to question it. In these cases a lot of convincing had to be done, or the planner had to be 'forced', with help of propositions and activating statements, to the disclosure of his / her mental models.
- Area of activity of the planner.
  Some experts are responsible for the total result of a planning process and therefore having rather the look for the 'big picture' than specialists who deal in daily business with very concrete questions. In the second case the strategic horizon of the research project and the desired exactness (± 20%) of the results had to be expelled over and over again.

- Security of employment.

  For some experts their experience (= mental models) is a kind of job security. Hence, at the beginning of the interviews some specialists had the fear that a 'supermodel' would produce the perfect result by pressing a button and therefore would make them redundant.

  This scepticism could only be overcome, while communicating to the planner that based on today's state of knowledge the human brain will always play a determining role for the dimensioning of a final assembly shop because of its complexity. In addition, for most of the specialists it was calmative that the tool mainly should be oriented on the planning of new greenfield final assembly shops. Furthermore, it was very helpful to show every single expert, how many other specialists would have been invited to such meetings. At the end, the experts understood that this research project should support them in their future work.

- Bad experience.

  In particular comparisons of key performance indicators where nobody can make sure that the figures are comparable have led with many experts to a bad opinion about key performance indicators. It is just half the truth, if someone compares key performance indicators and follows the principle of 'cherry picking'.

  Therefore, right at the beginning many experts argued that it would not be possible to dimension a new final assembly shop with few key performance indicators.

  At the moment, there is really no chance to dimension an automotive final assembly shop with isolated key performance indicators such as 'm^2 per unit' or 'stations per unit'. Hence, after the introduction of the 'System Thinking' approach, most of the doubts felt silent.

4.5.3 Results

After every meeting, the qualitative information collected during the interviews was transferred into a network of key performance indicators illustrated in the software 'Powersim'. Thus, the various elements of the key performance indicator system represent the most important planning parameters of a new final assembly shop of a car manufacturer.

As illustrated in figure 74, the numbering and classification system implemented in the KOPF, was also used in the model. Hence, automatically the most critical key performance indicators of the system are consistently defined.

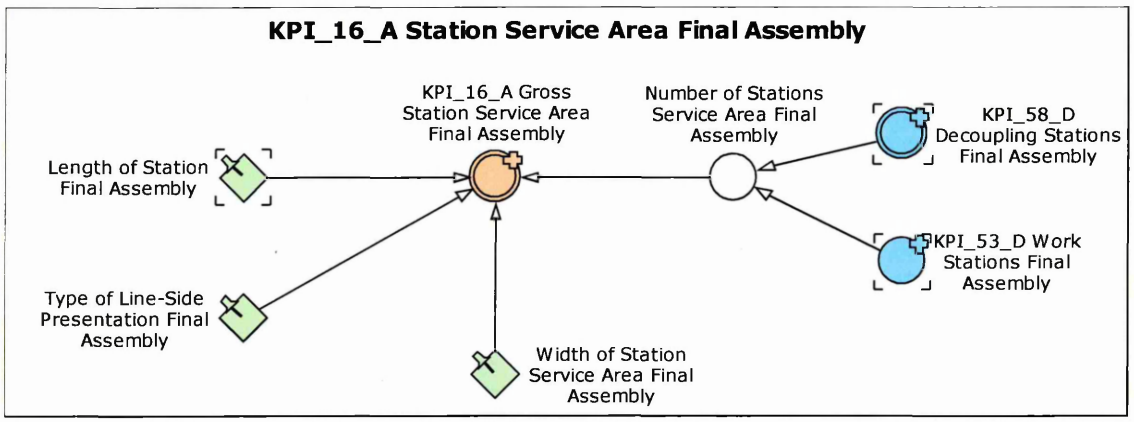


Figure 74 – Example of a Network of KPIs generated in Powersim.

Since the different elements of the network were approved by the experts, the author was quite confident that in spite of the size of the key performance indicator system it would be widely accepted.

The complexity of the total system becomes obvious with the help of the following figures (see Appendix C):

~ 750 KPIs (= Input Values and Output Values)

~ 1,800 Elements

These figures demonstrate that the planning of a new final assembly shop and perhaps even the comparison of existing final assembly shops, according to opinion of the planning experts, might not be realistic with 7 to 20 key performance indicators.

4.6 Summary

In this chapter it was presented that for this research project a huge number of quantitative and qualitative data were collected, using different techniques (= Excel spreadsheets and unstructured interviews) and also taking into account both higher enterprise objectives and general sources of information. The comments should demonstrate that in some stages of this process time and effort was high in order to make sure that information of highest quality was recorded.

Nevertheless, the decisions made in chapter 3 in terms of 'research strategy' and 'data collection techniques' have proved, as the achieved results should reveal. In particular, the developed network which reflects the mental models of the planners is very important for this research project. But also the introduction of the KOPF with its definitions was an essential milestone.

Since additionally at all stages of the data collection process basic philosophies such as objectivity and transparency were kept in mind, so far the research project definitely can be valued positively.

However, at this stage the interesting question is, whether with this gigantic system of key performance indicators reliable results are achievable and how the chosen software supports daily business of a planner.

5 Description of the Developed Model

5.1 Introduction

Before the quality of the results achieved with the developed system of key performance indicators is analysed in detail, the general attributes of the developed model are evaluated more precisely. From this evaluation first conclusions can be drawn about the chosen approach, regardless of the exactness of the results achieved with the developed system of key performance indicators.

Only if the developed system of key performance indicators can be rated positively, the control of the exactness of the system is still important.

Hence, soft criteria of the developed model such as 'user friendliness', 'support of planning process (= simulation of scenarios)', 'knowledge transfer' or also 'data availability' are evaluated below.

5.2 Network and Cockpit

As already mentioned, the numerous mental models were illustrated with help of corresponding networks. Since 'Powersim' also offers several very good control elements, in the entire model between the 'network level' and the so-called 'cockpit level' will be distinguished (see figure 75).

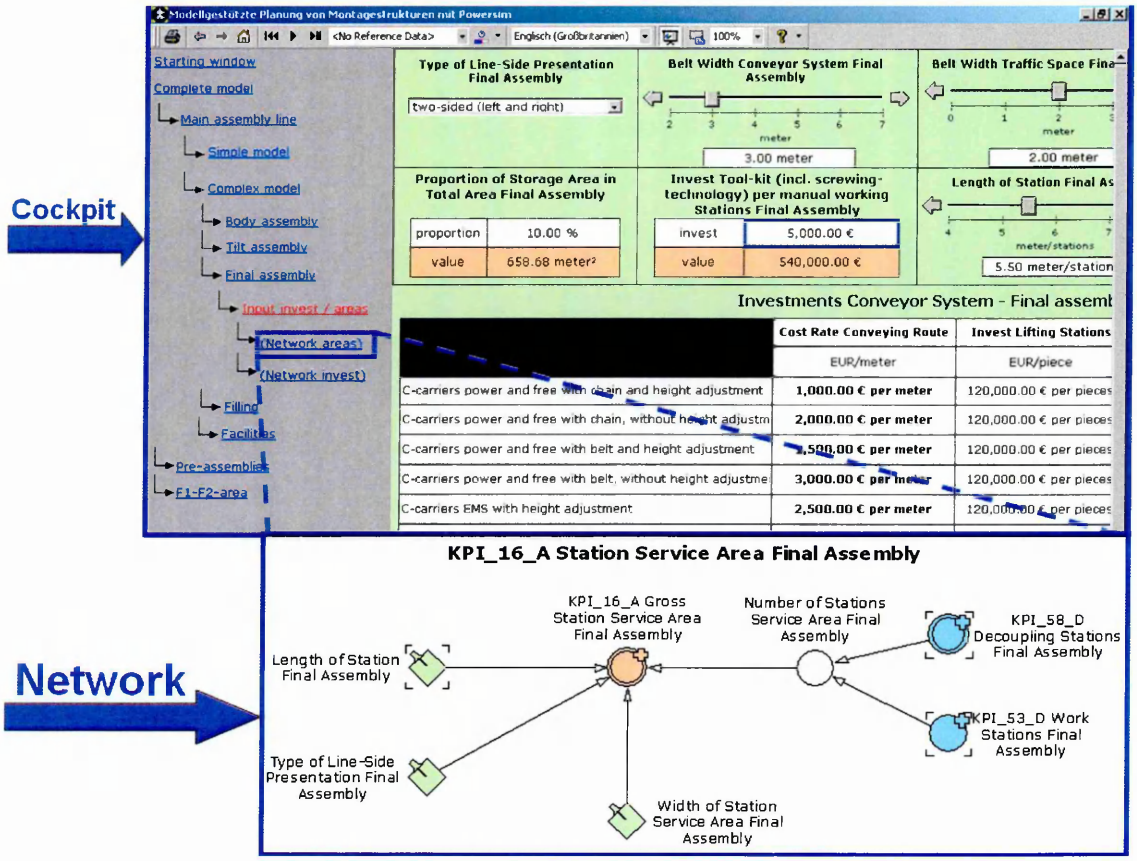


Figure 75 – Cockpit and Network on the Example of 'Area – Final Assembly Shop'.

First of all, this separation of both levels offers the advantage that not every planner has to understand the principle of modelling in general and of building a model in 'Powersim' in specific. As with electronic circuits in an airplane, the network represents the connections between the single elements / key performance indicators necessary in the background for the success of the system. Therefore, the network is the heart of the key performance indicator system illustrated in the model. Following the principle of the 'arithmetic key performance indicator system' (see section 2.7.5.1), the key performance indicators are linked to each other by using mathematical connections. Figure 76 displays such a calculation on the example of the area required for the body assembly.

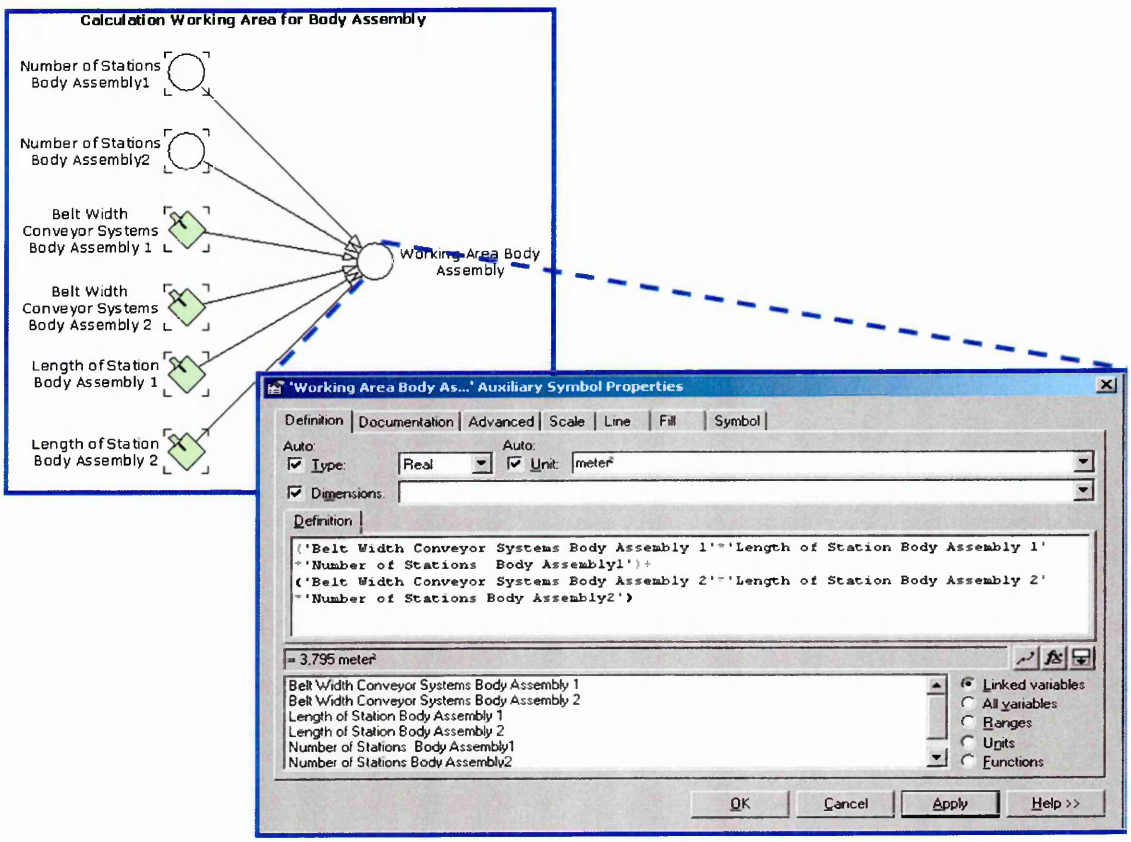


Figure 76 – Arithmetic KPI system on the Example of 'Area – Body Assembly'.

For the linkage of the key performance indicators 'Powersim' offers a huge number of functions to the person responsible for the network. Thus, besides the often required basic arithmetic operations (+, -, x, /) also stochastical or logical functions (see figure 77) are used within the model.

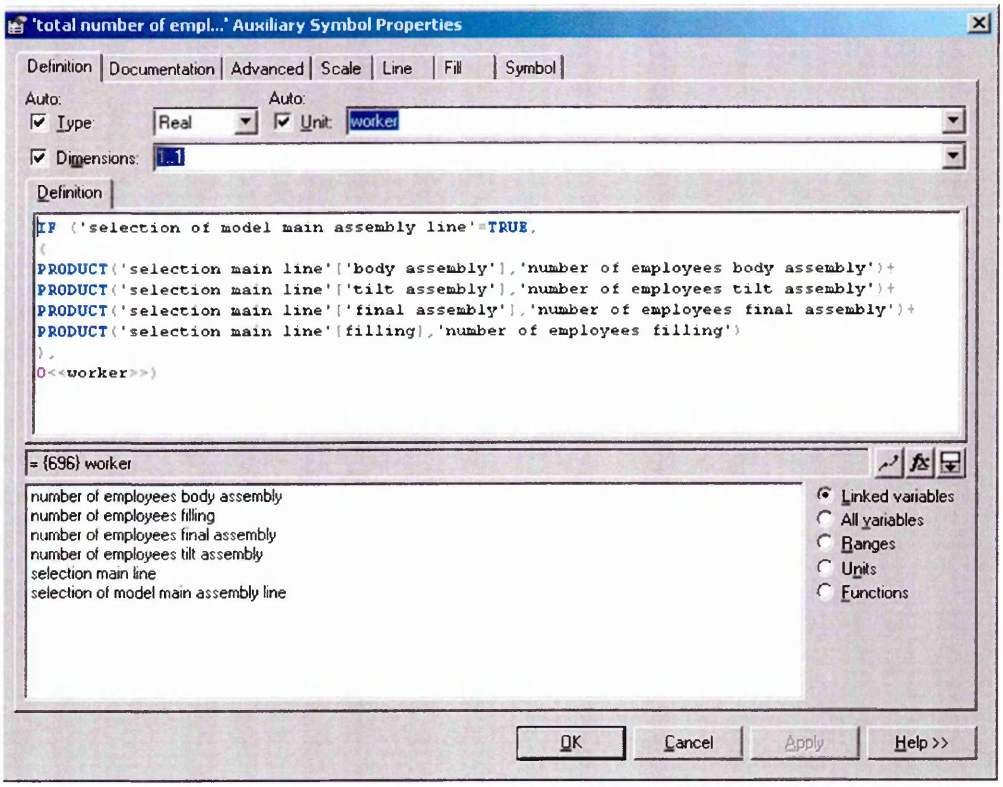


Figure 77 – 'If-Then Function' on the Example of the Calculated Employees.

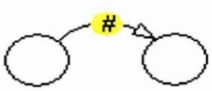
It is further especially worth mentioning that 'Powersim' reminds the modeller to link the key performance indicators correctly. By the addition of inconsistent key performance indicators or graphically illustrated however mathematically missing allocations, either automatic warning signals pop up (see figure 78) or the model will not run in the simulation mode. Since within the scope of this research project such discrepancies could be repaired, this is good evidence for plausible linking of the key performance indicators.

Error symbol



A symbol with a '?' (question mark) indicator indicates that the symbol is not properly defined. The undefined symbol can appear on variables and flows.

Inconsistency in diagram



A symbol with a '#' (hash mark) indicator indicates that there exists inconsistencies between the diagram and model definitions. The inconsistency symbol can appear on variables, links, and flows.

Figure 78 – Error Symbols – Reminder for Building a Plausible System of KPIs.

However, for being able to use the system of key performance indicators successfully, for the planner / manager merely the proper operation of the cockpit is necessary. Therefore, attention was paid to the fact that the cockpit of the system of key performance indicators is following the principle of 'classification systems' (see section 2.7.5.2).
In doing so, the final assembly shop is divided into its essential parts, known by the experts in the automotive industry (see figure 79):

- Main assembly line (station 1 up to the first start of the engine).
- F1 – F2 area (first start of the engine up to finished car).
- Pre-assemblies.

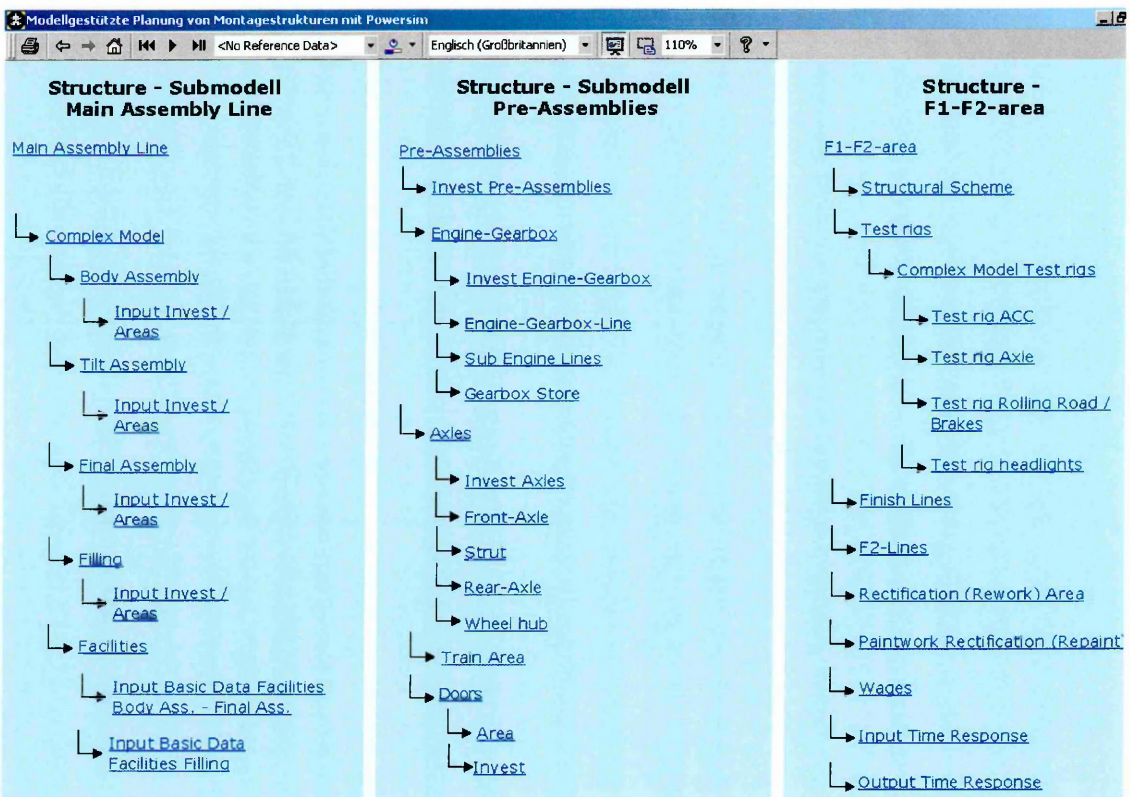


Figure 79 – Sitemap – Showing the Tree Structure of the Model.

By the use of such a tree structure and corresponding hyperlinks the user can very flexibly decide, according to his / her main focus, which key performance indicators he / she is particularly interested in.
Nevertheless, all users at any time have the possibility to move from the highest level of detail to the level where they can see the total picture.
Since the three levels are traceably linked with each other, it is obvious that every key performance indicator has a more or less strong influence on the result of the whole key performance indicator system. The three different main levels used in the model are described below:

Level 1

In this top level the most important levers for planning a final assembly shop can be found. On the basis of the key performance indicators of the second and third level the essential planning dimensions necessary to get the big picture will be calculated and presented.
Input of the main parameters such as 'daily units', 'production days per year' and 'basic working time model'.
Presentation of consolidated key performance indicators like 'cycle time', 'areas', 'number of employees', and 'required investment'.

Level 2

In this level essential parameters necessary for planning bigger sub-sections of a final assembly shop can be changed. To evaluate different structural options, the essential key performance indicators can be found in this level.
Input of key performance indicators such as 'planned time', 'availability', 'employee density', 'selected conveyor system', 'degree of automation' and so on, all fragmented into the major sections of a final assembly shop.
Calculation of the 'total stations', the 'areas', the 'investment', and the 'staff' necessary to build the cars required in level one. All figures are available for the major sections of a final assembly shop.

Level 3

In this level much detailed knowledge is necessary to enter the basic key performance indicators for the specific areas and facilities. This level provides the base for the calculations done in the higher levels.

The best known dimensions for the different kinds of conveyors and machines as well as the length / width of a station / a test rig has to be entered in this level. In addition, the cost rates for the options offered in level two (= different degree of automation, different conveyor systems) are part of this level.

For the purpose of the transparency of the system both, in the cockpit and in the network between input KPIs (= green), transfer KPIs (= blue) and result KPIs (= red) will be distinguished. This should help every user to grasp the meaning of the different key performance indicators faster. In figure 80 this teamwork of the cockpit level and the network level with the different colours is demonstrated on the example of the tilt assembly.

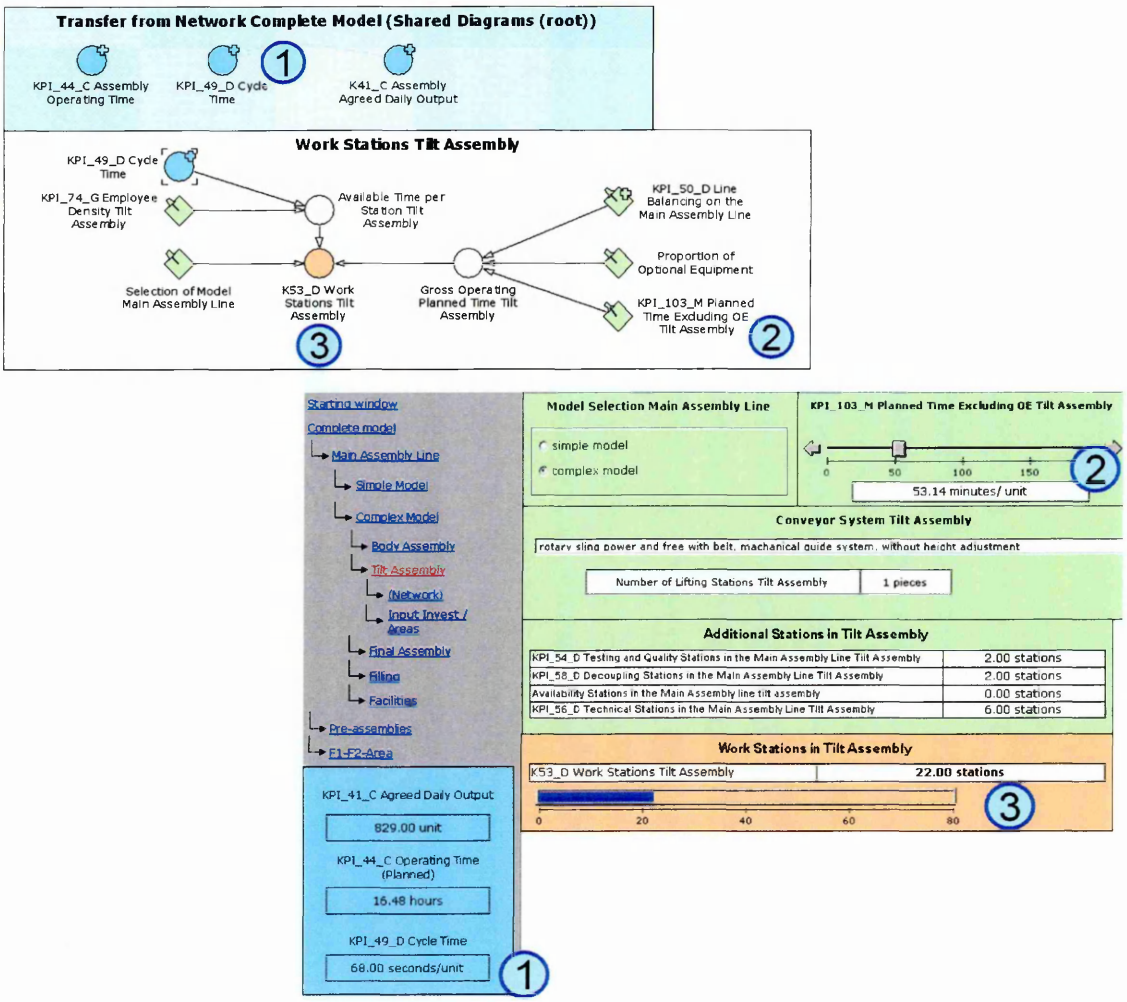


Figure 80 – Colours used in the Cockpit-Level and the Network-Level.

While the network is locked for the planner, the headquarters can make sure that by the use of the key performance indicator system in all locations permanently a comparable result will be produced. Should an adaptation of the model become necessary, e.g., as a result of new technologies, in the future the dependencies between the new key performance indicators can be generally defined by a team of experts from the different locations.

After an agreement of the specialists about the dependencies between the key performance indicators this new element of the entire network can be transferred into 'Powersim' by a central person responsible for the network. Therefore, all locations are obliged to contribute to the 'learning organisation'.

5.3 Multilingualism

Since the BMW Group has locations in Germany as well as in English-speaking countries, the multilingualism of the model was also an important issue. Ideally all planners, independent of their location, should be able to use the same system of key performance indicators. 'Powersim' again offers a very helpful option which was used in this research project. By the 'menu bar' illustrated in figure 81, the planner can select between German language and English language.



Figure 81 – Menu Bar for Changing the Language.

The network of both versions is always the same, just the labelling of the key performance indicators changes (see figure 82 and 83). With only pressing one button the know-how which perhaps just was available on the German plants easily can be made available to the experts from the English speaking locations.

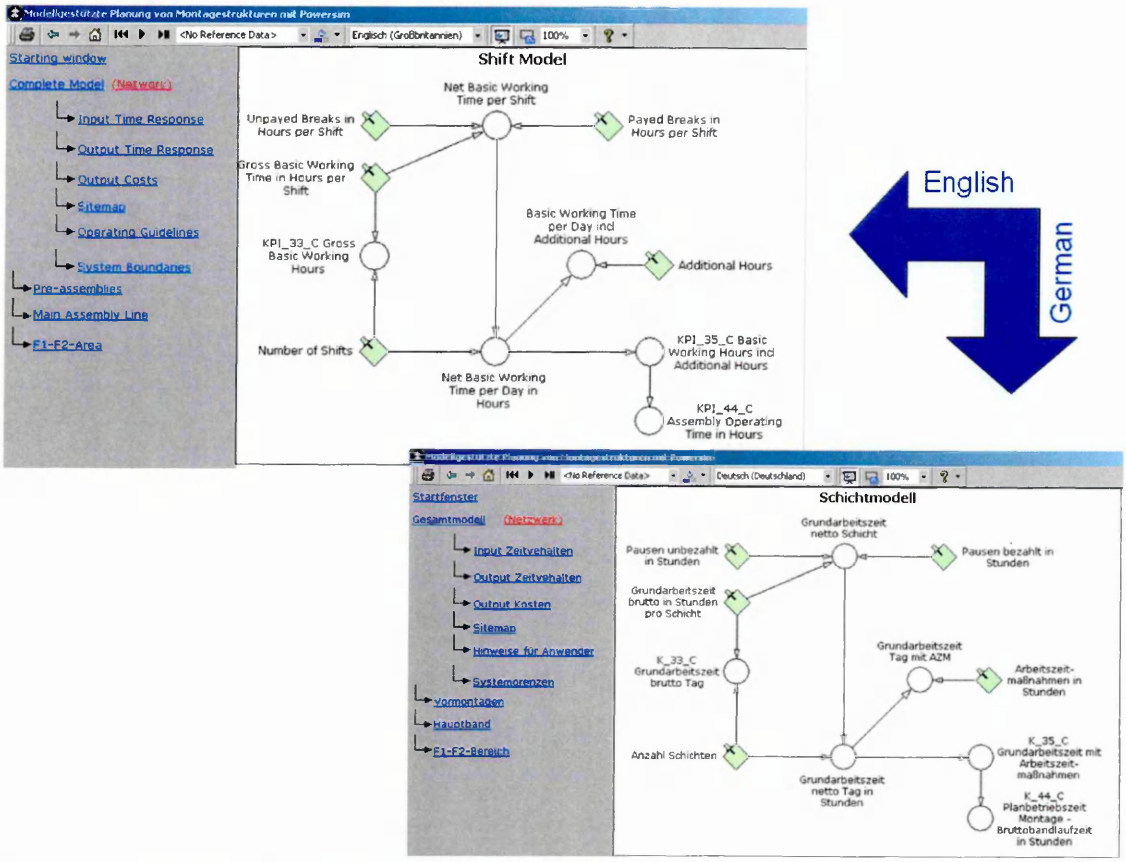


Figure 82 – Network in English and German Language.

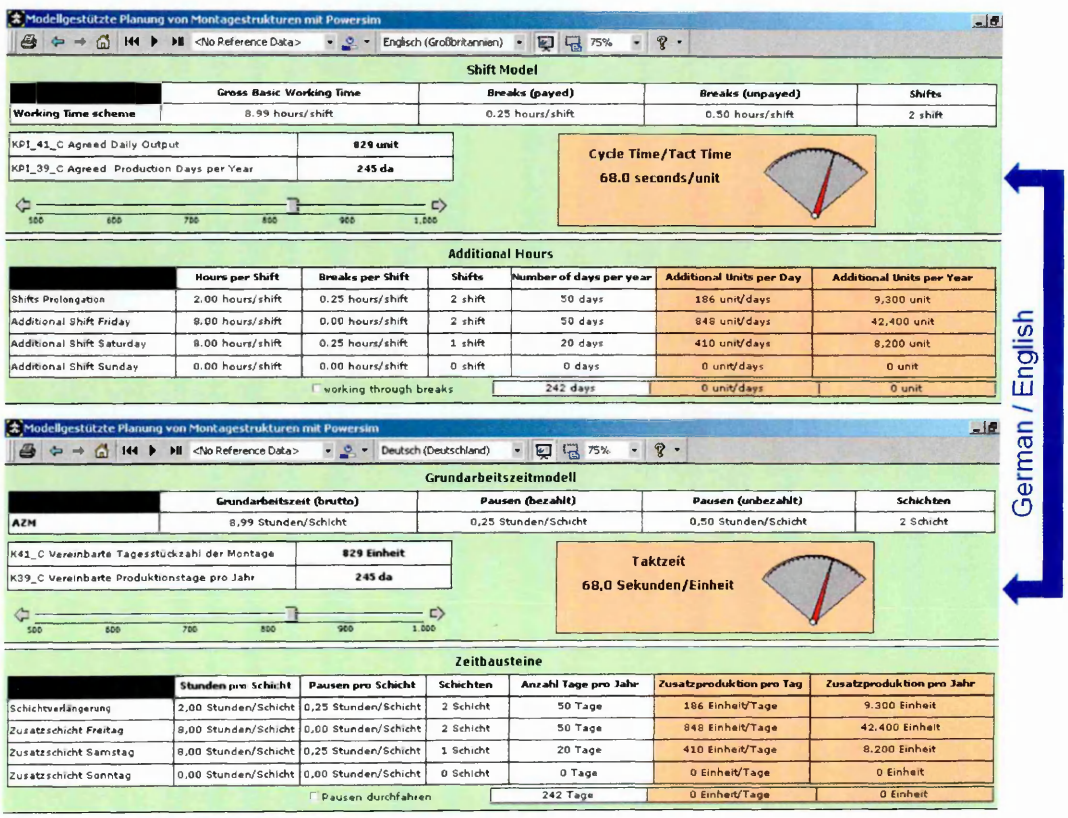


Figure 83 – Cockpit in English and German Language.

However, finally it must be mentioned that this translation does not occur automatically through the software itself, but by the generation of the model through the author.

5.4 Operating Guidelines & System Boundaries

As already mentioned several times, in a complex system it must be made sure that all parties involved have the same understanding about the system boundaries. Hence, about the links 'Operating Guidelines' (see figure 84) and 'System Boundaries' (see figure 85) essential information will be provided with the tool.

While using the key performance indicator system, for instance it has to be kept in mind that it is primarily developed for planning greenfield final assembly shops. This becomes obvious regarding the number of stations which are a variable resultant in the developed model, however these would be fixed in an existing final assembly shop and therefore, of course, need to be an input parameter. This separation of greenfield projects and brownfield plannings also must be taken into consideration with the capital investment, because with the demolition of old equipment additional costs could raise the total investment.

In addition, ideal processes are assumed in this key performance indicator system (e.g., number of test benches) which cannot be found in all existing final assembly shops.

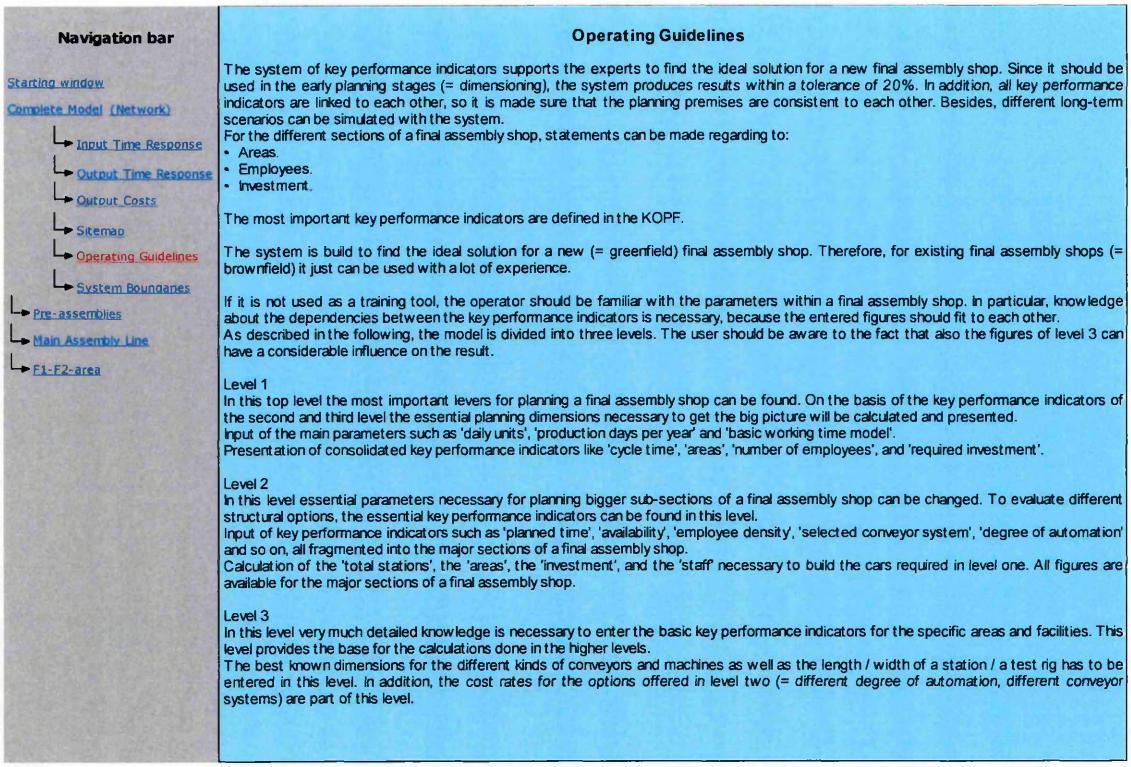


Figure 84 – Operating Guidelines included in the Model.

As highlighted in figure 85, some of the most important system boundaries are graphically illustrated within the model. They should help the user to better understand the boundaries of this system of key performance indicators.

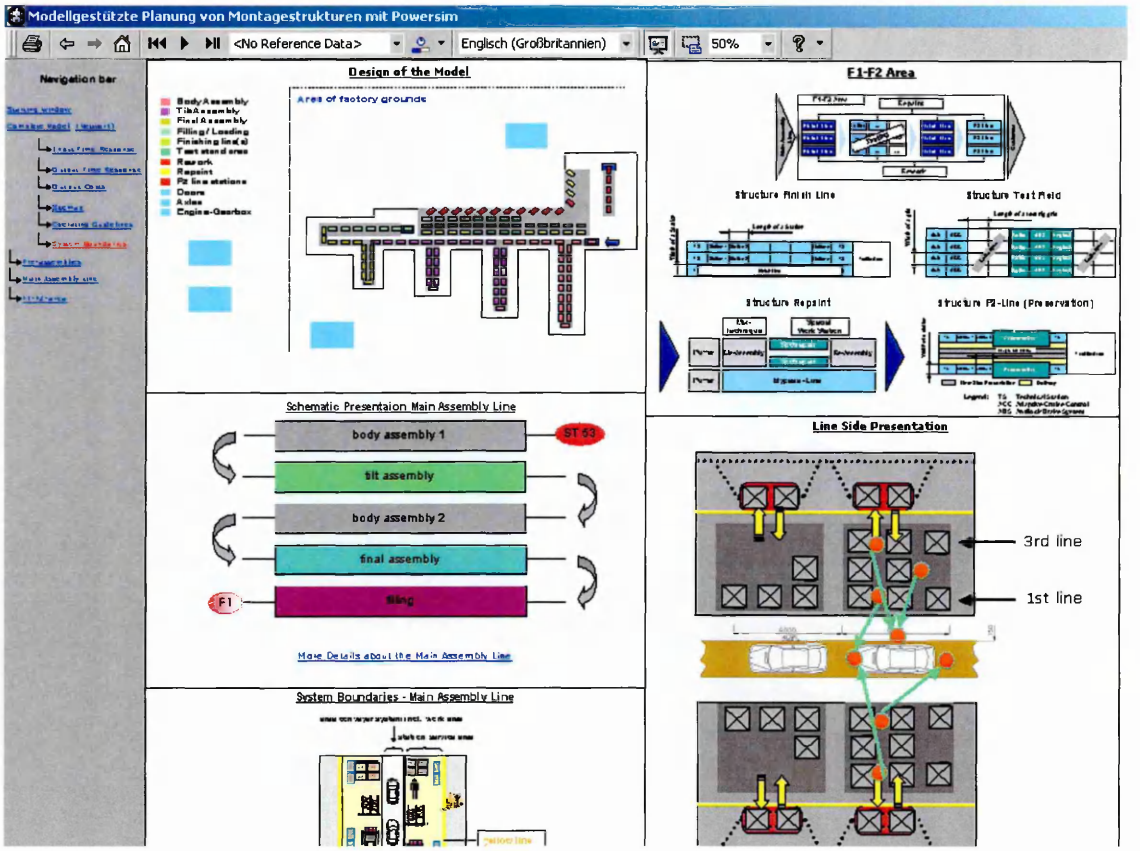


Figure 85 – System Boundaries included in the Model – Do not try to Read.

Finally, the essential information about the system boundaries is summarised below:

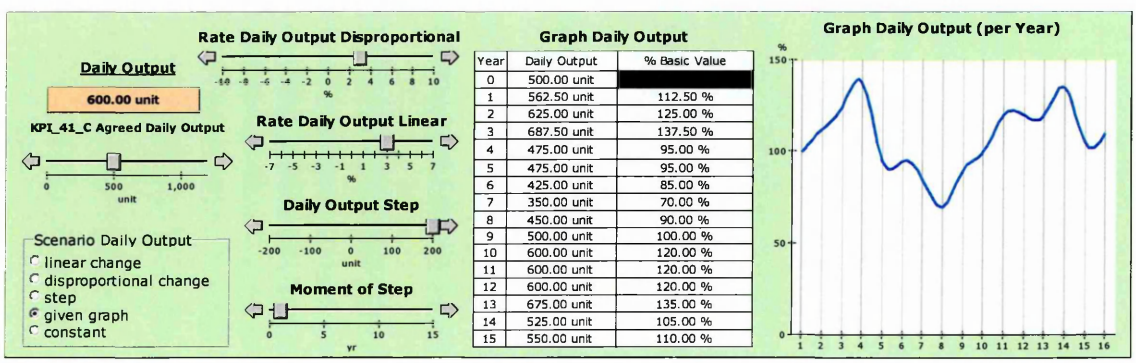
- Reproduction of a final assembly shop starting with the first station ending with the 'virtual' hand over to the customer.
- Optional enlargement by well-chosen sub-assemblies.
- Not included are secondary functions like planning offices, logistics zones, work fire brigade, canteen, etc.
- Mapping of an idealised greenfield final assembly shop of a car manufacturer.
- The definition of the essential key performance indicators occurs through a numbering system, identical with that used in the KOPF (= quantitiative recording).

5.5 Change over Time of some KPIs

As already mentioned, the software 'Powersim' is ordinarily used to map dynamic situations (= feedback loops, delays). Nevertheless, the dynamic within a final assembly shop is of minor importance for this research project. It rather should help to illustrate the interlinkage of a huge number (= complexity) of key performance indicators necessary for planning a final assembly shop in a traceable way and therefore, to promote the awareness about the dependencies.

Nevertheless, time plays a role in this key performance indicator system. Via the link 'input time response' some key performance indicators (= theoretically all KPIs that have to be entered) can be changed for the defined period of 15 years. As an example, the variations of the 'daily output' are illustrated in figure 86. They can be changed by the model user as follows:

- Linear increase / decrease of the daily output.
- Disproportional change.
- Step function.
- Given graph.
- Constant.



Year	Daily Output	% Basic Value
0	500.00 unit	
1	562.50 unit	112.50 %
2	625.00 unit	125.00 %
3	687.50 unit	137.50 %
4	475.00 unit	95.00 %
5	475.00 unit	95.00 %
6	425.00 unit	85.00 %
7	350.00 unit	70.00 %
8	450.00 unit	90.00 %
9	500.00 unit	100.00 %
10	600.00 unit	120.00 %
11	600.00 unit	120.00 %
12	600.00 unit	120.00 %
13	675.00 unit	135.00 %
14	525.00 unit	105.00 %
15	550.00 unit	110.00 %

Figure 86 – Change of KPIs on the Example of 'Given Graph – Daily Output'.

Some other key performance indicators that could be changed over time with this model are the assembly time required for one unit (= change of product complexity), the labor costs for employees or the direct runner rates to call only some examples. Basically every initial key performance indicator could be changed in this way.

To change some of the key performance indicators over time, gives the planner the chance to better assess possible long-term scenarios for the newly planned final assembly shop. Possible peaks e.g., in the areas required or for the employees needed become transparent as demonstrated in figure 87, and therefore help already at the beginning of the planning process to dimension the final assembly shop optimally.

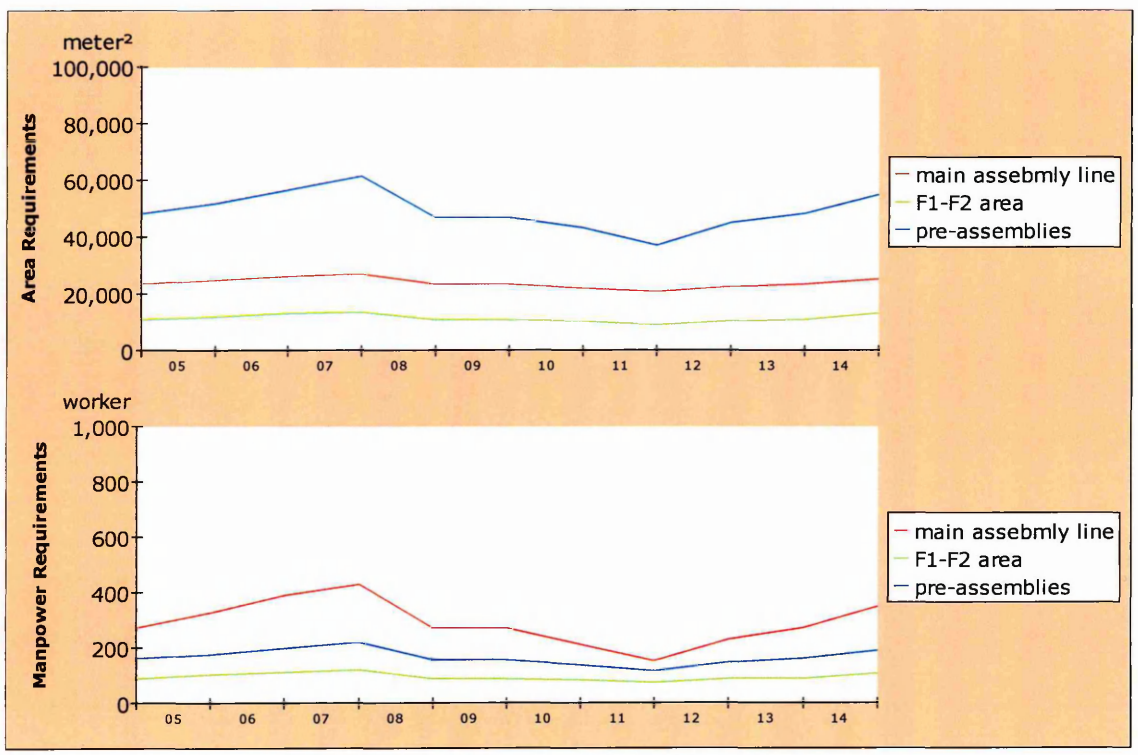


Figure 87 – Change of KPIs over Time as a Result of a Changed 'Daily Output'.

It is important to know that the model reacts directly to temporal changes of individual key performance indicators, i.e. no temporal delays are integrated. Of course it can be argued that a new installed machine will be depreciated over several years and, hence, it might come in the model only after the same period of time to a reduction of the machines.

By reason of transparency this system of key performance indicators was built without any delays. The author worried about the problem that the planner / manager could not understand the reasons for changing key performance indicators because of such delays.
Nevertheless, it should be an objective for the future to map a final assembly shop of a car manufacturer with 'delays' and 'feedback loops' according to the idea of 'System Dynamics'.

5.6 Availability of the KPIs

As already described in chapter 2, the data availability must not be underestimated with the construction of a complex system of key performance indicators. It was one of the objectives of this research project, to make the recorded figures better available to the model user, so that he / she can begin to plan and to analyse different scenarios without searching for missing figures. In doing so, a function offered by 'Powersim' was used intelligently, while it was sensibly interpreted for this research project. With help of the option 'reference data' illustrated in figure 88 the latest and also historical key performance indicators of the different locations can be loaded in the system within seconds.

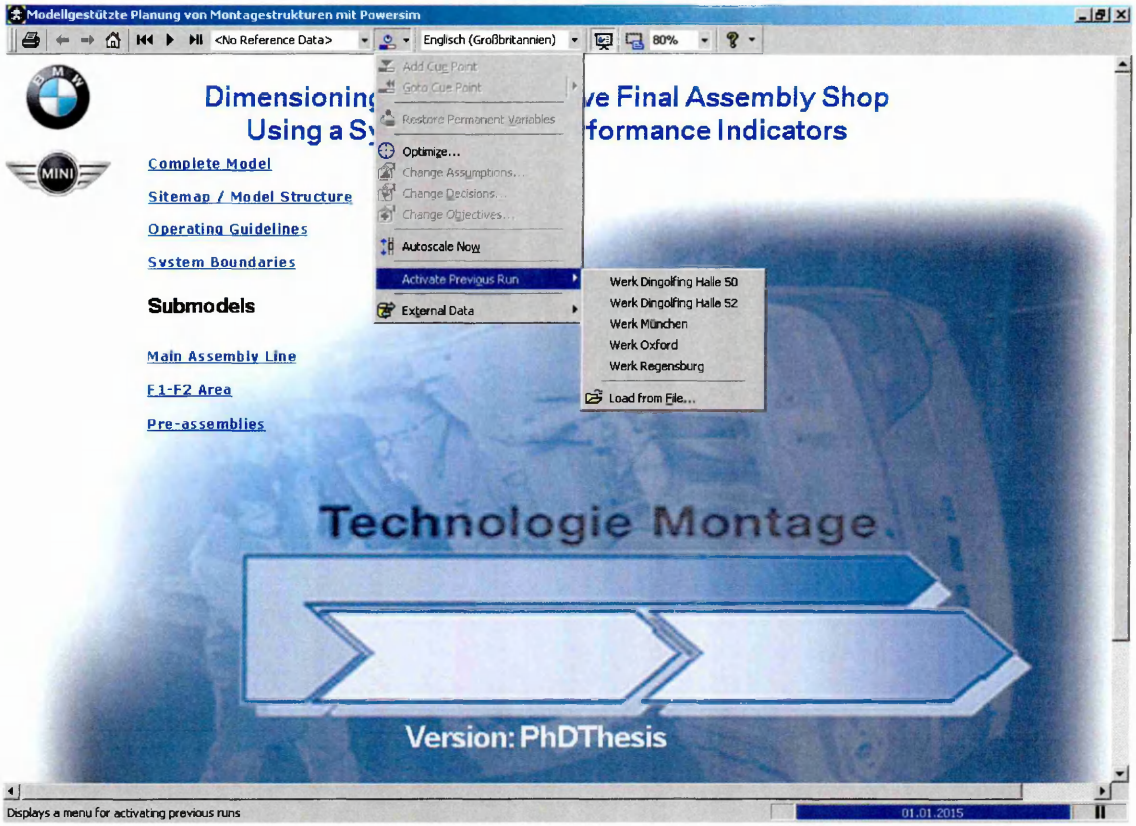


Figure 88 – Load Reference Data From Other Locations.

Having available a reliable set of key performance indicators from various locations, the planner has the chance to reach much faster an improved exactness for his / her planning.

In addition, at any time the intermediate data for the new final assembly shop can easily be compared with the key performance indicators of the best fitting existing final assembly shops.

The different planning scenarios also can be saved directly in the model and can be re-loaded after weeks, months and even years. It could be very helpful for the management having the chance to compare the real situation after the opening of the new final assembly shop with the premises set during the different planning stages. Furthermore, this documentation / transparency sometimes could be helpful, e.g. for setting the targets of a new planning project.

Ideally, the entire production network is available in only one computer, giving the planner in an early planning phase the chance to roughly judge the effect of a new vehicle (e.g., higher assembly time) for existing brownfield final assembly shops. Even if it is not the priority target of this research project, with this approach the optimisation of the existing production network at least can be supported.

5.7 Additional Warnings / Information

As a result of the varied possibilities to enter key performance indicators, an increased risk of wrong inputs exists. Again, the cockpit of this system can be compared to that of an airplane. Within the options offered by 'Powersim' different 'message boxes' were programmed which should support the planner / manager during the usage of the system. As illustrated in figure 89 they for instance pop-up, if important targets are missed or if essential planning premises are violated.

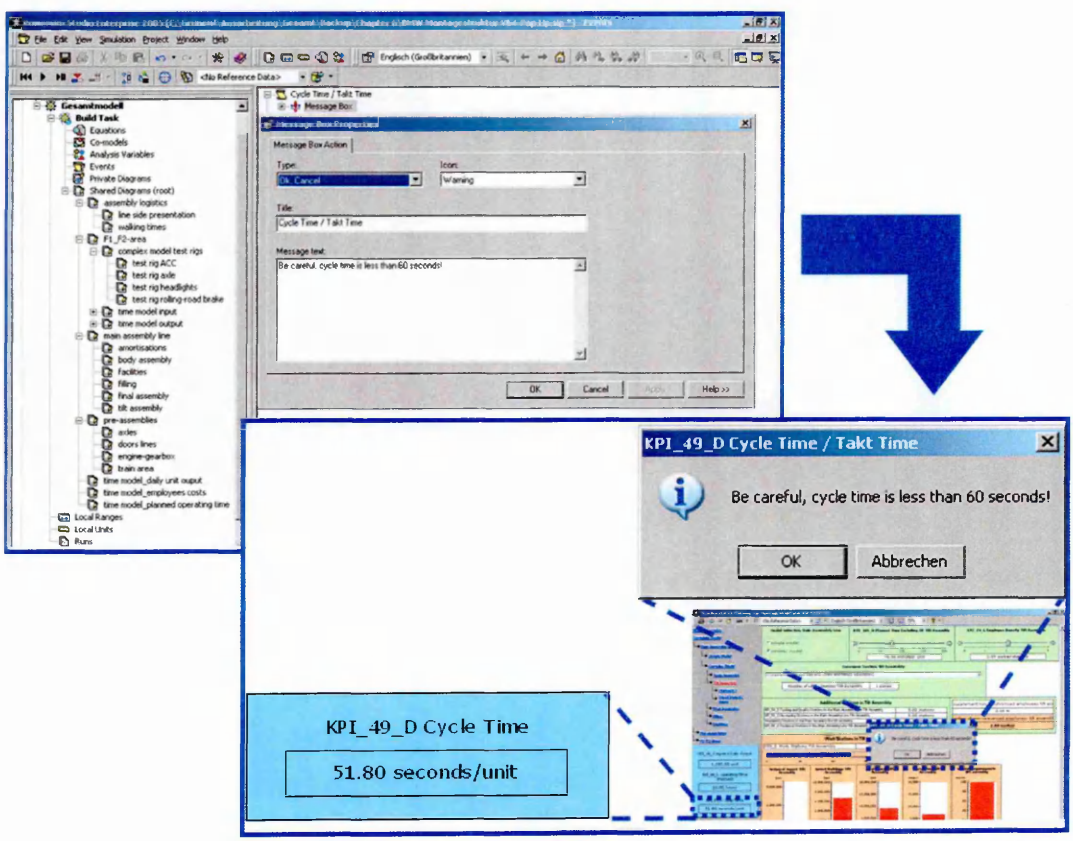


Figure 89 – Message Box – Cycle Time.

5.8 Summary

The above segment should demonstrate that this research project with help of the chosen software 'Powersim' tried to process a huge number of required key performance indicators in a very user-friendly way. In this context, especially the separation of the cockpit-level from the network-level is very important.
Having integrated numerous functions in the system, it could be achieved

- that the key performance indicators of individual locations are available in the entire organisation,
- that historical figures and planning premises are available within seconds,
- that the planning premises and system boundaries are better taken into consideration,
- that the idea of the 'learning organisation' is assisted with the developed system (= network),
- that different scenarios (= inclusive long-term scenarios) can be analysed faster and more reliably in the early stages of the planning process, and
- that the system can be used independently by German and English speaking planners.

Moreover it is important to highlight that the developed system of key performance indicators does not end in a single super key performance indicator. According to the interests of the planner and / or manager there are in every level key performance indicators which are more or less important for the individual user.
Altogether, the described advantages demonstrate that the chosen approach can be positively rated for this problem. Without software support, it would have been barely possible to sensibly record the complex dependencies between the various key performance indicators and still make the knowledge user-friendly accessible to other persons.
Independent of the other results this approach definitely should be promoted, whenever someone has to work with key performance indicators.

6 Model Validation

6.1 Introduction

Since the above section demonstrated that the developed system of key performance indicators can support daily business of both planning experts and managers, now the most important question must be answered: Does the key performance indicator network produce reliable results?

To be able to answer this question, the results of the system will be compared to the actual values of the four German BMW final assembly shops in Munich, Dingolfing, Regensburg and Leipzig. These locations were selected for this validation, because they are very different in many aspects and it was supposed that the availability of information might be very good. In addition, in terms of economic interests of this research project, it was another important criteria that they are all close to the FIZ (= central planning department) in Munich. So a visit on site was possible without causing extraordinary costs. Nevertheless, the remaining BMW locations were intermittently integrated in this validation process as well. Even if it is not discussed in this chapter, for the other locations results are available, consistent with those presented below.

First of all, the results generated by the whole model are compared to the real values of the above named locations. Based on it, the different sections of a final assembly shop, illustrated in the model, are introduced and analysed more precisely. For the various sections, the results of the system again are compared to the present figures of the locations. In doing so, indicated differences are discussed in detail.

At the end of the validation process, the stability of the developed system is tested with different scenarios. What influence the individual key performance indicators of the different levels have on key performance indicators of the first level is also examined.

6.2 Entire System

Although numerous data has been collected with the KOPF (= Key Performance Indicators for an Optimised Planning of a Final Assembly Shop), right at the beginning of the validation process it became evident that additional quantitative data would be required. The developed system needs much more detailed information than those offered by the KOPF.

In intensive collaboration with representatives from the different locations, the missing quantitative data was recorded with help of additional sheets as shown in figure 90.

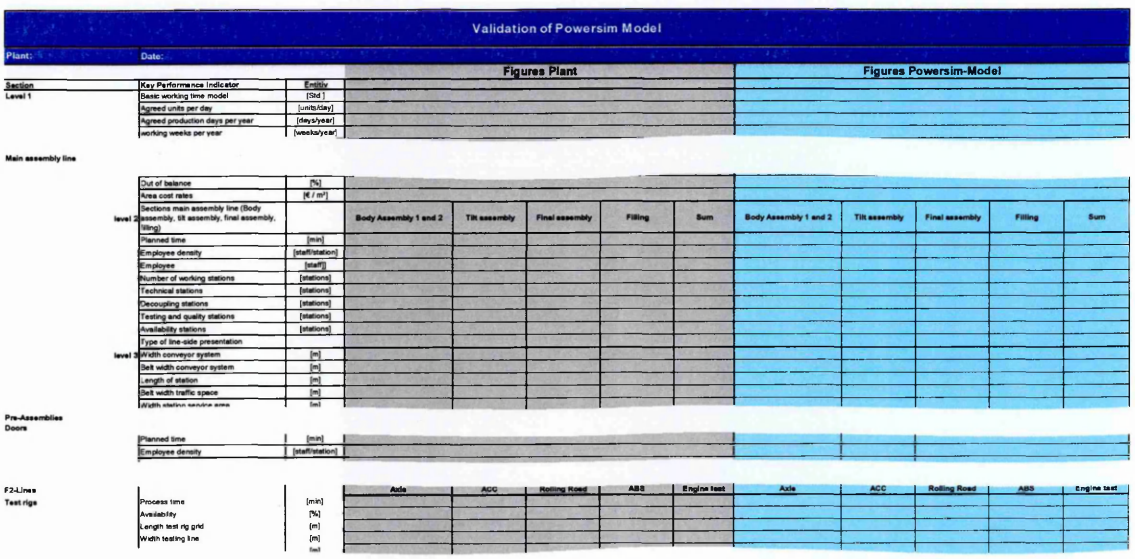


Figure 90 – Spreadsheet for Model Validation.

Figure 91 illustrates that the key performance indicators of the different subordinated sections are summarised on the level of the entire system. In addition, in this level also some basic key performance indicators will be calculated / determined which are important to the submodels as input key performance indicators (see figure 92).

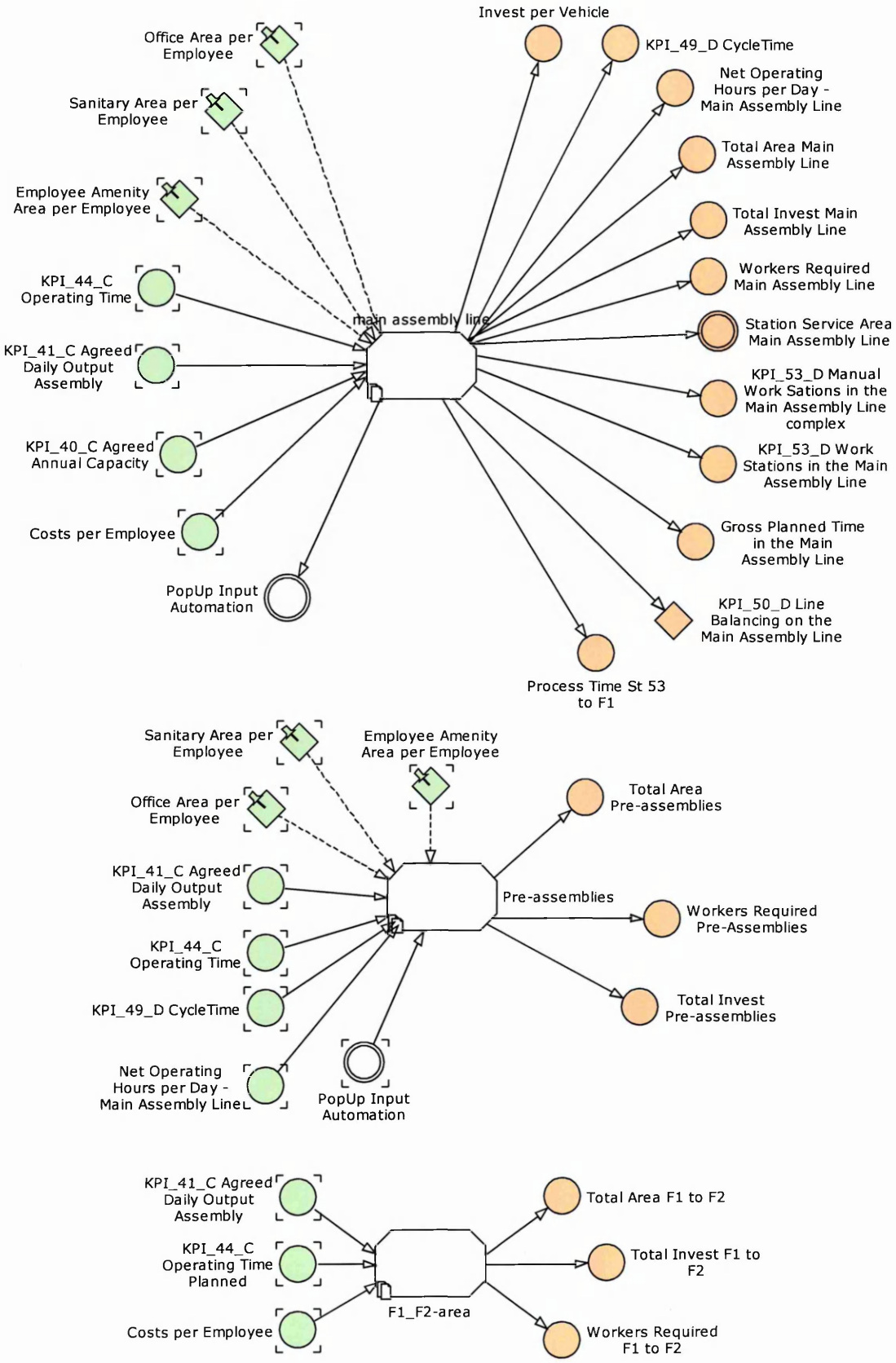


Figure 91 –Submodels for 'Main Assembly Line', 'Pre-assemblies' and 'F1-F2 Area'.

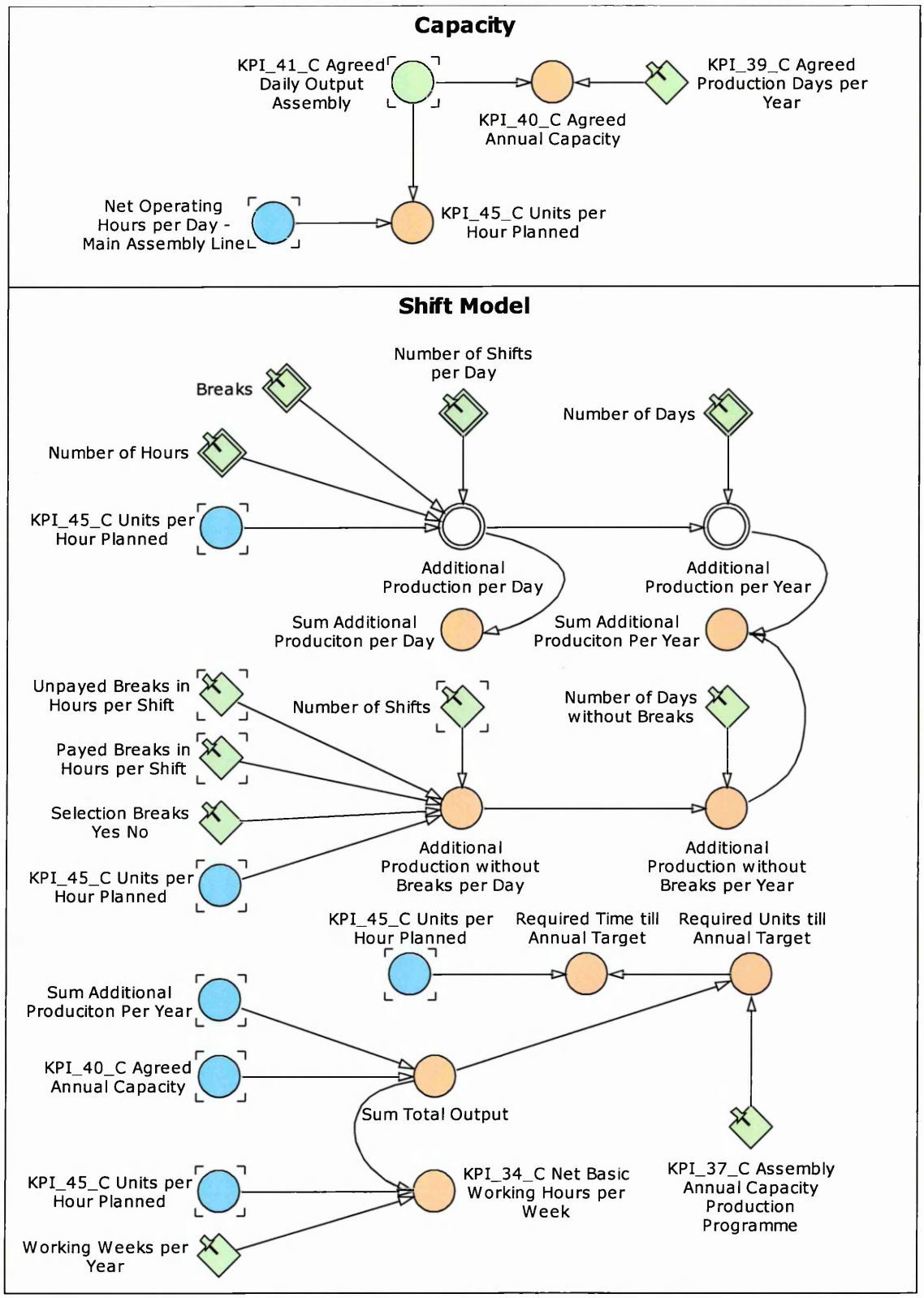


Figure 92 – Network for 'Capacity' and 'Shift Model'.

The analysis of the above networks is important for the judgement of the research project. For the acceptance of the model, it is important that the results of the entire system are within the given tolerance frame of ± 20%. The quality of the results will be evaluated against the following key performance indicators:

- Production area.
- Service areas nearby to the assembly line.
- Manpower.
- Planned time.
- Number of work stations.
- Number of total stations.
- Technical investment.

Thus, some of the most important key performance indicators both relevant for technical planning (= areas and stations) and for the economical planning (= costs and investments) will be analysed. Figure 93 illustrates that all values are within the set framework of tolerance of ± 20%.

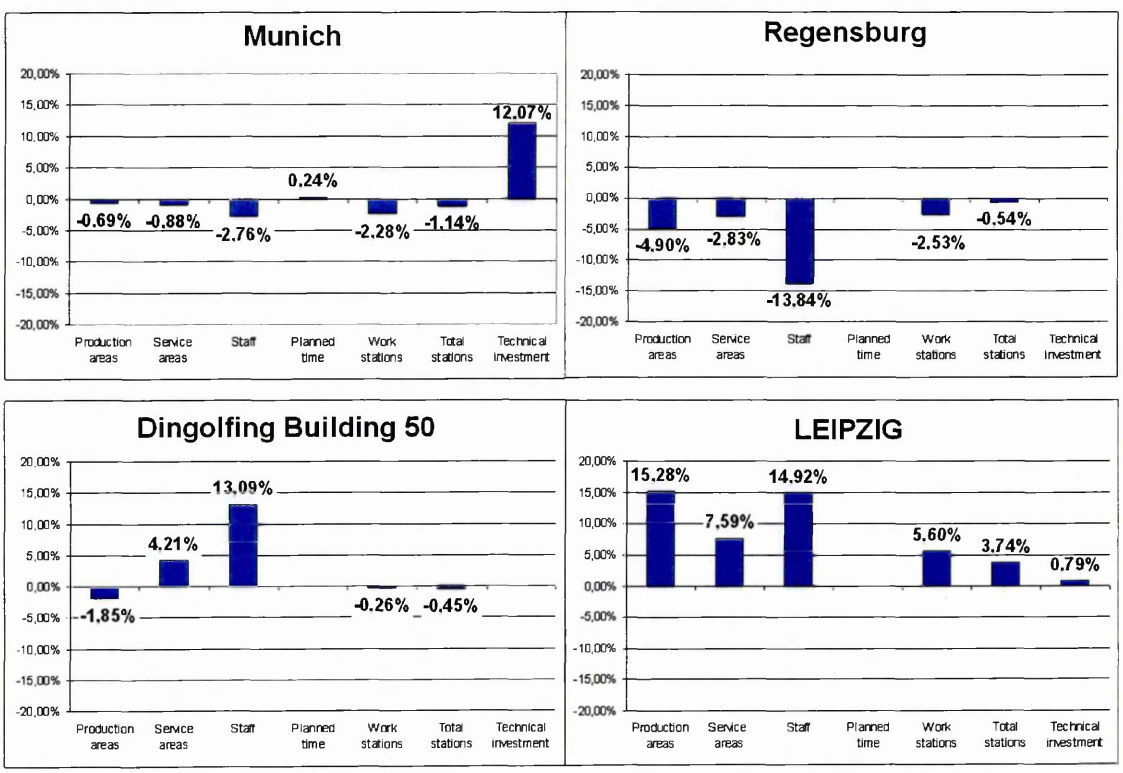


Figure 93 – Deviation of the System Against the Real Values – Entire System.

The charts for the four plants demonstrate that no basic trend is recognisable, since the values of the model are both too low and too high. However, it is striking that the results of the model in contrast to the real values of the individual locations are almost all above the 0-line or under the 0-line. What is the reason for this pattern? Perhaps, some of the key performance indicators have such a big influence on the results of the entire system that they determine whether the remaining figures are above or under the real values. Since this assumption so far is very theoretical, it has to be observed, whether this trend is also recognisable for the different sections analysed below. Just after additional analyses final conclusions can be made.

At this point, special attention should also be paid to the differences in the technical investment. As a result of the new plant in Leipzig and a bigger building work in plant Munich, reliable reference data for the comparison of the model with the existing final assembly shops were only accessible for these two locations. In the remaining final assembly shops just values of single facilities were available. With the help of paid bills for new machines the observance of the tolerance values was checked for some sections of such locations. However, an exact separation according to the sections offered by the model was not possible, so that the technical investments are no further subdivided in this thesis.

6.3 Station 1 until First Start of the Engine

The main assembly line is probably the most striking section during the process of planning a new final assembly shop of a car manufacturer. For the calculation of the essential key performance indicators a huge number of relevant input key performance indicators are necessary. As an example for plenty of connections within the network three of them are drawn to a larger scale in figure 94.

Special attention should be directed upon the network number one, because it serves for the calculation of the required number of working stations in the main assembly line. It is of vital importance, because both too short main assembly line (= compensation with help of employees working in the line) and too long assembly line (= rise of the processing time) later makes it difficult to achieve best practice key performance indicators.

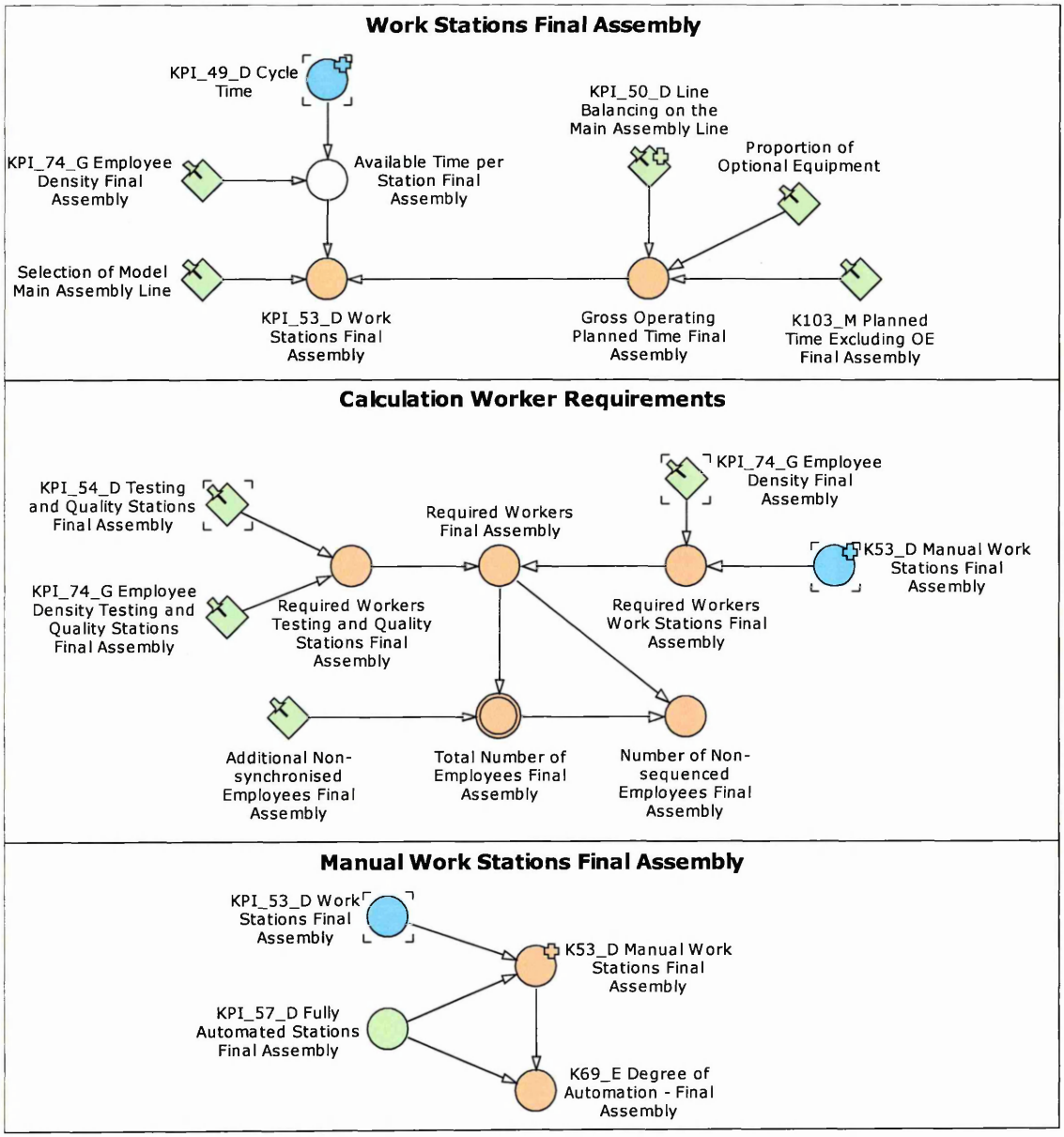


Figure 94 – Example of the Network for Final Assembly.

Since the traceability of such interrelationships is complicated without the software, figure 95 illustrates the calculation of the required number of work stations in a special format.

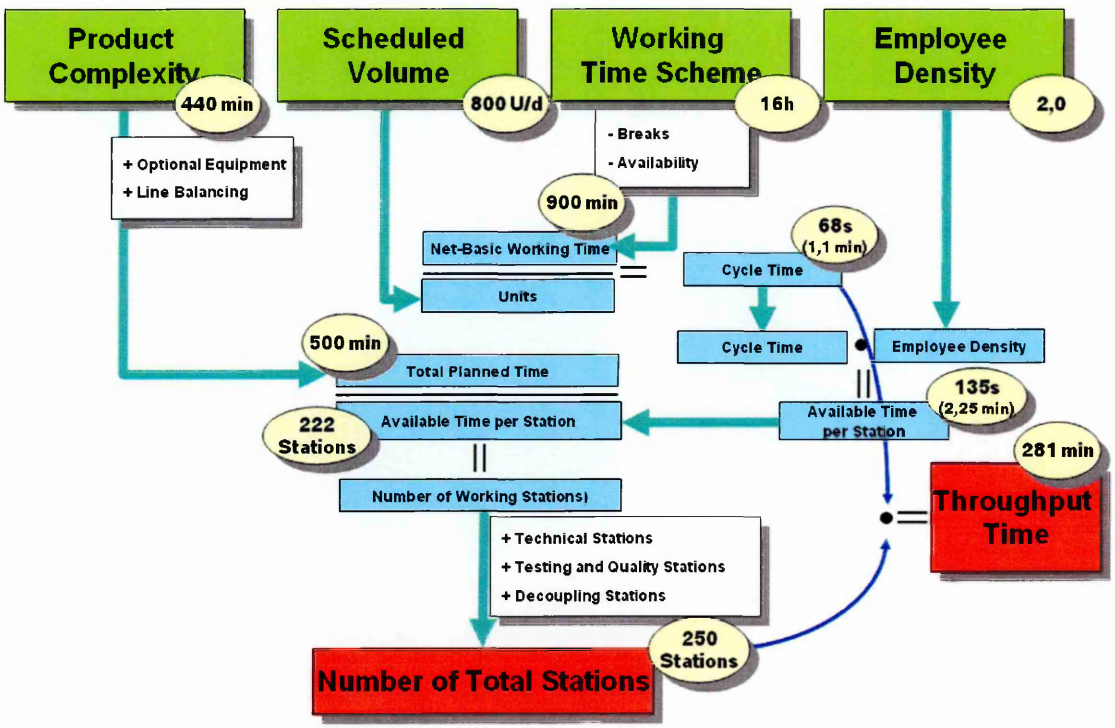


Figure 95 – Schematic Diagram for Calculating the Number of Total Stations.

In the analysis of the following charts (see figure 96), it has to be taken into consideration that the classification of the staff is especially problematic, even with a very good definition. Different organisational structures (e.g., allocation of manpower to the final assembly shop or to the logistics department), smaller pre-assemblies close to the main assembly line, different break down of the cost centres as well as the differentiation of the employees working in the line into value adding and non value adding employees quite easily can cause bigger divergences. Even with intensive efforts, there is no guarantee that the understanding of the definition is the same between the individual locations and between the locations and the system of key performance indicators.

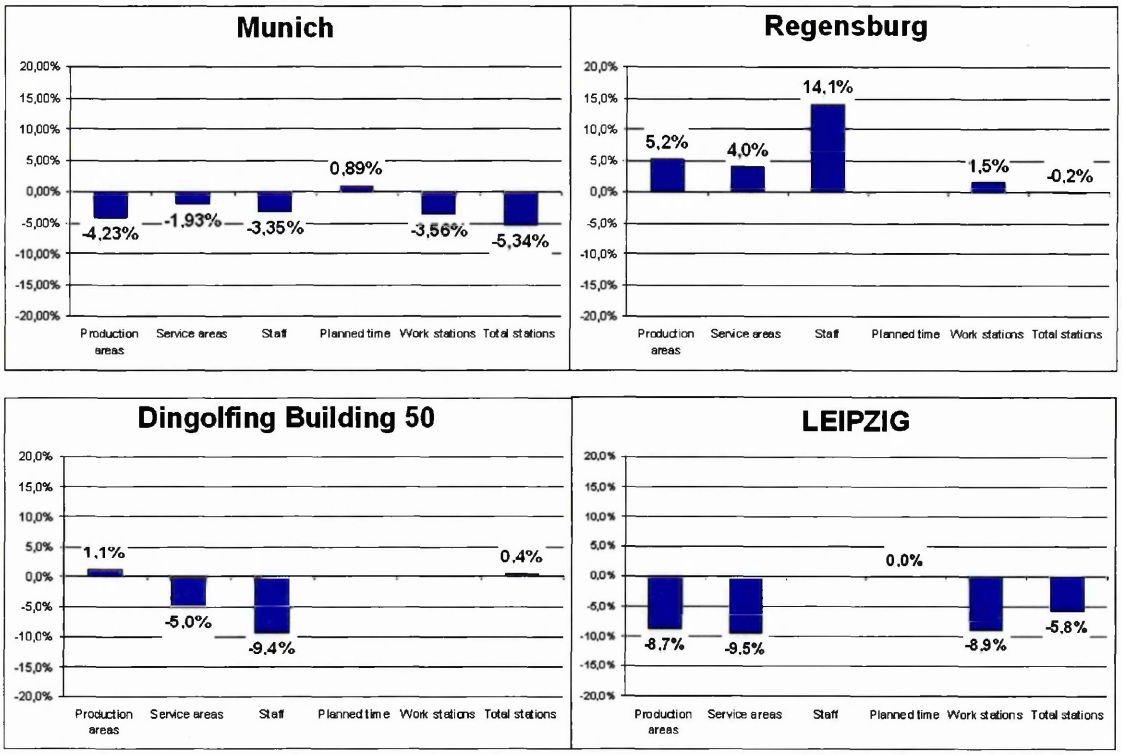


Figure 96 – Deviation of the System Against the Real Values – Station 1 until F1.

The divergences in the areas can be explained with the fact that in the model, ideal structures are assumed which in reality sometimes cannot be realised. For example, the service areas next to the main assembly line cannot be used to 100%, because of structural restrictions (e.g., abutment within the building). As illustrated in figure 97, in the model the planner can just select between one-sided or two-sided material supply. However, if he / she would like to map this section absolutely correctly, he / she would have to add at least one additional key performance indicator (e.g., percentage of useful area against the ideal area).

In addition, the shape of the assembly building only will be considered in this model with help of changed investment costs in the conveyor technology (see figure 97). Again, there is no doubt that the developed model could be designed even more exactly. However, in view of the complexity of the model and the required degree of accuracy it knowingly was built without adding additional key performance indicators.

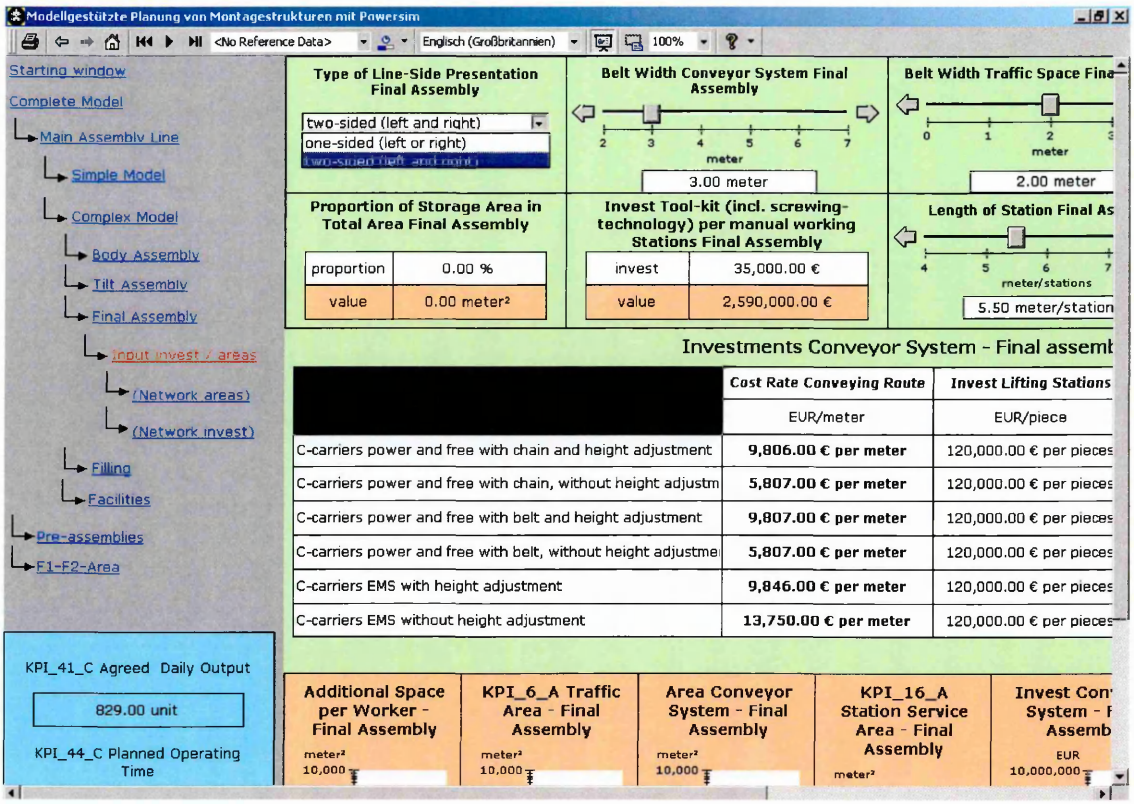


Figure 97 – Cockpit Showing Level 3 – Final Assembly.

Of major importance for the planner is the quality of the calculated number of stations. Concerning this matter, the network produces reliable figures in all parts of the main assembly line as proved with the help of a representative location in figure 98.

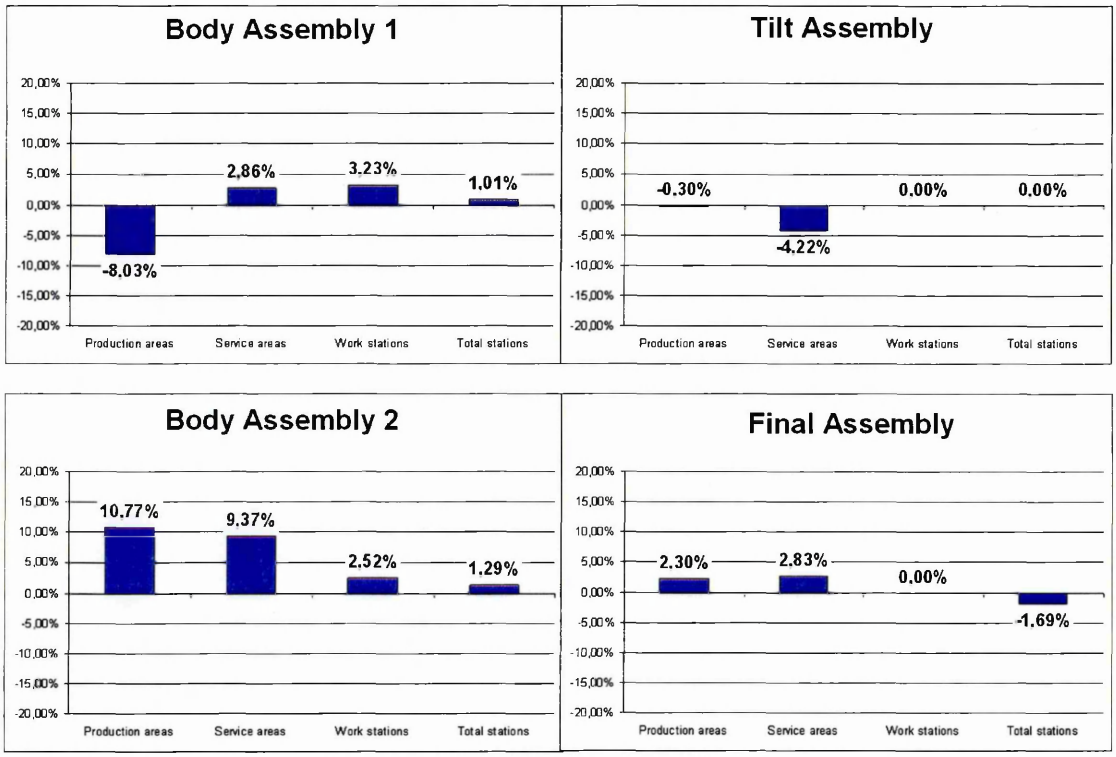


Figure 98 – Deviation of the System Against the Real Values – Station 1 until F1.

Even if the investments cannot be analysed in detail, the following figure (see figure 99) demonstrates that with the help of a representative final assembly shop (= defined within this research project) the planner can easily evaluate different scenarios for the degree of automation. For the typical, expensive and, big facilities with only one single mouse click the decision can be made whether the process step should be done manually, semi-automated or fully-automated. The network of key performance indicators takes this decision into consideration at all levels and calculates investments, required areas and employees in dependence of the selection made.

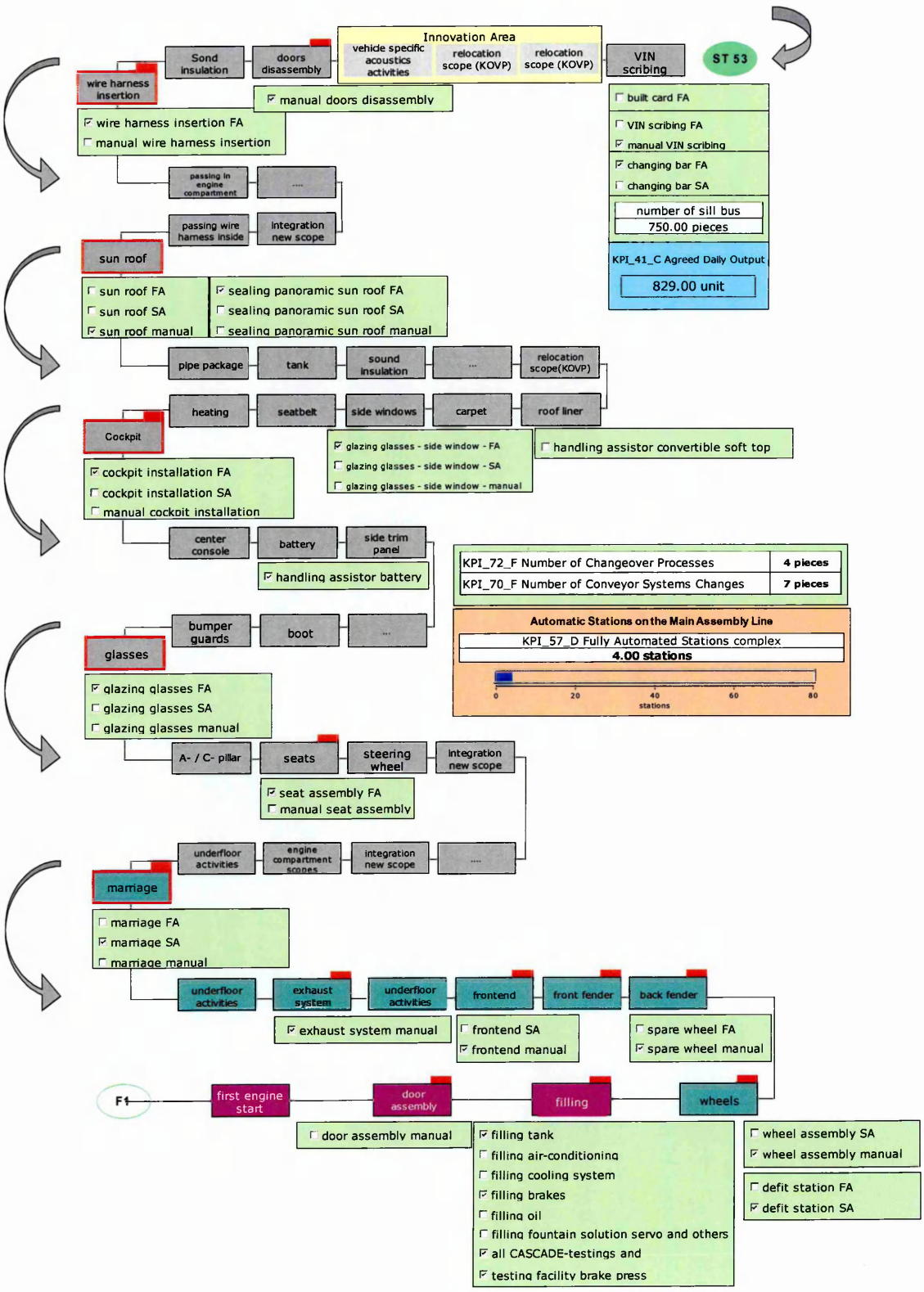


Figure 99 – Determination of the Degree of Automation.

6.4 First Start of the Engine until End of Final Assembly Shop

A big challenge was the mapping of the processes between the first start of the engine until the end of the final assembly shop, since the processes in this section are even more flexible. The new built car could be either on a conveyor system, in a test rig or in the rework area. Moreover, remarkable structural and technological differences are recognisable in this area. As a result of the already mentioned OEM-Benchmark of the German automobile manufacturers, it is known that the testing philosophy is different between the OEMs. Therefore, the transferability of the networks described below to other automobile manufacturers is limited. To make sure that there are at least no misunderstandings with regard to the system boundaries, figure 100 highlights the areas that could be planned with the developed system of key performance indicators.

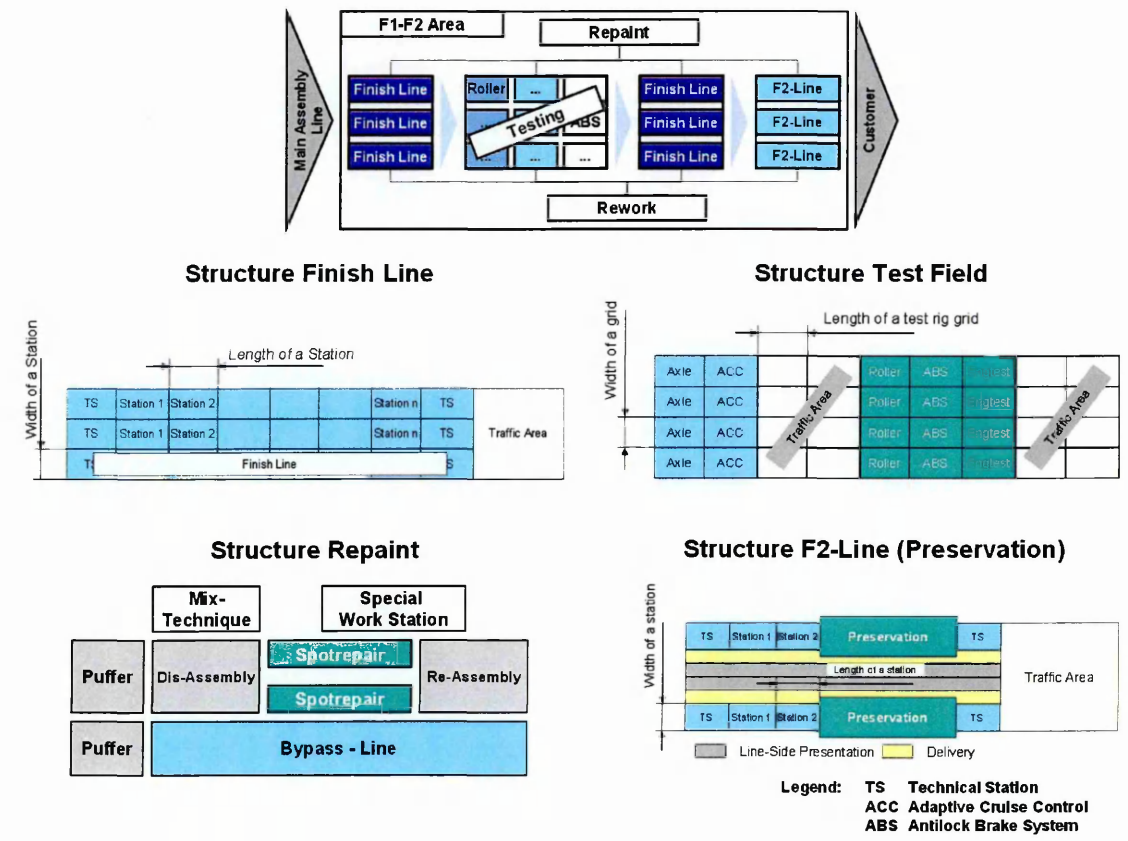


Figure 100 – Idealised Structure of the F1 – F2 Area.

In addition, this schematic diagram gives a hint that the KPIs calculated by the model are based on an ideal structure in terms of robust processes. However, the investment for every individual test stand is quite high, so that in reality every manager tries to reduce the number of required test benches to a minimum.

Furthermore, the product life cycle plays an essential role for planning this area of a final assembly shop. As a result of stabilsed processes, at the end of the product life cycle, for example less rework areas are required than shortly after a SOP (= start of production). All these arguments are understandable factors of influence which explain the divergences illustrated in figure 101.

As a result of the complexity of this area and resulting time delays only Munich and Leipzig could be validated within the scope of this research project.

Besides, both other locations have explained that a comparison of existing structures (= brownfield) with the idealised structure of the model would not be purpose-leading for this flexible area.

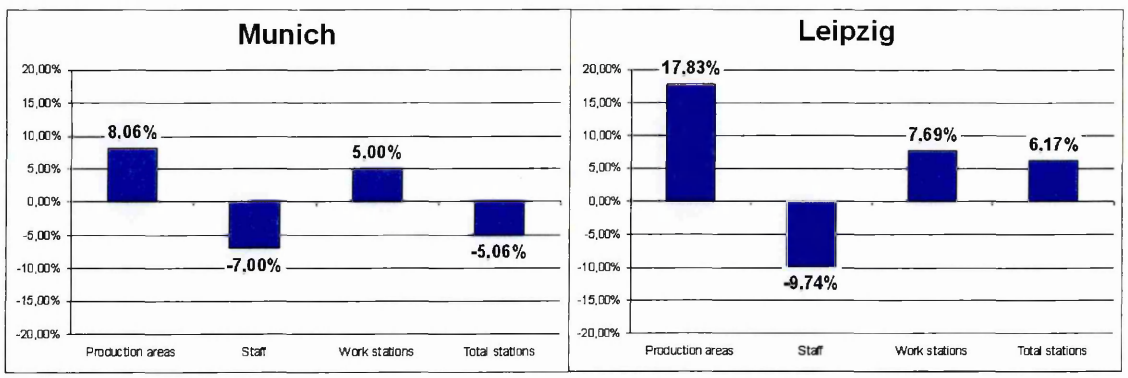


Figure 101 – Deviation of the System Against the Real Values – F1 until F2.

Even if this argument is basically understandable, the results of plant Munich demonstrate that the developed system of key performance indicators can also be used to reproduce existing final assembly shops. The cockpits illustrated below (see figures 102 and 103) should give an impression how varied the opportunities are for planning / reproducing this zone of a final assembly shop.



Parameters Test Rigs

Test Rig	Axle	ACC	Rolling Road	ABS	Engine Test
Process Time	4.10 min/unit	6.00 min/unit	5.50 min/unit	2.80 min/unit	2.10 min/unit
Invest Test Rig	470,000.00 €	300,000.00 €	480,000.00 €	220,000.00 €	100,000.00 €
Permanent Workers	1.00 worker	0.00 worker	0.00 worker	0.00 worker	0.00 worker
Availability	99.00 %	99.00 %	99.00 %	99.00 %	99.00 %
Calculated Time	4.55 min/unit	6.45 min/unit	5.70 min/unit	3.25 min/unit	2.55 min/unit
Value	6.00	6.00	6.00	6.00	6.00

Headlights Test in Axle Test Rig

Additional Time Headlights	0.00 min/unit
Invest Headlights Integrated	125,000.00 €

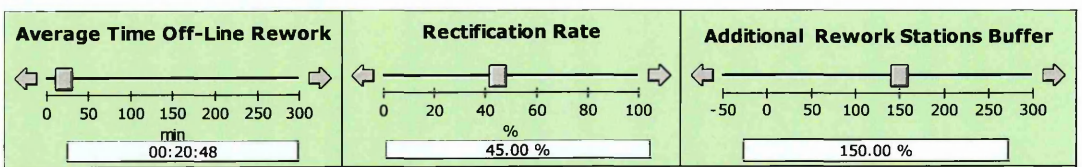
Traffic Areas

Number of Traffic Grids	5

Additional Times Workers

Walking Times	
Time Way Back	00:00:33
Additional Driving Times	
Driving Time Track Rolling Road	0.45 min/unit
Driving Time Test Rig	0.45 min/unit
Driving Time	2.50 min/unit

Figure 102 – Cockpit Test Rigs.



Parameters Rectification Rigs

Area Rectification Station	35.00 meter²
Traffic Area Rectification Station	24.00 meter²
Buffer Stations per Rectification Station	0.50
Area Buffer Station	20.00 meter²

Values Worker Times

Waiting Rate	10.00 %
Handling Time per Vehicle	5.00 min/unit

Invest Values

Technical Invest Rectification Station	42,000.00 €
Invest Filling	500,000.00 €

Results

Number of Rectification Stations	20.00
Buffer Stations Rectification	10.00
Area Requirements Rectification	1,380.00 meter²
Technical Invest Rectification	1,340,000.00 €
Invest of Buildings Rectification	1,380,000.00 €
Total Invest Rectification	2,720,000.00 €
Required Workers Rectification	11.00 worker

Figure 103 – Cockpit Rectification Zone.

It finally can be said that with help of the chosen, very flexible approach it at least was possible to bundle within one network the various planning alternatives of the BMW Group and still to stay within the given tolerance frame of ± 20%.

6.5 Selected Pre-Assemblies

The illustration of the pre-assemblies in this system of key performance indicators only occurred exemplarily with help of well-chosen examples, since every individual pre-assembly requires more or less other criteria / key performance indicators.
Moreover, the pre-assemblies are probably also the section of a final assembly shop where it is most difficult to transfer the dependencies recognised at BMW to other automobile manufacturers. Premium suppliers such as BMW for instance often clearly distinguish from volume suppliers in the vertical integration. Therefore it is most likely, that there are only few comparable pre-assemblies between the different car manufacturers. However, since the developed system of key performance indicators basically is very adaptable, necessary adjustments / increments could be made at any time.

6.5.1 Doors

Since all vehicles own doors, till this day the pre-assembly 'doors' exists with nearly all known automobile manufacturers in comparable way. In one of the first stations in the main assembly line the doors will be dismantled from the painted body and will be carried in special conveyors to a separate pre-assembly area.
Such as the painted body in the main assembly line, the doors will be assembled in numerous production steps in one or several assembly line(s). After completion, the handing over to the conveyor system occurs. Just in sequence it carries back the doors to the end of the main assembly line, where they will be assembled.

Compared to some other pre-assemblies, right at the beginning of the planning process, the basic question must be answered whether the shift model of the pre-assembly is identical with that of the main assembly line. It absolutely could be that some pre-assemblies should run faster than the main assembly line in order to have a buffer in case of any breakdowns. Similarly to the calculation of the number of stations in the main assembly line, this decision influences different other key performance indicators. In the upper left corner figure 104 illustrates the button, where the user can make the choice about the shift model.

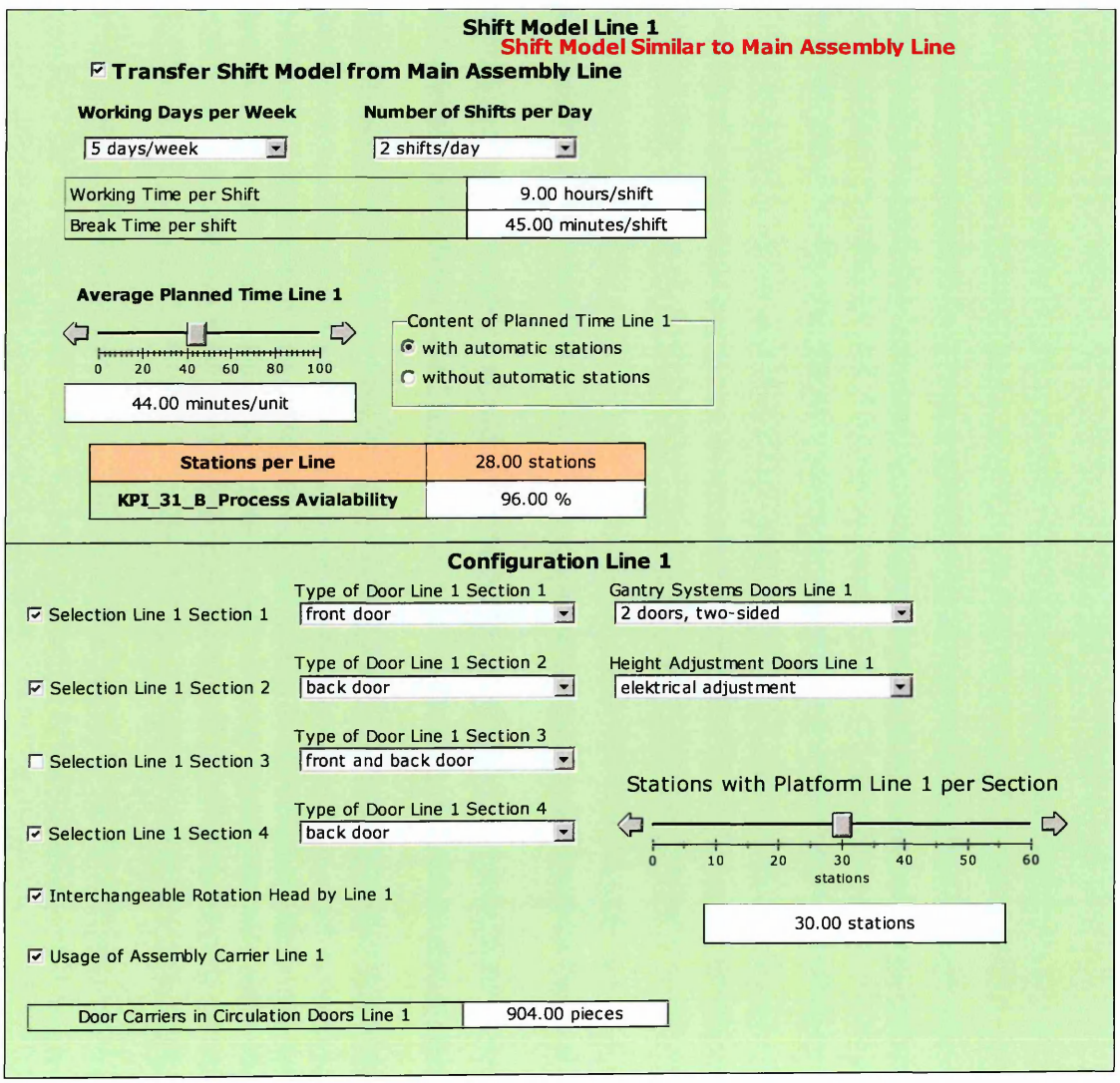


Figure 104 – Cockpit for the Doors.

In addition, the pre-assembly 'doors' offers a huge number of options with regard to the technologies used, the optimum process flows and the required areas. These decisions depend, e.g., on the number of doors that have to be assembled in this pre-assembly. Is it enough, if only vehicles with two doors (= only front doors) or four doors (= front doors and back doors) could be assembled in this new pre-assembly or is it in the middle-term future even necessary to assembly both kinds of cars? How complex are the present doors and the next generation of doors that have to be assembled in this area?
Every individual key performance indicator of level two that will be changed because of new planning premises will cause, as a result of the different key performance indicators in level three (see figure 105), different results in level two and level one.

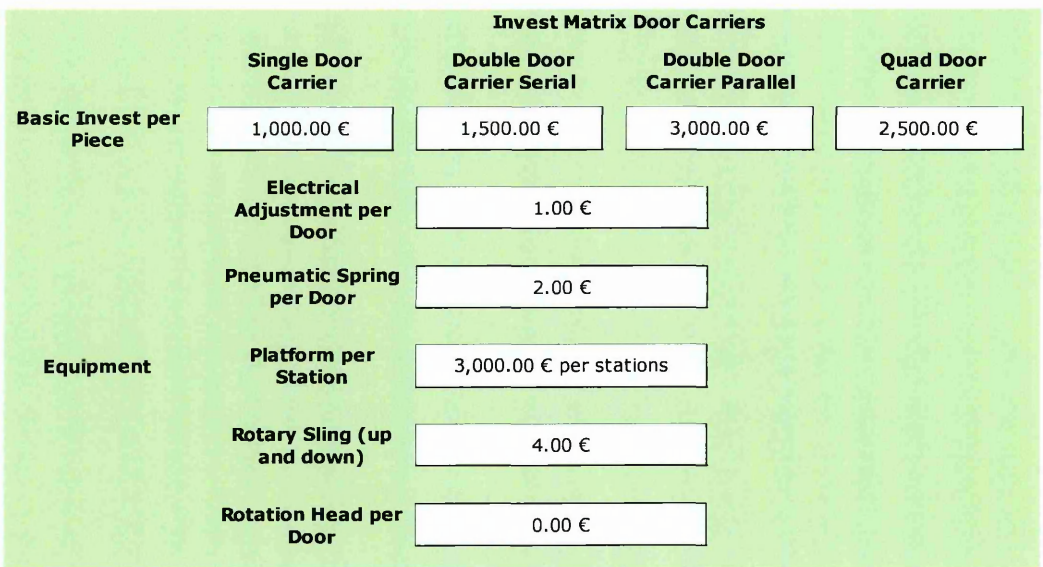


Figure 105 – Key Performance Indicators in Level 3 – Invest Doors.

As in all other areas also, the key performance indicators are linked to each other in a network. Even if the individual key performance indicators are unreadable in this illustration, figure 106 gives an idea of how complicated such a network normally is, since it has to consider all relevant eventualities.

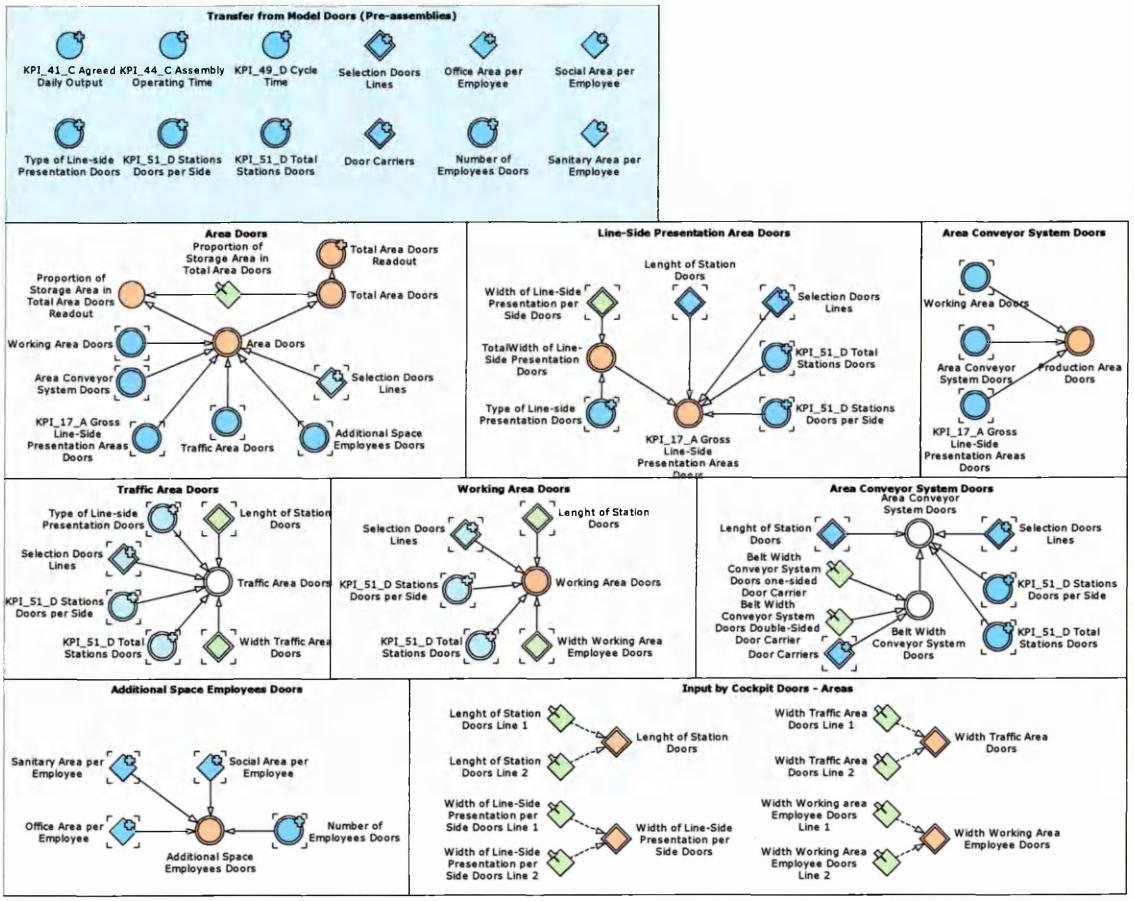


Figure 106 – Complexitiy of the Network.

In spite of all complexity in the background of the model figure 107 demonstrates that the developed system of key performance indicators produces very reliable results if it is used correctly. For a new final assembly shop (= Leipzig) as well as for one of the oldest vehicle plants in Europe (= Munich) and independent of the product range and thus the complexity of the doors the results of the system in the maximum differ from reality only 11.86%.

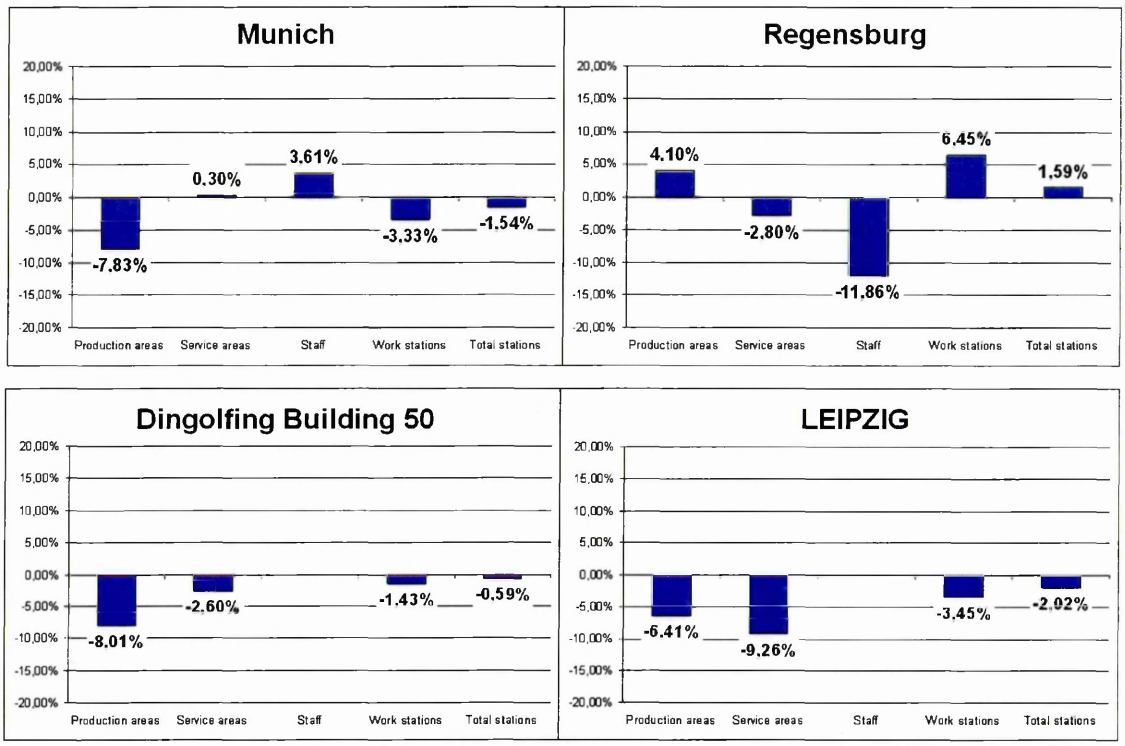


Figure 107 – Deviation of the System Against the Real Values – Doors.

6.5.2 Engine-Gearbox

In view of the outstanding handling characteristics of a car the engine plays an essential role for the BMW Group. Since the joining of the engine and the gearbox is a determining pre-assembly for all automobile manufacturers, the scope of this research project pre-assembly 'engine-gearbox' was also integrated into the developed system of key performance indicators. Figure 108 represents the layout of such an area.

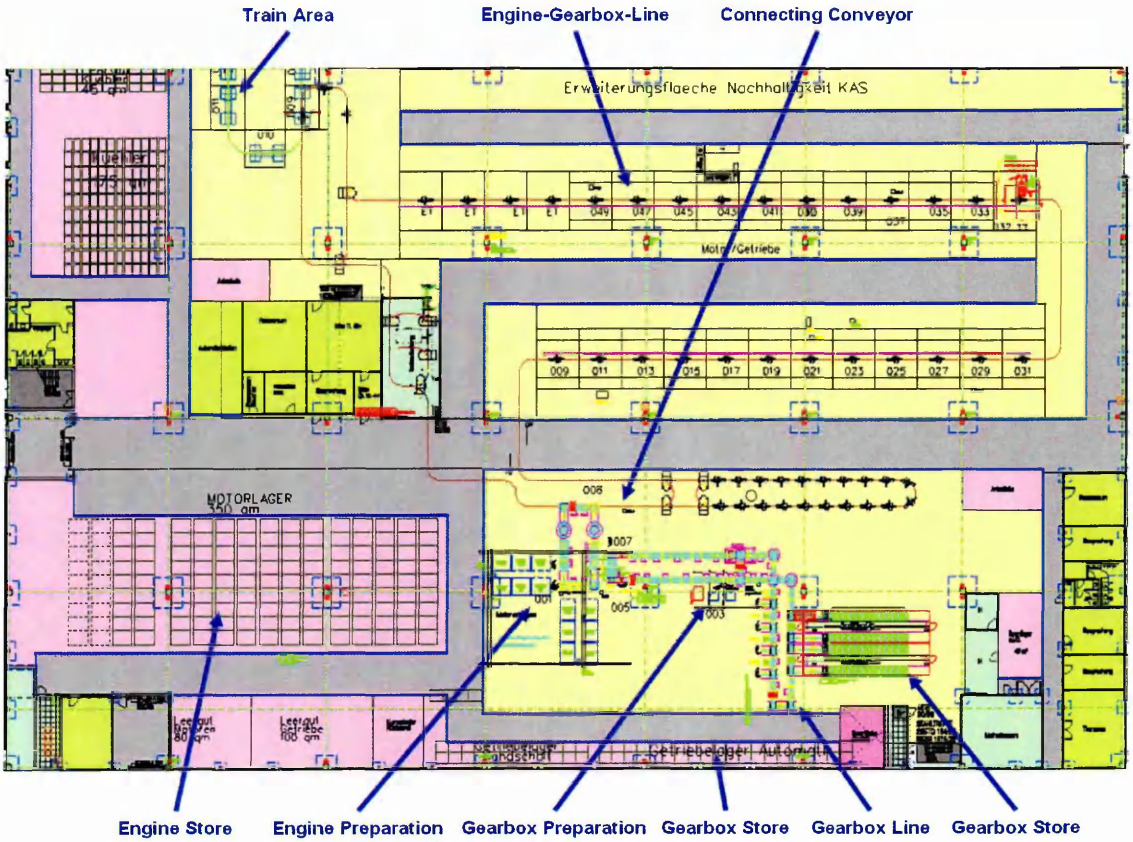


Figure 108 – Layout of an Engine-Gearbox-Line.

As with the pre-assembly 'doors', this segment of a final assembly shop of a car manufacturer is also difficult to compare to other pre-assemblies and again there is a huge number of planning alternatives. For example the question has to be answered, whether this section should be planned with or without a gearbox store, which automatically controls the required sequence of gearboxes.

Once more, the well-chosen conveyor system has a considerable influence on the amount that has to be invested for this section. For the line side presentation area, the size of a container of the engine-gearbox and the degree to which the containers can be filled are important planning premises. During the planning process such planning parameters can change, e.g., in response to new product information, at short notice.

Hence, it is very important that with the developed system of key performance indicators all essential key performance indicators can be illustrated in order to evaluate the different scenarios quickly and reliably.

For the example of the area of the 'engine-gearbox-line', figure 109 demonstrates how the key performance indicators from the different levels (= 1) and the various sections (=2 and 3) finally are summarised in another part of the network.

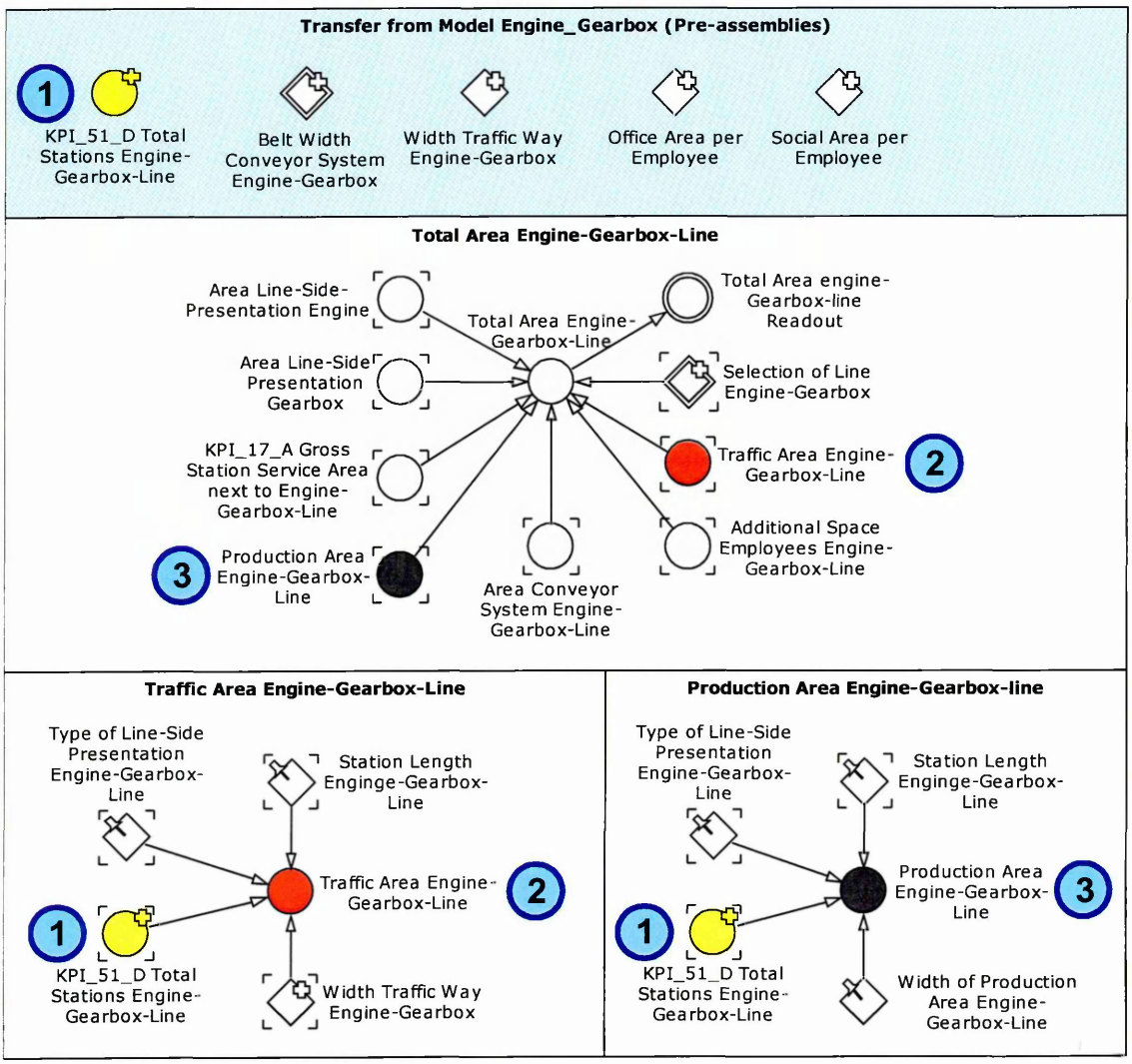


Figure 109 – Network of the Engine-Gearbox-Line.

This network level can be of interest to the planner if he / she wants to better understand the connections between the key performance indicators. However, in order to work with the system of key performance indicators, it is enough if the user carries out the right settings in the cockpit level (see figure 110). This is the determining point in dealing with the system. In the end only the experienced planner can decide which conveyor technology is required, whether a 'gearbox store' makes sense from an economic point of view or whether 'decoupling stations' have to be included in the plan. The developed system of key performance indicators can only support the planner in doing a better job.

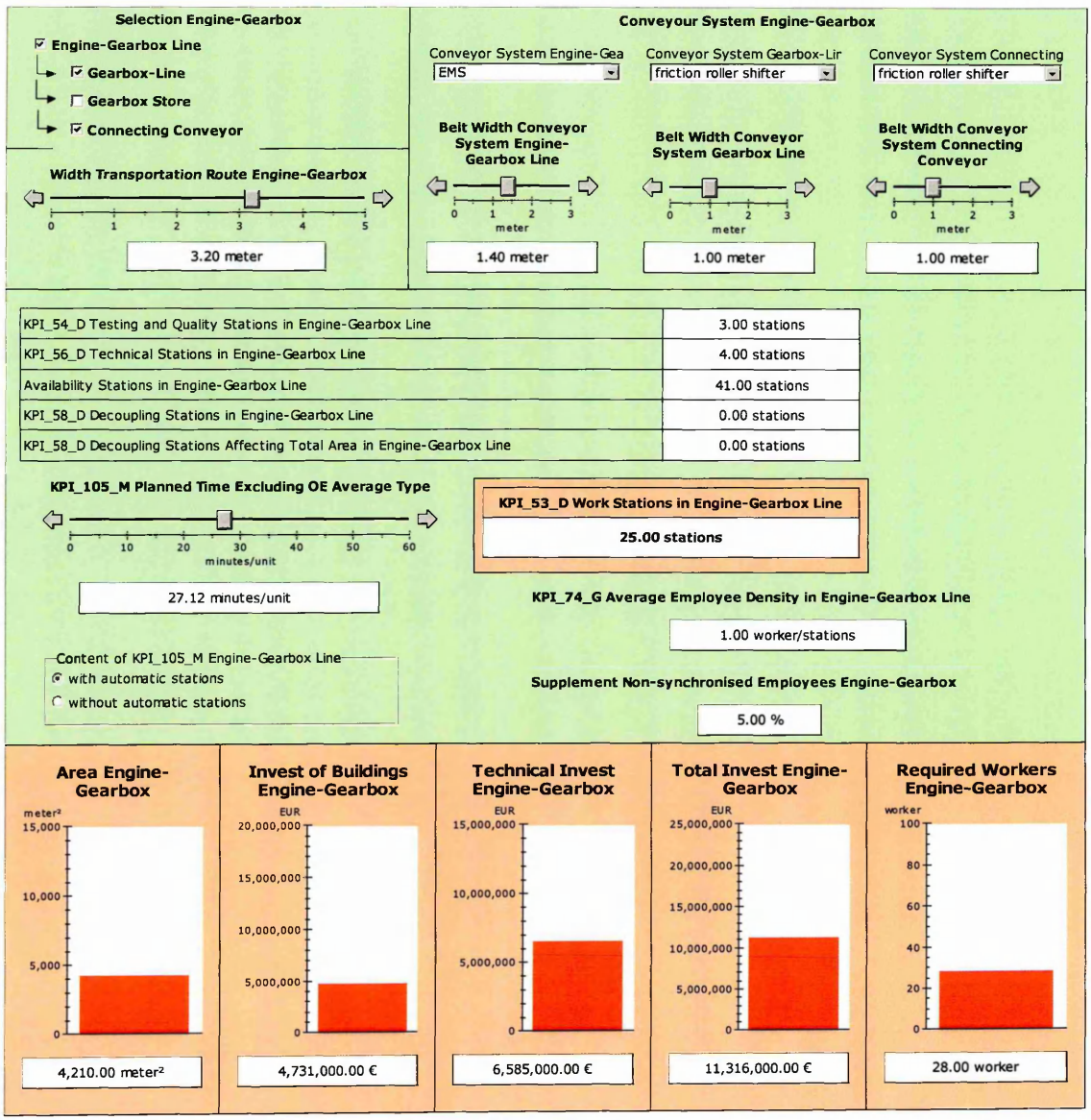


Figure 110 – Cockpit for Engine-Gearbox.

Single sub-areas of this pre-assembly were tested for all locations, but an entire statement is only available for Leipzig and Regensburg (see figure 111). Fortunately, there are only minor deviations between the results of the model and the existing pre-assemblies. Therefore, it seems that at least no important key performance indicator is missing.

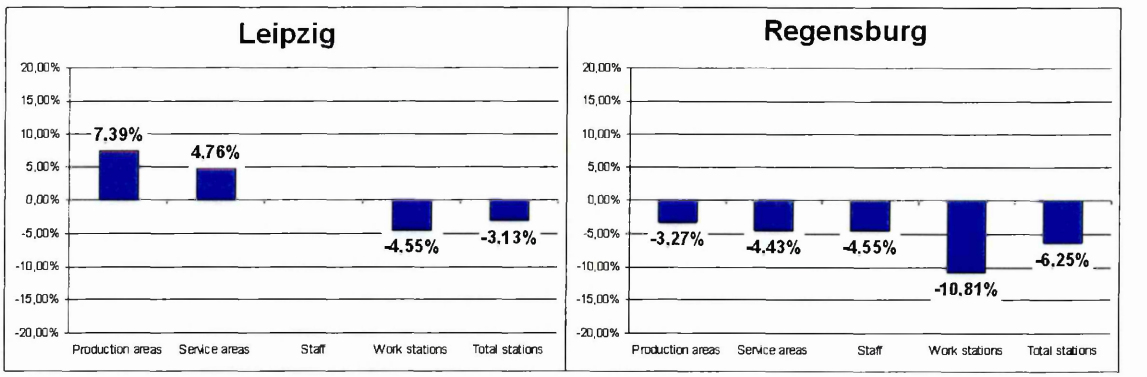


Figure 111 – Deviation of the System Against the Real Values – Engine-Gearbox.

6.5.3 Axles

As the last big pre-assembly the axles were illustrated in the new system of key performance indicators. It was interesting to map this section of a final assembly shop in the model. As a result of the complicated design, this pre-assembly is divided into four sections:

- Front-axle.
- Rear-axle.
- Wheel hub.
- Strut.

In view of possible restrictions of the research results, it is important to know that with the rear-wheel drive, typical for a BMW, suspension struts are part of the front-axles and the wheel hubs are a component of the rear-axles.

In addition to this fact, it is especially worthy mentioning that this is one of a few areas for which the general principle of calculating the required number of stations (see section 6.3) has no validity. As a result of the high level of automation in the 'wheel hub section', the dimensioning of this area is based on the capacity of the facilities itself. If the daily maximum capacity of the facilites is exceeded, a doubling of this area becomes necessary, thus a completely new line with all conveyor systems, machines and so on has to be installed.

Typically for the pre-assembly 'axles', for example are the investments for the manual power screw driver which can be linked to a quality inspection system. For the energy supply, electric supply or compressed air supply can be selected. Also the different torques of the screw drivers will be considered in this system of key performance indicators. The number of handling assistors which become necessary either as a result of the weight of the parts or a very precise joining position can also be entered in the cockpit of the system of key performance indicators. Since the planning results have to make sure that the process runs smoothly, the planning of some emergency strategies could become necessary.

Therefore, it could be sensible to plan that a certain percentage of handling devices will be ordered twice. With the help of various cockpits similarly to that shown in figure 112 these aspects can be considered at the early stages of the planning process.

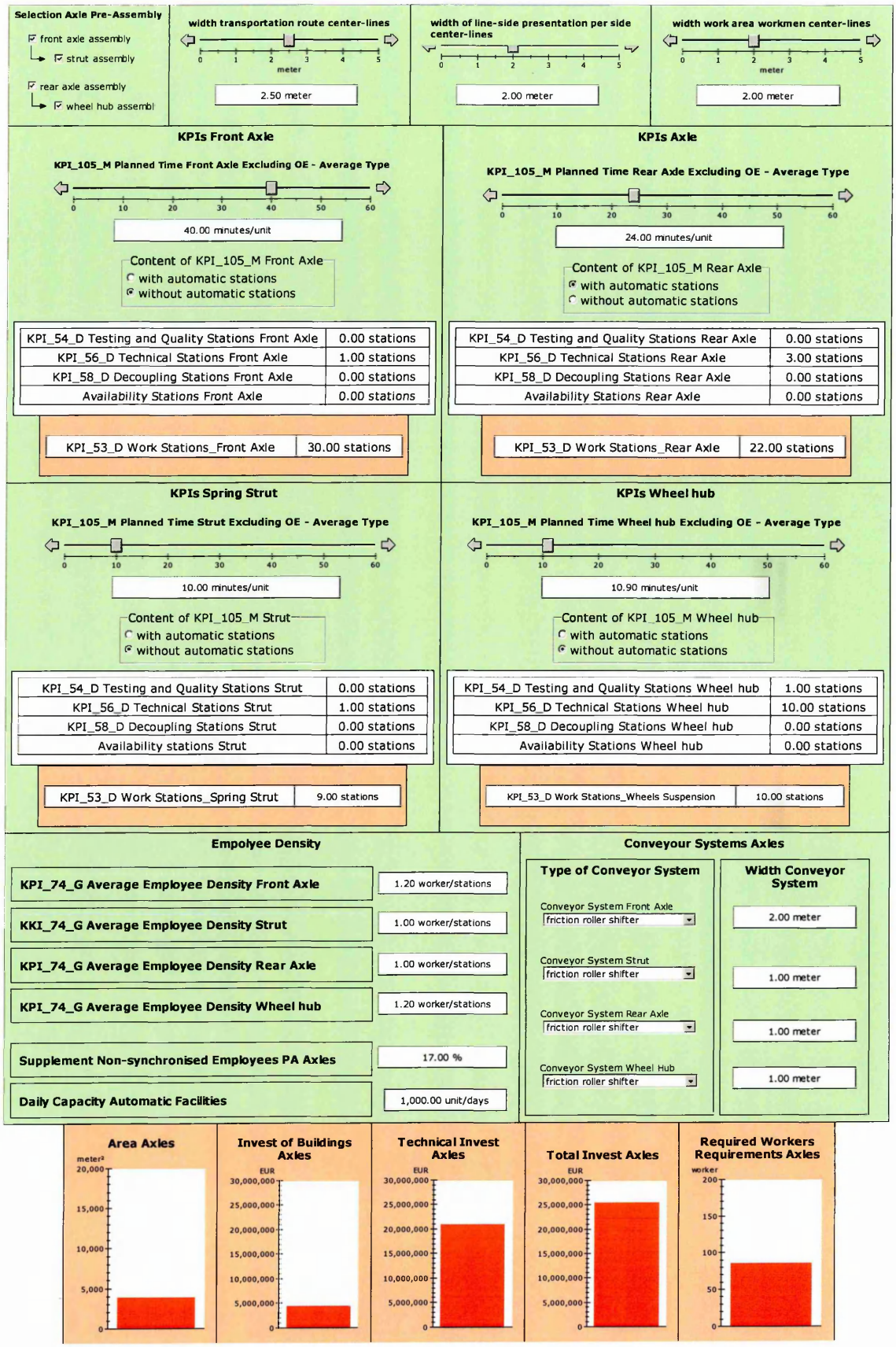


Figure 112 – Cockpit for the Axles.

The example of the network of the 'investments for the manual screwing technology rear axle' (see figure 113) should once more emphasise that the real know-how of this system of key performance indicators is played by the KPI- networks. With the help of such networks the key performance indicators will be calculated and the dependencies between the key performance indicators also will be clearly visualised.

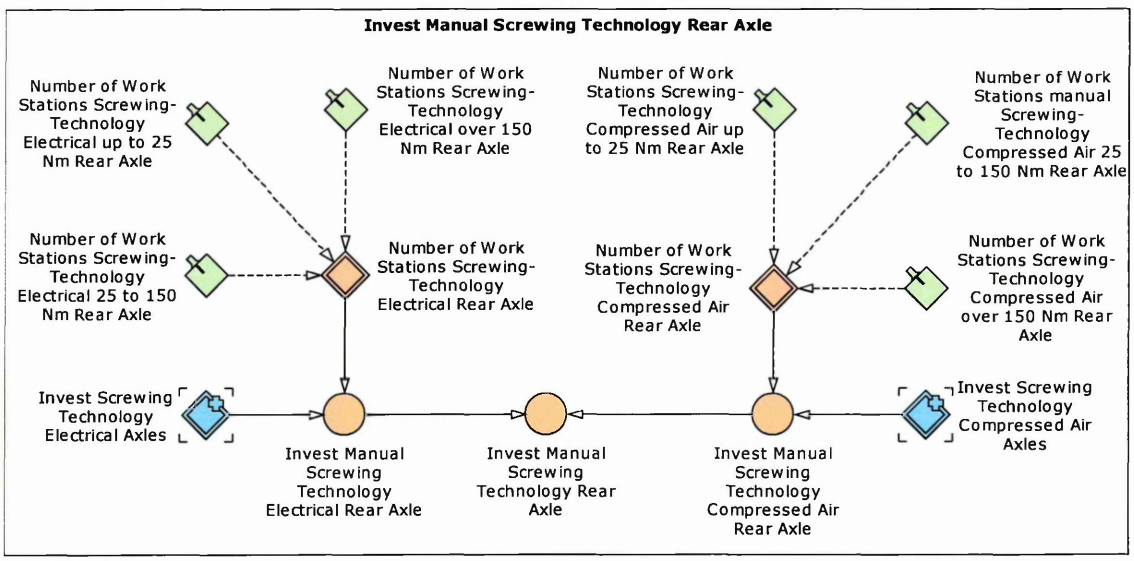


Figure 113 – Network for the Investment of the Manual Screwing Technology – Rear Axle.

For the pre-assembly 'axles' networks, such as the one shown above, have also led to results with which the structures of the BMW Group and most likely of other car manufacturers can be illustrated in sufficient exactness.

Noticeable on figure 114 is the fact that no basic statement can be made on whether the key performance indicators calculated by the system are generally too high or too low.

If the real values of a location are higher than those calculated by the model (= Regensburg), two reasons are possible:

- In Regensburg the pre-assembly 'axles' is dimensioned too large.
- The model does not include all essential key performance indicators.

However, if the values of the model are too high (= Munich), one reason for this distortion could be that the calculated values are based on ideal processes. Perhaps, the age of the location and with it indirectly the availability of area / space plays an essential role. Since plant Munich because of its position in the middle of Munich has to battle with very strong restrictions regarding space, in reality this could lead to smaller figures than those calculated by the model.

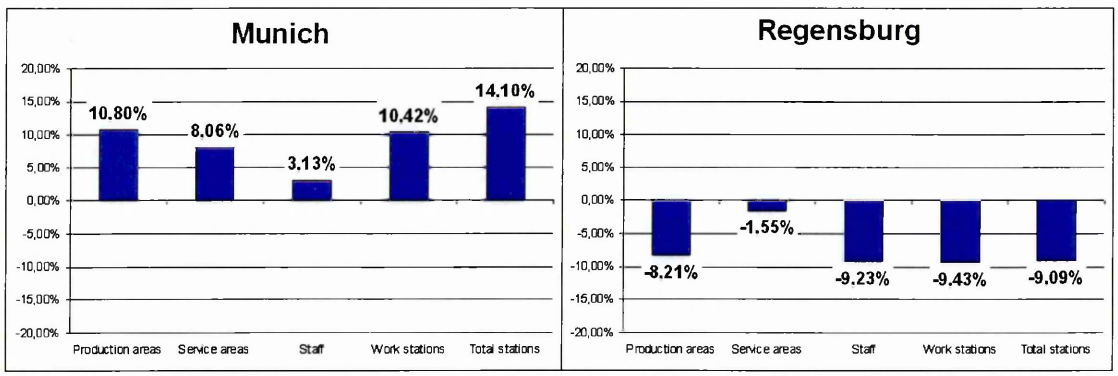


Figure 114 – Deviation of the System Against the Real Values – Axles.

6.6 Sensitivity Analysis with the Help of Different Scenarios

Since the developed system of key performance indicators delivers confidential results in the static area in comparison to the four German BMW locations Regensburg, Munich, Dingolfing and Leipzig in a closing test it should be checked whether the model reacts plausibly with changed key performance indicators. Based on the idea of 'rival theories' and the principle of 'falsification' with slightly changed key performance indicators it should be made sure that the results generated by the model are still logically explainable.

In addition, the quick evaluation of the most different scenarios demonstrates how powerful the developed system of key performance indicators is. While the model requires less than a second to support the planner with reliable results, without the model it would have taken days and weeks to produce results as those illustrated in figure 115. Moreover, without the model it would be very difficult to prove that the calculation of the data is consistent in itself.

	Change	Sensitivity Analysis - Level 1 Figures			
		Areas	Employees	Invest	Cycle Time
Complete Model					
Gross Basic Working Time	10%	-8,0%	-10,2%	-5,1%	10,9%
Agreed Daily Output	10%	7,2%	9,2%	5,5%	-9,2%
Production Days per Year	10%	0,0%	0,0%	0,0%	0,0%
Main Assembly Line					
Process Availability	2%	-1,2%	-1,7%	-0,9%	2,1%
Planned Time Complex Model	10%	4,5%	5,3%	3,0%	0,0%
Body Assembly	On-Off	-42,9%	-53,2%	-27,3%	0,0%
Tilt Assembly	On-Off	-2,9%	-4,8%	-2,0%	0,0%
Final Assembly	On-Off	-6,8%	-5,3%	-6,0%	0,0%
Filling	On-Off	-6,4%	-8,4%	-4,3%	0,0%
Body Assembly					
Planned Time Excluding OE	10%	3,0%	3,4%	1,9%	0,0%
Employee Density Body Assembly	10%	-1,9%	-0,1%	-1,2%	0,0%
Change of Conveyor System	Without Hight Adjustment	0,0%	0,0%	-5,9%	0,0%
Tilt Assembly					
Planned Time Excluding OE	10%	0,2%	0,4%	0,2%	0,0%
Employee Density Tilt Assembly	10%	-0,1%	0,1%	-0,1%	0,0%
Final Assembly					
Testing and Quality Stations	100%	0,2%	0,1%	0,2%	0,0%
Type pf Line-Side Presentation	One-Sided Line Side Presentation	-1,2%	0,0%	-0,3%	0,0%
Filling					
Planned time excluding OE	10%	0,5%	0,7%	0,3%	0,0%
Type of Line-Side Presentation	One-Sided Line Side Presentation	-0,4%	0,0%	-0,1%	0,0%
Change of Conveyor System	Slat Conveyor With Steel Slats	0,0%	0,0%	0,1%	0,0%
Facilities					
Number of Changeover Processes	100%	0,0%	0,0%	1,1%	0,0%
Number of Conveyor Systems Changes	100%	0,0%	0,0%	0,4%	0,0%
Sun Roof	Fully Automated to SA	0,1%	0,3%	-0,9%	0,0%
Cockpit	Fully Automated to Manual	0,1%	0,3%	-1,2%	0,0%
Glazing Glasses	Fully Automated to SA	0,2%	0,5%	-5,5%	0,0%
Marriage	Fully Automated to SA	0,2%	0,2%	-3,5%	0,0%
F1-F2-Area					
Test Rigs	On-Off	-3,8%	-2,1%	-5,5%	0,0%
Finish-A-Lines	Off-On	0,4%	0,0%	0,5%	0,0%
Finish-B-Lines	On-Off	-1,5%	-2,2%	-1,7%	0,0%
F2 Lines	On-Off	-2,0%	-0,5%	-1,8%	0,0%
Rectification (Rework)	On-Off	-1,5%	-0,6%	-0,9%	0,0%
Paintwork Rectification (Repaint)	On-Off	-4,7%	-1,2%	-3,5%	0,0%
Pre-Assemblies					
Doors	On-Off	-11,5%	-6,2%	-7,6%	0,0%
Axles	On-Off	-6,7%	-7,1%	-11,7%	0,0%
Engine Gearbox	On-Off	-8,0%	-3,2%	-6,6%	0,0%

Figure 115 – Results of the Sensitivity Analysis.

While the planner so far had to collect data and also had to make sure that they are harmonious, now he / she can concentrate on his / her real tasks. Evaluations such as the one made above, offers the specialists the chance to learn faster much more about the importance of the individual key performance indicators.

6.7 Summary

In this chapter it was demonstrated that the developed system of key performance indicators generates results of an exactness of ± 20% compared to real values of existing final assembly shops of the BMW Group. The whole system as well as the subordinated parts of the model achieve the demand for accuracy required for the planning of a new final assembly shop of a car manufacturer at the early stages of the planning process. Since the results of different scenarios seem to be plausible as well, there is at the moment no reason to doubt the correctness of the developed system of key performance indicators.

A limiting factor of course could be that all statements are based on information of the BMW Group. Therefore, it cannot be totally excluded that some of the dependencies illustrated in the developed model are only valid with restrictions for other automobile manufacturers (e.g., volume suppliers).

7 Discussion and Conclusion

7.1 Introduction

At the end of this research project the achieved results are compared to the originally formulated aim and its corresponding objectives. In doing so, whether the built model can improve the planning process will be reviewed. At the same time, for the developed system of key performance indicators both limitations and improvement potentials will be critically discussed. Moreover, the contribution to knowledge of this research project will be presented. The last section of this chapter is the conclusion of this research project.
At first, the research methodology is analysed for its strengths and weaknesses.

7.2 Discussion of the Research Methodology

Right at the beginning it should be stressed that the entire research project can be very positively judged. Hence, the author feels confident that the developed system of key performance indicators is helpful for everybody working in this field of interest. Nevertheless, on purpose, some of the following comments are formulated quite critically, because the author would like to indicate potential room for improvement to other researchers.
First of all, the successful data collection was very important for this research project, since the connections between the key performance indicators could only be reliably analysed with high quality primary data. All approaches introduced in chapter 3 and applied in chapter 4 were very useful for this research project. With help of the 'KOPF' (= **K**ey Performance Indicators for an **O**ptimised **P**lanning of a **F**inal Assembly Shop) and additional Excel-spreadsheets, a large volume of quantitative data was defined and recorded. In addition to the absolutely precise definition of the key performance indicators, the agreement about the communication of the collected figures was a very important milestone for the high response rate. Thus, a culture of trust was created, which made it possible to ask for additional figures at the end (= model validation) of this research project.

However, in his position as a moderator and during the interviews with the experts the author could have influenced the research project even unknowingly. Maybe another research colleague would have set different priorities regarding the importance of the individual key performance indicators or regarding the system boundaries. This aspect gets even more important, because the basic concept of this research project (= 'System Theory' & 'KOPF') and with it also the achieved results originate from the author.

Therefore, it is important to point out that there is absolutely no doubt that the collected quantitative and qualitative information can be reproduced any time. In terms of transparency, high standards were set for this research project. In particular, the used software 'Powersim' made a big contribution to the transparency within this research project. All results are based on the dependencies between the various key performance indicators which are all well documented within the network. 'Powersim' gives everyone the chance to understand the illustrated formal model. In terms of a good visualisation of the dependencies between the key performance indicators, 'Powersim' for instance is much better than 'Excel', since it displays the connections in a transparent network and not in one cell of a spreadsheet.

In addition, in contrast to the modelling of a 'virtual world' no 'software engineer' is necessary in this approach. Everyone familiar with a PC can start modelling in 'Powersim' within one day. This is a very important aspect for the transparency too.

The knowledge of the numerous experts is mapped in the network of the developed system. The technique of unstructured interviews used to grasp the qualitative information ran very well, probably because of the close collaboration of BMW colleagues. Therefore, the described advantages of a 'case study' have been confirmed in this research project. Important information which perhaps would not have been accessible with another research strategy could be gathered because of the daily attendance and the employment in BMW.

To realise the potentials offered by a 'case study', it should be mentioned that it was very important to have good communication skills such as 'talking' and 'listening'. For the discussions with the different experts, this was the only way to separate important and unimportant information from each other and to get information at all.

Another significant ability someone should have for this kind of 'case study', is the power to convince other persons. At the different stages of this research project both planners and managers had to be motivated to believe in the chances offered by the new system.

In addition, working with key performance indicators means that a researcher must be neutrally and absolutely diplomatic. With the 'absolute key performance indicators' recorded with the 'KOPF' it would not be a problem at all to generate simple 'ratio key performance indicators' pretending to show weaknesses and advantages of the different final assembly shops and causing a big furore. However, a superficial comparison would have been a fundamental error, because this would have forced the individual locations in a defensive position which would have destroyed the trust culture. Whenever someone wants to be permanently successful in the field of key performance indicators, he / she must very precisely analyse the interdependencies of the various parameters and may not aim at the quick short-term success.

Hence, a lot of time must be included in the plan for the work with key performance indicators, because it has to be made sure that the content of the figures is absolutely comparable and the underlying structure is well understood. This is the only way for an enterprise to gain helpful information and to move foreward.

In contrast to the above mentioned advantages, a case study definitely also implicates some disadvantages. While the availability of data within the BMW Group was very good indeed, an intensive exchange with other companies could not be realised within this research project. Maybe, this is a point of criticism.

Even if one tried to avoid any kind of subjectivity at all stages of the research project, it should be an objective for the future to compare the results of the developed system of key performance indicators to the real values of different automobile manufacturers. Just after such additional tests with other OEMs, the quality of the mapped dependencies, including the theories linked to it, could be judged conclusively.

Altogether, the chosen modules of the 'research methodology' were very useful and made a big contribution to achive valid research results. Hence, it still may be assumed that the results of this research project could support every automobile manufacturer in the world in the challenging task of dimensioning a new final assembly shop.

7.3 Discussion of the Research Aim and Objectives

Of course, in this chapter, the question must also be answered, how far the achieved results solve the original problem from chapter 1 and whether the aim and objectives formulated in chapter 2 could be achieved. As a reminder, the research question as well as the aim of this research project is listed below.

The research question of this research project is as follows:

How are the key performance indicators linked to each other and
is it possible to better consider these interrelationships
at the early stages of the greenfield planning process
for a final assembly shop of a car manufacturer?

According to the research question the following aim was formulated in chapter 2:

Development of a formal model
that considers the complex interdependencies
within a final assembly shop of a car manufacturer
in order to accelerate the planning process and
to increase the quality of planning results.

The achievement of the aim can be reviewed by judging the achievement of the formulated objectives. This examination is accomplished below.

7.3.1 Objective 1 – System Boundaries

Definition of the system boundaries and breakdown of the final assembly shop in general valid and meaningful segments.

This objective is achieved very well. The chosen segments correspond to the current understanding in the automobile industry. The sections precisely described in this thesis are listed below:

- Main Assembly Line (Station 1 to first start of the engine).
  - Body Assembly.
  - Tilt Assembly.
  - Final Assembly.
  - Filling.

- F1 to F2 Area (First start of the engine to hand over to the customer).
  - Test Rigs.
  - Finish Lines.
  - F2-Lines.
  - Rectification Area (= rework).
  - Paintwork Rectification (= repaint).

- Pre-Assemblies.
  - Doors.
  - Engine – Gearbox.
  - Axles.

However, it is possible that the final assembly shops of other car manufacturers are structured slightly differently.

The illustrated segment of pre-assemblies for instance, raises no claim to completeness, since vehicles of volume suppliers most of the time are assembled from more modules than vehicles from the premium segment. Pre-assemblies for the 'cockpit', the 'wheels / tyre' and the 'bumper' to list only some examples, could still be interesting to map. Also in the section of the 'test rigs', slightly different options exist for other car manufacturers. However, the illustrated 'main assembly line' is a standard for the production of more than 10 units per day.

Most of the boundaries for this system of key performance indicators are designed very transparently and can be understood any time. With areas and investments, there is no doubt which sections of a final assembly shop of a car manufacturer can and which cannot be planned with the developed system of key performance indicators.

The precise classification of the staff is difficult and probably remains difficult for the future. Among other challenges, organisational differences strongly influence the precise personnel allocation. Hence, a certain uncertainty about the key performance indicators for the staff still exists at the end of this research project.

This should also be taken into consideration for comparisons of existing final assembly shops. A key performance indicator 'units per employee' is not helpful for anybody as long as there are open questions on subjects such as 'vertical integration', 'temporary staff' and 'system boundaries'. Besides, it must be defined whether the figures should fit to the budget (= financial department) or to the physical attendance (= figures from the personnel department). During the internal benchmarking process (= 'Benchmarking Cube') (see section 4.3) it was demonstrated, how challenging it already can be within one company to make the figures comparable.

7.3.2 Objective 2 – Most Important Key Performance Indicators

Determination of the most important key performance indicators
relevant for the planning processes of a final assembly shop
of a car manufacturer both as input and output dimensions,
taking into account the higher enterprise purposes for this selection.

According to the validation of the model, the developed system of key performance indicators within the system boundaries covers the most important key performance indicators required for the dimensioning of a new final assembly shop of a car manufacturer. This statement can be explained with the results achieved with the developed model, which are all within the given tolerance of ± 20% (see chapter 6). Therefore, it is unlikely that an important lever is missing.

In view of the discussion about the ideal number of key performance indicators this research project tried to disengage from the pretended ideal of 7 to 20 key performance indicators because the basic concept of 'System Thinking' was pursued.

The author is aware that the number of recorded key performance indicators could be criticised for this research project. However, by the clear separation of a final assembly shop in different sections and in different levels the number of the relevant figures often decreases for the individual user. In addition, the results described in chapter 6 have demonstrated that even key performance indicators of the third level, as for example 'cost rate conveying route' can have a considerable influence on planning results. Many systems of key performance indicators have one or two main key performance indicators (e.g., return on investment) on top of the pyramid. The key performance indicators concerning the 'areas', the 'investment costs' and the 'staff' could maybe be regarded as major KPIs. Even so, it should be stressed again that for some planners a KPI such as 'process time of a test rig' can be very important for them and consequently for the planning result.

The key is that by the mathematical connection of all key performance indicators a change of a KPI at the lowest level still has a noticeable influence on other key performance indicators within the system.
However, in spite of these explanations the necessity for every key performance indicator used in the developed system should be critically and continuously questioned.

7.3.3 Objective 3 – Definition

Generally accepted definition of the most important key performance indicators.

With the so-called 'KOPF' (= Key Performance Indicators for an Optimised Planning of a Final Assembly Shop) and the definition of 108 key performance indicators it was tried as part of this research project to define key performance indicators for the final assembly shop of a car manufacturer in a standardised form. At least for the final assembly shops of the BMW Group the above objective is achieved, since the essential key performance indicators are generally defined.
Since the numbering of the 'KOPF' was also applied in the model, it was attempted to ensure that the most important key performance indicators used in the model are defined unambiguously. However, it has to be critically mentioned that the definition has not yet been fixed in a written form for all key performance indicators. Therefore, there is still a slight risk that a few key performance indicators pretending to be clearly defined will be entered in the system with different content, because of a disparate understanding of the users. Since the likelihood of this mistake is very low, no more figures were defined, for reasons of the economic efficiency of the research project.
Finally, it has to be said that the process of doing a benchmarking would be much easier if there would be an agreement of all automobile manufacturers to use the same definitions for the most compared key performance indicators.

Even if some parts of the definitions developed during this research project already have been applied in the OEM-Benchmark of the German automobile manufacturers, there are still potential improvements. The call of a round table for this challenging task is strongly recommended. An adaptation of the definitions (if available) would require continuous co-operation of all OEMs interested in the explanatory power of benchmarking results.
Besides, also the experiences of neutral organisations and management consultancies, as for example 'Harbour' should be taken into consideration as well.

7.3.4 Objective 4 – Analysis of the Dependencies

Analysis of the dependencies between the individual KPIs.

There is no doubt that this objective has been achieved. The dependencies between the different key performance indicators required for planning a new final assembly shop of a car manufacturer were examined and documented in a totally new and unique form.
The results of the developed model presented in chapter 6 demonstrate that the interconnection between the key performance indicators is very well mapped within the scope of the available information. Even if these analyses are the core element of this research project, they still have to be challenged critically. According to the principle of 'falsification' (see section 3.3), with the end of this research project it should be the purpose all researchers and users of the developed system to discover mistakes in the illustrated connections. Are important key performance indicators missing? Do the mapped dependencies fit to other automobile manufacturers? Are there a number of units – for instance the production of five Rolls Royce per day in the final assembly shop of Goodwood – where the logistics is more important for the dimensioning of the required stations than the assembly time? Can the dependencies between the key performance indicators be characterised even better with the help of a regression analysis? What influence do feedback loops and delays have on the dependencies?

Now these kinds of questions have to be answered, because this is the only chance to get more reliable theories about the connections within the system 'final assembly shop of a car manufacturer'. Even if the BMW Group, a leading automobile manufacturer from the premium market, supported this research project, it nevertheless would be good to get additional information from volume suppliers or other premium suppliers.

7.3.5 Objective 5 – User-Friendly Tool

Mapping of the formally described models in a user-friendly tool.

So far, literature about key performance indicators has hardly discussed the options to support the people working in this area with help of software solutions. For future investigations, this research project should inspire everybody not to neglect this aspect. The user-friendly mapping of this huge number of key performance indicators was only possible, since with 'Powersim' a suitable software was found.
Although the advantages of this software were described in detail in chapter 5, it cannot be excluded that there are even better options available. However, for the moment, the selected software definitely was an excellent choice. In view of the original problem, with the developed model it is possible, to better support the planners in the accomplishment of some of the challenges described in chapter 2. Since it is very important for this research project that everyone reading this thesis agrees to the advantages offered by the developed system, both the challenges and the offered advantages are listed below:

- Number of Variants.

  The developed system of key performance indicators offers the possibility to evaluate the consequences of a rising number of vehicles and therefore an increasing number of planning alternatives faster and more precisely.

- Optimisation of the Production Network.

  During this research project, the key performance indicators for four locations of the production network of the BMW Group were stored with the developed model. The figures for additional locations also could be stored easily.

  Even if the model is designed for greenfield plannings, experienced specialists will be supported in doing preliminary estimations regarding the consequences of changed conditions for existing final assembly shops (e.g., areas needed, number of stations required ...). What happens with a changed number of units? What consequences does a new type of car have on existing final assembly shops?

  It is not just that the model can support the process of answering such questions, it also could help to improve the relationship of OEMs and full-service-vehicle-suppliers such as Magna Steyr or Karmann. The system developed could be used to make the statements of external suppliers regarding the required investment costs for building another car much more transparent.

- Difficulties with the Comparability of the Plants.

  Already while entering the key performance indicators in the system, interesting differences between the existing final assembly shops could be identified. Here it is very helpful that all locations have to enter the figures in the same computer model using an absolutely identical structure.

  In addition, the developed system of key performance indicators also demonstrates how critically it can be to compare key performance indicators such as 'units per employee' if there is uncertainty about the boundary conditions (e.g., vertical integration).

- Involvement of Multiple Departments.

  During the planning process of a new final assembly shop normally experts from different departments have to work together. Since they all have to enter their figures in the same model, the system of key performance indicators can easily be distributed within the whole enterprise giving everybody the chance to compare the supposed planning premises.

  In addition, the model automatically makes sure that essential planning premises such as for example 'daily numbers of units' are identical in the whole system.

- Finding the Near Optimum.

  Since all key performance indicators are available in the same model, different scenarios can be rated shortly. Therefore, the likelihood to find a near optimum solution for the complex system 'final assembly shop' increases significantly.

- Lack of Knowledge Management

  Inexperienced personnel in planning or in other departments in the enterprise have the chance to play with the developed system of key performance indicators. Thus, the harmonised understanding of the experts about the complex dependencies within a final assembly shop can be distributed quickly and easily.

  The additional effect that during the process of building the model an exchange of perception could be achieved should also not be underestimated. Therefore, the know-how of all experts and locations involved in the process has already improved during the meetings with other experts.

  Furthermore, the annual values of the individual locations can be stored without additional efforts and consequently have very good availability, i.e. anytime. A very important side effect is the ability to recognise trends in the long-term better than it is currently possible.

- Proactive Cost Management.

  Most different long-term scenarios for the new final assembly shop can be evaluated more easily by the simulation ability of the developed system of key performance indicators. Hence, questions of the following kind can be better answered, so that hopefully wrong investments can be avoided. Should the new final assembly shop take into consideration the forecasted increase of around x% for the daily units built in this plant in 20xx? How is the ratio of add-on costs in comparison to the opportunity?

  What is necessary to integrate an additional type of car in the new final assembly shop in 20zz? Are additional investments justified in view of the required flexibility?

- Shortening of the Planning Process.

  If the developed system of key performance indicators is maintained with the latest figures, first reliable statements regarding the dimensioning of the new final assembly shop can be done quickly. Therefore, the model makes an essential contribution to the agility of the entire enterprise.

7.3.6 Objective 6 – Validation

Validation of the tool with help of existing final assembly shops.

The developed system of key performance indicators has been validated with four German BMW locations, which represent different criteria such as for example number of variants, numbers of units or age of the plant. Since the results of the developed system of key performance indicators in comparison to the real values of these heterogenous plants are within the required tolerance of ± 20%, this is a first indication that the developed system of key performance indicators produces reliable results. The fact that the developed model is also registered at the BMW Group as an official invention (see Appendix C) also gives a hint that the model contains interesting aspects.

Nevertheless, it cannot be completely excluded that locations of other automobile manufacturers would be out of this range. For example the question is left, whether the enterprise culture influences the mapped dependencies between the key performance indicators.

Therefore, it has to be pointed out again that it would be very desirable to validate the new system of key performance indicators with other car manufacturers. Unfortunately, because of the confidentiality of the data it was not possible to carry out such tests within this research project.

To guarantee the objectivity within the research project, at different stages of the design process the model was introduced to external experts such as professors and management consultants to check the ideas and basic connections.

In addition, the results of the sensitivity analysis introduced in chapter 6.6 did not show any indices that the developed model does not generate reliable results. The indicated effects could rather be very helpful for the experts. Such evaluations give the planners the opportunity to value the influence of the individual key performance indicators under the most different criteria much faster. With it a learning effect is also achieved, because the specialists can collect much more experience in a much shorter time.

7.4 Contribution

At the end of this research project for the first time a formal system of key performance indicators is developed that takes into consideration the dependencies between the different key performance indicators necessary for the dimensioning of a new final assembly shop of a car manufacturer. The illustrated connections show reliable theories about the collaboration between various key performance indicators within the final assembly shop of a car manufacturer.

According to the latest information, the holistic concept starting with the definition of the system boundaries and the definition of the key performance indicators to the point of mapping the dependencies in a user-friendly tool is unique for this stage of the planning process not only in the automobile industry but also in factory planning.

Thus, already in the earliest stages of the planning process, the developed system of key performance indicators offers the possibility to evaluate many more different planning alternatives, much more precisely and within shorter time. As no other known tool in this field, it gives the user the chance to take into consideration certain planning premises, as well as to assess the feasibility of such planning premises.

If it is for instance a target that the final assembly shop does not need more than 60,000 square metres, with help of the experience of the experts all the other key performance indicators can be adapted in one system, so that the required total area is smaller or equal to 60,000 square metres. This is comparable to an airplane, where the pilot must carry out other settings for its key performance indicators if he / she would like to fly at 5,000 metres height in contrast to a flying altitude of 10,000 metres.

With a transparent and lasting preparation of the dependencies between the different key performance indicators, the developed system – modelled in 'Powersim' – can also be used as a training tool for new planners or other departments. In this field of research, this can be understood as an essential milestone for the learning organisation.

At the end of this section, it also should be mentioned that the system developed supports the comparison with other automobile manufacturers, because a rough estimate about the coherence of key performance indicators collected from competitors can be made with this tool.

7.5 Limitations

However, by the end of this thesis it should not be hidden that the chosen approach is affected by some restrictions / risks as well.

There is, on the one hand, the complexity of the developed system of key performance indicators. Critics could be sceptical regarding the number of key performance indicators used in the model. Against it, it can be answered that for the future, the options offered by computer industry should be taken into consideration much more at work with key performance indicators.

As demonstrated in this thesis, the number of usable key performance indicators can be raised with intelligent software solutions. In a multi-layered system every user can have a closer look at those key performance indicators which matter to him / her (= applied subjectivity). In addition, everybody should answer the basic question, whether he or she would like to understand and influence the structure of complex systems or whether it is better to follow a simple but perhaps wrong key performance indicator.

The number of key performance indicators used obviously affects the operation of the input / edit mask (= cockpit) of the system. Like with a pilot flying an aeroplane, the operation of the cockpit may look very easy, although a lot of knowledge is actually required.

Hence, even if the cockpit is based on classification systems and also helpful warning notices are included in the model, an unskilled user must schedule a certain training time. In any case, the plausibility of the separated inputs should be verified by an experienced planner.

The explanatory power of this system of key performance indicators, just as of any other system, strongly depends of the data quality. Especially, the annual actualisation of all key performance indicators and all locations could cause problems. Referring to this, two solutions are recognisable.

On the one hand, there must be a central contact for the system who carries out changes on the network and also promotes the updating process.

On the other hand, as a result of acceptance the number of users of the model must reach a level with which the costs for the adjustment of the figures can be justified. If in the future the updating of the data is not automatically demanded by the planners, the system will not be effective anyway. Since with end of this research project, the developed model was given to five BMW locations for their day-to-day work, there is legitimate hope that the lasting implementation of the system was successful.

Finally, it should be stressed again at this point that the mapped dependencies between the key performance indicators have to be questioned critically. Although the achieved degree of accuracy corresponds to the requirements of this planning phase, the investigation about the interaction between the key performance indicators can still be improved. On the one hand, all statements are exclusively based on BMW information and on the other hand smaller mistakes during the data recording process cannot be completely excluded, as the statement of Sterman points out: "The act of measurement introduces distortions, delays, biases, errors, and other imperfections, some known, other unknown and unknowable" (Sterman, 1994).

In addition, linear dependencies between the key performance indicators are implicated which often cannot be found in reality. That this simplification for the original question is allowed, should become clear with help of the following statement of Zheng and Possel-Dölken (2002): "The number of relevant parameters that are required for an exact calculation are by no means determinable and the parameter amount would anyway be too huge to be processed. Therefore, the unpredicted non-linear behaviour of the system can never be excluded. [...] Any complex system has these points of resonance where certain input conditions cause a non-linear, often not predictable, and sometimes not controllable behaviour."

The called points lead to the fact that the exactness of the system can only be slightly improved. Maybe a tolerance frame of ± 10% still would be practicable. A tool more precise then ± 10% should be restricted to the individual locations, otherwise the number of useless key performance indicators would increase.

7.6 Recommendations for Further Research

The above statements should demonstrate that the author in agreement with Staudt et al. is aware that every model building process provides an opportunity for criticism, but also offers the chance for further developments (Staudt et al., 1985). The most significant developing potentials are briefly described in this section.

A very exciting next step could be the analysis of a final assembly shop following the idea of 'System Dynamics'. How does the system 'final assembly shop of a car manufacturer' behave, if 'feedback loops' and 'delays' are taken into consideration? While the developed system of key performance indicators had the target to better support the planning of a greenfield final assembly shop, from a dynamic model, highly interesting knowledge could be gained for the optimisation of a brownfield final assembly shop.

In terms of better planning results for an entire plant the developed model could be extended to other shops of an automotive plant. Thus, for instance, many planners have mental models about the ideal processes between the final assembly shop and the logistics, responsible for the material supply. However, as a result of many influencing parameters the question in terms of the 'big picture' is not yet answered. Which parameters have to be considered and which values the key performance indicators should have so that, for example, the building of 'car-sets' makes sense? However, for being able to do this, the product complexity (e.g., material codes) would have to be illustrated much more exactly.

Moreover, if there is the chance to enlarge the developed system of key performance indicators with other car manufacturers, additional pre-assemblies and maybe different test rigs would have to be mapped. In doing so, perhaps a 'regression analysis' could improve the exactness of the illustrated interconnections between the key performance indicators. Every additional final assembly shop, with which the model can be successfully validated, raises the explanatory power of the theories derived from it.

In spite of the concept of 'System Theory' it sometimes perhaps is possible, to dimension a new final assembly shop with less key performance indicators, since the theories about the dependencies are definitive, as described on the example of 'Pepsi' and 'Coke' in section 2.7.7.2. Therefore, for the future it should be the purpose of everybody to indicate weak spots in the developed system, following the idea of 'falsification' (see section 3.3).

In any case, this research project has demonstrated that, particularly the beginning of the planning process for a new factory, offers improvement potentials regarding the effective support by tools. For the agility of an enterprise it can be extremely economic, to support the experts in the planning process with better tools, so that they can meet the expectations described in section 2.5.2.

Even if this work concentrates exclusively upon the planning of a new final assembly shop of a car manufacturer, it finally should be stressed that the basic concept can also be transferred on other industries. Every enterprise or network with several locations can use the advantages introduced in this thesis. For instance, it would be interesting to illustrate, e.g. the dependencies between the key performance indicators required for the planning of an airport or a hospital in this form.

7.7 Conclusion

To summarise, it can be pointed out that with this research project, for the first time key performance indicators were defined specific for the planning of an automotive final assembly shop. In view of both the significance and the comparability of key performance indicators this was an essential basis for the results achieved with this research project.

In a next step, the collected absolute key performance indicators were not summarised to simple ratio key performance indicators with the help of 'Excel', as usually done so far. In fact, with the help of 'Powersim', the numerous key performance indicators were linked to each other in a huge system of key performance indicators following the basic concept of 'System Theory'.

Thus, in the early stages of the planning process, the dependencies between the different planning parameters can be a great deal better taken into consideration.

With the help of an input / edit mask (= cockpit) the planner has the chance to evaluate the most different scenarios for a new final assembly shop in shorter time and with better exactness. The results of the developed system are all within the limits of tolerance (± 20%).

In addition, the developed model offers a huge number of improvements, helping the planner to master various challenges of the planning process.

Therefore, the developed system of key performance indicators is definitely helpful to improve the agility of an enterprise.

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Appendix A – KOPF

KOPF

KPIs for an Optimised Planning of a Final Assembly Shop

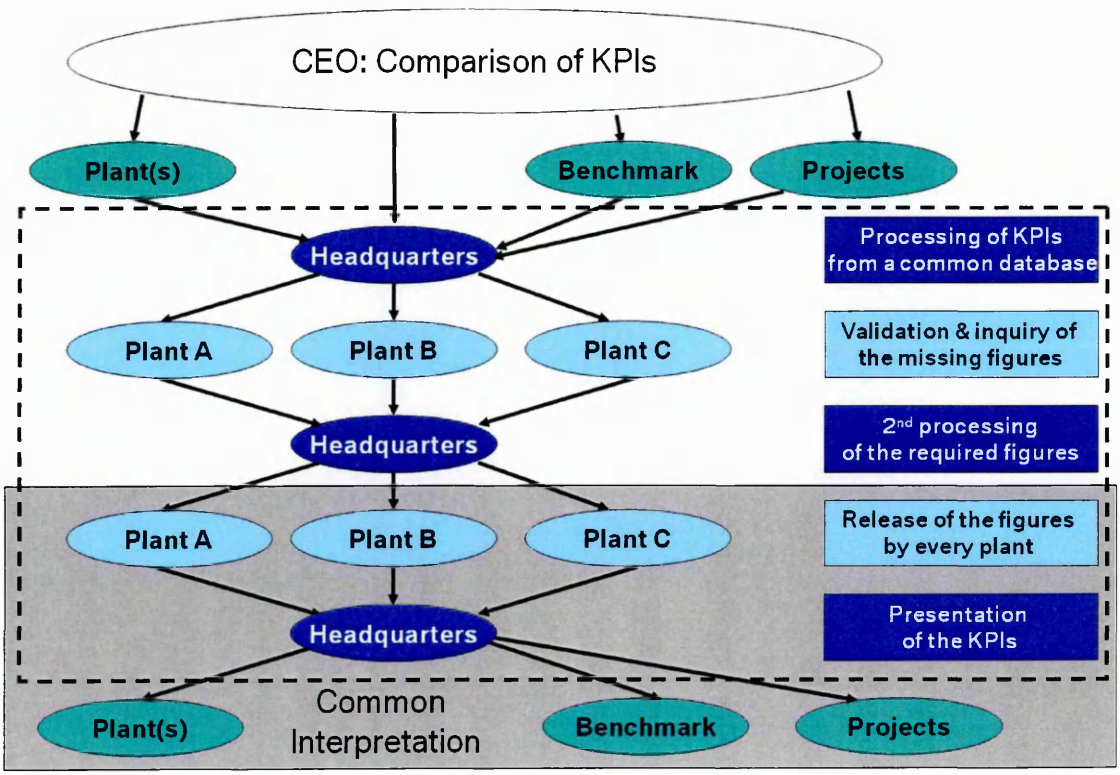
TECHNOLOGIE MONTAGE

22/02/2005

The pages that follow set out the definitions of the terms used on the KOPF system. The KOPF system for providing **k**ey performance indicators for **o**ptimised **p**lanning of a **f**inal assembly shop pursues the following seven main objectives:

- Unambiguous definition of the expressions used in planning departments.
- Continuous collection and distribution of relevant planning information
- Transparency of information sources between plants and across technologies.
- Fast and reliable prediction at the earliest planning stages.
- Constant monitoring of relevant trends.
- Comprehensive analysis of complex interrelationships.
- Prioristisation of long-term planning priorities.

Figures may only be communicated in connection with the KOPF system if they match the definition specified in this document. In order to ensure that information is up-to-date and content is comparable, the process set out below must be observed by all those involved.



At this point it should be pointed out that neither the catalogue nor the annually recorded KOPF figures are subject to systematic revision. That means that if in doubt, you must contact TI-40 to make sure that you definitely have the latest information.

If alteration / expansion of the key terms or of the content of a KPI should be necessary, it must first be cleared with TI-40 or the contacts at the plants.

In common with the individual contacts, I am convinced that by introducing the KOPF system we have taken a ground-breaking step in assembly technology that will help us to meet the challenges in vehicle assembly planning even more successfully in the future.

Following the three compilations completed to date, the fourth collection based on the definitions set out in this document is central to the development of the key performance indicator system. The figures collected must be of the highest integrity as they form the basis for the following topics:

- Continuing development of strategic key performance indicators.
- Background information for benchmarking of final assembly shops.
- Long-term plant development at the individual locations.
- Completion of plant comparisons with external competitors.
- Processing of the figures in a model based on System Theory.

Finally, it should be pointed out that this version of KOPF will contain inter-divisional assembly-related key figures for the first time. The excellent collaboration with our colleagues at TG-20 should not go without mention.

München, 27.01.2005



A Key Performance Indicators – Area

KPI_001_A	Net floor area, main assembly building (excluding supply centres)	m²
Definition Key Term	**Net basic area** **Entire floor area** (= plan view of floor space) of the building concerned excluding walls. **Main assembly building** Permanent building(s) (not temporary start-up areas [minimum 6 months]) in which the main assembly line (= Work station 1 to point F2) is located or which is/are directly connected to that/those building(s). A separate supply centre linked via conveying systems is not classed as part of the main assembly building.	
Content	Total of the net areas of the main assembly building (**excluding ouside areas**). Non assembly-related areas (= areas that are not used by Tx-1 or Tx-4) such as areas for the works fire service must be explicitly specified! Areas underneath **canopy rooves** are **not** to be included at this point.	
Significance	Ideal degree of area utilization	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_002_A	Net basic area of all assembly buildings	m²
Definition Key Term	**Net basic area** **Only** the **assembly-related part** (= areas used by Tx-1, Tx-4 or assembly suppliers in the supply centre) of the floor area (= plan view of floor space) of the building concerned excluding walls. **Assembly building** **All** permanent **buildings** involved in **assembly** (not temporary start-up areas [minimum 6 months]) **within** or **a short distance from** (= max. 30km) the **factory grounds**.	
Content	Total of the net floor areas of all buildings involved in assembly (**excluding outside areas**) on or near to (within 30 km of) the factory grounds. Areas for separate planning offices/administration buildings / head-office buildings are not to be included at this point. Areas underneath **canopy rooves** are **not** to be included at this point.	
Significance	Ideal degree of area utilization	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_003_A	Area requirements, main assembly building	m²
Definition Key Term	Area requirements Rectangular area covering the 4 outermost corners of the **main assembly building**. **Main assembly building** Permanent building(s) (not temporary start-up areas [minimum 6 months]) in which the main assembly line (= Work station 1 to point F2) is located or which is/are directly connected to that/those building(s). A separate supply centre linked via conveying systems is not classed as part of the main assembly building.	
Content	Rectangular area requirement for the main assembly building the actual shape of which may be a complex polygon. Basis is the wall plan of the ground floor!	
Significance	Assembly area requirement on the factory grounds	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_004_A	Useful area, main assembly building	m²
Definition Key Term	**Useful area** Area actually usable by Assembly, e.g. as production area, logistics area, employee amenity area, office space or service area. Useful areas also include partial areas such as platforms. Platforms must, however, have a completely closed floor surface (no grilles) in order to qualify as useful areas. **Main assembly building** Permanent building(s) (not temporary start-up areas [minimum 6 months]) in which the main assembly line (= Work station 1 to point F2) is located or which is/are directly connected to that/those building(s).	
Content	Total of the useful areas available for assembly (criterion: closed floor surface) in the main assembly building (**excluding outside areas**). Simplest case: Gross area of the main assembly building multiplied by the levels.	
Significance	Ideal degree of area utilization	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_005_A	Useful area of all assembly buildings	m²
Definition Key Term	**Useful area** Area actually usable by Assembly or suppliers, e.g. as production area, logistics area, employee amenity area, office space or service area. Useful areas also include partial areas such as platforms. **Assembly building** **All** permanent **buildings** involved in **assembly** (not temporary start-up areas [minimum 6 months]) **within** or **a short distance from** (= max. 30km) the **factory grounds**.	
Content	Total of all useful areas available to Assembly in the assembly buildings (**excluding outside areas**). Areas for separate planning offices / administration buildings / head-office buildings are not to be included at this point.	
Significance	Ideal degree of area utilization, measuring of platform areas	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_006_A	Main assembly building traffic area	m²
Definition Key Term	**Traffic area** Part of the net basic area that is used for access to the rooms, for traffic within the building, and for exiting the building in case of an emergency. **Main assembly building** Permanent building(s) (not temporary start-up areas [minimum 6 months]) in which the main assembly line (= Work station 1 to point F2) is located or which is/are directly connected to that/those building(s). A separate supply centre linked via conveying systems is not classed as part of the main assembly building.	
Content	Sum of the following traffic areas in the main assembly building: • Main production paths • Main logistics paths • Workshop paths • Access to production lines • In-house transport • Elevator systems • Stairwells • Internal ramps • Corridors • Escape balcony • Visitor paths Traffic areas in separate warehouses (engine store, high-rise storage-rack warehouse) are not included in this quantity.	
Significance	Ideal degree of area utilization	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_007_A	Main assembly building office space	m²
Definition Key Term	**Office space** Area for office activities, meetings or planning groups, for example. **Main assembly building** Permanent building(s) (not temporary start-up areas [minimum 6 months]) in which the main assembly line (= Work station 1 to point F2) is located or which is / are directly connected to that/those building(s). A separate supply centre linked via conveying systems is not classed as part of the main assembly building.	
Content	Sum of the following main office spaces in the main assembly building: Single office inc. Foreman's office (space for offices at the main assembly line must be specified separately) • Open-plan office • Office area for projects • Meeting pools within the office • Outer office • Office area for external partners This key figure **also includes main office spaces** such as employee offices, works council offices, etc., that **do not belong to Tx-4.** Areas for separate planning offices/administration buildings/head-office buildings are not to be included at this point.	
Significance	Ideal degree of area utilization	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_008_A	Main assembly building employee amenity area (break-time areas)	m²
Definition Key Term	**Employee amenity area (break-time area)** Area used for amenities provided for the benefit of employees. **Main assembly building** Permanent building(s) (not temporary start-up areas [minimum 6 months]) in which the main assembly line (= Work station 1 to point F2) is located or which is/are directly connected to that / those building(s). A separate supply centre linked via conveying systems is not classed as part of the main assembly building.	
Content	Sum of the following employee amenity areas (break-time areas) in the main assembly building: • Vending machine rooms • Leisure time rooms • Rest areas • Kitchens • Rest areas for pregnant employees/disabled employees • Worship areas • Areas for storing valuables	
Significance	Ideal degree of area utilization	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_009_A	Main assembly building sanitation areas	m²
Definition Key Term	**Sanitation area** Area required for providing basic changing/wash room/toilet facilities for employees. **Main assembly building** Permanent building(s) (not temporary start-up areas [minimum 6 months]) in which the main assembly line (= Work station 1 to point F2) is located or which is/are directly connected to that/those building(s). A separate supply centre linked via conveying systems is not classed as part of the main assembly building.	
Content	Sum of the following sanitation areas in the main assembly building: • Changing rooms • Wash rooms • Toilet facilities • Broom closets	
Significance	Ideal degree of area utilization	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_010_A	Logistics areas, external, total - Assembly	m²
Definition Key Term	**Logistics areas - Assembly** Areas available for utilization as part of the materials supply chain for Assembly. **External** Areas that are not on but are near to (within 30 km of) the factory grounds. **Total** No distinction is made between areas that are planned by Assembly and those that are planned by Logistics.	
Content	Sum of the external Logistics areas listed below: • Main logistics area • Idle equipment areas • Direct delivery areas • Buffer areas • Loading/unloading areas • High-rise storage rack areas (= floor plan area) • Consignment areas • ... • Secondary logistics area This figure also includes rental areas with a minimum rental period of >1 year. This figure is independent of the operator.	
Significance	Ratio of logistics area to production area	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_011_A	Logistics areas, plant total - Assembly	m²
Definition Key Term	**Logistics areas - Assembly** Areas available for utilization as part of the materials supply chain for Assembly. **Plant** Areas that are on the factory grounds. **Total** No distinction is made between areas that are planned by Assembly and those that are planned by Logistics.	
Content	Sum of the following internal logistics areas **(excluding outside areas)**: • Main logistics area • Idle equipment areas • Direct delivery areas • Buffer areas • Loading/unloading areas • High-bay storage areas (parts, **not bodies**) • Commissioning areas • ... • Secondary logistics area The station service area adjacent to the assembly line is not included in this figure as it is explicitly itemised under KPI_16_A. Areas underneath **canopy rooves** are **not** to be included at this point.	
Significance	Ratio of logistics area to production area	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_012_A	Direct delivery areas, plant total – Assembly	m²
Definition Key Term	**Direct delivery areas - Assembly** Area used for deliveries directly from suppliers or external warehouses without intermediate storage and therefore without warehouse stock entries. **Plant** Areas that are on the factory grounds. **Total** No distinction is made between areas that are planned by Assembly and those that are planned by Logistics.	
Content	Direct delivery area (inc. areas with canopy rooves)	
Significance	Ratio of direct delivery area to total logistics area	
Definition source		
Figure source	Area information system	Plant

KPI_013_A	Consignment areas, plant total - Assembly	m²
Definition Key Term	**Consignment areas - Assembly** Area in which personnel place groups of parts in job-related consignments or in special cases job-related sequences. **Plant** Areas that are on the factory grounds. **Total** No distinction is made between areas that are planned by Assembly and those that are planned by Logistics.	
Content	Commissioning areas	
Significance	Ratio of consignment area to total logistics area	
Definition source		
Figure source	Area information system	Plant

KPI_014_A	Loading/unloading areas, plant total - Assembly	m²
Definition Key Term	**Loading/unloading areas - Assembly** Area on which loading, unloading or transfer operations take place. Generally, they will be preceded/succeeded by a transport or storage process. On loading/unloading areas, neither transport nor storage functions are the primary activity; short-stay areas. **Plant** Areas that are on the factory grounds. **Total** No distinction is made between areas that are planned by Assembly and those that are planned by Logistics.	
Content	Loading/unloading areas (trailer depots/areas in front of lifts)	
Significance	Ratio of loading/unloading area to total logistics area	
Definition source		
Figure source	Area information system	Plant

KPI_015_A	Total assembly logistics areas – Main assembly building	m²
Definition Key Term	**Assembly logistics areas** Areas that are available for the Assembly materials supply chain and are located in the main assembly building. **Total** No distinction is made between areas that are planned by Assembly and those that are planned by Logistics. **Main assembly building** Permanent building(s) (not temporary start-up areas [minimum 6 months]) in which the main assembly line (= Work station 1 to point F2) is located or which is/are directly connected to that/those building(s). A separate supply centre linked via conveying systems is not classed as part of the main assembly building.	
Content	Sum of the following internal logistics areas: • Main logistics area • Idle equipment areas • Direct delivery areas • Buffer areas • Loading/unloading areas • High-bay storage areas (parts, **not bodies**) • Commissioning areas • ... • Secondary logistics area The station service area adjacent to the assembly line is not included in this figure as it is explicitly itemised under KPI_16_A.	
Significance	Ratio of logistics area to production area	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_016_A	Gross station service areas next to main assembly line	m²
Definition Key Term	**Gross station service areas** Areas next to the main assembly line (= Work station 1 to point F1) on which materials are placed for direct or indirect availability (including short-term supplies). **Total** No distinction is made between areas that are planned by Assembly and those that are planned by Logistics.	
Content	Station service areas (gross area) next to the main assembly line. This figure also includes areas such as those for foremen's offices if they are on the station service area.	
Significance	Ratio of station service area to total Assembly logistics area	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_017_A	Gross station service areas next to selected pre-assembly lines	m²
Definition Key Term	**Station service areas** Areas next to selected pre-assembly lines on which materials are placed for direct or indirect availability (including short-term supplies) **Total** No distinction is made between areas that are planned by Assembly and those that are planned by Logistics.	
Content	Station service areas (gross area) next to the following pre-assembly lines. • Engine / Gearbox / MAT • Bumpers, front and rear • Rear suspension (inc. spring strut) • Front suspension (inc. spring strut) • Doors • Front end • Wheels / tyres • Wiring package • Cockpit module (inc. centre console) • Roof liner/roof module This figure also includes areas such as those for foremen's offices if they are on the station service area.	
Significance	Ratio of station service area to total Assembly logistics area	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_018_A	Total main assembly building direct delivery areas – Assembly	m²
Definition Key Term	**Direct delivery areas - Assembly** Area used for deliveries directly from suppliers or external warehouses without intermediate storage and therefore without warehouse stock entries. **Main assembly building** Permanent building(s) (not temporary start-up areas [minimum 6 months]) in which the main assembly line (= Work station 1 to point F2) is located or which is/are directly connected to that/those building(s). A separate supply centre linked via conveying systems is not classed as part of the main assembly building. **Total** No distinction is made between areas that are planned by Assembly and those that are planned by Logistics.	
Content	Direct delivery area (inc. areas with canopy rooves)	
Significance	Ratio of direct delivery area to total logistics area	
Definition source		
Figure source	Area information system	Plant

KPI_019_A	Total main assembly building consignment areas – Assembly	m²
Definition Key Term	**Consignment areas - Assembly** Area in which personnel place groups of parts in job-related consignments or in special cases job-related sequences. **Main assembly building** Permanent building(s) (not temporary start-up areas [minimum 6 months]) in which the main assembly line (= Work station 1 to point F2) is located or which is/are directly connected to that/those building(s). A separate supply centre linked via conveying systems is not classed as part of the main assembly building. **Total** No distinction is made between areas that are planned by Assembly and those that are planned by Logistics.	
Content	Commissioning areas	
Significance	Ratio of consignment areas to total logistics area	
Definition source		
Figure source	Area information system	Plant

KPI_020_A	Total main assembly building loading/unloading areas – Assembly	m²
Definition Key Term	**Loading/unloading areas - Assembly** Area on which loading, unloading or transfer operations take place. Generally, they will be preceded/succeeded by a transport or storage process. On loading/unloading areas, neither transport nor storage functions are the primary activity; short-stay areas. **Main assembly building** Permanent building(s) (not temporary start-up areas [minimum 6 months]) in which the main assembly line (= Work station 1 to point F2) is located or which is/are directly connected to that/those building(s). A separate supply centre linked via conveying systems is not classed as part of the main assembly building. **Total** No distinction is made between areas that are planned by Assembly and those that are planned by Logistics.	
Content	Loading/unloading areas (trailer depots/areas in front of lifts)	
Significance	Ratio of loading/unloading area to total logistics area	
Definition source		
Figure source	Area information system	Plant

KPI_021_A	Total main assembly building logistics buffer areas – Assembly	m²
Definition Key Term	**Logistics buffer areas - Assembly** Area for use for internal deliveries from supply centres or stores that are assembly or assembly-line related. This area is characterised by the fact that it is a medium-stay area for materials. **Main assembly building** Permanent building(s) (not temporary start-up areas [minimum 6 months]) in which the main assembly line (= Work station 1 to point F2) is located or which is/are directly connected to that/those building(s). A separate supply centre linked via conveying systems is not classed as part of the main assembly building. **Total** No distinction is made between areas that are planned by Assembly and those that are planned by Logistics.	
Content	Buffer areas	
Significance	Ratio of buffer area to total logistics area	
Definition source		
Figure source	Area information system	Plant

KPI_022_A	External pre-assembly areas (BMW-operated)	m²
Definition Key Term	**External** Areas that are not on but are near to (within 30 km of) the factory grounds. **Pre-assembly areas** Area beyond the main assembly line in which, ideally, entire modules are produced.	
Content	Total of all external pre-assembly areas operated by BMW. The large external pre-assembly areas listed below are to be individually itemised if present: • Engine / Gearbox / MAT • Bumpers, front and rear • Rear suspension (inc. spring strut) • Front suspension (inc. spring strut) • Doors • Front end • Wheels / tyres • Wiring package • Cockpit module (inc. centre console) • Roof liner/roof module This figure also includes the respective logistics area, such as station service areas.	
Significance	Ideal degree of area utilization, assembly process	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_023_A	Internal pre-assembly areas (BMW-operated)	m²
Definition Key Term	**Internal** Areas that are on the factory grounds. **Pre-assembly areas** Area beyond the main assembly line in which, ideally, entire modules are produced.	
Content	Total of all internal pre-assembly areas operated by BMW. The large internal pre-assembly areas listed below are to be individually itemised if present: • Engine / Gearbox / MAT • Bumpers, front and rear • Rear suspension (inc. spring strut) • Front suspension (inc. spring strut) • Doors • Front end • Wheels / tyres • Wiring package • Cockpit module (inc. centre console) • Roof liner/roof module • Separate areas for substitute production This figure also includes the respective logistics area, such as station service areas.	
Significance	Ideal degree of area utilization, assembly process	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_024_A	Main assembly line (Work station 1 to F1) production area (inc. station service areas)	m²
Definition Key Term	**Production area** The width of the production area is made up of the conveyor unit width, the width of the aisles between the main assembly line and the station service area adjacent to the main assembly line, and the width of the direct station service area adjacent to the main assembly line. The length of the production area is measured from work station 1 to the point F1. In the case of parallel production lines, the length of each individual line is added together to obtain the length of the production area. **Work station 1** Work station at which the bodyshell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Sum of the production areas for the main assembly line.	
Significance	Ideal degree of area utilization	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_025_A	Production area, F1 to F2, all assembly buildings	m²
Definition Key Term	**Production area** The width of the production area is made up of the conveyor unit width, the width of the aisles between the conveyor unit and any station service areas, and the width of the station service area if present. The length of the production area is measured from the point F1 to the point F2. In the case of parallel production lines, the length of each individual line is added together to obtain the length of the production area. The areas for the transfers between the various assembly lines should also be included. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point. **Point F2** End of the assembly line. On reaching this point, the vehicle is passed on to Distribution/Sales. **Assembly building** **All** permanent **buildings** involved in **assembly** (not temporary start-up areas [minimum 6 months]) **within** or **a short distance from** (= max. 30km) the **factory grounds.**	
Content	Sum of the production areas from F1 to F2. This figure includes production inspection areas (= KPI_26_A). This figure does not include any rectification areas or areas for test tracks, analysis centres, etc.	
Significance	Ideal degree of area utilization	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_026_A	Production inspection areas, all assembly buildings	m²
Definition Key Term	Areas for test stands (roller-type test stand, track-type test stand, ABS test stand, or exhaust test stand) as a subset of KPI_25_A. **Assembly building** **All** permanent **buildings** involved in **assembly** (not temporary start-up areas [minimum 6 months]) **within** or **a short distance from** (= max. 30km) the **factory grounds.**	
Content	Sum of the production inspection areas	
Significance	Ideal degree of area utilization	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_027_A	Off-line rectification areas, all assembly buildings	m²
Definition Key Term	**Off-line rectification** Rectification that does not place on the main assembly line between work station 1 and the point F1. **Rectification areas** Area designated for rectification work (inc. road testing and leaks) on vehicles and on which rectification work is actually carried out. **Assembly building** **All** permanent **buildings** involved in **assembly** (not temporary start-up areas [minimum 6 months]) **within** or **a short distance from** (= max. 30km) the **factory grounds**.	
Content	Total of specially designated rectification areas (in which rectification is actually carried out) in the assembly buildings. The rectification area in the main assembly building must be explicitly itemised. This figure **does not include** areas for quality audits, traffic areas, vehicle analyses, rectification in pre-assembly areas, paintwork rectification, B.I.W. rectification or rectification areas integrated in the main assembly line.	
Significance	Ideal degree of area utilization	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_028_A	Paintwork rectification areas, all assembly buildings	m²
Definition Key Term	**Paintwork rectification area** Area designated for paintwork rectification and in which painting or dismantling/reassembly is carried out. **Assembly building** **All** permanent **buildings** involved in **assembly** (not temporary start-up areas [minimum 6 months]) **within** or **a short distance from** (= max. 30km) the **factory grounds**.	
Content	Total of specially designated paintwork rectification areas (in which painting or dismantling/reassembly takes place) in the assembly buildings. The paintwork rectification area in the main assembly building must be explicitly itemised.	
Significance	Ideal degree of area utilization	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_029_A	Area for analysis centres, all assembly buildings	m²
Definition Key Term	**Analysis centre** Area used for analysis of specific vehicles/functions. **Assembly building** **All** permanent **buildings** involved in **assembly** (not temporary start-up areas) **within** or **a short distance from** (= max. 30km) the **factory grounds**.	
Content	Total of specially designated analysis areas (e.g. bodywork, E/E, chassis, drivetrain, leak testing) in the assembly buildings.	
Significance	Ideal degree of area utilization	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

KPI_030_A	Area of factory grounds (Main assembly line)	m²
Definition Key Term	Area enclosed by the perimeter fence of the factory grounds on which the building housing the main assembly line is located.	
Content	Area enclosed by the perimeter fence of the factory grounds	
Significance	Ideal degree of area utilization	
Definition source	Adapted for assembly according to allocated usage (DIN 277)	
Figure source	Area information system	Plant

B Key Performance Indicators – Productivity

KPI_031_B	Process availability, main assembly line (Work station 1 to F1)	Percent
Definition Key Term	**Process availability** Availability refers to the probability that a component or system will be found to be fully functioning at a given time. For Assembly, the system is the area from Work station 1 to the point F1. **Work station 1** Work station at which the bodyshell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Process availability from Work station 1 to point F1 in the specified review period t. F1 units / Process units F1 (staffing calculation figure) Only disruptions which result in a reduction in units at the point F1 are taken into account. The following types of stoppage are to be explicitly itemised: • **Technical** stoppages (e.g. photoelectric barrier defective, EHB fault, lifting equipment fault, etc.) • **Organisation-related** stoppages (e.g. team discussions, collective breaks, shortages of materials, assembly problems, etc.) • **System-related** stoppages **(knock-on effects)** Reciprocal effects from preceding/succeeding production sections (e.g. shortage of vehicles, vehicle backlog, gantry-system backlog, gantry shortage, empty skid shortage, etc.)	
Significance	Process stability; Decoupling stations required; F2-On schedule	
Definition source	Adapted for assembly according to VDI 3649	
Figure source	KapFlex: availability / equipment availability	Plant

KPI_032_B	Average throughput time, F1 to F2	Minutes
Definition Key Term	**Throughput time** Time taken for the vehicle to pass from a defined starting point to a defined finishing point. The throughput time is made up of the operation completion time, idle time and waiting time. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point. **Point F2** End of the assembly line. On reaching this point, the vehicle is passed on to Distribution/Sales.	
Content	Average throughput time between the points F1 and F2 for the F2 vehicles produced in the reporting period t The reporting period should extend to at least four weeks. In Assembly, the times for the following areas are always included: test stand times, buffer times, rectification time, paintwork rectification time, time on the finishing lines, time on Line F2. The percentage distribution according to the following scheme is desirable: 0-5 hours; 5-10 hours; 10-15 hours; 15-20 hours; 20-30 hours; 30-40 hours; 40-50 hours; 50-60 hours; 60-80 hours; >100 hours	
Significance	Structural optimization	
Definition source		
Figure source		Plant

C Key Performance Indicators – Final Assembly Shop General

KPI_033_C	Basic working hours (gross)	Hours per week
Definition Key Term	**Basic working hours, gross** Gross basic working hours is the number of hours from start of shift to end of shift. That is the period for which employees are present. The figure is based on the collectively agreed working hours.	
Content	The gross basic working hours should be expressed as follows: Shifts x Hours per shift x Working days per week	
Significance	Transparency in statements of capacity	
Definition source		
Figure source	KapFlex: presence	Plant

KPI_034_C	Basic working hours (net)	Hours per week
Definition Key Term	**Basic working hours (net)** The net basic working hours is the number of hours for which an employee can be productively employed.	
Content	The net basic working hours is calculated as follows: Basic working hours (gross) [KPI_33_C] - Unpaid breaks - Paid breaks Team meetings are not deducted at this point.	
Significance	Transparency in statements of capacity	
Definition source		
Figure source	KapFlex: working hours net [h per week]	Plant

KPI_035_C	Basic working hours (net) inc. extensions to working hours	Hours per week
Definition Key Term	**Basic working hours (net)** The net basic working hours is the number of hours for which an employee can be productively employed. **Extensions to working hours** Extensions to working hours are additional working hours that are required to produce units that cannot be accommodated within the basic capacity. Examples include working through breaks (coffee/lunch breaks), extended shifts, additional shifts (night shifts, special shifts).	
Content	The net basic working hours inc. extensions to working hours are calculated as follows: Basic working hours (net) [KPI_34_C] + Extensions to working hours (net) All figures are to be expressed as follows: Shifts x Hours per shift x Working days per week = Hours per week	
Significance	Transparency in statements of capacity	
Definition source		
Figure source		Plant

KPI_036_C	Assembly production days per year as per production programme	Days per year
Definition Key Term	Number of days per calendar year on which production of vehicles is to take place at a location according to the agreed production programme.	
Content	Agreed number of production days at a location according to production programme.	
Significance	Plant capacity utilisation	
Definition source		
Figure source		Plant

KPI_037_C	Assembly annual capacity – production programme	Units per year
Definition Key Term	Number of units to be produced by a location's assembly facility in a year according to the current production programme.	
Content	Number of units to be produced annually according to the current production programme.	
Significance	Plant capacity utilisation	
Definition source		
Figure source		Plant

KPI_038_C	Assembly daily unit output as per production programme	Units per day
Definition Key Term	Number of units to be produced by a location's assembly facility in a day according to the current production programme.	
Content	Number of units to be produced daily according to the current production programme. The Assembly daily unit output as per production programme is calculated as follows: Assembly annual capacity as per production programme [KPI_37_C] divided by Assembly production days per year as per production programme [KPI_36_C].	
Significance	Vehicles per employee/per area/...	
Definition source		
Figure source		Plant

KPI_039_C	Agreed Assembly production days per year	Days per year
Definition Key Term	Agreed number of days per calendar year on which production of vehicles is to take place at a location.	
Content	Number of production days at a location agreed in long-term plan.	
Significance	Plant capacity utilisation	
Definition source		
Figure source		Plant

KPI_040_C	Agreed Assembly annual capacity	Units per year
Definition Key Term	The agreed annual capacity forms the basis for production planning in the LUP period and is the yardstick for assessing structural changes. It represents the long-term and sustainable output of vehicles per time unit by a plant.	
Content	Number of units to be produced annually as currently agreed for Assembly.	
Significance	Vehicles per employee / per area/...	
Definition source		
Figure source		Plant

KPI_041_C	Assembly agreed daily output	Units per day
Definition Key Term	The agreed daily output forms the basis for production planning in the LUP period and is the yardstick for assessing structural changes. It represents the long-term and sustainable output of vehicles per time by a plant.	
Content	Number of units to be produced daily as currently agreed for Assembly. The agreed Assembly daily unit output is calculated as follows: Agreed Assembly annual capacity [KPI_40_C] divided by Agreed Assembly production days per year [KPI_39_C].	
Significance	Vehicles per employee/per area/...	
Definition source		
Figure source		Plant

KPI_042_C	Annual base capacity Assembly	Units per year
Definition Key Term	The annual base capacity is the base operation time (without extensions to working hours) and represents the basis of normal budget.	
Content	Number of units to be produced annually within the Annual base capacity Assembly	
Significance	Separation Normal / Special Budget	
Definition source		
Figure source	KapFlex	Plant

KPI_043_C	Max. annual capacity Assembly	Units per year
Definition Key Term	The maximum annual capacity represents the maximum quantity that can be produced during the period of two years	
Content		
Significance	KapFlex -Strategy	
Definition source		
Figure source	KapFlex	Plant

KPI_044_C	Assembly operating time (planned)	Minutes per day
Definition Key Term	**Assembly operating time (planned)** Operating time planned under consideration of availability losses for the main assembly line (Work station 1 to point F1) and within which the planned daily unit output at F1 is to be achieved. **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point. This value takes into consideration, reduces caused by process availability (KPI_31_B).	
Content	Assembly planned operating time in minutes.	
Significance	Work station requirement; Number of persons required on the main assembly line	
Definition source		
Figure source		Plant

KPI_045_C	Units per hour – planned	Units per hour
Definition Key Term	**Units per hour – planned** The units per hour planned is the project-specific and/or technology-specific defined output (including CKD, SKD and substituted quantities) after taking account of the defined availability.	
Content	The design unit output is calculated as follows: Units per hour required to achieve agreed annual capacity. This value takes into consideration, reduces caused by process availability (KPI_31_B).	
Significance	Vehicles per employee/per area/...	
Definition source		
Figure source		Plant

KPI_046_C	Assembly technical maximum hourly output	Units per hour
Definition Key Term	The technical maximum hourly output is determined by the bottleneck installation. It indicates how many units an hour can be produced with 100% availability on the basis of technical constraints.	
Content	Units per hour at point F1 that can be produced based on technical constraints. This value is based on a theoretical maximum of 100% availability.	
Significance	Transparency in statements of capacity	
Definition source		
Figure source	KapFlex: technical hourly output	Plant

KPI_047_C	Units in course of assembly	Units
Definition Key Term	**Units in course of assembly** Average number of units that are simultaneously between Status 53 and the point F2 on a particular day. **Status 53** Defined point at the start of the assembly line. This is not necessarily identical with Work station 1. **Point F2** End of the assembly line. On reaching this point, the vehicle is passed on to Distribution/Sales.	
Content	Number of units that are simultaneously in the course of assembly (between Status 53 and the point F2) according to the production schedule..	
Significance	Area requirements; Capital tie-up	
Definition source		
Figure source		Plant

KPI_048_C	Units produced in the past	Units per year
Definition Key Term	F2 vehicles excluding CKD/SKD	
Content	Number of units produced by the plant in the past according to the production schedule.	
Significance	Actual unit production	
Definition source		
Figure source	http://www6.muc/gesamtlogistik/11/index.htm	TI-40

D Key Performance Indicators – Stations

KPI_049_D	Cycle time (takt time), main assembly line (Work station 1 to F1)	Seconds
Definition Key Term	Time required by a body on the main assembly line to pass through one cycle / one station.	
Content	Station/cycle time currently achieved in Assembly.	
Significance	Work station requirement; Employee density	
Definition source	Automotive industry	
Figure source		Plant

KPI_050_D	Line Balancing on the main assembly line (Work station 1 to F1)	Percent
Definition Key Term	**Line Balancing** Time difference between vehicles requiring different work operations including variations due to systems and processing sequences. This time difference prevents employees being able to work to full capacity. For more detailed information, refer to Appendix A. **Work station 1** Work station at which the bodyshell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Percentage representing the degree to which workers on the main assembly line are working below full capacity.	
Significance	Process planning and variant complexity	
Definition source		
Figure source	LEMO II	Plant

KPI_051_D	Total stations (Work station 1 to F2)	Quantity
Definition Key Term	**Total stations** Total number of stations (work stations [including fully automated stations], rectification stations [in-line & off-line], paintwork rectification stations, availability stations, decoupling stations, test stand stations, finishing line stations, F2 line stations) available in Assembly. **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F2** End of the assembly line. On reaching this point, the vehicle is passed on to Distribution/Sales.	
Content	Total number for all stations from Work station 1 to point F2. This figure does not include any stations in the analysis center, for B.I.W. rectification, for repaint rectification or in synchronized pre-assembly areas.	
Significance	Structural optimisation; DLZ; Cycle ratio	
Definition source		
Figure source		Plant

KPI_052_D	Essential body stations (Work station 1 to F2)	Quantity
Definition Key Term	**Essential stations** Minimum number of stations (work stations, rectification stations [in-line only], availability stations, technical stations, test stand stations, finishing line stations, F2-line stations) that a body must pass through under ideal circumstances (excluding off-line rectification, only one of x parallel lines) within the present assembly structure. **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F2** End of the assembly line. On reaching this point, the vehicle is passed on to Distribution/Sales.	
Content	Minimum number of stations from Work station 1 to point F2 that a body must pass through. Decoupling stations which it may be able to pass through more quickly should be counted.	
Significance	Structural optimisation	
Definition source		
Figure source		Plant

KPI_053_D	Work stations in the main assembly line (Work station 1 to F1)	Quantity
Definition Key Term	**Work station** Station at which the vehicle body is actually worked on or which is necessary for the assembly process of a vehicle. The assembly work may be performed either manually (by a person), semi-automatically or automatically (by a robot). **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point. **Body assembly** Vehicle is on skid or conveyor Possible tasks: wiring harness, plugs, hinges, fitting of vehicle interior. **Tilt line** Vehicle on Tilt line, adjustable angle of rotation. Possible tasks: underbody paneling on body, engine compartment interior panels, wiring package, fuel system, wheel arch lining, fitting to underbody and sill areas. **Final assembly** Vehicle on gantry hanger Core component: marriage, underbody, fitting of wheels, fitting of front and rear ends, engine compartment connections **Filling/loading** Vehicle is on conveyor (standing on its own 4 wheels) Possible tasks: filling with fluids (fuel, air con refrigerant, washer fluid, brake fluid), loading of data, etc...	
Content	Number of pure work stations in the main assembly line The following areas are to be explicitly itemized: • Body assembly • Tilt line • Final assembly • Filling/loading Availability stations, testing and quality stations, and decoupling stations are not included in this figure.	
Significance	Degree of automation; cycle ratio	
Definition source		
Figure source		Plant

KPI_054_D	Testing and quality stations in the main assembly line (Work station 1 to F1)	Quantity
Definition Key Term	**Testing stations (Work station 1 to F1)** Stations in the main assembly line where the vehicle undergoes standard inspection. **Quality stations (Work station 1 to F1)** Stations that are provided exclusively for rectification on the line. **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Total number of testing and quality stations in the main assembly line. Testing and quality stations are to be explicitly detailed.	
Significance	Possibility for in-line rectification	
Definition source		
Figure source		Plant

KPI_055_D	Test stand stations after F1	Quantity
Definition Key Term	**Test stand station** Permanent station at which essential function tests are performed on the vehicle. At present covers the following: Track-type test stands, roller-type test stands, ABS test stands, exhaust/ELDI test stands,... **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	List of all test stand stations after the point F1 at which scheduled vehicle tests are carried out. The figure is to be expressed as follows: a Lines x b Stations = c Test stand stations after F1 The testing time at each test stand station should be specified for the relevant type under review.	
Significance	Structural optimisation - bottlenecks	
Definition source		
Figure source		Plant

KPI_056_D	Technical stations in the main assembly line (Work station 1 to F1)	Quantity
Definition Key Term	**Technical station** Station at which the vehicle cannot be worked on but which is necessary due to the sequence of the assembly line structure. This generally involves the following areas: • Change-over processes • Road transfers • Change of conveyor direction with interruption • Feed/Pull-out stations before the lifting stations • Feed/Pull-out stations before the automation stations • Feed/Pull-out stations before decoupling areas **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Number of the technical stations in the main assembly line	
Significance	Cycle ratio	
Definition source		
Figure source		Plant

KPI_057_D	Fully automated stations in the main assembly line (Work station 1 to F1)	Quantity
Definition Key Term	**Fully automated station** Work station at which the productive work is performed without human intervention. These may be stations in window-bonding installations or sunroof robots, for example. **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Number of the fully automated stations in the main assembly line Doesn't include fully automated stations of changing paint- / sill bars.	
Significance	Automation in assembly	
Definition source		
Figure source		Plant

KPI_058_D	Decoupling stations in the main assembly line (Work station 1 to F1)	Quantity
Definition Key Term	**Decoupling station** Station that is used to increase the overall availability, in other words also referred to as a **buffer** station. No work is carried out at this station. **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Number of decoupling stations in the main assembly line. Feed/pull-out stations for the decoupling area (technology stations) and conveyor stations in the decoupling area (technology stations) are not included in this figure. The maximum figure must be specified, i.e. it should be assumed that the buffer is completely full.	
Significance	Availability optimisation; Throughput time	
Definition source		
Figure source		Plant

KPI_059_D	Finishing line stations	Quantity
Definition Key Term	**Finishing line** Line on which the final adjustments to the vehicle are made. The following list provides examples of the possible operations involved: Paintwork checks, final light checks, E/E operations ... The figure is to be expressed as follows: a Lines x b Stations = c Finishing line stations If this line incorporates work stations, they should be explicitly itemized. If there are more than one finishing line (finishing lines 1 and 2 or finishing lines A and B) the stations should be individually itemized.	
Content	Number of stations on the finishing line/finishing lines	
Significance	Structural optimization; Cycle ratio	
Definition source		
Figure source		Plant

KPI_060_D	F2 line stations	Quantity
Definition Key Term	**F2 line** Line on which the vehicle is prepared for delivery. The end of this line at point F2 marks the finish of the assembly process. The following list provides examples of the possible operations involved: Place owner's manual in vehicle, apply wax, ... **Point F2** End of the assembly line. On reaching this point, the vehicle is passed on to Distribution/Sales.	
Content	Number of stations on the F2 line. The figure is to be expressed as follows: a Lines x b Stations = c F2 line stations If this line incorporates work stations, they should be explicitly itemized.	
Significance	Structural optimisation; cycle ratio	
Definition source		
Figure source		Plant

KPI_061_D	Off-line rectification stations/storage areas after F1	Quantity
Definition Key Term	**Off-line rectification stations/storage areas** Station separate from the assembly lines where one or more work stages must be repeated due to insufficient quality. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Number of off-line rectification stations after F1. If the rectification stations are allocated to different areas such as finishing line, F1 rectification or road test rectification, those areas should be explicitly specified. This value does not include stations/storage for repaint rectification or for B.I.W. rectification.	
Significance	Cycle ratio; throughput time	
Definition source		
Figure source		Plant

KPI_062_D	Floor-based conveying system stations (no wheels reqd.) on main assembly line (Work station 1 to F1)	Quantity
Definition Key Term	**Floor-based conveying system** Station at which the body shell is conveyed by a floor-based system. **No wheels required** The conveying system used should not require that the wheels have been fitted. **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Number of work-, availability-, testing- and quality stations on main assembly line with floor-based conveying system at which the body shell can be conveyed without the wheels having been fitted. Transfer stations should be allocated to the preceding conveying system.	
Significance	Flexibility in assembly	
Definition source		
Figure source		Plant

KPI_063_D	Floor-based conveying system stations (wheels reqd.) on main assembly line (Work station 1 to F1)	Quantity
Definition Key Term	**Floor-based conveying system** Station at which the body shell is conveyed by a floor-based system. **Wheels required** The conveying system used should require that the wheels have been fitted. **Work station 1** Work station at which the bodyshell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Number of work-, availability-, testing- and quality stations on main assembly line with floor-based conveying system at which the body shell can only be conveyed if the wheels have been fitted. Transfer stations should be allocated to the preceding conveying system.	
Significance	Flexibility in assembly	
Definition source		
Figure source		Plant

KPI_064_D	Ride-on stations on the main assembly line (Work station 1 to F1)	Quantity
Definition Key Term	**Ride-on station** Station at which the fitter can ride on the body shell ergonomically. **Work station 1** Work station at which the bodyshell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Number of manual work-, availability-, testing- and quality stations on the main assembly line with facility for fitter to ride on body shell. Transfer stations should be allocated to the preceding conveying system.	
Significance	Quality; Ergonomics; staff satisfaction; outward image	
Definition source		
Figure source		Plant

KPI_065_D	Tilt stations on main assembly line (Work station 1 to F1)	Quantity
Definition Key Term	**Tilt line** Station at which the body shell is conveyed suspended from an overhead system and can be swiveled in at least one direction. **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point. Transfer stations should be allocated to the preceding conveying system.	
Content	Number of work-, availability-, testing- and quality stations on the main assembly line with tilt carriers.	
Significance	Flexibility in assembly	
Definition source		
Figure source		Plant

KPI_066_D	Gantry-system stations in main assembly line (Work station 1 to F1)	Quantity
Definition Key Term	**Gantry system** Station at which the body shell is conveyed suspended from an overhead gantry system. **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Number of work-, availability-, testing- and quality stations on the main assembly line with gantry system. Transfer stations should be allocated to the preceding conveying system.	
Significance	Flexibility in assembly	
Definition source		
Figure source		Plant

KPI_067_D	Adjustable-height stations on main assembly line (Work station 1 to F1)	Quantity
Definition Key Term	**Adjustable height** Station at which the vertical position of the body shell can be adjusted according to requirements. **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Number of manual work-, availability-, testing- and quality stations on the main assembly line with adjustable height. Transfer stations should be allocated to the preceding conveying system.	
Significance	Quality; ergonomics; staff satisfaction; outward image	
Definition source		
Figure source		Plant

E Key Performance Indicators – Automation

KPI_068_E	Fully automated stations on the main assembly line (Work station 1 to F1)	Quantity
Definition Key Term	**Fully automated station** Area with one or more stations at which work is performed without human intervention. These are frequently the window-bonding or sunroof-fitting areas, for example. **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Number of the fully automated stations on the main assembly line	
Significance	Technical availability; decoupling stations	
Definition source		
Figure source		Plant

KPI_069_E	Degree of automation on the main assembly line (Work station 1 to F1)	Percent
Definition Key Term	**Fully automated station** Work station at which the productive work is performed without human intervention. These may be stations in window-bonding installations or sunroof robots, for example. **Work station** Work station at which the body shell is actually worked on. The assembly work may be performed by persons or by an automated robot.	
Content	Quotient of fully automated stations on main assembly line (KPI_5_D) and work stations on main assembly line (KPI_53_D).	
Significance	Technical availability; decoupling stations required	
Definition source		
Figure source		Plant

F Key Performance Indicators – Conveyor System

KPI_070_F	Number of conveyor system changes (St 53 to F2)	Quantity
Definition Key Term	**Conveyor system change** Change-over from one conveying system (e.g. skid conveyor) to another (e.g. electric suspension rail). **Status 53** Defined point at the start of the assembly line. This is not necessarily identical with Work station 1. **Point F2** End of the assembly line. On reaching this point, the vehicle is passed on to Distribution/Sales.	
Content	List of all zones/areas between Status 53 and point F2 specifying the associated conveying system and the conveyor system change-overs in between.	
Significance	Assembly parameters	
Definition source		
Figure source		Plant

KPI_071_F	Number of removal points (St 53 to F1)	Quantity
Definition Key Term	**Removal point** Defined point in the assembly process at which the body can be removed for inspection purposes, because of defects, etc. **Status 53** Defined point at the start of the assembly line. This is not necessarily identical with Work station 1. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Number of removal points between Status 53 and point F1.	
Significance	"Bead chain" principle	
Definition source		
Figure source		Plant

KPI_072_F	Number of changeover processes (St 53 to F1)	Quantity
Definition Key Term	**Changeover process** Station on assembly line at which the conveying system is changed or at which there is a change of conveying direction/level involving an interruption. **Status 53** Defined point at the start of the assembly line. This is not necessarily identical with Work station 1. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Number of changeover processes between Status 53 and point F1.	
Significance	Assembly parameters	
Definition source		
Figure source		Plant

KPI_073_F	Fixed points, Assembly (St 53 to F1)	Quantity
Definition Key Term	**Fixed point** Station that has a decisive effect on the assembly process in that the fitting sequence cannot be altered without structural alterations or which stands in the way of straightforward (in terms of time/cost) modification of the assembly line structure. As a rule, these are fully automated stations, conveying system change-overs, body hoists (if associated with conveying system change-over) and the engine/transmission installation point.	
Content	Number of fixed points in Assembly.	
Significance	Flexibility in assembly	
Definition source		
Figure source		Plant

G Key Performance Indicators – Personnel

KPI_074_G	Average employee density (Work station 1 to F1)	Persons per work station
Definition Key Term	**Performance-related wage earners (production staff)** Performance-related wage earners, also called production staff, are waged employees in the production department whose pay is directly related to performance. **Synchronized** Performance-related wage earners planned for synchronized areas (main assembly line, synchronized pre-assembly areas) with LEMO. **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point. **Work station** Work station at which the body shell is actually worked on. The assembly work may be performed by persons or by an automated robot. **Body assembly** Vehicle is on skid or conveyor Possible tasks: wiring harness, plugs, hinges, fitting of vehicle interior. **Tilt line** Tilt carrier, adjustable angle of rotation. Possible tasks: underbody paneling on body, engine compartment interior panels, wiring package, fuel system, wheel arch lining, fitting to underbody and sill areas. **Final assembly** Vehicle on gantry hanger Core component: marriage, underbody, fitting of wheels, fitting of front and rear ends, engine compartment connections **Filling/loading** Vehicle is on conveyor (standing on its own 4 wheels) Possible tasks: filling with fluids (fuel, air con refrigerant, washer fluid, brake fluid), loading of data, etc... **Finishing line** Line on which the final adjustments to the vehicle are made. The following list provides examples of the possible operations involved: Paintwork checks, final light checks, E/E operations ... **F2 line** Line on which the vehicle is prepared for delivery. The end of this line at point F2 marks the finish of the assembly process. The following list provides examples of the possible operations involved: Place owner's manual in vehicle, apply wax, ...	

Content	Quotient of synchronized performance-related wage earners who work between Work station 1 and point F1 on the main assembly line and number of manual work stations in main assembly line (subset of K53_D). The basis for the number of employees is the figure for synchronised performance-related wage earners in LEMO The following areas are to be explicitly itemized: • Body assembly • Tilt line • Final assembly • Filling/loading • Finishing line • F2 line • Other areas The values of the numerator and the denominator must be explicitly stated.	
Significance	Work station requirement	
Definition source		
Figure source		Plant

H Key Performance Indicators – Product

KPI_075_H	Series/Models/Types in Assembly	Quantity
Definition Key Term	Designation of vehicles with the same fundamental dimensions (for example 3 Series, 5 Series) including modified designs (such as long-wheelbase versions). Internally, series are identified by development designation codes based on various technical and historical aspects (e.g. E36, E34/2). Series are further differentiated according to model and type. Models distinguish between vehicles of the same series on the basis of: • Engine type (e.g. 316i, 318i, 325 tds) • Drive configuration (e.g. 525i, 525iX) • Body type (e.g. 328i, 328i Convertible) • Motor sport version (e.g. M3) Types designate variations of the same model (e.g. 318i/4 saloon RHD Auto Cat) based on differences in technical equipment such as steering, transmission or catalytic converter. Internally, vehicle types are identified by numeric or alphanumeric type codes (e.g. GF51).	
Content	List of all type codes currently produced on the assembly line.	
Significance	Flexibility in assembly, supply of materials	
Definition source	http://www.muc/i_dienste/bwl/index/deutschf.htm	
Figure source		Plant

I Key Performance Indicators – Quality

KPI_076_I	QZ (quality figure) (AUDIT III)	Numerical value
Definition Key Term	A customer oriented quality figure for all test module groups (PMGs): 1, 2, 3, 4 and 5 with BI stage 6 or poorer. After introduction of the new Audit III target systems, reporting is according to QZF (function) and QZS (standard).	
Content	QZ for Tx-4 as installer over a period of at least 4 weeks. In addition to the type under review, the QZK for the complete vehicle must be specified for the same period.	
Significance	Possible effect on quality by assembly structure	
Definition source		
Figure source	http://www6.muc/qnet/indexn.html	Plant

KPI_077_I	QZF (customer oriented functional/dynamic quality figure) (AUDIT III)	Numerical value
Definition Key Term	A customer oriented quality figure for functionality while the vehicle is stationary or being driven; includes all faults from PMGs 3 (leaks), 4 (noises and odors) and 5 (functionality) if BI stage is 6 or poorer.	
Content	Despatch QZF for individual series from a comparable reporting month.	
Significance	Strategic key figure	
Definition source		
Figure source	http://www6.muc/qnet/indexn.html	Plant

KPI_078_I	QZS (customer oriented standard/static quality figure) (AUDIT III)	Numerical value
Definition Key Term	A customer-oriented quality figure for standard assessment; includes all faults from PMGs 1 (compliance with order) and 2 (visual and touch) - with BI stage 6 or poorer.	
Content	Dispatch QZS for individual series from a comparable reporting month.	
Significance	Strategic key figure	
Definition source		
Figure source	http://www6.muc/qnet/indexn.html	Plant

KPI_079_I	GWK – Level 4 (warranty and good will)	Cost per vehicle
Definition Key Term	**Warranty and good will** • GWK type 1: expenditure on the repair of defects on vehicles and sets of parts (CKD, SKD) • GWK type 2: expenditure on the repair of defects on genuine BMW parts and genuine BMW accessories • GWK type 3: expenditure on the repair of defects on genuine BMW exchange parts	
Content	GWK level 4: Repair of defects that are identified after transfer of the vehicle to the distribution organization but before delivery to the customer (dispatch defects) Not applicable to transport damage and deficiencies for which the distribution or dealer organization is responsible.	
Significance	Strategic key figure	
Definition source		
Figure source	http://www6.muc/qnet/indexn.html	Plant

KPI_080_I	Acceptable quota (St 53 to F2) overall - not adjusted	Percent
Definition Key Term	**Acceptable** Vehicle that leaves a defined area in the quickest possible time. **No Touch** Vehicle that reaches the point F2 without any rectification in Assembly (between status 53 and F2). **In-line rectification** Rectification work caused by Assembly that is carried out on the assembly line between Work station 1 and point F2 (without removal) and therefore does not result in any increase in throughput time. **Status 53** Defined point at the start of the assembly line. This is not necessarily identical with Work station 1. **Point F2** End of the assembly line. On reaching this point, the vehicle is passed on to Distribution/Sales. **Not adjusted** All off-line rectification work between status 53 and F2 (regardless of who it is caused by and the section performing the work) reduces the quota of acceptable.	
Content	This key figure is made up of the proportion of vehicles that reach the point F2 during the period under review t **without off-line rectification**. Explicit itemization of the following figure is desirable: F2 vehicles recorded **Only** rectification work recorded **in IPS-Q /NAER** is taken into account. Vehicles with planned time for assembly work off the assembly line (e.g. hardtop, rear spoiler) count as acceptable if they pass through without problems. For this key figure, a filter is not set for product random sampling, specialized vehicles, bars, body shell rectification and paintwork rectification. Problems in those areas reduce the quota of acceptable. Vehicles that are removed from the assembly line for rectification purposes are by definition not counted as acceptable.	
Significance	Zero-rectification vehicle; fault propagation; optimization of throughput time	
Definition source		
Figure source	IPS-Q / NAER	Plant

KPI_081_I	Average rectification time - Assembly	Minutes per vehicle
Definition Key Term	**Rectification time** Time spent on repetition of one or more assembly stages due to deficient quality. **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point.	
Content	Working time reported for in-line rectification work in Assembly after series production is in full swing (normal budget, from 7th month after SOP). The figures are based on the results accounts for rectification. Unit figures are based on the stable number of vehicles reaching F1, which must be explicitly itemized.	
Significance	Assembly team – zero rectification; optimisation of throughput time	
Definition source		
Figure source	IPS-Q / NAER	Plant

KPI_082_I	F2-On schedule	Percent
Definition Key Term	**On-schedule** Vehicle that reaches the destination point within a specified time frame (in this case the correct day). **Point F2** End of the assembly line. On reaching this point, the vehicle is passed on to Distribution/Sales.	
Content	Proportion of F2 vehicles that leave the point F2 on schedule (on correct day) or earlier during the period under review t. The percentage distribution according to the following scheme is desirable: <-5 days; -5 days; -4 days; -3 days; -2 days; -1 day; 0 days; +1 day; +2 days; +3 days; +4 days; +5 days; >+5 days	
Significance	Strategic key figure; process quality	
Definition source		
Figure source	http://www6.muc/gesamtlogistik/11/index.htm	Plant

J Key Performance Indicators – Logistics

KPI_083_J	Body storage spaces	Quantity
Definition Key Term	**Body storage** The storage area between paint shop and assembly line from where the assembly line takes its body shells. This is normally a warehouse with high-rise racking. In exceptional cases, however, it may equally be a straightforward floor storage area. **Storage space** 1 storage space = 1 painted body shell ready to be called off for assembly **Status 53** Defined point at the start of the assembly line. This is not necessarily identical with Work station 1.	
Content	Number of storage spaces for painted bodies before Status 53 Storage spaces for painted bodies that are not planned for assembly on-site must be explicitly itemized.	
Significance	Lead time for assembly; Process stability	
Definition source		
Figure source		Plant

KPI_084_J	Number of special containers (SFFG) per series	Quantity
Definition Key Term	Number of different special containers (types) used for each series.	
Content	Special containers	
Significance	Ratio of number of SFFG between different series	
Definition source		
Figure source	TI-4x Assembly Logistics	FIZ

KPI_085_J	Number of assembly-related article numbers	Quantity
Definition Key Term	Number of article numbers that as a subset of the number of active article numbers are definitely related to assembly. Assembly-related Article numbers that are supplied for direct fitting on main assembly lines or in synchronized pre-assembly areas.	
Content	Assembly-related article numbers	
Significance	Ratio of assembly-related article numbers to station service area	
Definition source		
Figure source	Plant assembly logistics	Plant

The following figures are to be taken from the manual Key Figures for Logistics Planning and are managed by TG-20:

KPI_086_J	Supply volume per vehicle	m^3 per unit

KPI_087_J	Fully automated supply volume (degree of automation)	Percent

KPI_088_J	Number of FFGs per vehicle	FFGs per unit

KPI_089_J	Number of FFGs per vehicle, fully automated (degree of automation)	Percent
KPI_090_J	Number of sequenced/consigned parts per vehicle	Picks per unit
KPI_091_J	Number of parts delivered in sequence per vehicle	Parts per unit
KPI_092_J	Packaging volume per vehicle	m^3 per unit
KPI_093_J	Number of FFGs turned over per employee and day	FFGs per employee and day
KPI_094_J	Average number of active article numbers	Art. nos.
KPI_095_J	Average number of active article numbers per employee (materials planning)	Art. nos. per employee and day
KPI_096_J	Average supplier distance (weighted according to volume)	km
KPI_097_J	Average total stock coverage	Working days

L Key Performance Indicators – Economic

KPI_098_L	Structural investment, Assembly, since 1989 (past)	Million EURO
Definition Key Term	**Structural investment** Maintenance, extension or alteration of the structure of the business, e.g. sheds/buildings, entire infrastructure, general safety requirements	
Content	Year slices for structural investment made by Assembly in the past.	
Significance	Investment pattern	
Definition source		
Figure source		TI-400

KPI_99_L	Product investment, Assembly, since 1989 (past)	Million EURO
Definition Key Term	**Product investments** Investments that comprise model and engine series, continuing developments, additional variations, country-specific designs, and special equipment. All investments in current and future projects. **Series** Designation of vehicles with the same fundamental dimensions (for example 3 Series, 5 Series) including modified designs (such as long-wheelbase versions).	
Content	Overall total of product investment made by Assembly for a series to date. Separate itemisation of the individual series is required.	
Significance	Investment pattern	
Definition source		
Figure source		TI-400

KPI_100_L	Assembly fixed costs per year	Million EURO
Definition Key Term	Costs that are unaffected by changes in employment or which are unaffected within specific intervals. If employment goes beyond or does not exceed interval limits, costs rise or fall in order to remain constant until the next interval limit is reached.	
Content	Fixed costs that are assigned to the year of assembly	
Significance	Development of costs	
Definition source	http://www.muc/i_dienste/bwl/index/deutschf.htm	
Figure source		Plant

KPI_101_L	Average FKprop – Assembly excluding paintwork rectification	EURO/Unit
Definition Key Term	Average FKprop per unit – Assembly excluding paintwork rectification	
Content	The FKprop – Assembly excluding paintwork rectification is calculated as follows: Assembly time [Hours per unit] multiplied by Hourly production labour rate [EURO per hour]	
Significance	Development of costs	
Definition source	FKprop – Agreed Assembly excluding paintwork rectification	
Figure source	FKprop - Standard sheets	TI-40

M Key Performance Indicators – Plan/Unscheduled Time

KPI_102_M	Total planned time/planned time volume excluding OE [Average type]	Minutes per unit
Definition Key Term	**Planned time (= Basic time)** Specified time for the productive operations of a production facility. Characteristics of planned time are: Directly serves the progress of work, can be planned for, occurs regularly and not dependent on product range, or the first time an operation is performed ("productive time"). For more detailed information, refer to Appendix A. **Excluding OE** The unit-weighted average type is represented without optional equipment.	
Content	Total of planned time in minutes for main assembly line and planned time in minutes for pre-assembly for the unit-weighted average type (excluding optional equipment).	
Significance	Cost rate; Work station requirement	
Definition source	Cost centre planning, Appendix 1;07/98; FC-2	
Figure source		Plant

KPI_103_M	Planned time on the main assembly line (Work station 1 to F1) excluding OE [Average type]	Minutes per unit
Definition Key Term	**Planned time (= Basic time)** Specified time for the productive operations of a production facility. Characteristics of planned time are: Directly serves the progress of work, can be planned for, occurs regularly and not dependent on product range, or the first time an operation is performed ("productive time"). For more detailed information, refer to Appendix A. **Work station 1** Work station at which the body shell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point. **Excluding OE** The unit-weighted average type is represented without optional equipment. **Body assembly** Vehicle is on skid or conveyor Possible tasks: wiring harness, plugs, hinges, fitting of vehicle interior. **Swivelling hoist** Vehicle on swivelling hoist, adjustable angle of rotation. Possible tasks: underbody panelling on body, engine compartment interior panels, wiring package, fuel system, wheel arch lining, fitting to underbody and sill areas. **Final assembly** Vehicle on gantry hanger Core component: marriage, underbody, fitting of wheels, fitting of front and rear ends, engine compartment connections **Filling/loading** Vehicle is on conveyor (standing on its own 4 wheels) Possible tasks: filling with fluids (fuel, air con refrigerant, washer fluid, brake fluid), loading of data, etc...	
Content	Planned time in minutes on main assembly line for the unit-weighted average type (excluding optional equipment). The planned time on the main assembly line should be divided into the following components: • Body assembly • Tilt line • Final assembly • Filling/loading	
Significance	Work station requirement; workers required on the main assembly line	
Definition source	Cost centre planning, Appendix 1;07/98; FC-2	
Figure source		Plant

KPI_104_M	Planned time between F1 and F2 excluding OE [Average type]	Minutes per unit
Definition Key Term	**Planned time (= Basic time)** Specified time for the productive operations of a production facility. Characteristics of planned time are: Directly serves the progress of work, can be planned for, occurs regularly and not dependent on product range, or the first time an operation is performed ("productive time"). For more detailed information, refer to Appendix A. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point. **Point F2** End of the assembly line. On reaching this point, the vehicle is passed on to Distribution/Sales. **Excluding OE** The unit-weighted average type is represented without optional equipment. **Finishing line** Line on which the final adjustments to the vehicle are made. The following list provides examples of the possible operations involved: Paintwork checks, final light checks, E/E operations ... **Test stand station** Permanent station at which essential function tests are performed on the vehicle. At present covers the following: Track-type test stands, roller-type test stands, ABS test stands, exhaust/ELDI test stands,... **F2 line** Line on which the vehicle is prepared for delivery. The end of this line at point F2 marks the finish of the assembly process. The following list provides examples of the possible operations involved: Place owner's manual in vehicle, apply wax, ...	
Content	Planned time between F1 and F2 for the unit-weighted average type (excluding optional equipment). The planned time between F1 and F2 should be divided into the following components: • Finishing line • Test stand stations • F2 line • Other planned time	
Significance	Work station requirement; workers required on the main assembly line	
Definition source	Cost centre planning, Appendix 1;07/98; FC-2	
Figure source		Plant

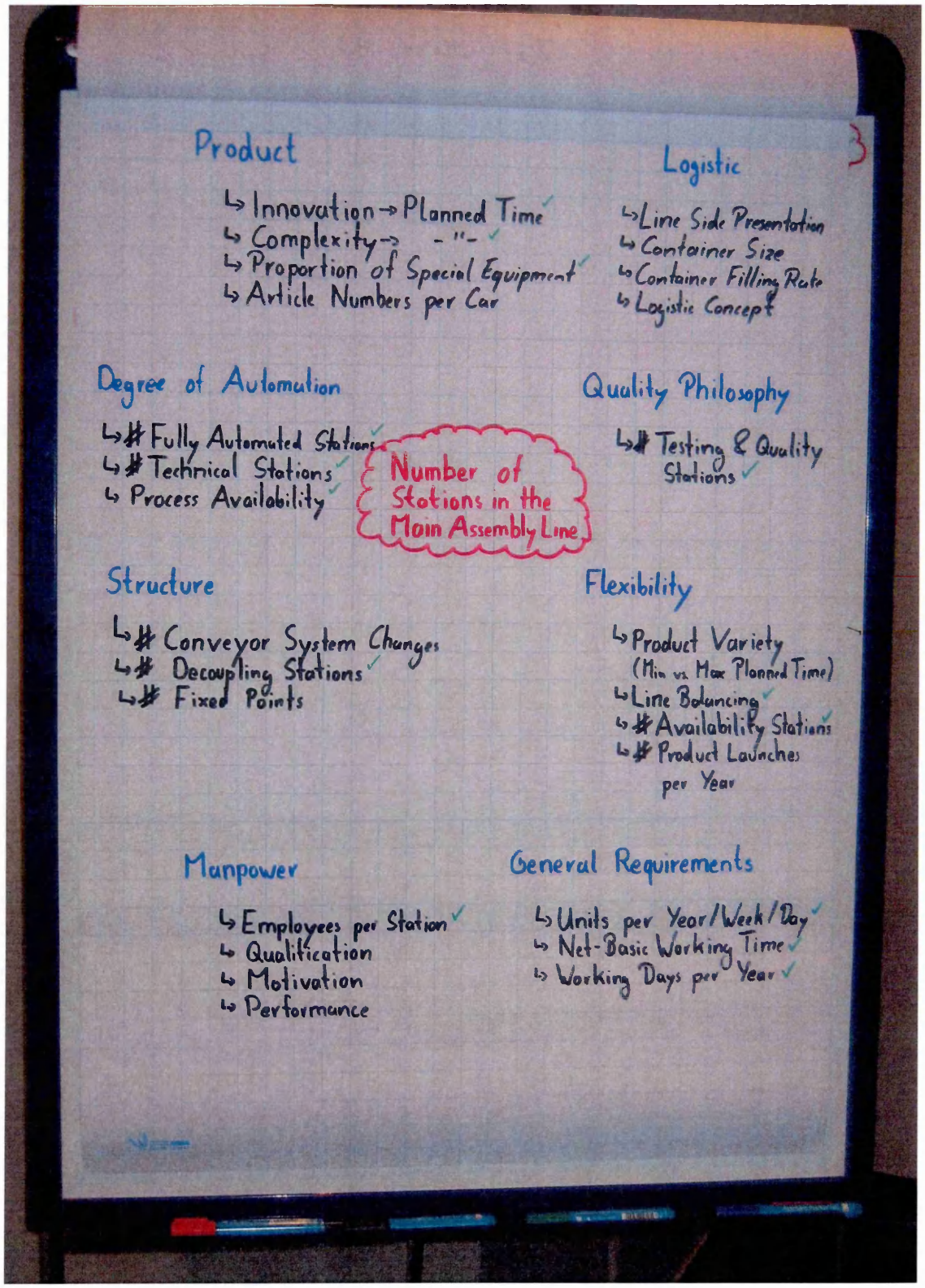
KPI_105_M	Planned time in selected pre-assembly areas excluding OE [Average type]	Minutes per unit
Definition Key Term	**Planned time (= Basic time)** Specified time for the productive operations of a production facility. Characteristics of planned time are: Directly serves the progress of work, can be planned for, occurs regularly and not dependent on product range, or the first time an operation is performed ("productive time"). For more detailed information, refer to Appendix A. **Pre-assembly area** Area beyond the main assembly line in which, ideally, entire modules are produced. Some examples of pre-assembly areas are: Engine/Transmission; Bumpers; Rear suspension; Front suspension; Doors; Front end; Centre console; Pipe bending; Cockpit module **Excluding OE** The unit-weighted average type is represented without optional equipment.	
Content	Planned time for all modules produced on the following pre-assembly lines for the unit-weighted average type (excluding optional equipment): • Engine/Gearbox/MAT • Bumpers, front and rear • Rear suspension • Front suspension • Doors • Front end • Wheels/ tyres • Wiring package • Cockpit module (inc. centre console) • Roof liner/roof module • Other pre-assembly operations	
Significance	Structural optimisation	
Definition source	FC-2; Cost centre planning, Appendix 1;07/98	
Figure source		Plant

KPI_106_M	Maximum planning time spread in the main assembly line (Work station 1 to F1) without OE	Minutes per unit
Definition Key Term	**Planning time spread** Time span between the vehicle with the shortest planned time and the vehicle with the longest planned time. **Work station 1** Work station at which the bodyshell is first worked on at the assembly plant. **Point F1** Defined point at the end of the main assembly line. According to the plan, the vehicle is ready to drive on reaching this point. **Excluding OE** The unit-weighted average type is represented without optional equipment.	
Content	Maximum planning time spread in the main assembly line (excluding optional equipment) The minimum and maximum planned times must be explicitly specified as well as the associated type under review.	
Significance	Process optimisation	
Definition source	FC-2; Cost centre planning, Appendix 1;07/98	
Figure source		Plant

KPI_107_M	Total unscheduled time excluding OE [Average type]	Minutes per unit
Definition Key Term	**Unscheduled time** Directly serves the progress of work, cannot be planned for, occurs irregularly and dependent on product range, or any repetition of an operation. For more detailed information, refer to Appendix A. **Excluding OE** The unit-weighted average type is represented without optional equipment.	
Content	Figure from standard sheet for FKprop Assembly excluding paintwork rectification	
Significance	Process optimisation	
Definition source	FKprop – Agreed Assembly excluding paintwork rectification	
Figure source	FKprop - Standard sheets	Plant

KPI_108_M	Total assembly time (inc. OE) [Average type]	Hours per unit
Definition Key Term	**Assembly time** All time accruing in Assembly.	
Content	tm [minutes / unit] + Order-related work [percentage of tm] = Value added [minutes/unit] + Total rectification (charged, not charged & and irrespective of originator) [Percentage of value added] + Other unscheduled time (inc. personnel & resource allocated times) [Percentage of value added] = Assembly time [minutes/unit] ÷ 60	
Significance	Strategic key performance indicator	
Definition source	FKprop – Agreed Assembly excluding paintwork rectification	
Figure source	FKprop - Standard sheets	TI-40

Appendix B – Example of a MindMap Drawing



Appendix C – Elements Used in the System

# Name of Element (KPI)	Unit	Definition
1 Addition Away	%	9%
2 Addition Electrical Adjustment per Door	EUR	0
3 Addition Platform per Station	EUR/stations	0
4 Addition Pneumatic Spring per Door	EUR	0
5 Addition Rotary Sling in Doors Pre-Assembly	EUR	0
6 Addition Rotation Head per Door	EUR	0
7 Additional Area Employee Body Assembly	meter²	SUM('Office Area per Employee','Sanitary Area per Employee','Social Area per Employee')*'Number of Employees Body Assembly'
8 Additional Area Employee Filling	meter²	SUM('Office Area per Employee','Sanitary Area per Employee','Social Area per Employee')*'Number of Employees Filling'
9 Additional Area Employee Final Assembly	meter²	SUM('Office Area per Employee','Sanitary Area per Employee','Social Area per Employee')*'Number of Employees Final Assembly'
10 Additional Area Employee Tilt Assembly	meter²	SUM('Office Area per Employee','Sanitary Area per Employee','Social Area per Employee')*'Number of Employees Tilt Assembly'
11 Additional Hours	hours	0
12 Additional Manpower Requirement	worker	3 <<worker>>
13 Additional Non-synchronised Employees Final Assembly	%	2%
14 Additional Production per Day	unit/days	ROUND('KPI_45_C Units per Hour Planned'*('Number of Hours'-Breaks))*'Number of Shifts per Day'*1<<1/days>>
15 Additional Production per Year	unit/yr	'Additional Production per Day'*'Number of Days'
16 Additional Production without Breaks per Day	unit/days	IF('Selection Breaks Yes No'=TRUE, ROUND('KPI_45_C Units per Hour Planned'*('Payed Breaks in Hours per Shift'+'Unpayed Breaks in Hours per Shift')*'Number of Shifts'*1<<1/days>>), 0<<unit/days>>)
17 Additional Production without Breaks per Year	unit/yr	'Additional Production without Breaks per Day'*'Number of Days without Breaks'
18 Additional Recirculation	%	0%
19 Additional Rework Stations Buffer	%	100%
20 Additional Space Employees Body Assembly	meter²	IF('Selection of Model Main Assembly Line'=TRUE, 'Body Assembly'.'Additional Area Employee Body Assembly', 0<<meter²>>)
21 Additional Space Employees Doors	meter²	PRODUCT (SUM ('Office Area per Employee', 'Sanitary Area per Employee', 'Social Area per Employee'), 'Number of Employees Doors')
22 Additional Space Employees Engine-Gearbox-Line	meter²	PRODUCT ('Number of Employees Engine-Gearbox-Line', SUM ('Office Area per Employee', 'Sanitary Area per Employee', 'Social Area per Employee')
23 Additional Space Employees Filling	meter²	Filling.'Additional Area Employee Filling'
24 Additional Space Employees Final Assembly	meter²	Final Assembly'.'Additional Area Employee Final Assembly'
25 Additional Space Employees Front Axle	meter²	PRODUCT (SUM ('Office Area per Employee', 'Sanitary Area per Employee', 'Social Area per Employee'), 'Number of Employees Pre-Assembly Axle'['Front Axle'])
26 Additional Space Employees Main Assembly Line Simple Model	meter²	{PRODUCT('Employees Main Assembly Line Overall Simple Model', SUM('Office Area per Employee', 'Sanitary Space per Employee', 'Social Space per Employee')}}
27 Additional Space Employees Rear Axle	meter²	PRODUCT (SUM ('Office Area per Employee', 'Sanitary Area per Employee', 'Social Area per Employee'), 'Number of Employees Pre-Assembly Axle'['Rear Axle'])
28 Additional Space Employees Strut	meter²	PRODUCT (SUM ('Office Area per Employee', 'Sanitary Area per Employee', 'Social Area per Employee'), 'Number of Employees Pre-Assembly Axle'[Strut])
29 Additional Space Employees Sub-Engine-Line	meter²	PRODUCT ('Number of Manual Work Stations Sub-Engine-Lines', SUM ('Office Area per Employee', 'Sanitary Area per Employee', 'Social Area per Employee')) * 1 <<worker>>
30 Additional Space Employees Tilt Assembly	meter²	Tilt Assembly'.'Additional Area Employee Tilt Assembly'

# Name of Element (KPI)	Unit	Definition
31 Additional Space Employees Wheel hub	meter²	PRODUCT (SUM ('Office Area per Employee', 'Sanitary Area per Employee', 'Social Area per Employee'), 'Number of Employees Pre-Assembly Axle'['Wheel Hub'])
32 Additional Stations Body Assembly	stations	*Auxiliary Stations Body Assembly1'+'Auxiliary Stations Body Assembly2'*
33 Additional Stations Body Assembly 1	stations	Parent~'Auxiliary Stations Body Assembly1'
34 Additional Stations Body Assembly 2	stations	Parent~'Auxiliary Stations Body Assembly2'
35 Additional Stations Filling	stations	{'KPI_54_D Testing and Quality Stations in the Main Assembly Line Filling', 'KPI_53_D Availability Stations in the Main Assembly Line Filling', 'KPI_56_D Technical Stations in the Main Assembly Line Filling', 'KPI_58_D Decoupling Stations in the Main Assembly Line Filling'}
36 Additional Stations Final Assembly	stations	{'KPI_54_D Testing and Quality Stations Final Assembly', 'KPI_53_D Availability Stations in the Main Assembly Line Final Assembly', 'KPI_56_D Technical Stations in the Main Assembly Line Final Assembly', 'KPI_58_D Decoupling Stations in the Main Assembly Line Final Assembly'}
37 Additional Stations Sum	stations	IF('Selection of Model Main Assembly Line'=TRUE, SUM('Additional Stations Body Assembly', 'Additional Stations Tilt Assembly', 'Additional Stations Final Assembly', 'Additional Stations Filling'), 0<<stations>>)
38 Additional Stations Tilt Assembly	stations	{'KPI_54_D Testing and Quality Stations in the Main Assembly Line Tilt Assembly', 'Availability Stations in the Main Assembly Line Tilt Assembly', 'KPI_56_D Technical Stations in the Main Assembly Line Tilt Assembly', 'KPI_58_D Decoupling Stations in the Main Assembly Line Tilt Assembly'}
39 Additional Stations Tilt Assembly	stations	Parent~'Additional Stations Tilt Assembly'
40 Additional Time Headlights	min/unit	0 <<min/unit>>
41 Additional Times Finish Line	min/unit	{10,0} <<min/unit>>
42 Additional_All Wheel	%	0%
43 Additional_M Variant	%	0%
44 Agreed Daily Output	*unit*	*Parent~'KPI_41_C Assembly Agreed Daily Output'*
45 All Areas	meter²	{'Total Area Main Assembly Line', 'Total Area F1 to F2', 'Total Area Pre-Assemblies', 0 <<meter^2>>}
46 All Investments	EUR	{'Total Invest Main Assembly Line', 'Total Invest F1 to F2', 'Total Invest Pre-Assemblies', 0 <<EUR>>}
47 Amortisation Period Buildings	year	20
48 Amortisation Period Technics	year	7
49 Annual Budget	EUR	Personnel Costs Prop'*('Supplement Fixed Personnel Costs'+'Supplement Imputed Costs'+'Supplement Material Costs') +'Personnel Costs Paintwork Rectification'+'Sum Amortisation Over All'
50 Area Buffer Station	meter²	15 <<meter^2>>
51 Area Buffer Station 2	meter²	15 <<meter^2>>
52 Area Complete Line	meter²	{1500,1500} <<meter^2>>
53 Area Connecting Conveyor	meter²	PRODUCT ('Length Floor Area Connecting Conveyor', 'Belt Width Bottom Area Connecting Conveyor')
54 Area Conveyer System Body Assembly	meter²	Body Assembly'.'Area Conveyor Systems Body Assembly'
55 Area Conveyer System Filling	meter²	Filling.'Area Conveyor Systems Filling'
56 Area Conveyer System Final Assembly	meter²	Final Assembly'.'Area Conveyor Systems Final Assembly'
57 Area Conveyer System Simple Model	meter²	IF('Selection of Model Main Assembly Line'=FALSE, {PRODUCT('Belt Width Materials Handling per Station', 'Number of Stations Materials Handling', 'Length of Station')}, 0<<meter²>>)
58 Area Conveyer System Tilt Assembly	meter²	Tilt Assembly'.'Area Conveyor Systems Tilt Assembly'
59 Area Conveyor System Doors	meter²	PRODUCT ('Lenght of Station Doors', 'Belt Width Conveyor System Doors', SUM (PRODUCT ('KPI_51_D Stations Doors per Side', 'Selection Doors Lines'), 'KPI_51_D Total Stations Doors')) / 1 <<stations>>
60 Area Conveyor System Engine-Gearbox-Line	meter²	PRODUCT ('KPI_51_D Total Stations Engine-Gearbox-Line', 'Station Length Enginge-Gearbox-Line', 'Belt Width Conveyor System Engine-Gearbox'['Engine Line']) / 1 <<stations>>
61 Area Conveyor System Front Axle	meter²	PRODUCT ('KPI_51_D Total Stations Axle Pre-Assembly'['Front Axle'], 'Length of Station Front Axle', 'Belt Width Conveyor System Axles'['Front Axle']) / 1 <<stations>>

# Name of Element (KPI)	Unit	Definition
62 Area Conveyor System Rear Axle	meter²	PRODUCT ('KPI_51_D Total Stations Axle Pre-Assembly'['Rear Axle'], 'Length of Station Rear Axle', 'Belt Width Conveyor System Axles'['Rear Axle']) / 1 <<stations>>
63 Area Conveyor System Strut	meter²	PRODUCT ('KPI_51_D Total Stations Axle Pre-Assembly'[Strut], 'Length of Station Strut', 'Belt Width Conveyor System Axles'[Strut]) / 1 <<stations>>
64 Area Conveyor System Wheel Hub	meter²	PRODUCT ('KPI_51_D Total Stations Axle Pre-Assembly'['Wheel Hub'], 'Length of Station Wheel Hub', 'Belt Width Conveyor System Axles'['Wheel Hub']) / 1 <<stations>>
65 Area Conveyor Systems Body Assembly	meter²	{ (('Belt Width Conveyor Systems Body Assembly 1'*'Length of Station Body Assembly 1')+('Belt Width Conveyor Systems Body Assembly 2'*'Length of Station Body Assembly 2'))*'Number of Stations Conveyor Systems Body Assembly' }
66 Area Conveyor Systems Filling	meter²	{ ('Belt Width Conveyor Systems Filling'*'Length of Station Filling'*'Number of Stations Conveyor Systems Filling') }
67 Area Conveyor Systems Final Assembly	meter²	{ 'Belt Width Conveyor System Final Assembly'*'Number of Stations Conveyor Systems Final Assembly'*'Length of Station Final Assembly' }
68 Area Conveyor Systems Tilt Assembly	meter²	{ 'Belt Width Conveyor Systems Tilt Assembly'*'Length of Station Tilt Assembly'*'Number of Stations Conveyor Systems Tilt Assembly' }
69 Area Conveyor Technology_Train Area	meter²	{'Number of Stations Conveyor System'*'Width Conveyor Technology'*'Length of Station'}
70 Area Cost Rate	EUR/meter²	{950,950,950,1080,1000,1000}
71 Area Cost Rate F2-Line	EUR/meter²	Area Cost Rate'['F2-Lines']
72 Area Cost Rate Finish-Line	EUR/meter²	{ 'Area Cost Rate'[FinishA], 'Area Cost Rate'[FiinishB] }
73 Area Cost Rate Paintwork Rectification	EUR/meter²	Area Cost Rate'['Paintwork Rectification']
74 Area Cost Rate Rectification	EUR/meter²	Area Cost Rate'[Rectification]
75 Area Cost Rate Test Rigs	EUR/meter²	Area Cost Rate'['Test Rig Area']
76 Area Doors	meter²	FOR (i='Door Lines'[ARRSUM (PRODUCT (SUM ('Working Area Doors', 'Area Conveyor System Doors', 'Additional Space Employees Doors', 'Traffic Area Doors', 'KPI_17_A Gross Line-Side Presentation Areas Doors'), 'Selection Doors Lines'[i])))
77 Area Efficiency	unit/meter²	Working Stations per Year'*'Agreed Daily Output'/'Total Area'/1 <<da>>
78 Area Efficiency 2	unit/meter²	Agreed Daily Output'*'Working Stations per Year'/ARRSUM('Area Stock')/1<<da>>
79 Area Extra Working Stations	meter²	80 <<meter^2>>
80 Area F2 Line Transpack	meter²	IF('Ratio Transpack'>0%, ('Width of F2-Line'+'Width of Delivery Area'+'Width of Line-Side Presentation Area')* ('Total Stations F2-Line Wax'*'Length of Station F2-Line'+'Length Traffic Area'), 0<<meter²>>)
81 Area F2 Line Wax	meter²	IF('Ratio Wax'>0%, MAX('Width of F2-Line','Width Wax Station')* ('Stations per F2-Line Wax'*'Length of Station F2-Line'+'Length Traffic Area'), 0<<meter²>>)
82 Area Front-Axle	meter²	IF ('Selection Axle Assembly'['Front Axle'] = 1, SUM ('Working Area Front Axle', 'Area Conveyor System Front Axle', 'Additional Space Employees Front Axle', 'Traffic Area Front Axle', 'KPI_17_A Gross Line-Side Service Area Front Axle'), 0 <<meter²>>)
83 Area Gearbox Store Shuttles	meter²	PRODUCT ('Number of Gearbox Store Shuttles', 'Number of Gearboxes per Row', 'Gearbox Deviations'[Width], 'Width of Withdrawal Unit')
84 Area Gearbox-Line	meter²	PRODUCT ('Length Floor Area Gearbox-Line', 'Belt Width Bottom Area Gearbox-Line')
85 Area Gearbox-Store Net	meter²	PRODUCT ('Gearbox Deviations'[Length], 'Gearbox Deviations'[Width], 'Number of Gearboxes per Level Gearbox Store', 150 %)
86 Area Grid	meter²	Width Testing Line'*'Length Test Rig Grid'
87 Area Installations Fully-Automated	meter²	Facilities.'Readout Auxiliary Space Installations Fully-Automated'

# Name of Element (KPI)	Unit	Definition
88 Area Line-Side Presentation Gearbox	meter²	PRODUCT('KPI_41_C Assembly Agreed Daily Output', 'Proportion of Gearbox-Line-Side Presentation in Assembly Daily Unit Output', 'Area per Line-Side Presentation-Unit Gearbox') * 1 <<days>>
89 Area Line-Side-Presentation Engine	meter²	PRODUCT('KPI_41_C Assembly Agreed Daily Output', 'Proportion of Engine-Line-Side Presentation in Assembly Daily Unit Output', 'Area per Line-Side Presentation-Unit Engine') * 1 <<days>>
90 Area Main Line Completely	meter²	IF('Selection of Model Main Assembly Line'=FALSE, 'Total Area Main Line Simple Model', 'Total Area Main Line Complex Model')
91 Area Manual Work Stations Sub-Engine-Lines	meter²	PRODUCT ('Number of Manual Work Stations Sub-Engine-Lines', SUM ('Working Area per Manual Workstation Sub-Engine-Lines', 'Station Service Area per Manual Work Station Sub-Engine-Line'))
92 Area MAT Storage	meter²	0
93 Area Paint Mix Facility	meter²	150 <<meter^2>>
94 Area per Daily Unit	meter²/unit	Total Area'/('Agreed Daily Output')
95 Area per Line-Side Presentation-Unit Engine	meter²/unit	DIVZX (PRODUCT ('Length Line-Side Presentation-Unit Engine', 'Width of Line-Side Presentation-Unit Engine'), 'Engine-Units per Line-Side Presentation-Unit', 0 <<meter²/unit>>)
96 Area per Line-Side Presentation-Unit Gearbox	meter²/unit	DIVZX (PRODUCT ('Length Line-Side Presentation-Unit Gearbox', 'Width of Line-Side Presentation-Unit Gearbox'), 'Gearbox-Units Per Line-Side Presentation-Unit', 0 <<meter²/unit>>)
97 Area per Toe-Camber-Adjustment Facility Rear Axle	meter²	40
98 Area Rear Axle	meter²	IF ('Selection Axle Assembly'['Rear Axle'] = 1, SUM ('Working Area Rear Axle', 'Area Conveyor System Rear Axle', 'Additional Space Employees Rear Axle', 'Area Toe-Camber-Adjustment Facilities Rear Axle', 'Traffic Area Rear Axle', 'KPI_17_A Gross Line-Side Service Area Rear Axle'), 0 <<meter²>>)
99 Area Rectification Station	meter²	30 <<meter*meter>>
100 Area Requirements Finish Lines	meter²	('Belt Width of Finish Line'*'Station Length Finish Line'*'Number of Stations Finish Line' +'Length Traffic Area Finish Line'*'Belt Width of Finish Line')*'Number of Finish-Lines'
101 Area Requirements Paintwork Lines	meter²	ARRSUM('Number of Complete Lines'*'Area Complete Line')+ 'Number of Spotrepair Lines'*'Total Area Requirements Spotrepair-Line'
102 Area Requirements Rectification	meter²	Area Requirements Rectification Stations'+'Required Area Buffer Stations Rectification'+'Traffic Area Rectification'
103 Area Requirements Rectification Stations	meter²	Number of Rectification Stations'*'Area Rectification Station'
104 Area Spotrepair	meter²	200 <<meter^2>>
105 Area Spotrepair Assembly	meter²	150 <<meter^2>>
106 Area Stock	meter²	Time Model Output'.'Area Stock'
107 Area Strut	meter²	IF ('Selection Axle Assembly'[Strut] = 1, SUM ('Working Area Strut', 'Area Conveyor System Strut', 'Additional Space Employees Strut', 'KPI_17_A Gross Line-Side Service Area Strut'), 0 <<meter²>>)
108 Area Supplement	%	30%
109 Area Toe-Camber-Adjustment Facilities Rear Axle	meter²	PRODUCT ('Number of Facilities Toe-Camber-Adjustment Rear Axle', 'Area per Toe-Camber-Adjustment Facility Rear Axle')
110 Area Wheel Hub	meter²	IF ('Selection Axle Assembly'['Wheel Hub'] = 1, PRODUCT (SUM ('Working Area Wheel Hub', 'Area Conveyor System Wheel Hub', 'Additional Space Employees Wheel Hub', 'KPI_17_A Gross Line-Side Service Area Wheel Hub'), 'Number of Lines Wheel Hub'), 0 <<meter²>>)
111 Area Working Area Main Assembly Line	meter²	IF('Selection of Model Main Assembly Line'=FALSE, 'Number of Stations Station Service Area'*'Belt Width Materials Handling per Station'*'Length of Station', 0<<meter²>>)
112 Area Working Area Tilt Assembly	meter²	Belt Width Conveyor Systems Tilt Assembly'*'Length of Station Tilt Assembly'*'Number of Stations Station Service Areas Tilt Assembly'
113 Array Area	meter²	{'Area Requirements Finish Lines', 'KPI_26_A Inspection Area', 'Area Requirements Finish Lines', 'Area Requirements F2 Lines', 'Area Requirements Rectification', 'KPI_28_A Paintwork Rectification Area'} *'Bin Total'
114 Array Conveyor		{{0,0},{1,0},{0,1},{1,1}}

#	Name of Element (KPI)	Unit	Definition
115	Array Invest of Buildings	EUR	('Array Area'*'Area Cost Rate'+ 'Pit Array'*'Pit Cost Rate')

116	Assembly Carrier in Circulation Doors by Lines	pieces	{
			'Assembly Carrier in Circulation Doors Line 1',
			IF(ARRSUM('Selection Doors Lines Line 2')=0,
			0<<pieces>>,
			'Assembly Carrier in Circulation Doors Line 2')
			}

117	Assembly Carrier in Circulation Doors Line 1	pieces	100
118	Assembly Carrier in Circulation Doors Line 1	pieces	Parent-'Assembly Carrier in Circulation Doors Line 1'
119	Assembly Carrier in Circulation Doors Line 2	pieces	100
120	Assembly Carrier in Circulation Doors Line 2	pieces	Parent-'Assembly Carrier in Circulation Doors Line 2'
121	Assembly Planned Operating Time_t - Gross Line Operating Time	min	Parent-'KPI_44_C Operating Time Planned'*60<<min/hours>>
122	Automation Marriage		{'Selection Non-Automation'['Marriage NA'], 'Selection Semi-Automation'['Marriage SA'], 'Selection Automation'['Marriage FA']}
123	Auxiliary Space Installations Fully Automated	meter²	300
124	Auxiliary Space Installations Semi Automated	meter²	300
125	Auxiliary Space Installations Semi-Automated	meter²	Facilities.'Readout Auxiliary Space Installations Semi-Automated'
126	Auxiliary Stations Filling	stations	Parent-'Additional Stations Filling'
127	Availability	%	99%
128	Availability Complete Line	%	{98,98} %
129	Availability Employees Doors	%	{'Availability Employees Doors Line 1', 'Availability Employees Doors Line 2'}
130	Availability Employees Doors Line 1	%	98%
131	Availability Employees Doors Line 2	%	98%
132	Availability Finish Line	%	{100%, 100%}
133	Availability Spotrepair Line	%	98%
134	Availability Stations Front Axle	stations	1
135	Availability Stations in Engine-Gearbox Line	stations	10
136	Availability Stations in Parallel Lines Doors Line 2 per Section	stations	1
137	Availability Stations in Parallel Lines Doors per Section	stations	{'Availability Stations in Parallel Lines Doors Line 1 per Section', 'Availability Stations in Parallel Lines Doors Line 2 per Section'}
138	Availability Stations in the Main Assembly Line	stations	0
139	Availability Stations in the Main Assembly Line Body Assembly 1	stations	5
140	Availability Stations in the Main Assembly Line Body Assembly 2	stations	5
141	Availability Stations in the Main Assembly Line Filling	stations	5
142	Availability Stations in the Main Assembly Line Final Assembly	stations	5
143	Availability Stations in the Main Assembly Line Tilt Assembly	Stations	5
144	Availability Stations in the Train Area	stations	Parent-'Technical Stations in the Pre-Assembly Line'
145	Availability Stations Pre-Assembly Axle	stations	{'Availability Stations Front Axle', 'Availability Stations Strut', 'Availability Stations Rear Axle', 'Availability Stations Wheel Hub'}
146	Availability Stations Rear Axle	stations	1
147	Availability Stations Strut	stations	1
148	Availability Stations Wheel Hub	stations	1
149	Availability Transpack	%	99.5 %
150	Availability Wax Facility	%	99%
151	Available Time per Station Final Assembly	seconds/stations	'KPI_49_D Cycle Time'*'KPI_74_G Employee Density Final Assembly'*1<<unit/worker>>
152	Available Time per Station Tilt Assembly	seconds/stations	'KPI_49_D Cycle Time'*'KPI_74_G Employee Density Tilt Assembly'*1<<unit/worker>>
153	Available Working Hours per Station in Engine-Gearbox Line	minutes/station	PRODUCT ('KPI_49_D Cycle Time', 'KPI_74_G Average Employee Density in Engine-Gearbox Line') * 1 <<unit/worker>>
154	Available Working Hours per Station Pre-Assembly Axle	minutes/station	PRODUCT ('KPI_49_D Cycle Time Axles', 'KPI_74_G Average Employee Density Pre-Assembly Axle') * 1 <<unit/worker>>
155	Available Working Hours per Station Pre-Assembly Doors	minutes/station	PRODUCT ('KPI_74_G Average Employee Density Doors', 'KPI_49_D Cycle Time Doors') * 1 <<unit/worker>>
156	Average Area Cost Rate Pre-Assembly	EUR/meter²	1000
157	Average Number of Engine Line-Side Presentation Units at Line-Side Presentation		CEIL(DIVZX (PRODUCT ('Proportion of Engine-Line-Side Presentation in Assembly Daily Output', 'KPI_41_C Assembly Agreed Daily Output', 1 <<days/(%*unit)>>), 'Engine-Units per Line-Side Presentation-Unit' * 100 <<1/unit>>, 0))

#	Name of Element (KPI)	Unit	Definition
158	Average Number of Gearbox Line-Side Presentation Units at Line-Side Presentation		CEIL(DIVZX (PRODUCT ('Proportion of Gearbox-Line-Side Presentation in Assembly Daily Unit Output', 'KPI_41_C Assembly Agreed Daily Output', 1 <<days/(%*unit)>>), 'Gearbox-Units per Line-Side Presentation-Unit' * 100 <<1/unit>>, 0))
159	Average Planned Operating Time	minutes	ARRSUM('Proportions of Units'*'Planned Operating Times')/'Sum of Units'
160	Average Time Off-Line Rework	min	100 <<min>>
161	Basic Invest Doors Carriers	EUR	{'Basic Invest Single Door Carriers per Piece', 'Basic Invest Double Door Carriers Serial per Piece', 'Basic Invest Double Door Carriers Parallel per Piece', 'Basic Invest Quad Door Carriers per Piece'}
162	Basic Invest Double Door Carriers Parallel per Piece	EUR	2000
163	Basic Invest Double Door Carrierss Serial per Piece	EUR	0
164	Basic Invest Quad Door Carriers per Piece	EUR	0
165	Basic Invest Single Door Carriers per Piece	EUR	0
166	Basic Times Test Rigs	min/unit	{ 'Process Time'[Trail], 'Process Time'[ACC], 'Process Time Rolling Road Test Rig_t', 'Process Time'[ABS], 'Process Time'['Engine Test'], 'Process Time'[Headlight] }
167	Belt Width Bottom Area Connecting Conveyor	meter	70
168	Belt Width Bottom Area Gearbox-Line	meter	10
169	Belt Width Conveyor System Axles	meter	Parent-'Belt Width Conveyor System Center-Lines'
170	Belt Width Conveyor System Center-Lines	meter	{'Belt Width Conveyor System Front Axle', 'Belt Width Conveyor System Strut', 'Belt Width Conveyor System Rear Axle', 'Belt Width Conveyor System Wheel Hub'}
171	Belt Width Conveyor System Connecting Conveyor	meter	1
172	Belt Width Conveyor System Doors	meter	FOR (i= 'Door Lines'| IF ('Door Carriers'[i] > 3, 'Belt Width Conveyor System Doors Double-Sided Door Carrier', 'Belt Width Conveyor System Doors One-Sided Door Carrier'))
173	Belt Width Conveyor System Doors Double-Sided Door Carrier	meter	2
174	Belt Width Conveyor System Doors One-Sided Door Carrier	meter	1.5
175	Belt Width Conveyor System Engine-Gearbox	meter	{'Belt Width Conveyor System Gearbox Line','Belt Width Conveyor System Connecting Conveyor','Belt Width Conveyor System Engine-Gearbox Line'}
176	Belt Width Conveyor System Engine-Gearbox	meter	Parent-'Belt Width Conveyor System Engine-Gearbox'
177	Belt Width Conveyor System Engine-Gearbox Line	meter	1
178	Belt Width Conveyor System Final Assembly	meter	5
179	Belt Width Conveyor System Front Axle	meter	2
180	Belt Width Conveyor System Gearbox Line	meter	1
181	Belt Width Conveyor System Rear Axle	meter	1.5
182	Belt Width Conveyor System Strut	meter	1
183	Belt Width Conveyor System Wheel Hub	meter	2
184	Belt Width Conveyor Systems Body Assembly 1	meter	5
185	Belt Width Conveyor Systems Body Assembly 2	meter	4
186	Belt Width Conveyor Systems Filling	meter	5
187	Belt Width Conveyor Systems Tilt Assembly	meter	5
188	Belt Width Materials Handling per Station	meter	4.2
189	Belt Width of Finish Line	meter	7
190	Belt Width Traffic Space Body Assembly 1	meter	2
191	Belt Width Traffic Space Body Assembly 2	meter	2
192	Belt Width Traffic Space Filling	meter	2
193	Belt Width Traffic Space Final Assembly	meter	2
194	Belt Width Traffic Space Tilt Assembly	meter	2
195	Bin F2-Lines		1
196	Bin Finish A		1
197	Bin Finish B		1
198	Bin Paintwork Rectification		1
199	Bin Rectification		1
200	Bin Test Rig		1
201	Bin Total		{'Bin Finish A', 'Bin Test Rig', 'Bin Finish B', 'Bin F2-Lines', 'Bin Rectification', 'Bin Paintwork Rectification'}

# Name of Element (KPI)	Unit	Definition
202 Breaks per Shift Doors	minutes/shift	{'Breaks per Shift Doors Line 1', 'Breaks per Shift Doors Line 2'}
203 Breaks per Shift Doors Line 1	minutes/shift	45
204 Breaks per Shift Doors Line 2	minutes/shift	45
205 Buffer Area Paintwork Rectification	meter²	('Number of Buffer Stations Spotrepair'*'Number of Spotrepair Lines' +'Number of Buffer Stations Complete Line'*ARRSUM('Number of Complete Lines')) *'Area Buffer Station 2'
206 Buffer Stations per Rectification Station		0.5
207 Buffer Stations Rectification		CEIL('Number of Rectification Stations'*'Buffer Stations per Rectification Station',1)
208 Busy Time Test Rigs	min/unit	{'Basic Times Test Rigs'[Trail]+'Additional Time Headlights', 'Basic Times Test Rigs'[ACC], 'Basic Times Test Rigs'['Rolling Road'], 'Basic Times Test Rigs'[ABS], 'Basic Times Test Rigs'['Engine Test'], 'Basic Times Test Rigs'[Headlight] }+ FOR(i='Test Rigs'IIF('Basic Times Test Rigs'[i]=0 <<min/unit>>,0<<min/unit>>,'Driving Time Test Rig'))

209 Calculation Model Area Cost Rates Pre-Assemblies	EUR/meter²	IF ('Selection Calculation Model Cost Rate Pre-Assembly Area'=1,
		FOR (i = 'Pre-Assembly']'Average Area Cost Unit Rate Pre-Assembly'),
		'Cost Rate Pre-Assembly Area')

210 Capacity Complete Line	unit/hr	{4,8} <<unit/hr>>
211 Capacity Gearbox-Store	unit	600
212 Capacity Spotrepair Line	unit/hr	3 <<unit/hr>>

213 Check 100 Percent		IF(ARRSUM(Proportions)<100%, 1,
		IF(ARRSUM(Proportions)>100%, 2,
		0))

214 Check 100%		IF('Ratio-Total'>=100<<%>>,1,0)
215 Choice_Carrier Technology		1
216 Choice_Mode of Drive		1
217 Complete Lines		ARRSUM('Number of Complete Lines')
218 Connecting Conveyor		1
219 Content of KPI 105_M Average Planned Operating Time		{'Content of KPI_105_M Average Planned Operating Time Line 1', 'Content of KPI_105_M Average Planned Operating Time Line 2'}
220 Content of KPI 105_M Average Planned Operating Time Line 1		1
221 Content of KPI 105_M Average Planned Operating Time Line 2		1
222 Content of KPI_105_M Axle		{'Content of KPI_105_M Front Axle', 'Content of KPI_105_M Strut', 'Content of KPI_105_M Rear Axle', 'Content of KPI_105_M Wheel Hub'}
223 Content of KPI_105_M Engine-Gearbox Line		1
224 Content of KPI_105_M Front Axle		1
225 Content of KPI_105_M Rear Axle		1
226 Content of KPI_105_M Strut		1
227 Content of KPI_105_M Wheel Hub		1
228 Conveyor System Connecting Conveyor		1
229 Conveyor System Engine-Gearbox-Line		1
230 Conveyor System Front Axle		2
231 Conveyor System Gearbox-Line		1
232 Conveyor System Rear Axle		2
233 Conveyor System Strut		1
234 Conveyor System Wheel Hub		1
235 Copy of Additional Costs	%	60%
236 Cost Rate Automated Stations Areas	EUR/meter²	1000
237 Cost Rate Body Assembly Areas	EUR/meter²	1000
238 Cost Rate Center-Lines Area	EUR/meter²	1000
239 Cost Rate Doors Area	EUR/meter²	1000
240 Cost Rate Engine-Gearbox Area	EUR/meter²	1000
241 Cost Rate Filling Areas	EUR/meter²	1000
242 Cost Rate Final Assembly Areas	EUR/meter²	1000
243 Cost Rate Main Assembly Line Areas	EUR/meter²	Parent~'Cost Rates Main Line Areas'
244 Cost Rate Main Assembly Line Areas	EUR/meter²	Parent~'Cost Rates Main Line Areas'
245 Cost Rate Main Assembly Line Areas	EUR/meter²	Parent~'Cost Rates Main Line Areas'
246 Cost Rate Main Assembly Line Areas	EUR/meter²	Parent~'Cost Rates Main Line Areas'
247 Cost Rate Main Assembly Line Areas	EUR/meter²	Parent~'Cost Rates Main Line Areas'
248 Cost Rate Main Line Simple Model Areas	EUR/meter²	1000
249 Cost Rate Power Train Area	EUR/meter²	1000

#	Name of Element (KPI)	Unit	Definition
250	Cost Rate Pre-Assembly Area	EUR/meter²	{'Cost Rate Engine-Gearbox Area', 'Cost Rate Center-Lines Area', 'Cost Rate Power Train Area', 'Cost Rate Doors Area'}
251	Cost Rate Technology per Automated Station Simple Model	EUR	10000
252	Cost Rate Tilt Assembly Areas	EUR/meter²	1000
253	Cost Rates Main Line Areas	EUR/meter²	{'Cost Rate Automated Stations Areas', 'Cost Rate Body Assembly Areas', 'Cost Rate Tilt Assembly Areas', 'Cost Rate Final Assembly Areas', 'Cost Rate Filling Areas'}
254	Costs Carrier	EUR	Facilities.'Costs Carriers'
255	Costs Carriers	EUR	Number of Carriers'*'Invest Carriers'
256	Costs Changes of Conveyor Systems	EUR	KPI_70_F Number of Conveyor Systems Changes'*'Invest Conveyor System Changes'
257	Costs Converters	EUR	Facilities.'Costs Converters'
258	Costs Converters	EUR	KPI_72_F Number of Changeover Processes'*'Invest Converters'
259	Costs Conveyor System Changes	EUR	Facilities.'Costs Changes of Conveyor Systems'
260	Costs per meter F2-Line	EUR/meter	4500
261	Costs per Meter Finish-Line	EUR	6000
262	Course Paintwork Rectification Rate	%	Time Model Input'.'Lapse Paintwork Rectification Rate'
263	Course Planned Time Finish B	min/unit	Time Model Input'.'Lapse Planned Time Finish B'
264	Course Rectification Rate	%	Time Model Input'.'Lapse Rectification Rate'
265	Course Time Rolling Road	min/unit	Time Model Input'.'Lapse Time Rolling Road'
266	Daily Capacity Automatic Facilites	unit/days	Parent~'Daily Capacity Automatic Facilities'
267	Daily Capacity Automatic Facilities	unit/days	1000
268	Daily Output Transpack	unit	Ratio Transpack'*'Agreed Daily Output'
269	Daily Output Wax	unit	Ratio Wax'*'Agreed Daily Output'
270	Depreciation Total per Year	EUR/year	Sum of Depreciation Buildings'+'Sum of Depreciation Technology'
271	Direction Shifter Conveyor System Strut	EUR	IF ('Selection Conveyor System Axles'[Strut] = 1, SUM (PRODUCT ('Number of Corner Sections Strut', 'Invest Corner Section in Friction Roller Tracks'), PRODUCT ('Number of Handling Assistors Side Way Shifting Units Strut', 'Invest Side Way Shifting Units in Friction Roller Track')), 0 <<EUR>>)
272	Direction Shifter Conveyor System Wheel Hub	EUR	IF ('Selection Conveyor System Axles'['Wheel Hub'] = 1, SUM (PRODUCT ('Number of Corner Sections Wheel Hub', 'Invest Corner Section in Friction Roller Tracks'), PRODUCT ('Number of Handling Assistors Side Way Shifting Units Wheel Hub', 'Invest Side Way Shifting Units in Friction Roller Track')), 0 <<EUR>>)
273	Door Carriers		Parent~'Gantry Systems Doors'

274	Door Carriers in Circulation Doors by Lines	pieces	{
			'Door Carriers in Circulation Doors Line 1',
			IF(ARRSUM('Selection Doors Lines Line 2')=0,
			0<<pieces>>,
			'Door Carriers in Circulation Doors Line 2')
			}

275	Door Carriers in Circulation Doors Line 1	pieces	100
276	Door Carriers in Circulation Doors Line 1	pieces	Parent~'Door Carriers in Circulation Doors Line 1'
277	Door Carriers in Circulation Doors Line 2	pieces	100
278	Door Carriers in Circulation Doors Line 2	pieces	Parent~'Door Carriers in Circulation Doors Line 1'
279	Driving Time	min/unit	2 <<min/unit>>
280	Driving Time Test Rig	min/unit	0.25
281	Driving Time Track Rolling Road	min/unit	0.5
282	Employee Density	worker/stations	2
283	Employee Density PQ-Cycles	worker/stations	1<<worker/stations>>
284	Employees Main Assembly Line Overall Simple Model	worker	Workers Payed per Shift
285	Employees Requirement Axles Readout	worker	ROUND ({ARRSUM ('Number of Workmen Pre-Assembly Axles')}, 1 <<worker>>)
286	Employees Requirement Doors Readout	worker	{ARRSUM('Number of Workmen Doors')}
287	Employees Requirement Engine-Gearbox Readout	worker	SUM ('Number of Workmen Sub-Engine-Lines', 'Number of Workmen Engine-Gearbox-Line')
288	Employees Requirement Power Train Readout	worker	ROUND({{'Manual Work Station_Pre-Assembly Line'+'KPI_54_D Testing and Quality Stations in the Main Assembly Line Body Assembly 1')*'Employee Density'})

# Name of Element (KPI)	Unit	Definition
289 Employees Requirement Pre-Assembly Areas Readout	worker	SUM (PRODUCT ('Selection Pre-Assembly'['PA Engine_Gearbox'], 'Employees Requirement Engine-Gearbox Readout'), PRODUCT ('Selection Pre-Assembly'['PA Axles'], 'Employees Requirement Axles Readout'), PRODUCT ('Selection Pre-Assembly'['PA Doors'], 'Employees Requirement Doors Readout'), PRODUCT ('Selection Pre-Assembly'['PA Power Train'], 'Employees Requirement Power Train Readout'))
290 Engine-Gearbox Line		1
291 Engine-Units per Line-Side Presentation-Unit	unit	2
292 Expenses per Unit	EUR/unit	Annual Budget'/('Working Stations per Year'*'Agreed Daily Output')* 1 <<da>>
293 Extra Buffer Stations in Axle Line	stations	Parent~'KPI_58_D Decoupling Stations Pre-Assembly Axle'
294 F2 Line Driver	worker	CEIL('Transfer Time Vehicle'*'Agreed Daily Output'/'Assembly Planned Operating Time_t - Gross Line Operating time') * 1<<worker/unit>>
295 F2 Line Invest Conveyor System Transpack	EUR	('Total Stations F2-Line Wax'-'Stations Lifting Ramp')*'Costs per Meter F2-Line'*'Length of Station F2-Line' +'Invest Control Engeneering'
296 F2 Line Invest Conveyor System Wax	EUR	Stations per F2-Line Wax'*'Costs per Meter F2-Line'*'Length of Station F2-Line' +'Invest Control Engeneering'
297 F2 Line Invest Facilities Transpack	EUR	IF('Ratio Transpack'>0%, 'F2 Line Invest Conveyor System Transpack'+'Invest Lifting Ramp'+'Invest Transpack Oven', 0<<EUR>>)
298 F2 Line Invest Facilities Wax	EUR	IF('Ratio Wax'>0%, 'F2 Line Invest Conveyor System Wax'+'Invest Wax Station', 0<<EUR>>)
299 F2 Line Pit Requirements Transpack	meter³	IF('Ratio Transpack'>0%, ('Pit Width F2-Line'*'Pit Depth F2-Line'*'Length of Station F2-Line'*('Total Stations F2-Line Wax'-'Stations Lifting Ramp')*1<<stations>>), 0<<meter³>>)
300 F2 Line Pit Requirements Wax	meter³	IF('Ratio Wax'>0%, 'Pit Width F2-Line'*'Pit Depth F2-Line'*'Length of Station F2-Line'*'Stations per F2-Line Wax'*1<<stations>>+'Pit Requirements Wax Station', 0<<meter³>>)
301 Floor Transportation System Vehicles Rear Axle	EUR	IF ('Selection Conveyor System Axles'['Rear Axle'] = 2, PRODUCT ('Single Invest Floor Transportation System Vehicle Front- and Rear Axle', 'KPI_51_D Total Stations Axle Pre-Assembly'['Rear Axle'], 'Floor Transportation Systems in Circulation Rear Axle') / 1 <<stations>>, 0 <<EUR>>)
302 Floor Transportation Systems in Circulation Front Axle	%	100
303 Floor Transportation Systems in Circulation Rear Axle	%	50
304 Floor Transportation Systems in Circulation Strut	%	50
305 Floor Transportation Systems in Circulation Wheel Hub	%	50
306 Floor Transporting System Vehicles in Circulation Engine-Gearbox-Line	%	100
307 Flow Rate Complete Line	unit/hr	Capacity Complete Line'*'Availability Complete Line'
308 Flow Rate of Finish-Lines	unit/min	Agreed Daily Output'*(1+'Rectification Rate Finish Line')/'Assembly Planned Operating Time_t - Gross Line Operating Time'
309 Flow Rate Spot Repair	unit/hr	Capacity Spotrepair Line'/'Availability Spotrepair Line'
310 Foremen Main Assembly Line	Worker	ROUND('Workers Required Main Assembly Line'/'Proportion of Foremen')
311 Foremen Requirements Main Assembly Line	Worker	ROUND(('Foremen Main Assembly Line')+('Foremen Main Assembly Line'*'Supplement Caused by Absence'))
312 Front Axle		Parent~'Front Axle Drive Shaft'
313 Front Axle Assembly		0
314 Front Axle Drive Shaft		0
315 Fully Automated Stations_Pre-Assembly Line	stations	0
316 Gantry Systems Doors		{'Gantry Systems Doors Line 1', 'Gantry Systems Doors Line 2'}
317 Gantry Systems Doors Line 1		1
318 Gantry Systems Doors Line 2		1
319 Gearbox Deviations	meter	{'Length Gearbox', 'Width Gearbox', 'Gearbox Height'}
320 Gearbox Height	meter	0.3

# Name of Element (KPI)	Unit	Definition
321 Gearbox-Line		1
322 Gearbox-Store Rows		2
323 Gearbox-Units per Line-Side Presentation-Unit	unit	6
324 Glazing Sound Insulation Door Line 1		1
325 Glazing Sound Insulation Door Line 2		1
326 Graph Daily Output	%	Parent~'Graph Daily Output'
327 Graph Daily Unit Output	%	{100,95,94,90,85,80,75,70,70,70,75,85,95,105,110,112} %
328 Graph Paintwork Rectification Rate	%	{100,95,94,90,85,80,75,70,70,70,75,85,95,105,110,112} %
329 Graph Planned Time	%	{100,95,94,90,85,80,75,70,70,70,75,85,95,105,110,112} %
330 Graph Planned Time Finish B	%	{100,95,94,90,85,80,75,70,70,70,75,85,95,105,110,112} %
331 Graph Rectification-Rate	%	{100,95,94,90,85,80,75,70,70,70,75,85,95,105,110,112} %
332 Graph Time Rolling Road	%	{100,95,94,90,85,80,75,70,70,70,75,85,95,105,110,112} %
333 Graph Workers Costs	%	{100,95,94,90,85,80,75,70,70,70,75,85,95,105,110,112} %
334 Gross Basic Working Time in Hours per Shift	hours/shift	9
335 Gross Operating Planned Time Body Assembly	minutes/unit	('KPI_103_M Planned Time Excluding OE Body Assembly'*(1+'Proportion of Optional Equipment'))*(1+'KPI_50_D Line Balancing on the Main Assembly Line')*(1+'Planning Time Spread')
336 Gross Operating Planned Time Filling	minutes/unit	('KPI_103_M Planned Time Excluding OE Filling'*(1+'Proportion of Optional Equipment'))*(1+'KPI_50_D Line Balancing on the Main Assembly Line')*(1+'Planning Time Spread')
337 Gross Operating Planned Time Final Assembly	minutes/unit	('KPI_103_M Planned Time Excluding OE Final Assembly'*(1+'Proportion of Optional Equipment'))*(1+'KPI_50_D Line Balancing on the Main Assembly Line')*(1+'Planning Time Spread')
338 Gross Operating Planned Time Tilt Assembly	minutes/unit	('KPI_103_M Planned Time Excluding OE Tilt Assembly'*(1+'Proportion of Optional Equipment'))*(1+'KPI_50_D Line Balancing on the Main Assembly Line')*(1+'Planning Time Spread')
339 Gross Planned Operating Time_Pre Assembly	minutes/unit	IF('Choice_Mode of Drive'=1, 'KPI_103_M Planned Operating Time Excluding OE_Pre-Assembly'*(1+(Ratio_OE+'Additional_M Variant')), 'KPI_103_M Planned Operating Time Excluding OE_Pre-Assembly'*(1+(Ratio_OE+'Additional_All Wheel'+'Additional_M Variant')))
340 Gross Planned Time in the Main Assembly Line	minutes/unit	Main Assembly Line'.'Gross Operating Planned Time Main Assembly Line'
341 Handling Time per Vehicle	min/unit	5<<min/unit>>
342 Handling Time Vehicle Finish	min/unit	1
343 Height Adjustment Doors		{'Height Adjustment Doors Line 1', 'Height Adjustment Doors Line 2'}
344 Height Adjustment Doors		Parent~'Height Adjustment Doors'
345 Height Adjustment Doors Line 1		1
346 Height Adjustment Doors Line 2		1
347 Hourly Rate Worker	EUR/hours	40 <<EUR/hours>>
348 Hourly Wage Rate Employee_t	EUR/hours	Parent~'Costs per Employee'
349 Hourly Wage Rate Worker	EUR/(hr*worker)	Parent~'Costs per Employee'*1<<hours/(hr*worker)>>
350 Hours	hr	16 <<hr>>
351 Hours in Minutes	minutes	HOUR(DATE(0,1,1,0,0,0)+hours) * 60 <<minutes>> + MINUTE(DATE(0,1,1,0,0,0)+hours) * 1<<minutes>> + SECOND(DATE(0,1,1,0,0,0)+hours) * 1<<minutes>>/60
352 Hours per Shift Doors	hours/shift	{'Hours per Shift Doors Line 1', 'Hours per Shift Doors Line 2'}
353 Hours per Shift Doors Line 1	hours/shift	8
354 Hours per Shift Doors Line 2	hours/shift	9
355 Installation and Roll Sound Insulation Line 1		1
356 Installation and Roll Sound Insulation Line 2		1
357 Installation Conveyors		1
358 Interchangeable Rotation Head by Line 1		1
359 Interchangeable Rotation Head by Line 2		1
360 Interchangeable Rotation Head by Lines		{'Interchangeable Rotation Head by Line 1', 'Interchangeable Rotation Head by Line 2'}
361 Interchangeable Rotation Head by Lines		Parent~'Interchangeable Rotation Head by Lines'
362 Internal Rectification Rate	%	10%
363 Invest Application Plat Sound Insulation	EUR	20000
364 Invest Area Paintwork Rectification	EUR	Area Cost Rate Paintwork Rectification'*'KPI_28_A Paintwork Rectification Area'
365 Invest Attaching Engine	EUR	10000
366 Invest Attaching Gearbox	EUR	10000

#	Name of Element (KPI)	Unit	Definition
367	Invest Automated Glazing Door Glass -Triangular Glass	EUR	300000
368	Invest Automated Station Screwing or Clamping Technology Linked Axles	EUR	200000
369	Invest Automated Stations Exhaust Manifold Screwing	EUR	500000
370	Invest Automatic	EUR	IF('Number of Automatic Stations_Train Area'>0<<stations>>, ('Invest per Automatic Station'*'Number of Automatic Stations_Train Area')+ ('Invest per Testing and Quality Station'*'KPI_54_D Testing and Quality Stations in the Train Area'), 0<<EUR>>)
371	Invest Automatic Gearbox Store-Shuttle per Slice	EUR	50000
372	Invest Automatic Gearbox Store-Shuttles	EUR	PRODUCT ('Number of Gearbox Store Shuttles', 'Invest Automatic Gearbox Store-Shuttle per Slice')
373	Invest Automatical Station Screwing- and Clamping Technology Linked Axles	EUR	Parent~'Invest Automated Station Screwing or Clamping Technology Linked Axles'
374	Invest Automatical Station Wheelbearing Press Unlinked Wheel Hub	EUR	160000
375	Invest Brake Test Wheel Hub	EUR	240000
376	Invest Buildings Axle Readout	EUR	SUM (Axles.'Invest Buildings Front Axle Readout', Axles.'Invest Buildings Strut Readout', Axles.'Invest Buildings Rear Axle Readout', Axles.'Invest Buildings Wheel Hub Readout')
377	Invest Buildings Body Assembly	EUR	Body Assembly'.'Invest Buildings Body Assembly'
378	Invest Buildings Body Assembly	EUR	PRODUCT('Cost Rate Main Assembly Line Areas'['Body Assembly'],'Total Area Body Assembly')
379	Invest Buildings Doors	EUR	PRODUCT ('Area Doors', 'Mathematical Model Area Cost Rates Pre-Assembly'['PA Doors'])
380	Invest Buildings Doors Readout	EUR	Doors Lines'.'Invest Buildings Doors Readout'
381	Invest Buildings Doors Readout	EUR	ROUND ({ARRSUM ('invest buildings doors')}, 1000 <<EUR>>)
382	Invest Buildings Engine-Gearbox Readout	EUR	Engine-Gearbox'.'Invest of Buildings Engine-Gearbox-Line Readout'
383	Invest Buildings Filling	EUR	Filling.'Invest Buildings Filling'
384	Invest Buildings Filling	EUR	PRODUCT('Cost Rate Main Assembly Line Areas'[Filling],'Total Area Filling')
385	Invest Buildings Final Assembly	EUR	Final Assembly'.'Invest Buildings Final Assembly'
386	Invest Buildings Final Assembly	EUR	PRODUCT('Cost Rate Main Assembly Line Areas'['Final Assembly'],'Total Area Final Assembly')
387	Invest Buildings Front Axle	EUR	PRODUCT ('Total Area Front Axle', 'Mathematical Model Area Cost Units Pre-Assembly'['PA Axles'])
388	Invest Buildings Front Axle Readout	EUR	ROUND ({'Invest Buildings Front Axle'}, 1000 <<EUR>>)
389	Invest Buildings Fully-Automated Stations	EUR	Facilities.'Invest Buildings Fully-Automated Stations'
390	Invest Buildings Fully-Automated Stations	EUR	Readout Auxiliary Space Installations Fully-Automated'* 'Cost Rate Main Assembly Line Areas'['Automatic Stations']
391	Invest Buildings Installations	EUR	SUM('Invest Buildings Semi-Automated Stations', 'Invest Buildings Fully-Automated Stations')
392	Invest Buildings Main Line Complex Model	EUR	IF ('Selection of Model Main Assembly Line'=TRUE, (PRODUCT('Selection Main Line'['Body Assembly'],'Invest Buildings Body Assembly')+ PRODUCT('Selection Main Line'['Tilt Assembly'],'Invest Buildings Tilt Assembly')+ PRODUCT('Selection Main Line'['Final Assembly'],'Invest Buildings Final Assembly')+ PRODUCT('Selection Main Line'[Filling],'Invest Buildings Filling')+ PRODUCT('Selection Main Line'['Automatic Stations'],'Invest Buildings Installations')), 0<<EUR>>)
393	Invest Buildings Main Line Simple Model	EUR	IF('Selection of Model Main Assembly Line'=FALSE, (PRODUCT('Cost Rate Main Line Simple Model Areas', 'Total Area Main Line Simple Model')), 0<<EUR>>)
394	Invest Buildings Power Train Readout	EUR	PRODUCT ('Total Area Power Train Readout', 'Calculation Model Area Cost Rates Pre-Assemblies'['PA Power Train'])
395	Invest Buildings Pre-Assembly Readout	EUR	SUM (PRODUCT ('Selection Pre-Assembly'['PA Engine_Gearbox'], 'Invest Buildings Engine-Gearbox Readout'), PRODUCT ('Selection Pre-Assembly'['PA Axles'], 'Invest Buildings Axle Readout'), PRODUCT ('Selection Pre-Assembly'['PA Doors'], 'Invest Buildings Doors Readout'), PRODUCT ('Selection Pre-Assembly'['PA Power Train'], 'Invest Buildings Power Train Readout'))
396	Invest Buildings Rear Axle	EUR	PRODUCT ('Area Rear Axle', 'Mathematical Model Area Cost Units Pre-Assembly'['PA Axles'])

# Name of Element (KPI)	Unit	Definition
397 Invest Buildings Rear Axle Readout	EUR	ROUND ({'Invest Buildings Rear Axle'}, 1000 <<EUR>>)
398 Invest Buildings Semi-Automated Stations	EUR	Facilities.'Invest Buildings Semi-Automated Stations'
399 Invest Buildings Semi-Automated Stations	EUR	Readout Auxiliary Space Installations Semi-Automated'* 'Cost Rate Main Assembly Line Areas'['Automatic Stations']
400 Invest Buildings Strut	EUR	PRODUCT ('Total Area Strut', 'Mathematical Model Area Cost Units Pre-Assembly'['PA Axles'])
401 Invest Buildings Strut Readout	EUR	ROUND ({'Invest Buildings Strut'}, 1000 <<EUR>>)
402 Invest Buildings Tilt Assembly	EUR	Tilt Assembly'.'Invest Buildings Tilt Assembly'
403 Invest Buildings Tilt Assembly	EUR	PRODUCT('Cost Rate Main Assembly Line Areas'['Tilt Assembly'],'Total Area Tilt Assembly')
404 Invest Buildings Wheel Hub	EUR	PRODUCT ('Total Area Wheel Hub', 'Mathematical Model Area Cost Units Pre-Assembly'['PA Axles'])
405 Invest Buildings Wheel Hub Readout	EUR	ROUND (PRODUCT ({'Invest Buildings Wheel Hub'}, 'Number of Lines Wheel Hub'), 1000 <<EUR>>)
406 Invest Carriers	EUR/pieces	1000
407 Invest Charging Set Conveyor prop	EUR/meter	1500<<EUR/meter>>
408 Invest Complete Line	EUR	{3700000,4200000}
409 Invest Confirmation of Variants Strut	EUR	50000
410 Invest Connecting Conveyor	EUR	PRODUCT (SUM ('Length Floor Area Connecting Conveyor', 'Belt Width Bottom Area Connecting Conveyor'),2, 'Prop Costs Conveyor System Connecting Conveyor')
411 Invest Control Engeneering	EUR	140000
412 Invest Control Engeneering per Line	EUR	140000
413 Invest Converter on Engine-Gearbox-Line	EUR	100000
414 Invest Converters	EUR/pieces	3
415 Invest Converting Station on Connecting Conveyor	EUR	30000
416 Invest Conveyor Fixed	EUR	Array Conveyor'[INDEX('Installation Conveyors'),Finish] *'Number of Finish-Lines'*'Invest Fixed Conveyors per Line'
417 Invest Conveyor System	EUR	Tilt Assembly'.'Invest Conveyor Systems Tilt Assembly'
418 Invest Conveyor System Body Assembly	EUR	Invest Conveyor System Body Assembly1'+'Invest Conveyor System Body Assembly2'
419 Invest Conveyor System Body Assembly 1	EUR	Body Assembly'.'Invest Conveyor Systems Body Assembly 1'
420 Invest Conveyor System Body Assembly 2	EUR	Body Assembly'.'Invest Conveyor Systems Body Assembly 2'
421 Invest Conveyor System Changes	EUR/pieces	3
422 Invest Conveyor System Connecting Conveyor	EUR	SUM ('Invest Converting Station on Connecting Conveyor', 'Invest Direction Shifter Conveyor System Connecting Conveyor', 'Invest Connecting Conveyor')
423 Invest Conveyor System Engine-Gearbox-Line	EUR	SUM ('Invest Engine-Gearbox-Line', 'Invest Direction Shifter Conveyor System Engine-Gearbox-Line', 'Invest Floor Transporting System Vehicles Engine-Gearbox-Line')
424 Invest Conveyor System Filling	EUR	Filling.'Invest Conveyor Systems Filling'
425 Invest Conveyor System Final Assembly	EUR	Final Assembly'.'Invest Conveyor Systems Final Assembly'
426 Invest Conveyor System Front Axle	EUR	SUM ('Invest Front Axle Line', 'Invest Direction Shifter Conveyor System Front Axle', 'Invest Floor Transportation System Vehicles Front Axle')
427 Invest Conveyor System Gearbox-Line	EUR	SUM ('Invest Direction Shifter Conveyor System Gearbox-Line', 'Invest Gearbox-Line')
428 Invest Conveyor System Rear Axle	EUR	SUM ('Invest Rear Axle Line', 'Invest Direction Shifter Conveyor System Rear Axle', 'Floor Transportation System Vehicles Rear Axle')
429 Invest Conveyor System Simple	EUR	IF('Selection of Model Main Assembly Line'=FALSE, FOR(i=1..1| 'Invest Distances'[INDEX(INTEGER('Selection of Carrier Technology Simple Model Modell'[i]))]*'Length of Station'*'Number of Stations Materials Handling' *(100%+'Additional Recirculation'[INDEX(INTEGER('Selection of Carrier Technology Simple Model Modell'[i]))]+'Proportion of Control Technology'[INDEX(INTEGER('Selection of Carrier Technology Simple Model Modell'[i]))])), 0<<EUR>>)
430 Invest Conveyor System Strut	EUR	SUM ('Invest Conveyor System Strut-Line', 'Direction Shifter Conveyor System Strut', 'Invest Floor Transportation System Vehicles Strut')
431 Invest Conveyor System Strut-Line	EUR	PRODUCT ('Prop Costs Conveyor System Strut', 'Length of Station Strut', 'KPI_51_D Total Stations Axle Pre-Assembly'[Strut]) / 1 <<stations>>
432 Invest Conveyor System Wheel Hub	EUR	SUM ('Invest Wheel Hub Line', 'Direction Shifter Conveyor System Wheel Hub', 'Invest Floor Transportation System Vehicles Wheel Hub')

#	Name of Element (KPI)	Unit	Definition
433	Invest Conveyor Systems Body Assembly 1	EUR	(FOR(i=1..1| ('Invest Distances Body Assembly'[INDEX(INTEGER('Selection Conveyor Systems Body Assembly 1'[i]))]*'Length of Station Body Assembly 1'*'Number of Stations Conveyor Systems Body Assembly 1'+ 'Invest Lifting Station Body Assembly'[INDEX(INTEGER('Selection Conveyor Systems Body Assembly 1'[i]))]*'Number of Lifting Stations Body Assembly1')* (100%+'Proportion of Control Technique Body Assembly'[INDEX(INTEGER('Selection Conveyor Systems Body Assembly 1'[i]))]+ 'Proportion of Equipment Body Assembly'[INDEX(INTEGER('Selection Conveyor Systems Body Assembly 1'[i]))))))
434	Invest Conveyor Systems Body Assembly 2	EUR	(FOR(i=1..1| ('Invest Distances Body Assembly'[INDEX(INTEGER('Selection Conveyor Systems Body Assembly 1'[i]))]*'Length of Station Body Assembly 1'*'Number of Stations Conveyor Systems Body Assembly 1'+ 'Invest Lifting Station Body Assembly'[INDEX(INTEGER('Selection Conveyor Systems Body Assembly 1'[i]))]*'Number of Lifting Stations Body Assembly1')* (100%+'Proportion of Control Technique Body Assembly'[INDEX(INTEGER('Selection Conveyor Systems Body Assembly 1'[i]))]+ 'Proportion of Equipment Body Assembly'[INDEX(INTEGER('Selection Conveyor Systems Body Assembly 1'[i]))))))
435	Invest Conveyor Systems Filling	EUR	(FOR(i=1..1| ('Invest Distances Filling'[INDEX(INTEGER('Selection Conveyor Systems Filling'[i]))]*'Length of Station Filling'*'Number of Stations Conveyor Systems Filling'+ 'Invest Lifting Station Filling'[INDEX(INTEGER('Selection Conveyor Systems Filling'[i]))]*'Number of Lifting Stations Filling')* (100%+'Proportion of Control Technique Filling'[INDEX(INTEGER('Selection Conveyor Systems Filling'[i]))]+ 'Proportion of Equipment Filling'[INDEX(INTEGER('Selection Conveyor Systems Filling'[i]))))))
436	Invest Conveyor Systems Final Assembly	EUR	(FOR(i=1..1| ('Invest Distances Final Assembly'[INDEX(INTEGER('Selection Conveyor Systems Final Assembly'[i]))]*'Length of Station Final Assembly'*'Number of Stations Conveyor Systems Final Assembly'+ 'Invest Lifting Station Final Assembly'[INDEX(INTEGER('Selection Conveyor Systems Final Assembly'[i]))]*'Number of Lifting Stations Final Assembly')* (100%+'Proportion of Control Technique Final Assembly'[INDEX(INTEGER('Selection Conveyor Systems Final Assembly'[i]))]+ 'Proportion of Equipment Final Assembly'[INDEX(INTEGER('Selection Conveyor Systems Final Assembly'[i]))))))
437	Invest Conveyor Systems Tilt Assembly	EUR	(FOR(i=1..1| ('Invest Distances Tilt Assembly'[INDEX(INTEGER('Selection Conveyor Systems Tilt Assembly'[i]))]*'Length of Station Tilt Assembly'*'Number of Stations Conveyor Systems Tilt Assembly'+ 'Invest Lifting Station Tilt Assembly'[INDEX(INTEGER('Selection Conveyor Systems Tilt Assembly'[i]))]*'Number of Lifting Stations Tilt Assembly')* (100%+'Proportion of Control Technique Tilt Assembly'[INDEX(INTEGER('Selection Conveyor Systems Tilt Assembly'[i]))]+ 'Proportion of Equipment Tilt Assembly'[INDEX(INTEGER('Selection Conveyor Systems Tilt Assembly'[i]))))))
438	Invest Conveyor Technology	EUR	IF('Selection Conveyor System'=1, 'Invest per BTS'*'Number of MAT in Circulation'*(1+'Proportion of Control Technique Filling'), 'Number of Stations Conveyor System'*'Length of Station'*'Invest Distances Filling')
439	Invest Corner Section in Friction Roller Track	EUR	Parent~'Invest Rotary Converter in Friciton Roller Track'
440	Invest Corner Section in Friction Roller Tracks	EUR	Parent~'Invest Rotary Converter in Fricíton Roller Track'
441	Invest Direction Shifter Conveyor System Connecting Conveyor	EUR	IF ('Selection Conveyor System Engine-Gearbox'['Connecting Conveyor'] = 1, SUM (PRODUCT ('Number of Corner Sections Connecting Conveyor', ('Invest Corner Section in Friction Roller Track'-8000 <<EUR>>)), PRODUCT ('Number of Side Way Shifting Units Connecting Conveyor', 'Invest Side Way Shifting Units in Friction Roller Track')), 0 <<EUR>>)
442	Invest Direction Shifter Conveyor System Engine-Gearbox-Line	EUR	IF ('Selection Conveyor System Engine-Gearbox'['Engine Line'] = 1, SUM (PRODUCT ('Number of Corner Sections Engine-Gearbox-Line', 'Invest Corner Section in Friction Roller Track'), PRODUCT ('Number of Side Way Shifting Units Engine-Gearbox-Line', 'Invest Side Way Shifting Units in Friction Roller Track')), 0 <<EUR>>)
443	Invest Direction Shifter Conveyor System Front Axle	EUR	IF ('Selection Conveyor System Axles'['Front Axle'] = 1, SUM (PRODUCT ('Number of Corner Sections Front Axle', 'Invest Corner Section in Friction Roller Tracks'), PRODUCT ('Number of Handling Assistors Side Way Shifting Units Front Axle', 'Invest Side Way Shifting Units in Friction Roller Track')), 0 <<EUR>>)

#	Name of Element (KPI)	Unit	Definition
444	Invest Direction Shifter Conveyor System Gearbox-Line	EUR	IF ('Selection Conveyor System Engine-Gearbox'['Gearbox Line'] = 1, SUM (PRODUCT ('Number of Corner Sections Gearbox-Line', 'Invest Corner Section in Friction Roller Track'), PRODUCT ('Number of Side Way Shifting Units Gearbox-Line', 'Invest Side Way Shifting Units in Friction Roller Track')), 0 <<EUR>>)
445	Invest Direction Shifter Conveyor System Rear Axle	EUR	IF ('Selection Conveyor System Axles'['Rear Axle'] = 1, SUM (PRODUCT ('Number of Corner Sections Rear Axle', 'Invest Corner Section in Friction Roller Tracks'), PRODUCT ('Number of Handling Assistors Side Way Shifting Units Rear Axle', 'Invest Side Way Shifting Units in Friction Roller Track')), 0 <<EUR>>)
446	Invest Distances Body Assembly	EUR/meter	0
447	Invest Distances Filling	EUR/meter	0
448	Invest Distances Filling	EUR/meter	0
449	Invest Distances Final Assembly	EUR/meter	0
450	Invest Distances Tilt Assembly	EUR/meter	0

451	Invest Door Carriers Doors	EUR	PRODUCT (FOR (i = 'Door Lines'[
			SUM (ARRSUM (FOR (j = 'Door Conveyors'[
			IF ('Door Carriers'[i] = j,
			'Basic Invest Doors Carriers'[j],
			0 <<EUR>>))),
			ARRSUM (FOR (k = 'Heigth Adjustment Doors'[
			IF ('Height Adjustment Doors'[i] = k,
			'Invest Height Adjustment Doors'[k],
			0 <<EUR>>))),
			PRODUCT ('Interchangeable Rotation Head by Lines'[i],
			'Addition Rotation Head per Door'))),
			'Door Carriers in Circulation Doors by Lines')
			/ 1 <<pieces>>

452	Invest Door Seal Facilities	EUR	PRODUCT ('Number of Facilities Door Selas by Lines Doors', 'Invest Facility Door Seal')
453	Invest Engine-Gearbox-Line	EUR	PRODUCT ('Prop Costs Conveyor System Engine-Gearbox-Line', 'Station Length Engine-Gearbox-Line', 'KPI_51_D Total Stations With Influence Areas in Engine-Gearbox-Line') / 1 <<stations>>
454	Invest Equipment Manual Work Stations Engine-Gearbox-Line	EUR	PRODUCT (SUM ('Invest Screwing-Technology per Manual Work Station Engine-Gearbox-Line', 'Invest Equipment per Manual Work Station Engine-Gearbox-Line'), 'Manual Work Stations in Engine-Gearbox-Line', 'KPI_74_G Average Employee Density Engine-Gearbox') / 1 <<worker>>
455	Invest Equipment Manual Work Stations Sub-Engine-Lines	EUR	PRODUCT ('Number of Employees Sub-Engine-Lines', 'Invest Equipment per Manual Work Station Sub-Engine-Line') / 1 <<worker>>
456	Invest Equipment per Manual Work Station Engine-Gearbox-Line	EUR	20000
457	Invest Equipment per Manual Work Station Sub-Engine-Line	EUR	20000
458	Invest Extra Working Stations	EUR	40000<<EUR>>

459	Invest Facilities Doors	EUR	{
			'Invest Facilities Doors Line 1',
			IF(ARRSUM('Selection Doors Lines Line 2')=0,
			0<<EUR>>,
			'Invest Facilities Doors Line 2')
			}

460	Invest Facilities Doors Line 1	EUR	1
461	Invest Facilities Doors Line 2	EUR	1
462	Invest Facilities Engine-Gearbox-Line	EUR	150000
463	Invest Facilities Front Axle	EUR	150000
464	Invest Facilities Rear Axle	EUR	150000
465	Invest Facilities Strut	EUR	150000
466	Invest Facilities Sub-Engine-Line	EUR	150000
467	Invest Facilities Wheel Hub	EUR	150000
468	Invest Facility Door Seal	EUR	300000
469	Invest Filling	EUR	500000
470	Invest Fixed Conveyors per Line	EUR	50000
471	Invest Floor Transportation System Vehicles Front Axle	EUR	IF ('Selection Conveyor System Axles'['Front Axle'] = 2, PRODUCT ('Single Invest Floor Transportation System Vehicle Front- and Rear Axle', 'KPI_51_D Total Stations Axle Pre-Assembly'['Front Axle'], 'Floor Transportation Systems in Circulation Front Axle') / 1 <<stations>>, 0 <<EUR>>)

#	Name of Element (KPI)	Unit	Definition
472	Invest Floor Transportation System Vehicles Strut	EUR	IF ('Selection Conveyor System Axles'[Strut] = 2, PRODUCT ('Single Invest Floor Transportation System Vehicle Strut', 'KPI_51_D Total Stations Axle Pre-Assembly'[Strut], 'Floor Transportation Systems in Circulation Strut') / 1 <<stations>>, 0 <<EUR>>)
473	Invest Floor Transportation System Vehicles Wheel Hub	EUR	IF ('Selection Conveyor System Axles'['Wheel Hub'] = 2, PRODUCT ('Single Invest Floor Transportation System Vehicle Wheel Hub', 'KPI_51_D Total Stations Axle Pre-Assembly'['Wheel Hub'], 'Floor Transportation Systems in Circulation Wheel Hub') / 1 <<stations>>, 0 <<EUR>>)
474	Invest Floor Transporting System Vehicles Engine-Gearbox-Line	EUR	IF ('Selection Conveyor System Engine-Gearbox'['Engine Line'] = 2, PRODUCT ('Single Invest Floor Transporting System Vehicle Engine-Gearbox-Line', 'KPI_51_D Total Stations with Influence Areas in Engine-Gearbox-Line', 'Floor Transporting System Vehicles in Circulation Engine-Gearbox-Line') / 1 <<stations>>, 0 <<EUR>>)
475	Invest Front Axle Line	EUR	PRODUCT ('Prop Costs Conveyor System Front Axle', 'Length of Station Front Axle', 'KPI_51_D Total Stations Axle Pre-Assembly'['Front Axle']) / 1 <<stations>>
476	Invest Front Drive Shaft_One-Piece	EUR	0<<EUR>>
477	Invest Front Drive Shaft_Two-Piece	EUR	0<<EUR>>
478	Invest Fully-Automated Stations Engine-Gearbox-Line	EUR	SUM ('Invest Automated Stations Exhaust Manifold Screwing', PRODUCT ('Invest per Gearbox-Programming Station', 'Number of Stations Gearbox-Programming'))
479	Invest Gearbox-Line	EUR	PRODUCT (SUM ('Length Floor Area Gearbox-Line', 'Belt Width Bottom Area Gearbox-Line'), 2, 'Prop Costs Conveyor System Gearbox-Line')
480	Invest Glazing Door Glass -Triangular Glass	EUR	PRODUCT ('Number of Facilities Glazing Glasses - Triangle Glasses - by Doors Lines', 'Invest Automated Glazing Door Glass - Triangular Glass')
481	Invest Handling Assistor Front Axle	EUR	ARRSUM (PRODUCT ('Single Invest Handling Assistor Axles', {'Number of Handling Assistors Component Front Axle', PRODUCT ('Number of Handling Assistors Sub-Assembly Front Axle', 166 %), PRODUCT ('Number of Handling Assistors Assembly Front Axle', 166 %)}))
482	Invest Handling Assistor Rear Axle	EUR	ARRSUM (PRODUCT ('Single Invest Handling Assistor Axles', {'Number of Handling Assistors Component Rear Axle', PRODUCT ('Number of Handling Assistors Sub-Assembly Rear Axle', 166 %), PRODUCT ('Number of Handling Assistors Assembly Rear Axle', 166 %)}))
483	Invest Handling Assistor Strut	EUR	ARRSUM (PRODUCT ('Single Invest Handling Assistor Axles', {'Number of Handling Assistors Component Strut', PRODUCT ('Number of Handling Assistors Sub-Assembly Strut', 166 %), PRODUCT ('Number of Handling Assistors Assembly Strut', 166 %)}))
484	Invest Handling Assistor Wheel Hub	EUR	ARRSUM (PRODUCT ('Single Invest Handling Assistor Axles', {'Number of Handling Assistors Component Wheel Hub', PRODUCT ('Number of Handling Assistors Sub-Assembly Wheel Hub', 166 %), PRODUCT ('Number of Handling Assistors Assembly Wheel Hub', 166 %)}))
485	Invest Handling Equipment Assembling Axles	EUR	40000
486	Invest Handling Equipment Component Part Axles	EUR	10000
487	Invest Handling Equipment Sub-Assembling Axles	EUR	20000
488	Invest Headlights Integrated	EUR	150000
489	Invest Height Adjustment Doors	EUR	{'Addition Electrical Adjustment per Door', 'Addition Pneumatic Spring per Door'}
490	Invest Industrial Robot	EUR	450000
491	Invest Injector Adhesive Layer	EUR	50000
492	Invest Installations Filling	EUR	10000
493	Invest Installations Fully-Automated	EUR	Facilities.'Readout Invest Installations Fully-Automated'
494	Invest Installations Fully-Automated	EUR	10000
495	Invest Installations Non-Automated	EUR	10000
496	Invest Installations Semi-Automated	EUR	{0,0,0,0,0,0,0,0,0,0,0}
497	Invest Jointing Station Engine-Gearbox	EUR	200000
498	Invest Lifting Ramp	EUR	100000<<EUR>>
499	Invest Lifting Station Body Assembly	EUR/pieces	0
500	Invest Lifting Station Filling	EUR/pieces	0

#	Name of Element (KPI)	Unit	Definition
501	Invest Lifting Station Final Assembly	EUR/pieces	0
502	Invest Lifting Station Tilt Assembly	EUR/pieces	0
503	Invest Lifting Stations	EUR	//ARRSUM// (PRODUCT (//2;// 'Selection Doors Lines', 'Single Invest Lifting Station'))
504	Invest Logistic Engine-Gearbox-Line	EUR	600000
505	Invest Logistic Sub-Engine-Line	EUR	600000
506	Invest Main Line Completely	EUR	Total Invest Main Line Simple Model'+'Total Invest Main Line Complex Model'
507	Invest Manual Screwing Technology Compressed Air Front Axle	EUR	ARRSUM (PRODUCT ('Percentage Screwing Technology Compressed Air at Manual Working Stations Front Axle', 'Invest Screwing Technology Compressed Air Axles'))
508	Invest Manual Screwing Technology Compressed Air Rear Axle	EUR	ARRSUM (PRODUCT ('Number of Work Stations Screwing-Technology Compressed Air Rear Axle', 'Invest Screwing Technology Compressed Air Axles'))
509	Invest Manual Screwing Technology Compressed Air Strut	EUR	ARRSUM (PRODUCT ('Number of Workstations Screwing-Technology Compressed Air Strut', 'Invest Screwing Technology Compressed Air Axles'))
510	Invest Manual Screwing Technology Compressed Air Wheel Hub	EUR	ARRSUM (PRODUCT ('Number of Workstations Screwing-Technology Compressed Air Wheel Hub', 'Invest Screwing Technology Compressed Air Axles'))
511	Invest Manual Screwing Technology Doors	EUR	{ARRSUM (FOR (i='Door Sections'] IF ('Type of Doors Line 1'[i]<>2, PRODUCT ('Selection Doors Lines Line 1'[i], SUM ('Single Invest Screwing-Facility Crash-Sensor Doors', 'Single Invest Screwing-Facility Crash-Strut Doors')), 0 <<EUR>>))), ARRSUM (FOR (i='Door Sections'] IF ('Type of Doors Line 2'[i]<>2, PRODUCT ('Selection Doors Lines Line 2'[i], SUM ('Single Invest Screwing-Facility Crash-Sensor Doors', 'Single Invest Screwing-Facility Crash-Strut Doors')), 0 <<EUR>>))))}
512	Invest Manual Screwing Technology Electrical Front Axle	EUR	ARRSUM (PRODUCT ('Number of Workstations Manual Screwing-Technology Electrical Front Axle', 'Invest Screwing Technology Electrical Axles'))
513	Invest Manual Screwing Technology Electrical Rear Axle	EUR	ARRSUM (PRODUCT ('Number of Work Stations Screwing-Technology Electrical Rear Axle', 'Invest Screwing Technology Electrical Axles'))
514	Invest Manual Screwing Technology Electrical Strut	EUR	ARRSUM (PRODUCT ('Number of Workstations Screwing-Technology Electrical Strut', 'Invest Screwing Technology Electrical Axles'))
515	Invest Manual Screwing Technology Electrical Wheel Hub	EUR	ARRSUM (PRODUCT ('Number of Workstations Screwing-Technology Electrical Wheel Hub', 'Invest Screwing Technology Electrical Axles'))
516	Invest Manual Screwing Technology Front Axle	EUR	SUM ('Invest Manual Screwing Technology Electrical Front Axle', 'Invest Manual Screwing Technology Compressed Air Front Axle')
517	Invest Manual Screwing Technology Rear Axle	EUR	SUM ('Invest Manual Screwing Technology Electrical Rear Axle', 'Invest Manual Screwing Technology Compressed Air Rear Axle')
518	Invest Manual Screwing Technology Strut	EUR	SUM ('Invest Manual Screwing Technology Electrical Strut', 'Invest Manual Screwing Technology Compressed Air Strut')
519	Invest Manual Screwing Technology Wheel Hub	EUR	SUM ('Invest Manual Screwing Technology Electrical Wheel Hub', 'Invest Manual Screwing Technology Compressed Air Wheel Hub')
520	Invest MAT All Wheel	EUR/pieces	0<<EUR/pieces>>
521	Invest MAT Rear-End	EUR/pieces	0<<EUR/pieces>>
522	Invest MAT Storage	EUR	0
523	Invest of Buildings	EUR	Area Requirements F2 Lines'*'Area Cost Rate F2-Line'+ 'Pit Requirements F2-Lines'*'Pit Cost Rate'
524	Invest of Buildings Engine-Gearbox	EUR	PRODUCT ('Total Area Engine-Gearbox-Line', 'Mathematical Model Cost Unit Rate Areas Pre-Assembly['PA Engine_Gearbox'])
525	Invest of Buildings Engine-Gearbox-Line	EUR	ROUND ({'Invest of Buildings Engine-Gearbox'}, 1000 <<EUR>>)
526	Invest of Buildings Engine-Gearbox-Line Readout	EUR	SUM ('Invest of Buildings Engine-Gearbox-Line', 'Invest of Buildings Sub-Engine-Lines Readout', 'Invest of Buildings Gearbox-Store Readout', 'Invest of Buildings Storage Area Engine-Gearbox')
527	Invest of Buildings Finish-Lines	EUR	Area Requirements Finish Lines'*'Area Cost Rate Finish-Line'+ 'Pit Requirements Finish-Lines'*'Pit Cost Rate'
528	Invest of Buildings Gearbox-Store	EUR	PRODUCT ('Total Area Gearbox-Store', 'Mathematical Model Cost Unit Rate Areas Pre-Assembly['PA Engine_Gearbox'])
529	Invest of Buildings Gearbox-Store Readout	EUR	ROUND ({'Invest of Buildings Gearbox-Store'}, 1000 <<EUR>>)
530	Invest of Buildings Paintwork Rectification	EUR	Invest Area Paintwork Rectification'+'Pit Costs Paintwork Rectification'
531	Invest of Buildings Rectification	EUR	Area Requirements Rectification'*'Area Cost Rate Rectification'+ 'Pit Requirements Rectification'*'Pit Cost Rate'

# Name of Element (KPI)	Unit	Definition
532 Invest of Buildings Storage Area Engine-Gearbox	EUR	ROUND ({PRODUCT ('Storage Area Engine-Gearbox-Line', 'Mathematical Model Cost Unit Rate Areas Pre-Assembly'['PA Engine_Gearbox']})}, 1000 <<EUR>>)
533 Invest of Buildings Sub-Engine-Lines	EUR	PRODUCT ('Total Area Sub-Engine-Lines', 'Mathematical Model Cost Unit Rate Areas Pre-Assembly'['PA Engine_Gearbox'])
534 Invest of Buildings Sub-Engine-Lines Readout	EUR	ROUND ({'Invest of Buildings Sub-Engine-Lines'}, 1000 <<EUR>>)
535 Invest of Buildings Test Rigs	EUR	Area Cost Rate Test Rigs'*'KPI_26_A Inspection Area'+'Pit Requirements Test Rigs'*'Pit Cost Rate'
536 Invest Overhead Conveyor Rails	EUR	PRODUCT ('Lenght of Station Doors', 'Prop Costs Carrier Overhead Conveyor', 'KPI_51_D Total Stations Doors') / 1 <<stations>>
537 Invest Paint Mix Facility	EUR	850000
538 Invest Paintwork Rectification	EUR	Invest of Buildings Paintwork Rectification'+'Technical Invest Paintwork Rectification'
539 Invest per Automatic Station	EUR/stations	0
540 Invest per BTS	EUR/pieces	0
541 Invest per Gearbox-Programming Station	EUR	150000
542 Invest per Testing and Quality Station	EUR/stations	0
543 Invest per Vehicle	EUR/unit	Main Assembly Line'.'Share in the Costs Invest per Vehicle'

544 Invest Platform or Rotary Sling in Doors Pre-Assembly	EUR	FOR (i = 'Door Lines'}
		SUM (IF ('Height Adjustment Doors'[i] = 3,
		PRODUCT ('Addition Platform per Station',
		'Stations with Platforms by Door Lines per Track'[i]),
		0 <<EUR>>),
		IF ('Height Adjustment Doors'[i] = 4,
		'Addition Rotary Sling in Doors Pre-Assembly',
		0 <<EUR>>)))

545 Invest Process Control Doors	EUR	{
		'Invest Process Control Doors Line 1',
		IF(ARRSUM('Selection Doors Lines Line 2')=0,
		0<<EUR>>,
		'Invest Process Control Doors line 2')
		}

546 Invest Process Control Doors Line 1	EUR	1
547 Invest Process Control Doors Line 2	EUR	1
548 Invest Process Control Front Axle	EUR	100000
549 Invest Process Control Rear Axle	EUR	100000
550 Invest Process Control Strut	EUR	100000
551 Invest Process Control Wheel Hub	EUR	250000
552 Invest Production Control Engine-Gearbox-Line	EUR	100000
553 Invest Production Control Gearbox-Store	EUR	100000
554 Invest Production Control Sub-Engine-Line	EUR	100000
555 Invest Prop Conveyor	EUR	Invest Charging Set Conveyor Prop'*'Stations Conveyors'*'Station Length Finish Line'
556 Invest Pump for Adhesive Layer	EUR	350000
557 Invest Rack	EUR	45000
558 Invest Rear Axle Line	EUR	PRODUCT ('Prop Costs Conveyor System Rear Axle', 'Length of Station Rear Axle', 'KPI_51_D Total Stations Axle Pre-Assembly'['Rear Axle']) / 1 <<stations>>
559 Invest Rework Area Front Axle	EUR	PRODUCT ('KPI_54_D Testing and Quality Stations Axle Pre-Assembly'['Front Axle'], 'Technical Invest per Rework Station Front Axle') / 1 <<stations>>
560 Invest Rework Area Rear Axle	EUR	PRODUCT ('KPI_54_D Testing and Quality Stations Axle Pre-Assembly'['Rear Axle'], 'Technical Invest per Rework Station Rear Axle') / 1 <<stations>>
561 Invest Rotary Converter in Friciton Roller Track	EUR	18000
562 Invest Screwing- and Clamping Technology Front Axle	EUR	SUM (PRODUCT ('Number of Automatical Stations Screwing- and Clamping Technology Linked Front Axle', 'Invest Automatical Station Screwing- and Clamping Technology Linked Axles'), PRODUCT ('Number of Semi-Automatical Stations Screwing- and Clamping Technology Linked Front Axle', 'Invest Semi-Automatical Station Screwing- and Clamping Technology Linked Axles'), PRODUCT (SUM ('Number of Semi-Automatical Stations Screwing- and Clamping Technology Linked Front Axle', 'Number of Automatical Stations Screwing- and Clamping Technology Linked Front Axle'), 'Invest Semi-Automatical Station Screwing- and Clamping Technology Linked Axles'))

#	Name of Element (KPI)	Unit	Definition
563	Invest Screwing- and Clamping Technology Rear Axle	EUR	SUM (PRODUCT ('Number of Automatical Stations Screwing- and Clamping Technology Linked Rear Axle', 'Invest Automatical Station Screwing- and Clamping Technology Linked Axles'), PRODUCT ('Number of Semiautomated Stations Screwing- and Clamping Technology Linked Rear Axle', 'Invest Semi-Automatical Station Screwing- and Clamping Technology Linked Axles'), PRODUCT (SUM ('Number of Semiautomated Stations Screwing- and Clamping Technology Linked Rear Axle', 'Number of Automatical Stations Screwing- and Clamping Technology Linked Rear Axle'), 'Invest Semi-Automatical Station Screwing- and Clamping Technology Linked Axles'))
564	Invest Screwing- and Clamping Technology Strut	EUR	SUM (PRODUCT ('Number of Automatical Stations Screwing- and Clamping Technology Linked Strut', 'Invest Automatical Station Screwing- and Clamping Technology Linked Axles'), PRODUCT ('Number of Semiautomated Stations Screwing- and Clamping Technology Linked Strut', 'Invest Semi-Automatical Station Screwing- and Clamping Technology Linked Axles'), PRODUCT (SUM ('Number of Semiautomated Stations Screwing- and Clamping Technology Linked Strut', 'Number of Automatical Stations Screwing- and Clamping Technology Linked Strut'), 'Invest Semi-Automatical Station Screwing- and Clamping Technology Linked Axles'))
565	Invest Screwing- and Clamping Technology Wheel Hub	EUR	SUM (PRODUCT ('Number of Automatical Stations Screwing- and Clamping Technology Linked Wheel Hub', 'Invest Automatical Station Screwing- and Clamping Technology Linked Axles'), PRODUCT ('Number of Semiautomated Stations Screwing- and Clamping Technology Linked Wheel Hub', 'Invest Semi-Automatical Station Screwing- and Clamping Technology Linked Axles'), PRODUCT (SUM ('Number of Semiautomated Stations Screwing- and Clamping Technology Linked Wheel Hub', 'Number of Automatical Stations Screwing- and Clamping Technology Linked Wheel Hub'), 'Invest Semi-Automatical Station Screwing- and Clamping Technology Linked Axles'))
566	Invest Screwing Technology Compressed Air 25 to 150 Nm	EUR	15000
567	Invest Screwing Technology Compressed Air Axles	EUR	Parent~'Single Invest Screwing Technology Compressed Air Center-Lines'
568	Invest Screwing Technology Compressed Air over 150 Nm	EUR	0
569	Invest Screwing Technology Compressed Air up to 25 Nm	EUR	5000
570	Invest Screwing Technology Electrical 25 to 150 Nm	EUR	25000
571	Invest Screwing Technology Electrical Axles	EUR	Parent~'Single Invest Electrical Screwing Technology Center-Lines'
572	Invest Screwing Technology Electrical over 150 Nm	EUR	32000
573	Invest Screwing Technology Electrical up to 25 Nm	EUR	15000
574	Invest Screwing-Technology per Manual Work Station Engine-Gearbox-Line	EUR	5000
575	Invest Self Propelling Carrier Overhead Conveyor Doors	EUR	PRODUCT ('Single Invest Self Propelling Carrier Overhead Conveyor Doors', 'Self Propelling Carrier Overhead Conveyor in Circulation Doors by Lines') *1<<1/pieces>>
576	Invest Semi-Automated Station Screwing or Clamping Technology Linked Axles	EUR	70000
577	Invest Semiautomatic Machines Engine-Gearbox	EUR	SUM ('Invest Attaching Gearbox', 'Invest Attaching Engine', 'Invest Jointing Station Engine-Gearbox', 'Invest Converter on Engine-Gearbox-Line')
578	Invest Semi-Automatical Station Screwing- and Clamping Technology Linked Axles	EUR	Parent~'Invest Semi-Automated Station Screwing or Clamping Technology Linked Axles'
579	Invest Side Way Shifting Units in Friciton Roller Track	EUR	50000
580	Invest Side Way Shifting Units in Friction Roller Track	EUR	Parent~'Invest Side Way Shifting Units in Friciton Roller Track'
581	Invest Side Way Shifting Units in Friction Roller Track	EUR	Parent~'Invest Side Way Shifting Units in Friciton Roller Track'
582	Invest Sound Insulation	EUR	{'Invest Sound Insulation Line 1', 'Invest Sound Insulation Line 2'}
583	Invest Sound Insulation Adhesive Layer Doors	EUR	{'Invest Sound Insulation Adhesive Layer Doors Manually', 0 <<EUR>>, 'Invest Sound Insulation Adhesive Layer Doors Automated'}
584	Invest Sound Insulation Adhesive Layer Doors Automated	EUR	SUM ('Invest Pump for Adhesive Layer', 'Invest Injector Adhesive Layer', 'Invest Industrial Robot')
585	Invest Sound Insulation Adhesive Layer Doors Manually	EUR	SUM ('Invest Pump for Adhesive Layer', 'Invest Injector Adhesive Layer')

#	Name of Element (KPI)	Unit	Definition
586	Invest Sound Insulation Assembly Pressing Doors	EUR	{'Invest Sound Insulation Assembly Pressing Doors Manual', 'Invest Sound Insulation Assembly Pressing Doors Semi-Automated', 'Invest Sound Insulation Assembly Pressing Doors Automated'}
587	Invest Sound Insulation Assembly Pressing Doors Manual	EUR	0
588	Invest Sound Insulation Assembly Pressing Doors Semi-Automated	EUR	Invest Industrial Robot'
589	Invest Sound Insulation Line 1	EUR	PRODUCT (IF ('Sound Insulation Doors Line 1'[1]=1, SUM (LOOKUP ('Single Invest Facility Sound Insulation'[2], 'Sound Insulation Doors Line 1'[2]), LOOKUP ('Single Invest Facility Sound Insulation'[3], 'Sound Insulation Doors Line 1'[3])), IF ('Sound Insulation Doors Line 1'[1]=2, LOOKUP ('Single Invest Facility Sound Insulation'[4], 'Sound Insulation Doors Line 1'[4]), LOOKUP ('Single Invest Facility Sound Insulation'[5], 'Sound Insulation Doors Line 1'[5]))), 'Number of Facilities Sound Insulation by Lines Doors'['Line 1'])
590	Invest Sound Insulation Line 2	EUR	PRODUCT (IF ('Sound Insulation Doors Line 2'[1]=1, SUM (LOOKUP ('Single Invest Facility Sound Insulation'[2], 'Sound Insulation Doors Line 2'[2]), LOOKUP ('Single Invest Facility Sound Insulation'[3], 'Sound Insulation Doors Line 2'[3])), IF ('Sound Insulation Doors Line 2'[1]=2, LOOKUP ('Single Invest Facility Sound Insulation'[4], 'Sound Insulation Doors Line 2'[4]), LOOKUP ('Single Invest Facility Sound Insulation'[5], 'Sound Insulation Doors Line 2'[5]))), 'Number of Facilities Sound Insulation by Lines Doors'['Line 2'])
591	Invest Sound Insulation Parts Carrier Doors	EUR	{'Invest Sound Insulation Parts Carrier Doors Manually', 0 <<EUR>>, 'Invest Sound Insulation Parts Carrier Doors Automated'}
592	Invest Sound Insulation Parts Carrier Doors Automated	EUR	Invest Industrial Robot'
593	Invest Sound Insulation Parts Carrier Doors Manually	EUR	0
594	Invest Sound Insulation Pre-Applicated Sealing Bead Doors	EUR	{'Invest Sound Insulation Pre-Applicated Sealing Bead Doors Manually', 'Invest Sound Insulation Pre-Applicated Sealing Bead Doors Semi-Automated', 0 <<EUR>>}
595	Invest Sound Insulation Pre-Applicated Sealing Bead Doors Manually	EUR	0
596	Invest Sound Insulation Pre-Applicated Sealing Bead Doors Semi-Automated	EUR	SUM ('Invest Application Plat Sound Insulation', 'Invest Industrial Robot')
597	Invest Spotrepair Line	EUR	450000 <<EUR>>
598	Invest Test Rig	EUR	{700000,300000,700000,300000,50000,300000} <<EUR>>
599	Invest Toe-Camber-Adjustment Rear Axle	EUR	PRODUCT ('Number of Facilities Toe-Camber-Adjustment Rear Axle', 'Single Invest Facility Toe-Camber-Adjustment Rear Axle')
600	Invest Tool Kit Body Assembly	EUR	Body Assembly'.'Invest Tool-Kits Body Assembly'
601	Invest Tool Kit Filling	EUR	Filling.'Invest Tool-Kits Filling'
602	Invest Tool Kit Final Assembly	EUR	Final Assembly'.'Invest Tool-Kits Final Assembly'
603	Invest Tool Kit Manual Work Stations Front Axle	EUR	PRODUCT ('Invest Tool Kit per Manual Work Station Front Axle', 'Number of Employees Pre-Assembly Axle'['Front Axle']) / 1 <<worker>>
604	Invest Tool Kit Manual Work Stations Rear Axle	EUR	PRODUCT ('Invest Tool Kit per Manual Work Station Rear Axle', 'Number of Employees Pre-Assembly Axle'['Rear Axle']) / 1 <<worker>>
605	Invest Tool Kit Manual Work Stations Strut	EUR	PRODUCT ('Invest Tool Kit per Manual Work Station Strut', 'Number of Employees Pre-Assembly Axle'[Strut]) / 1 <<worker>>
606	Invest Tool Kit Manual Work Stations Wheel Hub	EUR	PRODUCT ('Number of Employees Pre-Assembly Axle'['Wheel Hub'], 'Invest Tool Kit per Manual Work Station Wheel Hub') / 1 <<worker>>

607	Invest Tool Kit per Manual Work Station Doors	EUR	{
			'Invest Tool Kit per Manual Work Station Doors Line 1',
			IF(ARRSUM('Selection Doors Lines Line 2')=0,
			0<<EUR>>,
			'Invest Tool Kit per Manual Work Station Doors Line 2')
			}

608	Invest Tool Kit per Manual Work Station Doors Line 1	EUR	1
609	Invest Tool Kit per Manual Work Station Doors Line 2	EUR	1
610	Invest Tool Kit per Manual Work Station Front Axle	EUR	20000
611	Invest Tool Kit per Manual Work Station Rear Axle	EUR	20000
612	Invest Tool Kit per Manual Work Station Strut	EUR	20000
613	Invest Tool Kit per Manual Work Station Wheel Hub	EUR	25000
614	Invest Tool Kit Tilt Assembly	EUR	Tilt Assembly'.'Invest Tool-Kits Tilt Assembly'

#	Name of Element (KPI)	Unit	Definition
615	Invest Tool-Kits Body Assembly	EUR	PRODUCT ('Invest Tool-Kits per Manual Work Station Body Assembly', 'Employees Main Assembly Line Overall Simple Model') / 1 <<worker>>
616	Invest Tool-Kits Body Assembly	EUR	PRODUCT ('Invest Tool-Kits per Manual Work Station Body Assembly', 'Number of Employees Body Assembly') / 1 <<worker>>
617	Invest Tool-Kits Filling	EUR	PRODUCT ('Invest Tool-Kits per Manual Work Station Filling', 'Number of Employees Filling') / 1 <<worker>>
618	Invest Tool-Kits Final Assembly	EUR	PRODUCT ('Invest Tool-Kits per Manual Work Station Final Assembly', 'Number of Employees Final Assembly') / 1 <<worker>>
619	Invest Tool-Kits per Manual Work Station Body Assembly	EUR	0
620	Invest Tool-Kits per Manual Work Station Body Assembly	EUR	20000
621	Invest Tool-Kits Per Manual Work Station Filling	EUR	20000
622	Invest Tool-Kits per Manual Work Station Filling	EUR	20000
623	Invest Tool-Kits Per Manual Work Station Final Assembly	EUR	20000
624	Invest Tool-Kits per Manual Work Station Tilt Assembly	EUR	20000
625	Invest Tool-Kits Tilt Assembly	EUR	PRODUCT ('Invest Tool-Kits per Manual Work Station Tilt Assembly', 'Number of Employees Tilt Assembly') / 1 <<worker>>
626	Invest Transpack Oven	EUR	700000
627	Invest Wax Station	EUR	6000000
628	Invest Wheel Hub Line	EUR	PRODUCT ('Prop Costs Conveyor System Wheel Hub', 'Length of Station Wheel Hub', 'KPI_51_D Total Stations Axle Pre-Assembly'['Wheel Hub']) / 1 <<stations>>
629	Invest Workpiece Carrier Connecting Conveyor	EUR	PRODUCT ('Number of Workpiece Holders Connecting Conveyor', 'Invest Workpiece Carrier Connecting Conveyor per Slice')
630	Invest Workpiece Carrier Connecting Conveyor per Slice	EUR	3000
631	Invest Workpiece Carrier Engine-Gearbox-Line	EUR	PRODUCT ('Invest Workpiece Carrier Engine-Gearbox-Line per Slice', 'KPI_51_D Total Stations with Influence Areas in Engine-Gearbox-Line', SUM ('Workpiece Carrier in Circulation Engine-Gearbox-Line', 100 %)) / 1 <<stations>>
632	Invest Workpiece Carrier Engine-Gearbox-Line per Slice	EUR	2000
633	Invest Workpiece Carrier Front Axle	EUR	PRODUCT ('Invest Workpiece Carrier Front Axle per Piece', 'KPI_51_D Total Stations Axle Pre-Assembly'['Front Axle'], 'Workpiece Carrier in Circulation Front Axle') / 1 <<stations>>
634	Invest Workpiece Carrier Front Axle per Piece	EUR	20000
635	Invest Workpiece Carrier Gearbox-Line and -Store	EUR	PRODUCT ('Number of Workpiece Holders in Circulation Gearbox-Line and -Store', 'Invest Workpiece Carrier Gearbox-Line and -Store per Piece')
636	Invest Workpiece Carrier Gearbox-Line and -Store per Piece	EUR	3000
637	Invest Workpiece Carrier Rear Axle	EUR	PRODUCT ('Invest Workpiece Carrier Rear Axle per Piece', 'KPI_51_D Total Stations Axle Pre-Assembly'['Rear Axle'], 'Workpiece Carrier in Circulation Rear Axle') / 1 <<stations>>
638	Invest Workpiece Carrier Rear Axle per Piece	EUR	20000
639	Invest Workpiece Carrier Strut	EUR	PRODUCT ('Invest Workpiece Carrier Strut per Piece', 'KPI_51_D Total Stations Axle Pre-Assembly'[Strut], 'Workpiece Carrier in Circulation Strut') / 1 <<stations>>
640	Invest Workpiece Carrier Strut per Piece	EUR	20000
641	Invest Workpiece Carrier Wheel Hub	EUR	PRODUCT ('Invest Workpiece Carrier Wheel Hub per Piece', 'KPI_51_D Total Stations Axle Pre-Assembly'['Wheel Hub'], 2, 'Workpiece Carrier in Circulation Wheel Hub') / 1 <<stations>>
642	Invest Workpiece Carrier Wheel Hub per Piece	EUR	500
643	Invest_Drive_Train Area	EUR	IF('Selection_Mode of Drive'=2, IF('Front Axle'=1, 'Invest Front Drive Shaft_One-Piece', 'Invest Front Drive Shaft_Two-Piece'), 0<<EUR>>)
644	Invst Assembly Carrier Doors	EUR	PRODUCT ('Usage of Assembly Carrier by Door Lines', 'Single Invest Assembly Carrier Doors', 'Assembly Carrier in Circulation Doors by Lines') / 1 <<pieces>>
645	K73_G Performance-Related Wage Earners per Shift Synchronised on the Main Assembly Line Simple Model	worker	Manual Work Stations on the Main Assembly Line Simple Model'*'KPI_74_G Average Employee Density Simple Model'

#	Name of Element (KPI)	Unit	Definition
646	KPI_103_M Planned Operating Time Excluding OE_Pre Assembly	minutes/unit	0
647	KPI_103_M Planned Time Excluding OE Body Assembly	minutes/unit	230
648	KPI_103_M Planned Time Excluding OE Filling	minutes/unit	100
649	KPI_103_M Planned Time Excluding OE Final Assembly	minutes/unit	50
650	KPI_103_M Planned Time Excluding OE Tilt Assembly	minutes/unit	100
651	KPI_103_M Planned Time On The Main Assembly Line Excluding OE	minutes/unit	450
652	KPI_105_M Planned Time Axle Excluding OE - Average Type	minutes/unit	{'KPI_105_M Planned Time Front Axle Excluding OE - Average Type', 'KPI_105_M Planned Time Strut Excluding OE - Average Type', 'KPI_105_M Planned Time Rear Axle Excluding OE - Average Type', 'KPI_105_M Planned Time Wheel Hub Excluding OE - Average Type'}
653	KPI_105_M Planned Time Front Axle Excluding OE - Average Type	minutes/unit	45
654	KPI_105_M Planned Time in Selected Pre-Assembly Areas Excluding OE - Average Type	minutes/unit	{'KPI_105_M Planned Time in Selected Pre-Assembly Areas Excluding OE - Average Type Doors Line 1', 'KPI_105_M Planned Time in Selected Pre-Assembly Areas Excluding OE - Average Type Doors Line 2'}
655	KPI_105_M Planned Time in Selected Pre-Assembly Areas Excluding OE - Average Type Doors Line 1	minutes/unit	45
656	KPI_105_M Planned Time in Selected Pre-Assembly Areas Excluding OE - Average Type Doors Line 2	minutes/unit	12
657	KPI_105_M Planned Time Rear Axle Excluding OE - Average Type	minutes/unit	35
658	KPI_105_M Planned Time Strut Excluding OE - Average Type	minutes/unit	10
659	KPI_105_M Planned Time Wheel Hub Excluding OE - Average Type	minutes/unit	11
660	KPI_126_M Planned Time on the Main Assembly Line	min	1000

661	KPI_16_A Gross Station Service Area Final Assembly	meter²	{
			('Type of Line-Side Presentation Final Assembly'*'Width of Station Service Area Final Assembly')* 'Number of Stations Service Area Final Assembly'*'Length of Station Final Assembly'
			}

662	KPI_16_A Station Service Area Body Assembly	meter²	Body Assembly'.'KPI_16_A Station Service Area Body Assembly'
663	KPI_16_A Station Service Area Body Assembly	meter²	{'KPI_16_A Station Service Area Body Assembly 1'+'KPI_16_A Station Service Area Body Assembly 2'}
664	KPI_16_A Station Service Area Body Assembly 1	meter²	Number of Stations Body Assembly1'*'Stations Service Area Line Section 1'*'Length of Station Body Assembly 1'
665	KPI_16_A Station Service Area Body Assembly 2	meter²	Number of Stations Body Assembly2'*'Stations Service Area Line Section 2'*'Length of Station Body Assembly 2'
666	KPI_16_A Station Service Area Filling	meter²	Filling.'KPI_16_A Station Service Area Filling'

667	KPI_16_A Station Service Area Filling	meter²	{
			('Type of Line-Side Presentation Filling'*
			'Width Station Service Area Filling'*
			'Number of Stations Station Service Areas Filling'*
			'Length of Station Filling')
			}

668	KPI_16_A Station Service Area Final Assembly	meter²	Final Assembly'.'KPI_16_A Gross Station Service Area Final Assembly'
669	KPI_16_A Station Service Area Simple Model	meter²	IF('Selection of Model Main Assembly Line'=FALSE, {IF('Line-Side Presentation One-Double-Sided'=FALSE, (PRODUCT(1, 'Width Station Service Area', 'Number of Stations Station Service Area', 'Length of Station')), (PRODUCT(2, 'Width Station Service Area', 'Number of Stations Station Service Area', 'Length of Station')))}, 0<<meter²>>)
670	KPI_16_A Station Service Area Tilt Assembly	meter²	Tilt Assembly'.'KPI_16_A Station Service Area Tilt Assembly'

671	KPI_16_A Station Service Area Tilt Assembly	meter²	{
			'Type of Line-Side Presentation Tilt Assembly'*
			'Width Station Service Area Tilt Assembly'*
			'Number of Stations Station Service Areas Tilt Assembly'*
			'Length of Station Tilt Assembly'
			}

672	KPI_17_A Gross Line-Side Presentation Areas Doors	meter²	PRODUCT ('Lenght of Station Doors', 'Total Width of Line-Side Presentation Doors', SUM (PRODUCT ('KPI_51_D Stations Doors per Side', 'Selection Doors Lines'), 'KPI_51_D Total Stations Doors')) / 1 <<stations>>
673	KPI_17_A Gross Line-Side Service Area Front Axle	meter²	PRODUCT ('Length of Station Front Axle', 'KPI_51_D Total stations axle pre-assembly'['front axle'], 'Width of Line-Side Presentation Front Axle') / 1 <<stations>>

#	Name of Element (KPI)	Unit	Definition
674	KPI_17_A Gross Line-Side Service Area Rear Axle	meter²	PRODUCT ('Length of Station Rear Axle', 'KPI_51_D Total Stations Axle Pre-Assembly'['Rear Axle'], 'Width of Line-Side Presentation Rear Axle') / 1 <<stations>>
675	KPI_17_A Gross Line-Side Service Area Strut	meter²	PRODUCT ('Length of Station Strut', 'KPI_51_D Total Stations Axle Pre-Assembly'[Strut], 'Width of Line-Side Presentation Axles per Side') / 1 <<stations>>
676	KPI_17_A Gross Line-Side Service Area Wheel Hub	meter²	PRODUCT ('Length of Station Wheel Hub', 'KPI_51_D Total Stations Axle Pre-Assembly'['Wheel Hub'], 'Width of Line-Side Presentation Wheel Hub') / 1 <<stations>>
677	KPI_17_A Gross Station Service Area next to Engine-Gearbox-Line	meter²	PRODUCT ('Width of Line-Side Presentation Engine-Gearbox-Line', 'Station Length Engine-Gearbox-Line', 'KPI_51_D Total Stations Engine-Gearbox-Line') / 1 <<stations>>
678	KPI_24_A Production Area Body Assembly	meter²	Body Assembly'.'KPI_24_A Production Area Body Assembly'
679	KPI_24_A Production Area Body Assembly	meter²	'Working Area Body Assembly'+'KPI_16_A Station Service Area Body Assembly'
680	KPI_24_A Production Area Filling	meter²	Filling.'KPI_24_A Production Area Filling'
681	KPI_24_A Production Area Filling	meter²	Working Area B'+'KPI_16_A Station Service Area Filling'
682	KPI_24_A Production Area Final Assembly	meter²	Final Assembly'.'KPI_24_A Production Area Final Assembly'
683	KPI_24_A Production Area Final Assembly	meter²	Working Area Final Assembly'+'KPI_16_A Gross Station Service Area Final Assembly'
684	KPI_24_A Production Area Main Assembly Line	meter²	IF ('Selection of Model Main Assembly Line'=TRUE, (PRODUCT('Selection Main Line'['Body Assembly'],'KPI_24_A Production Area Body Assembly')+ PRODUCT('Selection Main Line'['Tilt Assembly'],'KPI_24_A Production Area Tilt Assembly')+ PRODUCT('Selection Main Line'['Final Assembly'],'KPI_24_A Production Area Final Assembly')+ PRODUCT('Selection Main Line'[Filling],'KPI_24_A Production Area Filling')), 0<<meter²>>)
685	KPI_24_A Production Area Simple Model	meter²	Area Working Area Main Assembly Line'+'KPI_16_A Station Service Area Simple Model'
686	KPI_24_A Production Area Tilt Assembly	meter²	Tilt Assembly'.'KPI_24_A Production Area Tilt Assembly'
687	KPI_24_A Production Area Tilt Assembly	meter²	'Area Working Area Tilt Assembly'+'KPI_16_A Station Service Area Tilt Assembly'
688	KPI_26_A Inspection Area	meter²	Area Grid'*ARRMAX('Test Rigs in Line')* (COUNTGT('Test Rigs in Line'[Trail..'Engine Test'],0)+'Number of Traffic Grids')
689	KPI_27_A Rectification Area	meter²	Number of Rectification Stations'*'Area Rectification Station'
690	KPI_28_A Paintwork Rectification Area	meter²	IF('Vehicles Paintwork Rectification'=0 <<unit>>, 0 <<meter^2>>, ('Area Requirements Paintwork Lines'+'Buffer Area Paintwork Rectification'+ 'Area Extra Working Stations'+'Area Paint Mix Facility') *(1+'Area Supplement'))
691	KPI_31_B Process Availability Main Assembly Line	%	96
692	KPI_33_C Basic Working Hours Gross Doors	hours/week	Number of Shifts per Day Doors' * 'Hours per Shift Doors' * 'Workdays per Week Doors'
693	KPI_33_C Gross Basic Working Hours	hours	'Number of Shifts'*'Gross Basic Working Time in Hours per Shift'
694	KPI_34_C Basic Working Hours Net Doors	hours/week	PRODUCT (SUM ('KPI_33_C Basic Working Hours Gross Doors', - PRODUCT ('Breaks per Shift Doors', 'Number of Shifts per Day Doors', 'Workdays per Week Doors')), 'Availability Employees Doors')
695	KPI_34_C Net Basic Working Hours per Week	hours/week	'Sum Total Output'/'Working Weeks per Year'/'KPI_45_C Units per Hour Planned'
696	KPI_35_C Basic Working Hours incl Additional Hours	hours	'Net Basic Working Time per Day in Hours'
697	KPI_36_C Assembly Production Days	da	250<<da>>
698	KPI_37_C Assembly Annual Capacity Production Programme	unit	300000
699	KPI_39_C Agreed Production Days per Year	da	200<<da>>
700	KPI_40_C Agreed Annual Capacity	unit	'KPI_39_C Agreed Production Days per Year'*'KPI_41_C Agreed Daily Output Assembly'/1<<da>>
701	KPI_40_C Agreed Assembly Annual Capacity	unit	Parent~'KPI_40_C Agreed Annual Capacity'
702	KPI_41_C Assembly Agreed Daily Output	unit/days	Parent~'KPI_41_C Assembly Agreed Daily Output' / 1 <<days>>
703	KPI_41_C Assembly Agreed Daily Output	unit/days	CEIL('Time Model_Daily Ouput'.Var_out_t)
704	KPI_41_D Assembly Agreed Daily Output Doors Line 1	unit/days	800

#	Name of Element (KPI)	Unit	Definition
705	KPI_44_C Assembly Operating Time in Hours	hours	'KPI_44_C Operating Time'
706	KPI_44_C Assembly Planned Operating Time	hours	Parent~'KPI_44_C Assembly Operating Time'
707	KPI_44_C Operating Time	hours	Time Model_Planned Operating Time'.Var_out
708	KPI_44_C Operating Time Planned	minutes	KPI_44_C Operating Time'
709	KPI_45_C Design Unit Output per Working Day	unit/hours	'KPI_41_C Agreed Daily Output'/('Net Basic Working Time per Day in Hours'+'Additional Hours')
710	KPI_45_C Units per Hour Planned	unit/hours	KPI_41_C Assembly Agreed Daily Output ' /'Net Operating Hours per Day - Main Assembly Line'
711	KPI_49_Cycle Time	seconds/unit	Parent~'KPI_49_D Cycle Time'
712	KPI_49_D Cycle Time Axles	seconds/unit	{'KPI_49_D Cycle Time', 'KPI_49_D Cycle Time', 'KPI_49_D Cycle Time', 'K49_D Cycle Time Wheel Hub'}
713	KPI_49_D Cycle Time Doors	seconds/unit	IF ('Transfer Shift Model from Main Assembly Line'=TRUE, DIVZX('Net Line Operating Time_Doors', 'Split-up Daily Output Door Lines', {0,0} <<hours/unit>>), DIVZX (DIVZX ('KPI_34_C Basic Working Hours Net Doors', 'Workdays per Week Doors', {0,0} <<hours/days>>), 'Split-up Daily Output Door Lines', {0,0} <<hours/unit>>))
714	KPI_49_D Cycle Time Wheel Hub	seconds/unit	CEIL (DIVZX ('Net Operating Time Main Assembly Line per Day', 'Daily Capacity Automatic Facilities', 0 <<seconds*days/unit>>) * 3600 <<seconds/hours>>) / 1 <<days>>
715	KPI_49_D CycleTime	secons/unit	Main Assembly Line'.'KPI_49_D Cycle Time'
716	KPI_50_D Line Balancing on the Main Assembly Line	%	Main Assembly Line'.'KPI_50_D Line Balancing on the Main Assembly Line'
717	KPI_50_D Line Balancing on the Main Assembly Line	%	10
718	KPI_51_D Total Stations Axles Pre-Assembly Area	stations	SUM ('KPI_53_D Work Stations Pre-Assembly Axles', 'KPI_54_D Testing and Quality Stations Pre-Assembly Axle', 'Availability Stations Pre-Assembly Axle', 'KPI_56_D Technical Stations Pre-Assembly Axle', 'KPI_58_D Decoupling Stations Pre-Assembly Axle')
719	KPI_51_D Total Stations Doors	stations	Parent~'KPI_51_D Total Stations In Technical Areas Doors'
720	KPI_51_D Total Stations Doors	stations	SUM (PRODUCT ('KPI_51_D Work Stations Doors per Side', 'Selection Doors Lines'), 'KPI_51_D Total Stations Doors', 'KPI_58_D Decoupling Stations out of Parallel Line Doors')
721	KPI_51_D Total Stations Engine-Gearbox-Line	stations	Parent~'KPI_51_D Total Stations with Influence Total Area in Engine-Gearbox Line'
722	KPI_51_D Total Stations in Engine-Gearbox Line	stations	SUM ('KPI_53_D Work Stations in Engine-Gearbox Line', 'KPI_54_D Testing and Quality Stations in Engine-Gearbox Line', 'Availability Stations in Engine-Gearbox Line', 'KPI_56_D Technical Stations in Engine-Gearbox Line', 'KPI_58_D Decoupling Stations in Engine-Gearbox Line')
723	KPI_51_D Total Stations in Parallel Lines Doors	stations	SUM ('KPI_53_D Work Stations in Parallel Lines Doors per Section', 'KPI_54_D Testing and Quality Stations in Parallel Lines Doors per Section', 'KPI_53_D Availability Stations in Parallel Lines Doors per Section', 'KPI_56_D Technical Stations in Parallel Lines Doors per Section', 'KPI_58_D Decoupling Stations in Parallel Line Doors per Section')
724	KPI_51_D Total Stations Pre-Assembly Axle	stations	Parent~'KPI_51_D Total Stations Pre-Assembly Axles'
725	KPI_51_D Total Stations with Influence Areas in Engine-Gearbox-Line	stations	Parent~'KPI_51_D Total Stations in Engine-Gearbox Line'
726	KPI_51_D Total Stations with Influence Total Area in Engine-Gearbox Line	stations	SUM ('KPI_51_D Total Stations in Engine-Gearbox Line', -'KPI_58_D Decoupling Stations Non Affecting Total Area in Engine-Gearbox Line')
727	KPI_53_D Manual Work Stations Body Assembly	stations	Body Assembly'.'KPI_53_D Manual Work Stations Body Assembly'
728	KPI_53_D Manual Work Stations Body Assembly	stations	IF ('Selection of Model Main Assembly Line'=TRUE, 'KPI_53_D Work Stations Body Assembly'-'KPI_57_D Fully Automated Stations Body Assembly', 0<<stations>>)
729	KPI_53_D Manual Work Stations Body Assembly	stations	Parent~'KPI_53_D Manual Work Stations Body Assembly'
730	KPI_53_D Manual Work Stations in the Main Assembly Line Complex	stations	Main Assembly Line'.'KPI_53_D Manual Work Stations in the Main Assembly Line Complex'
731	KPI_53_D Manual Work Stations in the Main Assembly Line Complex	stations	IF('Selection of Model Main Assembly Line'=TRUE, (ARRSUM('KPI_53_D Manual Work Stations of Sectors')), 0<<stations>>)
732	KPI_53_D Manual Work Stations in the Main Assembly Line Simple	stations	IF('Selection of Model Main Assembly Line'=FALSE, ('KPI_53_D Work Stations in the Main Assembly Line Simple'-'KPI_57_D Fully Automated Stations Simple'), 0<<stations>>)
733	KPI_53_D Manual Work Stations of Sectors	stations	{'KPI_53_D Manual Work Stations Body Assembly', 'KPI_53_D Manual Work Stations Tilt Assembly', 'KPI_53_D Manual Work Stations Final Assembly', 'KPI_53_D Manual Work Stations Filling'}

#	Name of Element (KPI)	Unit	Definition
734	KPI_53_D Work Stations Body Assembly	stations	IF ('Selection of Model Main Assembly Line'=TRUE, FLOOR('Gross Operating Planned Time Body Assembly' / 'Working Time per Station Body Assembly' * 60 <<unit*seconds/minutes>>), 0 <<stations>>)
735	KPI_53_D Work Stations Doors per Side	stations	Parent~'KPI_53_D Work Stations in Parallel Lines Doors per Section'
736	KPI_53_D Work Stations Filling	stations	Filling.'KPI_53_D Work Stations Filling'
737	KPI_53_D Work Stations Filling	stations	IF ('Selection of Model Main Assembly Line'=TRUE, FLOOR('Gross Operating Planned Time Filling' / 'Working Time per Station Filling' * 60 <<unit*seconds/minutes>>), 0 <<stations>>)
738	KPI_53_D Work Stations Filling	stations	Parent~'KPI_53_D Work Stations Filling'
739	KPI_53_D Work Stations Final Assembly	stations	IF ('Selection of Model Main Assembly Line'=TRUE, FLOOR('Gross Operating Planned Time Final Assembly' / 'Available Time per Station Final Assembly' * 60 <<unit*seconds/minutes>>), 0 <<stations>>)
740	KPI_53_D Work Stations Final Assembly	stations	Parent~'KPI_53_D Manual Work Stations Final Assembly'
741	KPI_53_D Work Stations in Engine-Gearbox Line	stations	CEIL (DIVZX ('KPI_105_M Planned Time Excluding OE Average Type', 'Available Working Hours per Station in Engine-Gearbox Line', 0 <<stations/unit>>) * 1 <<unit>>)
742	KPI_53_D Work Stations in Parallel Lines Doors per Section	stations	CEIL (DIVZX ('KPI_105_M Planned Time in Selected Pre-Assembly Areas Excluding OE - Average Type', 'Available Working Hours per Station Doors', {0,0} <<stations/unit>>) * 1 <<unit>>)

743	KPI_53_D Work Stations in Technical Areas Doors	stations	{IF ('Selection Door Conveyers'['Line 1'] > 0,
			PRODUCT ('Selection Technical Area Doors'['Line 1'],
			'Stations Facilities in Technical Areas'['Line 1']),
			0 <<stations>>),
			IF ('Selection Door Conveyers'['Line 2'] > 0,
			IF (ARRSUM ('Selection Technical Area Doors') = 2
			AND 'Shared Technical Area Line 1' = 1,
			0 <<stations>>,
			PRODUCT ('Selection Technical Area Doors'['Line 2'],
			'Stations Facilities in Technical Areas'['Line 2'])),
			0 <<stations>>)}

744	KPI_53_D Work Stations in the Main Assembly Line	stations	Main Assembly Line'.'KPI_53_D Work Stations in the Main Assembly Line Complex'
745	KPI_53_D Work Stations in the Main Assembly Line Complex	stations	IF('Selection of Model Main Assembly Line'=TRUE, (ARRSUM('KPI_53_D Work Stations Main Assembly Line')), 0<<stations>>)
746	KPI_53_D Work Stations in the Main Assembly Line Simple	stations	IF('Selection of Model Main Assembly Line'=FALSE, (FLOOR('Gross Operating Planned Time Main Assembly Line' / 'Working Time per Station' * 60<<unit*seconds/minutes>>)), 0<<stations>>)
747	KPI_53_D Work Stations Main Assembly Line	stations	{'KPI_53_D Work Stations Body Assembly', 'KPI_53_D Work Stations Final Assembly', 'KPI_53_D Work Stations Tilt Assembly', 'KPI_53_D Work Stations Filling'}
748	KPI_53_D Work Stations Pre-Assembly Axles	stations	CEIL (FOR (i=Axles| DIVZX ('KPI_105_M Planned Time Axle Excluding OE - Average Type'[i], 'Available Working Hours per Station Axle Pre-Assembly Area'[i], 0 <<stations/unit>>)) * 1 <<unit>>)
749	KPI_53_D Work Stations Tilt Assembly	stations	IF ('Selection of Model Main Assembly Line'=TRUE, FLOOR('Gross Operating Planned Time Tilt Assembly' / 'Available Time per Station Tilt Assembly' * 60 <<unit*seconds/minutes>>), 0 <<stations>>)
750	KPI_53_D Work Stations Tilt Assembly	stations	Parent~'KPI_53_D Work Stations Tilt Assembly'
751	KPI_53_D Work Stations_Front Axle	stations	KPI_53_D Work Stations Pre-Assembly Axles['Front Axle']
752	KPI_53_D Work Stations_Pre-Assembly Line	stations	ROUND('Gross Planned Operating Time_Pre-Assembly' / 'Working Time per Station_Pre-Assembly' * 60 <<unit*seconds/minutes>>)
753	KPI_53_D Work Stations_Rear Axle	stations	KPI_53_D Work Stations Pre-Assembly Axles['Rear Axle']
754	KPI_53_D Work Stations_Spring Strut	stations	KPI_53_D Work Stations Pre-Assembly Axles[Strut]
755	KPI_53_D Work Stations_Wheels Suspension	stations	KPI_53_D Work Stations Pre-Assembly Axles['Wheel Hub']
756	KPI_54_D Test Rig Station after F1		ARRSUM('Test Rigs in Line')
757	KPI_54_D Testing and Quality Stations Final Assembly	stations	5
758	KPI_54_D Testing and Quality Stations Front Axle	stations	1
759	KPI_54_D Testing and Quality Stations in Engine-Gearbox Line	stations	1
760	KPI_54_D Testing and Quality Stations in Parallel Lines Doors Line 1 per Section	stations	1

#	Name of Element (KPI)	Unit	Definition
761	KPI_54_D Testing and Quality Stations in Parallel Lines Doors Line 2 per Section	stations	1
762	KPI_54_D Testing and Quality Stations in Parallel Lines Doors per Section	stations	{'KPI_54_D Testing and Quality Stations in Parallel Lines Doors Line 1 per Section', 'KPI_54_D Testing and Quality Stations in Parallel Lines Doors Line 2 per Section'}
763	KPI_54_D Testing and Quality Stations in the Main Assembly Line	stations	13.2
764	KPI_54_D Testing and Quality Stations in the Main Assembly Line Body Assembly 1	stations	5
765	KPI_54_D Testing and Quality Stations in the Main Assembly Line Body Assembly 2	stations	5
766	KPI_54_D Testing and Quality Stations in the Main Assembly Line Filling	stations	5
767	KPI_54_D Testing and Quality Stations in the Main Assembly Line Tilt Assembly	stations	5
768	KPI_54_D Testing and Quality Stations in the Train Area	stations	Parent~'Testing and Quality Stations in the Pre-Assembly Line'
769	KPI_54_D Testing and Quality Stations Pre-Assembly Axle	stations	{'KPI_54_D Testing and Quality Stations Front Axle', 'KPI_54_D Testing and Quality Stations Strut', 'KPI_54_D Testing and Quality Stations Rear Axle', 'KPI_54_D Testing and Quality Stations Wheel Hub'}
770	KPI_54_D Testing and Quality Stations Pre-Assembly Axle	stations	Parent~'KPI_54_D Testing and Quality Stations Pre-Assembly Axle'
771	KPI_54_D Testing and Quality Stations Rear Axle	stations	1
772	KPI_54_D Testing and Quality Stations Strut	stations	1
773	KPI_54_D Testing and Quality Stations Wheel Hub	stations	1
774	KPI_56_D Technical Stations Front Axle	stations	1
775	KPI_56_D Technical Stations in Engine-Gearbox Line	stations	25
776	KPI_56_D Technical Stations in Parallel Lines Doors Line 1 per Section	stations	1
777	KPI_56_D Technical Stations in Parallel Lines Doors Line 2 per Section	stations	1
778	KPI_56_D Technical Stations in Parallel Lines Doors per Section	stations	{'KPI_56_D Technical Stations in Parallel Lines Doors Line 1 per Section', 'KPI_56_D Technical Stations in Parallel Lines Doors Line 2 per Section'}
779	KPI_56_D Technical Stations in the Main Assembly Line	stations	10
780	KPI_56_D Technical Stations in the Main Assembly Line Body Assembly 1	stations	5
781	KPI_56_D Technical Stations in the Main Assembly Line Body Assembly 2	stations	5
782	KPI_56_D Technical Stations in the Main Assembly Line Filling	stations	5
783	KPI_56_D Technical Stations in the Main Assembly Line Final Assembly	stations	5
784	KPI_56_D Technical Stations in the Main Assembly Line Tilt Assembly	stations	5
785	KPI_56_D Technical Stations Pre-Assembly Axle	stations	{'KPI_56_D Technical Stations Front Axle', 'KPI_56_D Technical Stations Strut', 'KPI_56_D Technical Stations Rear Axle', 'KPI_56_D Technical Stations Wheel Hub'}
786	KPI_56_D Technical Stations Rear Axle	stations	1
787	KPI_56_D Technical Stations Strut	stations	1
788	KPI_56_D Technical Stations Wheel Hub	stations	1
789	KPI_57_D Fullly Automated Stations Axle Pre-Assembly Area	stations	{'Number of Automated Stations Linked Screwing- or Clamping Technology - Front Axle', 'Number of Automated Stations Linked Screwing- or Clamping Technology - Strut', 'Number of Automated Stations Rear Axle', 'Number of Automated Stations Linked Screwing- or Clamping Technology - Wheel Hub'} * 1 <<stations>>
790	KPI_57_D Fullly Automated Stations in Engine-Gearbox Line	stations	Engine-Gearbox'.'KPI_57_D Fully Automated Stations in Engine-Gearbox-Line'

#	Name of Element (KPI)	Unit	Definition

791	KPI_57_D Fullly Automated Stations in Parallel Lines Doors	stations	{IF ('Selection Technical Area Doors'['Line 1'] = 0
			AND 'Sound Insulation Doors Line 1'[1] = 1,
			PRODUCT ('Selection Door Conveyers'['Line 1'],
			SUM (IF ('Sound Insulation Doors Line 1'[2] = 3,
			1,
			0),
			IF ('Sound Insulation Doors Line 1'[3] = 3,
			1,
			0),
			IF ('Sound Insulation Doors Line 1'[5] = 3,
			1, 0)))
			* 1 <<stations>>,
			0 <<stations>>),
			IF ('Selection Technical Area Doors'['Line 2'] = 0
			AND 'Sound Insulation Doors Line 2'[1] = 1,
			PRODUCT ('Selection Door Conveyors'['Line 1'],
			SUM (IF ('Sound Insulation Doors Line 2'[2] = 3,
			1,
			0),
			IF ('Sound Insulation Doors Line 2'[3] = 3,
			1,
			0),
			IF ('Sound Insulation Doors Line 2'[5] = 3,
			1, 0)))
			* 1 <<stations>>,
			0 <<stations>>)}

792	KPI_57_D Fullly Automated Stations in Technical Areas Doors	stations	{IF ('Selection Door Conveyers'['Line 1'] > 0,
			PRODUCT ('Selection Technical Area Doors'['Line 1'],
			SUM (IF ('Sound Insulation Doors Line 1'[2] = 3,
			1,
			0),
			IF ('Sound Insulation Doors Line 1'[3] = 3,
			1,
			0),
			IF ('Sound Insulation Doors Line 1'[5] = 3,
			1,
			0))), 0),
			IF ('Selection Door Conveyers'['Line 2'] > 0,
			IF (ARRSUM ('Selection Technical Area Doors') = 2
			AND 'Shared Technical Area Line 1' = 1,
			0
			PRODUCT ('Selection Technical Area Doors'['Line 2'],
			SUM (IF ('Sound Insulation Doors Line 2'[2] = 3,
			1,
			0),
			IF ('Sound Insulation Doors Line 2'[3] = 3,
			1,
			0),
			IF ('Sound Insulation Doors Line 2'[5] = 3,
			1,
			0))), 0)}
			* 1 <<stations>>

793	KPI_57_D Fully Automated Stations Body Assembly	stations	SUM('Total Stations Installations Fully-Automated'['Glazing Glasses FA'], 'Total Stations Installations Fully-Automated'['Seat Assembly FA'], 'Total Stations Installations Fully-Automated'['Wire Harness Insertion FA'], 'Total Stations Installations Fully-Automated'['Sun Roof FA'], 'Total Stations Installations Fully-Automated'['Spare Wheel FA'], 'Total Stations Installations Fully-Automated'['Built Card FA'], 'Total Stations Installations Fully-Automated'['Cockpit Installation FA'], 'Total Stations Installations Fully-Automated'['VIN Scribing FA'], 'Total Stations Installations Fully-Automated'['Glazing Glasses - Side Window - FA'], 'Total Stations Installations Fully-Automated'['Sealing Panoramic Sun Roof FA']+ 'Total Stations Installations Fully-Automated'['Changing Bar FA'])
794	KPI_57_D Fully Automated Stations Body Assembly	stations	Facilities.'KPI_57_D Fully Automated Stations Body Assembly'
795	KPI_57_D Fully Automated Stations complex	stations	IF ('Selection of Model Main Assembly Line'=TRUE, ARRSUM('Total Stations Installations Fully-Automated'), 0<<stations>>)
796	KPI_57_D Fully Automated Stations Final Assembly	stations	Facilities.'KPI_57_D Fully Automated Stations in the Main Assembly Line'
797	KPI_57_D Fully Automated Stations in Engine-Gearbox-Line	stations	SUM (DIVZX ('Invest Automated Stations Exhaust Manifold Screwing', 'Invest Automated Stations Exhaust Manifold Screwing', 0), PRODUCT ('Number of Stations Gearbox-Programming', 'Layout Gearbox Programming Stations')) * 1 <<stations>>
798	KPI_57_D Fully Automated Stations in the Main Assembly Line	stations	Total Stations Installations Fully-Automated'['Marriage FA']+ 'Total Stations Installations Fully-Automated'['Defit Station FA']
799	KPI_57_D Fully Automated Stations Simple	stations	7

#	Name of Element (KPI)	Unit	Definition
800	KPI_57_D Fully Automated Stations_Body Assembly	stations	Parent~'KPI_57_D Fully Automated Stations Body Assembly'
801	KPI_58_D Decoupling Stations Affecting Total Area in Engine-Gearbox Line	stations	0
802	KPI_58_D Decoupling Stations Final Assembly	stations	Parent~'Additional Stations Final Assembly'
803	KPI_58_D Decoupling Stations Front Axle	stations	1
804	KPI_58_D Decoupling Stations in Engine-Gearbox Line	stations	1
805	KPI_58_D Decoupling Stations in Parallel Line Doors Line 1 per Section	stations	4
806	KPI_58_D Decoupling Stations in Parallel Line Doors Line 2 per Section	stations	6
807	KPI_58_D Decoupling Stations in Parallel Line Doors per Section	stations	{'KPI_58_D Decoupling Stations in Parallel Line Doors Line 1 per Section', 'KPI_58_D Decoupling Stations in Parallel Line Doors Line 2 per Section'}
808	KPI_58_D Decoupling Stations in the Main Assembly Line	stations	33
809	KPI_58_D Decoupling Stations in the Main Assembly Line Body Assembly 1	stations	5
810	KPI_58_D Decoupling Stations in the Main Assembly Line Body Assembly 2	stations	5
811	KPI_58_D Decoupling Stations in the Main Assembly Line Filling	stations	5
812	KPI_58_D Decoupling Stations in the Main Assembly Line Final Assembly	stations	5
813	KPI_58_D Decoupling Stations in the Main Assembly Line Tilt Assembly	stations	5
814	KPI_58_D Decoupling Stations Non Affecting Total Area in Engine-Gearbox Line	stations	SUM ('KPI_58_D Decoupling Stations in Engine-Gearbox Line', -'KPI_58_D Decoupling Stations Affecting Total Area in Engine-Gearbox Line')
815	KPI_58_D Decoupling Stations Out of Parallel Line Doors	stations	{'KPI_58_D Decoupling Stations out of Parallel Line Doors Line 1', 'KPI_58_D Decoupling Stations out of Parallel Line Doors Line 2'}
816	KPI_58_D Decoupling Stations out of Parallel Line Doors	stations	Parent~'KPI_58_D Decoupling Stations Out of Parallel Line Doors'
817	KPI_58_D Decoupling Stations Out of Parallel Line Doors Line 1	stations	7
818	KPI_58_D Decoupling Stations Out of Parallel Line Doors Line 2	stations	5
819	KPI_58_D Decoupling Stations Pre-Assembly Axle	stations	{'KPI_58_D Decoupling Stations Front Axle', 'KPI_58_D Decoupling Stations Strut', 'KPI_58_D Decoupling Stations Rear Axle', 'KPI_58_D Decoupling Stations Wheel Hub'}
820	KPI_58_D Decoupling Stations Rear Axle	stations	1
821	KPI_58_D Decoupling Stations Strut	stations	1
822	KPI_58_D Decoupling Stations Wheel Hub	stations	1
823	KPI_6_A Traffic Area Body Assembly	meter²	IF('Selection of Model Main Assembly Line'=TRUE, 'Body Assembly'.'KPI_6_A Traffic Area Body Assembly', 0<<meter²>>)

824	KPI_6_A Traffic Area Body Assembly	meter²	{
			(('Belt Width Traffic Space Body Assembly 1'*'Length of Station Body Assembly 1')+('Belt Width Traffic Space Body Assembly 2'*'Length of Station Body Assembly 2'))*'Number of Stations Traffic Space Body Assembly'
			}

825	KPI_6_A Traffic Area Filling	meter²	Filling.'KPI_6_A Traffic Area Filling'

826	KPI_6_A Traffic Area Filling	meter²	{
			('Belt Width Traffic Space Filling'*'Length of Station Filling'*'Number of Stations Traffic Space Filling')
			}

827	KPI_6_A Traffic Area Final Assembly	meter²	Final Assembly'.'KPI_6_A Traffic Area Final Assembly'

828	KPI_6_A Traffic Area Final Assembly	meter²	{
			'Belt Width Traffic Space Final Assembly'*'Number of Stations Traffic Space Final Assembly'*'Length of Station Final Assembly'
			}

829	KPI_6_A Traffic Area Simple Model	meter²	IF('Selection of Model Main Assembly Line'=FALSE, {PRODUCT('Number of Stations Traffic Area', 'Width Traffic Area Simple Model', 'Length of Station')}, 0<<meter²>>)
830	KPI_6_A Traffic Area Tilt Assembly	meter²	Tilt Assembly'.'KPI_6_A Traffic Area Tilt Assembly'

#	Name of Element (KPI)	Unit	Definition

831	KPI_6_A Traffic Area Tilt Assembly	meter²	{
			'Belt Width Traffic Space Tilt Assembly'*'Length of Station Tilt Assembly'*'Number of Stations Traffic Space Ailt Assembly'
			}

832	KPI_69_E Degree of Automation - Final Assembly	%	KPI_57_D Fully Automated Stations Final Assembly'/'KPI_53_D Manual Work Stations Final Assembly'
833	KPI_69_E Degree of Automation in the Body Assembly	%	KPI_57_D Fully Automated Stations Body Assembly'/'KPI_53_D Manual Work Stations Body Assembly'
834	KPI_69_E Degree of Automation on the Main Assembly Line	%	DIVZX('KPI_57_D Fully Automated Stations Simple', 'KPI_53_D Manual Work Stations in the Main Assembly Line Simple', 0%)
835	KPI_69_E Degree of Automation on the Main Assembly Line complex	%	KPI_57_D Fully Automated Stations Complex'/'KPI_53_D Manual Work Stations in the Main Assembly Line Complex'
836	KPI_7_A Main Assembly Building Office Space	meter²	Office Area per Employee'*'Total Number of Employees in Shift'
837	KPI_70_F Number of Conveyor Systems Changes	pieces	3
838	KPI_70_F Number of Conveyor Systems Changes	pieces	Parent~'KPI_70_F Number of Conveyor Systems Changes'
839	KPI_72_F Number of Changeover Processes	pieces	3
840	KPI_72_F Number of Changeover Processes	pieces	Parent~'KPI_72_F Number of Changeover Processes'
841	KPI_73_G Performance-Related Wage Earners per Shift Synchronised in the Body Assembly	worker	ROUND('Workers Necessary Body Assembly'+'Workers Necessary Testing and Quality Stations Body Assembly')
842	KPI_73_G Performance-Related Wage Earners per Shift Synchronised in the Tilt Assembly	worker	ROUND('Workers Necessary Tilt Assembly')
843	KPI_74_G Average Employee Density Doors	worker/stations	{'KPI_74_74_G Average Employee Density Doors Line 1', 'KPI_74_G Average Employee Density Doors Line 2'}
844	KPI_74_G Average Employee Density Doors Line 1	worker/stations	1
845	KPI_74_G Average Employee Density Doors Line 2	worker/stations	1.5
846	KPI_74_G Average Employee Density Engine-Gearbox	worker/stations	Parent~'KPI_74_G Average Employee Density in Engine-Gearbox Line'
847	KPI_74_G Average Employee Density Front Axle	worker/stations	1.2
848	KPI_74_G Average Employee Density in Engine-Gearbox Line	worker/stations	1
849	KPI_74_G Average Employee Density Pre-Assembly Axle	worker/stations	{'KPI_74_G Average Employee Density Front Axle', 'KPI_74_G Average Employee Density Strut', 'KPI_74_G Average Employee Density Rear Axle', 'KPI_74_G Average Employee Density Wheel Hub'}
850	KPI_74_G Average Employee Density Rear Axle	worker/stations	1.2
851	KPI_74_G Average Employee Density Simple Model	worker/stations	2
852	KPI_74_G Average Employee Density Strut	worker/stations	1.2
853	KPI_74_G Average Employee Density Wheel Hub	worker/stations	1.2
854	KPI_74_G Employee Density Body Assembly	worker/stations	3
855	KPI_74_G Employee Density Filling	worker/stations	3
856	KPI_74_G Employee Density Final Assembly	worker/stations	3
857	KPI_74_G Employee Density Testing and Quality Stations Body Assembly	worker/stations	1
858	KPI_74_G Employee Density Testing and Quality Stations Final Assembly	worker/stations	1
859	KPI_74_G Employee Density Tilt Assembly	worker/stations	1.5
860	KPI_8_A Main Assembly Building Employee Amenity Area	meter²	Total Number of Employees in Shift'*'Employee Amenity Area per Employee'
861	KPI_9_A Main Assembly Building Sanitation Areas	meter²	Total Number of Employees in Shift'*'Sanitary Area per Employee'
862	Lapse Daily Output	unit	KPI_41_C Agreed Daily Output'*'Graph Daily Output'
863	Lapse Planned Operating Time	hours	KPI_44_C Assembly Operating Time in Hours'*'Graph Planned Time'
864	Lapse Workers Costs	EUR/hours	Graph Workers Costs'*'Hourly Rate Worker'
865	Layout Gearbox Programming Stations		1
866	Layout Gearbox-Store		{'Capacity Gearbox-Store' / 1 <<unit>>, 'Stacking Factor Gearbox-Store', 'Gearbox-Store Rows'}
867	Lead Time Axle-ACC	min/unit	ARRSUM('Busy Time Test Rigs'[Trail..ACC])
868	Lead Time Rolling Road-Eninge-Test	min/unit	ARRSUM('Busy Time Test Rigs'['Rolling Road'..'Engine Test'])
869	Lenght of Station Doors	meter	{'Lenght of Station Doors Line 1', 'Lenght of Station Doors Line 2'}

# Name of Element (KPI)	Unit	Definition
870 Lenght of Station Doors Line 1	meter	3
871 Lenght of Station Doors Line 2	meter	3
872 Length Floor Area Connecting Conveyor	meter	60
873 Length Floor Area Gearbox-Line	meter	100
874 Length Gearbox	meter	0.4
875 Length Line-Side Presentation-Unit Engine	meter	2.3
876 Length Line-Side Presentation-Unit Gearbox	meter	1.2
877 Length Main Assembly Line_Simple Model	meter	IF('Selection of Model Main Assembly Line'=FALSE, {'Number of Stations Materials Handling'*'Length of Station'}, 0<<meter>>)
878 Length of Station	meter/stations	6
879 Length of Station	meter/stations	3<<meter/stations>>
880 Length of Station Body Assembly 1	meter/stations	6
881 Length of Station Body Assembly 2	meter/stations	6
882 Length of Station F2-Line	meter/stations	6 <<meter>>
883 Length of Station Filling	meter/stations	6
884 Length of Station Final Assembly	meter/stations	6
885 Length of Station Front Axle	meter	5
886 Length of Station Rear Axle	meter	5
887 Length of Station Strut	meter	3
888 Length of Station Tilt Assembly	meter/stations	6
889 Length of Station Wheel hub	meter	3
890 Length Test Rig Grid	meter	8 <<meter>>
891 Length Traffic Area	meter	15 <<meter>>
892 Length Traffic Area Finish Line	meter	{15,15}
893 Length_Carrier Technology Body Assembly 1	meter	(ARRSUM('Additional Stations Body Assembly 1')+'Number of Working Stations Body Assembly 1')*'Length of Station Body Assembly 1'
894 Length_Carrier Technology Body Assembly 2	meter	(ARRSUM('Additional Stations Body Assembly 2')+'Number of Working Stations Body Assembly 2')*'Length of Station Body Assembly 2'
895 Length_Carrier Technology Final Assembly	meter	(ARRSUM('KPI_58_D Decoupling Stations Final Assembly')+'KPI_53_D Work Stations Final Assembly')*'Length of Station Final Assembly'
896 Length_Carrier Technology_Filling Line	meter	(ARRSUM('Auxiliary Stations Filling')+'KPI_53_D Work Stations Filling')*'Length of Station Filling'
897 Line-Side Presentation One-Double-Sided		True
898 Logistics Invest Front Axle	EUR	600000
899 Logistics Invest Rear Axle	EUR	600000
900 Logistics Invest Strut	EUR	600000
901 Logistics Invest Wheel Hub	EUR	600000
902 Maintenance Access Area Gearbox-Store Readout	meter²	PRODUCT ('Total Area Gearbox-Store', 'Proportion of Maintenance Access Area in Total Area Gearbox Store')
903 Manpower Requirements Finish-Lines	worker	('Planned Time Finish-Line_t'+'Additional Times Finish Line'+'Handling Time Vehicle Finish') *'Agreed Daily Output'/'Assembly Planned Operating Time_t - Gross Line Operating Time'*'Rectification Rate Finish Line'* 1 <<worker>>
904 Manpower Requirements Wax Station	worker	2 <<worker>>
905 Manual Work Station_Pre-Assembly Line	stations	KPI_53_D Work Stations_Pre-Assembly Line'-'Fully Automated Stations_Pre-Assembly Line'
906 Manual Work Stations Doors	stations	IF ('Content of KPI_105_M Average Planned Operating Time' = 1, SUM ('KPI_53_D Work Stations in Parallel Lines Doors per Section', -'KPI_57_D Fully Automated Stations in Parallel Lines Doors'), 'KPI_53_D Work Stations in Parallel Lines Doors per Section')
907 Manual Work Stations in Engine-Gearbox Line	stations	IF ('Content of KPI_105_M Engine-Gearbox Line' = 1, SUM ('KPI_53_D Work Stations in Engine-Gearbox Line', -'KPI_57_D Fully Automated Stations in Engine-Gearbox Line'), 'KPI_53_D Work Stations in Engine-Gearbox Line')
908 Manual Work Stations in Engine-Gearbox-Line	stations	Parent-'Manual Work Stations in Engine-Gearbox Line'
909 Manual Work Stations on the Main Assembly Line Simple Model	stations	IF('Selection of Model Main Assembly Line'=FALSE, ('KPI_53_D Work Stations in the Main Assembly Line Simple'-'KPI_57_D Fully Automated Stations Simple'+'KPI_54_D Testing and Quality Stations in the Main Assembly Line'), 0<<stations>>)
910 Manual Work Stations Pre-Assembly Axle	stations	IF ('Content of KPI_105_M Axle' = 1, SUM ('KPI_53_D Work Stations Pre-Assembly Axles', -'KPI_57_D Fully Automated Stations Axle Pre-Assembly Area'), 'KPI_53_D Work Stations Pre-Assembly Axles')

#	Name of Element (KPI)	Unit	Definition
911	MAT Storage		TRUE
912	MAT Storage		Parent~'MAT Speicher'
913	Mathematical Model Area Cost Rates Pre-Assembly	EUR/meter²	Parent~'Calculation Model Area Cost Rates Pre-Assemblies'
914	Mathematical Model Area Cost Units Pre-Assembly	EUR/meter²	Parent~'Calculation Model Area Cost Rates Pre-Assemblies'
915	Mathematical Model Cost Unit Rate Areas Pre-Assembly	EUR/meter²	Parent~'Calculation Model Area Cost Rates Pre-Assemblies'
916	Method of Service		1
917	Minimum Requirements Complete Line		FLOOR('Number of Complete Lines Intermediate Value'[2])
918	Minutes	minutes	1000 <<minutes>>
919	Minutes in Hours	min	NUMBER(Minutes)*1<<min>>
920	Net Basic Working Time per Day in Hours	hours	'Number of Shifts'*'Net Basic Working Time per Shift'
921	Net Basic Working Time per Shift	hours/shift	'Gross Basic Working Time in Hours per Shift'-'Payed Breaks in Hours per Shift'-'Unpayed Breaks in Hours per Shift'
922	Net Line Operating Time_Doors	hours/days	KPI_44_C Assembly Planned Operating Time'*'Availability Employees Doors'*1<<1/days>>
923	Net Line Running Time Main Assembly Line per Day	hours	KPI_44_C Assembly Operating Time'*'KPI_31_B Process Availability Main Assembly Line'
924	Net Line Running Time Main Assembly Line per Day Readout	hours	{'Net Line Running Time Main Assembly Line per Day'}
925	Net Operating Hours per Day - Main Assembly Line	hours	Main Assembly Line'.'Net Line Running Time Main Assembly Line per Day'
926	Net Operating Time Main Assembly Line per Day	hours	Parent~'Net Operating Hours per Day - Main Assembly Line'
927	Non Value-Adding Time per Station	seconds/station	Assembly Logistics'.'Non Value-Adding Time per Station'
928	Number of Floor Transporting System-Vehicles in Circulation Engine-Gearbox-Line Readout		CEIL (PRODUCT ('KPI_51_D Total Stations with Influence Areas in Engine-Gearbox-Line'/ 1 <<stations>>, 'Floor Transporting System Vehicles in Circulation Engine-Gearbox-Line'/ 100 <<%>>))
929	Number of Automated Stations Linked Screwing- or Clamping Technology - Front Axle	stations	Axles.'Number of Automatical Stations Screwing- and Clamping Technology Linked Front Axle'
930	Number of Automated Stations Linked Screwing- or Clamping Technology - Strut	stations	Axles.'Number of Automatical Stations Screwing- and Clamping Technology Linked Strut'
931	Number of Automated Stations Linked Screwing- or Clamping Technology - Wheel Hub	stations	Axles.'Number of Automatical Stations Screwing- and Clamping Technology Linked Wheel Hub'
932	Number of Automated Stations Rear Axle	stations	Axles.'Number of Automatical Stations Rear Axle'
933	Number of Automatic Stations_Train Area	stations	Parent~'Fully Automated Stations_Pre-Assembly Line'
934	Number of Automatical Stations Rear Axle	stations	SUM ('Number of Facilities Toe-Camber-Adjustment Rear Axle', 'Number of Automatical Stations Screwing- and Clamping Technology Linked Rear Axle')
935	Number of Automatical Stations Screwing- and Clamping Technology Linked Front Axle	stations	3
936	Number of Automatical Stations Screwing- and Clamping Technology Linked Rear Axle	stations	2
937	Number of Automatical Stations Screwing- and Clamping Technology Linked Strut	stations	2
938	Number of Automatical Stations Screwing- and Clamping Technology Linked Wheel Hub	stations	2
939	Number of Buffer Stations	stations	20
940	Number of Buffer Stations Complete Line	stations	9
941	Number of Buffer Stations Spotrepair	stations	5
942	Number of Carriers	pieces	Parent~'Number of Sill Bus'
943	Number of Complete Lines		{ 'Required Other Lines'[1], 'Required Other Lines'[2]+'Minimum Requirements Complete Line' }
944	Number of Complete Lines Intermediate Value		Required Flow Rate Complete Line'/'Flow Rate Complete Line'
945	Number of Corner Sections Connecting Conveyor		4
946	Number of Corner Sections Engine-Gearbox-Line		5
947	Number of Corner Sections Front Axle		5
948	Number of Corner Sections Gearbox-Line		2
949	Number of Corner Sections Rear Axle		5
950	Number of Corner Sections Strut		5
951	Number of Corner Sections Wheel Hub		5
952	Number of Days	days	25
953	Number of Days without Breaks	days	25
954	Number of Employees Body Assembly	worker	{ROUND('KPI_73_G Performance-Related Wage Earners per Shift Synchronised in the Body Assembly'*(1+'Supplement Non-Synchronised Employees Body Assembly'))}
955	Number of Employees Body Assembly	worker	Parent~'Number of Employees Body Assembly'
956	Number of Employees Doors	worker	Parent~'Number of Workmen Doors'

#	Name of Element (KPI)	Unit	Definition
957	Number of Employees Engine-Gearbox-Line	worker	Parent~'Number of Workmen Engine-Gearbox-Line'
958	Number of Employees Engine-Gearbox-Line Readout	worker	{'Number of Employees Engine-Gearbox-Line'}

959	Number of Employees Filling	worker	{
			ROUND('Performance Related Wage Earners per Shift Synchronised'*
			(1+'Supplement Non-Synchronised Employees Filling'))
			}

960	Number of Employees Filling	worker	Parent~'Number of Employees Filling'
961	Number of Employees Final Assembly	worker	Parent~'Total Number of Employees Final Assembly'
962	Number of Employees Front Axle Readout	worker	{'Number of Employees Pre-Assembly Axle'['Front Axle']}
963	Number of Employees Pre-Assembly Axle	worker	Parent~'Number of Workmen Pre-Assembly Axles'
964	Number of Employees Rear Axle Readout	worker	{'Number of Employees Pre-Assembly Axle'['Rear Axle']}
965	Number of Employees Strut Readout	worker	{'Number of Employees Pre-Assembly Axle'[Strut]}
966	Number of Employees Sub-Engine-Lines	worker	IF (SUM ('Selection of Line Engine-Gearbox'['Gearbox Line'], 'Selection of Line Engine-Gearbox'['Connecting Conveyor']) > 0, PRODUCT ('Number of Manual Work Stations Sub-Engine-Lines', (100 % + 'Supplement Non-Sequenced Employees Engine-Gearbox')) * 1 <<worker>>, 0 <<worker>>)
967	Number of Employees Sub-Engine-Lines Readout	worker	ROUND ({'Number of Employees Sub-Engine-Lines'}, 1 <<worker>>)
968	Number of Employees Tilt Assembly	worker	{ROUND('KPI_73_G Performance-Related Wage Earners per Shift Synchronised in the Tilt Assembly'*(1+'Supplement Non-Synchronised Employees Tilt Assembly'))}
969	Number of Employees Tilt Assembly	worker	Parent~'Number of Employees Tilt Assembly'
970	Number of Employees Wheel Hub Readout	worker	PRODUCT ({'Number of Employees Pre-Assembly Axle'['Wheel Hub']}, 'Number of Lines Wheel Hub')

971	Number of Facilities Door Seal by Lines - Doors		FOR (i = 'Door Lines'|
			IF ('Selection Technical Area Doors'[i] = 1,
			'Number of Facilities Door Seal Technical Areas'[i],
			PRODUCT ('Selection Door Conveyors'[i],
			'Way of Line-Side Presentation Doors'[i]))))

972	Number of Facilities Door Seal Technical Areas		{'Number of Facilities Door Seal Technical Areas Line 1', 'Number of Facilities Door Seal Technical Areas Line 2'}
973	Number of Facilities Door Seal Technical Areas Line 1		1
974	Number of Facilities Door Seal Technical Areas Line 2		1
975	Number of Facilities Door Selas by Lines Doors		Parent~'Number of Facilities Door Seal by Lines - Doors'

976	Number of Facilities Glazing Door Glass - Triangular Glass - by Lines - Doors		FOR (i = 'Door Lines'|
			IF ('Selection Technical Area Doors'[i] = 1,
			'Number of Facilities Glazing Door Glass - Triangular Glass - Technical Areas'[i],
			PRODUCT ('Selection Door Conveyors'[i],
			'Way of Line-Side Presentation Doors'[i]))))

977	Number of Facilities Glazing Door Glass - Triangular Glass - Technical Areas		{'Number of Facilities Glazing Door Glass - Triangular Glass - Technical Area Line1', 'Number of Facilities Glazing Door Glass - Triangular Glass - Technical Area Line2'}
978	Number of Facilities Glazing Door Glass -Triangular Glass - Technical Area Line1		1
979	Number of Facilities Glazing Door Glass -Triangular Glass - Technical Area Line2		1
980	Number of Facilities Glazing Glasses-Triangle Glasses by Doors Lines		Parent~'Number of Facilities Glazing Door Glass - Triangular Glass - by Lines - Doors'
981	Number of Facilities Sound Insulation by Lines Doors		Parent~'Number of Sound Insulation Facilities by Lines - Doors'
982	Number of Facilities Sound Insulation Technical Area Line 1		1
983	Number of Facilities Sound Insulation Technical Area Line 2		1
984	Number of Facilities Sound Insulation Technical Areas		{'Number of Facilities Sound Insulation Technical Area Line 1', 'Number of Facilities Sound Insulation Technical Area Line 2'}
985	Number of Facilities Toe-Camber-Adjustment Rear Axle		3
986	Number of Finish-Lines		INTEGER(ARRMAX('Test Rigs in Line'))
987	Number of Floor Transporting Vehicles Front Axle Readout	unit	CEIL (PRODUCT ('KPI_51_D Total Stations Pre-Assembly Axle'['Front Axle']/ 1 <<stations>>, 'Floor Transportation Systems in Circulation Front Axle'/ 100 <<%>>))
988	Number of Floor Transporting Vehicles Rear Axle Readout	unit	CEIL (PRODUCT ('KPI_51_D Total Stations Pre-Assembly Axle '['Rear Axle']/ 1 <<stations>>, 'Floor Transportation Systems in Circulation Rear Axle'/ 100 <<%>>)) * 1 <<unit>>

#	Name of Element (KPI)	Unit	Definition
989	Number of Floor Transporting Vehicles Strut Readout	units	CEIL (PRODUCT ('KPI_51_D Total Stations Pre-Assembly Axle'[Strut]/ 1 <<stations>>, 'Floor Transportation Systems in Circulation Strut'/ 100 <<%>>)) * 1 <<unit>>
990	Number of Floor Transporting Vehicles Wheel Hub Readout	units	CEIL (PRODUCT ('KPI_51_D Total Stations Axle Pre-Assembly'[Wheel Hub']/ 1 <<stations>>, 'Floor Transportation Systems in Circulation Wheel Hub'/ 100 <<%>>)) * 1 <<unit>>
991	Number of Gearbox Store Shuttles		CEIL (DIVZX ('Layout Gearbox-Store'[Rows], 2, 0))
992	Number of Gearboxes per Level Gearbox Store		DIVZX ('Layout Gearbox-Store'[Capacity], 'Layout Gearbox-Store'['Stacking Factor'], 0)
993	Number of Gearboxes per Row		CEIL (DIVZX ('Number of Gearboxes per Level Gearbox Store', 'Layout Gearbox-Store'[Rows], 0))
994	Number of Handling Assistors Assembly Front Axle		1
995	Number of Handling Assistors Assembly Rear Axle		1
996	Number of Handling Assistors Assembly Strut		1
997	Number of Handling Assistors Assembly Wheel Hub		1
998	Number of Handling Assistors Component Front Axle		3
999	Number of Handling Assistors Component Rear Axle		3
1000	Number of Handling Assistors Component Strut		3
1001	Number of Handling Assistors Component Wheel Hub		3
1002	Number of Handling Assistors Side Way Shifting Units Front Axle		2
1003	Number of Handling Assistors Side Way Shifting Units Rear Axle		2
1004	Number of Handling Assistors Side Way Shifting Units Strut		2
1005	Number of Handling Assistors Side Way Shifting Units Wheel Hub		2
1006	Number of Handling Assistors Sub-Assembly Front Axle		1
1007	Number of Handling Assistors Sub-Assembly Rear Axle		1
1008	Number of Handling Assistors Sub-Assembly Strut		1
1009	Number of Handling Assistors Sub-Assembly Wheel Hub		1
1010	Number of Hours	hours/shift	2
1011	Number of Lifting Stations Body Assembly 1	stations	1
1012	Number of Lifting Stations Body Assembly 1	stations	Parent-'Number of Lifting Stations Body Assembly 1'
1013	Number of Lifting Stations Body Assembly 2	stations	1
1014	Number of Lifting Stations Body Assembly 2	stations	Parent-'Number of Lifting Stations Body Assembly 2'
1015	Number of Lifting Stations Filling	stations	1
1016	Number of Lifting Stations Filling	stations	Parent-'Number of Lifting Stations Filling'
1017	Number of Lifting Stations Final Assembly	stations	1
1018	Number of Lifting Stations Final Assembly	stations	Parent-'Number of Lifting Stations Final Assembly'
1019	Number of Lifting Stations Tilt Assembly	stations	1
1020	Number of Lifting Stations Tilt Assembly	stations	Parent-'Number of Lifting Stations Tilt Assembly'
1021	Number of Lines F2		Number of Lines F2 Transpack'+'Number of Lines F2 Wax'
1022	Number of Lines F2 Transpack		Number of Transpack
1023	Number of Lines F2 Wax		CEIL('KPI_41_C Assembly Agreed Daily Output'*'Ratio Wax'*'Process Time Wax Station'/'Assembly Planned Operating Time_t - Gross Line Operating Time'/'Availability Wax Facility',1)
1024	Number of Lines Wheel Hub		IF ('KPI_41_C Assembly Agreed Daily Output' > 'Daily Capacity Automatic Facilites', CEIL (DIVZX ('KPI_41_C Assembly Agreed Daily Output', 'Daily Capacity Automatic Facilites', 0)), 1)
1025	Number of Manual Work Stations Sub-Engine-Lines	stations	2
1026	Number of MAT in Circulation	units	Parent-'Number of MAT in Circulation'

#	Name of Element (KPI)	Unit	Definition
1027	Number of Non-Sequenced Employees Body Assembly	worker	ARRSUM('Number of Employees Body Assembly'-'KPI_73_G Performance-Related Wage Earners per Shift Synchronised in the Body Assembly')
1028	Number of Non-Sequenced Employees Filling	worker	ARRSUM('Number of Employees Filling'-'Performance Related Wage Earners per Shift Synchronised')
1029	Number of Non-Sequenced Employees Final Assembly	worker	ARRSUM('Total Number of Employees Final Assembly'-'Required Workers Final Assembly')
1030	Number of Non-Sequenced Employees Tilt Assembly	worker	ARRSUM('Number of Employees Tilt Assembly'-'KPI_73_G Performance-Related Wage Earners per Shift Synchronised in the Tilt Assembly')
1031	Number of Rectification Stations	stations	CEIL('Number of Rectification Stations Basic Requirements'*(1+'Additional Rework Stations Buffer'))
1032	*Number of Rectification Stations Basic Requirements*	*stations*	CEIL('KPI_41_C Assembly Agreed Daily Output'*'Rectification Rate_t'*'Average Time Off-Line Rework'/'Assembly Planned Operating Time_t - Gross Line Operating Time'/1<<unit>>,1)
1033	Number of Semiautomated Stations Screwing- and Clamping Technology Linked Rear Axle	stations	2
1034	Number of Semiautomated Stations Screwing- and Clamping Technology Linked Strut	stations	2
1035	Number of Semiautomated Stations Screwing- and Clamping Technology Linked Wheel Hub	stations	2
1036	Number of Semi-Automatical Stations Screwing- and Clamping Technology Linked Front Axle	stations	3
1037	Number of Shifts	shift	2
1038	Number of Shifts per Day	shift	2
1039	Number of Shifts per Day Doors	shift/days	{'Number of Shifts per Day Doors Line 1', 'Number of Shifts per Day Doors Line 2'}
1040	Number of Shifts per Day Doors Line 1	shift/days	2
1041	Number of Shifts per Day Doors Line 2	shift/days	2
1042	Number of Side Way Shifting Units Connecting Conveyor		2
1043	Number of Side Way Shifting Units Engine-Gearbox-Line		2
1044	Number of Side Way Shifting Units Gearbox-Line		3
1045	Number of Sill Bus	pieces	1000
1046	Number of Sound Insulation Facilities by Lines - Doors		FOR (i = 'Door Lines'| IF ('Selection Technical Area Doors'[i] = 1, 'Number of Facilities Sound Insulation Technical Areas'[i], PRODUCT ('Selection Door Conveyors'[i], *'Way of Line-Side Presentation Doors'[i]*)))
1047	Number of Spotrepair Lines		CEIL('Required Flow Rate Spot Repair'/'Flow Rate Spot Repair')
1048	Number of Stations	stations	FOR(i=1..6|IF(i<='Number of Finish-Lines','Number of Stations Finish Line',0 <<stations>>))
1049	Number of Stations Body Assembly 1	stations	15
1050	Number of Stations Body Assembly 2	stations	IF('KPI_53_D Work Stations Body Assembly'-'Number of Stations Body Assembly 1'<0<<stations>>, 0<<stations>>, 'KPI_53_D Work Stations Body Assembly'-'Number of Stations Body Assembly 1')
1051	Number of Stations Conveyor Systems Body Assembly	stations	SUM('KPI_49_D Cycle Time', ARRSUM('Additional Stations Body Assembly 1'), ARRSUM('Additional Stations Body Assembly 2'))
1052	Number of Stations Conveyor Systems Body Assembly 1	stations	ARRSUM('Additional Stations Body Assembly 1')+ 'Number of Working Stations Body Assembly 1'
1053	Number of Stations Conveyor Systems Body Assembly 2	stations	ARRSUM('Additional Stations Body Assembly 2')+ 'Number of Working Stations Body Assembly 2'
1054	Number of Stations Conveyor Systems Filling	stations	SUM('KPI_53_D Work Stations Filling', ARRSUM('Auxiliary Stations Filling'))
1055	Number of Stations Conveyor Systems Final Assembly	stations	SUM('KPI_53_D Work Stations Final Assembly', ARRSUM('KPI_58_D Decoupling Stations Final Assembly'))
1056	Number of Stations Conveyor Systems Tilt Assembly	stations	SUM('KPI_53_D Work Stations Tilt Assembly', ARRSUM('Additional Stations Tilt Assembly'))
1057	Number of Stations Finish Line	stations	CEIL('Total Working Stations Finish Area' DIVZ0 'Number of Finish-Lines'/('Availability Finish Line'/100%)) +IF('Total Working Stations Finish Area'=0 <<stations>>, 0 <<stations>>,'Technical Stations per Finish Line')
1058	Number of Stations Gearbox-Programming	stations	4
1059	Number of Stations Materials Handling	stations	KPI_53_D Work Stations in the Main Assembly Line Simple'+ 'Availability Stations in the Main Assembly Line'+ 'KPI_54_D Testing and Quality Stations in the Main Assembly Line'+ 'KPI_56_D Technical Stations in the Main Assembly Line'+ 'KPI_58_D Decoupling Stations in the Main Assembly Line'
1060	Number of Stations Service Area Final Assembly	stations	KPI_58_D Decoupling Stations Final Assembly'[INDEX(1)]+ 'KPI_58_D Decoupling Stations Final Assembly'[INDEX(2)]+ 'KPI_53_D Work Stations Final Assembly'

#	Name of Element (KPI)	Unit	Definition
1061	Number of Stations Station Service Area	stations	SUM('KPI_54_D Testing and Quality Stations in the Main Assembly Line', 'Availability Stations in the Main Assembly Line', 'KPI_53_D Work Stations in the Main Assembly Line Simple')
1062	Number of Stations Station Service Areas Filling	stations	Auxiliary Stations Filling'[INDEX(1)]+ 'Auxiliary Stations Filling'[INDEX(2)]+ 'KPI_53_D Work Stations Filling'
1063	Number of Stations Station Service Areas Tilt Assembly	stations	Additional Stations Tilt Assembly'[INDEX(1)]+ 'Additional Stations Tilt Assembly'[INDEX(2)]+ 'KPI_53_D Work Stations Tilt Assembly'
1064	Number of Stations Traffic Area	stations	KPI_53_D Work Stations in the Main Assembly Line Simple'+ 'KPI_54_D Testing and Quality Stations in the Main Assembly Line'+ 'Availability Stations in the Main Assembly Line'+ 'KPI_56_D Technical Stations in the Main Assembly Line'+ 'KPI_58_D Decoupling Stations in the Main Assembly Line'
1065	Number of Stations Traffic Space Body Assembly	stations	SUM('KPI_49_D Cycle Time', ARRSUM('Additional Stations Body Assembly 1'), ARRSUM('Additional Stations Body Assembly 2'))
1066	Number of Stations Traffic Space Filling	stations	SUM('KPI_53_D Work Stations Filling', ARRSUM('Auxiliary Stations Filling'))
1067	Number of Stations Traffic Space Final Assembly	stations	SUM('KPI_53_D Work Stations Final Assembly', ARRSUM('KPI_58_D Decoupling Stations Final Assembly'))
1068	Number of Stations Traffic Space Tilt Assembly	stations	SUM('KPI_53_D Work Stations Tilt Assembly', ARRSUM('Additional Stations Tilt Assembly'))
1069	Number of Test Lines		{ARRMAX('Test Rigs in Line')}
1070	Number of Test Rigs Perfect Value		Agreed Daily Output'*'Busy Time Test Rigs'/'Assembly Planned Operating Time_t - Gross Line Operating Time'
1071	Number of Test Rigs Unlinked		CEIL ('Number of Test Rigs Perfect Value'/ (Availability)* (1+'Total Rectification Rate'),1)
1072	Number of Traffic Grids		4
1073	Number of Transpack		CEIL('Daily Output Transpack'*'Process Time Transpack'/'Assembly Planned Operating Time_t - Gross Line Operating Time'/'Availability Transpack',1)
1074	Number of Work Stations	stations	269
1075	Number of Work Stations Manual Screwing-Technology Compressed Air 25 to 150 Nm Rear Axle	stations	0
1076	Number of Work Stations Screwing-Technology Compressed Air over 150 Nm Rear Axle	stations	0
1077	Number of Work Stations Screwing-Technology Compressed Air Rear Axle	stations	{'Number of Work Stations Screwing-Technology Compressed Air up to 25 Nm Rear Axle', 'Number of Work Stations Manual Screwing-Technology Compressed Air 25 to 150 Nm Rear Axle', 'Number of Work Stations Screwing-Technology Compressed Air over 150 Nm Rear Axle'}
1078	Number of Work Stations Screwing-Technology Compressed Air up to 25 Nm Rear Axle	stations	20
1079	Number of Work Stations Screwing-Technology Electrical 25 to 150 Nm Rear Axle	stations	80
1080	Number of Work Stations Screwing-Technology Electrical over 150 Nm Rear Axle	stations	80
1081	Number of Work Stations Screwing-Technology Electrical Rear Axle	stations	{'Number of Work Stations Screwing-Technology Electrical up to 25 Nm Rear Axle', 'Number of Work Stations Screwing-Technology Electrical 25 to 150 Nm Rear Axle', 'Number of Work Stations Screwing-Technology Electrical over 150 Nm Rear Axle'}
1082	Number of Work Stations Screwing-Technology Electrical up to 25 Nm Rear Axle	stations	20
1083	Number of Working Stations Body Assembly 1	stations	Parent~'KPI_53_D Work Stations Body Assembly 1'
1084	Number of Working Stations Body Assembly 2	stations	Parent~'KPI_53_D Work Stations Body Assembly 2'
1085	Number of Workmen Doors	worker	CEIL (PRODUCT (SUM ('Number of Workmen Parallel Line Doors', 'Number of Workmen Technical Areas'), SUM (100 %, 'Supplement Non-Synchronised Employees Doors')), 1 <<worker>>)
1086	Number of Workmen Engine-Gearbox-Line	worker	IF ('Engine-Gearbox Line' = 1, ROUND (PRODUCT ('Performance-Related Wage Earners at Engine-Gearbox-Line', (1+'Supplement Non-Synchronised Employees Engine-Gearbox')), 1 <<worker>>, 0 <<worker>>), 0 <<worker>>)
1087	Number of Workmen Parallel Line Doors	worker	PRODUCT (IF ('Selection Door Conveyors' > 0, ROUND ('Performance-Related Wage Earners at Parallel Line Doors', 1 <<worker>>), 0 <<worker>>), 'Selection Door Conveyors')

#	Name of Element (KPI)	Unit	Definition
1088	Number of Workmen Pre-Assembly Axles	worker	PRODUCT ('Selection Axle Assembly', ROUND (PRODUCT ('Performance-Related Wage Earners Pre-Assembly Axle', (1+'Supplement Non-Synchronised Employees PA Axles')), 1 <<worker>>, 0 <<worker>>))
1089	Number of Workmen Sub-Engine-Lines	worker	Engine-Gearbox'.'Number of Employees Sub-Engine-Lines Readout'
1090	Number of Workmen Technical Areas	worker	CEIL (PRODUCT ('KPI_74_G Average Employee Density Doors', SUM ('KPI_53_D Work Stations in Technical Areas Doors', - 'KPI_57_D Fully Automated Stations In Technical Areas Doors')))
1091	Number of Workpiece Holders Connecting Conveyor		5
1092	Number of Workpiece Holders in Circulation Engine-Gearbox-Line Readout		CEIL (PRODUCT ('KPI_51_D Total Stations with Influence Areas in Engine-Gearbox-Line'/ 1 <<stations>>, 'Workpiece Carrier in Circulation Engine-Gearbox-Line'/ 100 <<%>>))
1093	Number of Workpiece Holders in Circulation Gearbox-Line and -Store		240
1094	Number of Workpiece-Carrier Front Axle Readout		CEIL (PRODUCT ('KPI_51_D Total Stations Pre-Assembly Axle '['Front Axle'] / 1 <<stations>>, 'Workpiece Carrier in Circulation Front Axle' / 100 <<%>>))
1095	Number of Workpiece-Carrier Rear Axle Readout	unit	CEIL (PRODUCT ('KPI_51_D Total Stations Pre-Assembly Axle '['Rear Axle'] / 1 <<stations>>, 'Workpiece Carrier in Circulation Rear Axle' / 100 <<%>>)) * 1 <<unit>>
1096	Number of Workpiece-Carrier Strut Readout	unit	CEIL (PRODUCT ('KPI_51_D Total Stations Axle Pre-Assembly'[Strut] / 1 <<stations>>, 'Workpiece Carrier in Circulation Strut' / 100 <<%>>)) * 1 <<unit>>
1097	Number of Workpiece-Carrier Wheel Hub Readout	unit	CEIL (PRODUCT ('KPI_51_D Total Stations Axle Pre-Assembly'['Wheel Hub'] / 1 <<stations>>, 'Workpiece Carrier in Circulation Wheel Hub' / 100 <<%>>)) * 2 <<unit>>
1098	Number of Workstations Manual Screwing-Technology Compressed Air 25 to 150 Nm at Manual Workstations Strut	stations	0
1099	Number of Workstations Manual Screwing-Technology Compressed Air 25 to 150 Nm at Manual Workstations Wheel Hub	stations	0
1100	Number of Workstations Manual Screwing-Technology Compressed Air 25 to 150 Nm Front Axle	stations	0
1101	Number of Workstations Manual Screwing-Technology Compressed Air over 150 Nm Front Axle	stations	0
1102	Number of Workstations Manual Screwing-Technology Compressed Air up to 25 Nm Front Axle	stations	20
1103	Number of Workstations Manual Screwing-Technology Electrical 25 to 150 Nm Front Axle	stations	80
1104	Number of Workstations Manual Screwing-Technology Electrical Front Axle	stations	{'Number of Workstations Manual Screwing-Technology Electrical up to 25 Nm Front Axle', 'Number of Workstations Manual Screwing-Technology Electrical 25 to 150 Nm Front Axle', 'Number of Workstations Manual Screwing-Technology Electrical over 150 Nm Front Axle'}
1105	Number of Workstations Manual Screwing-Technology Electrical over 150 Nm Front Axle	stations	80
1106	Number of Workstations Manual Screwing-Technology Electrical up to 25 Nm Front Axle	stations	20
1107	Number of Workstations Screwing-Technology Compressed Air over 150 Nm Strut	stations	0
1108	Number of Workstations Screwing-Technology Compressed Air over 150 Nm Wheel Hub	stations	0
1109	Number of Workstations Screwing-Technology Compressed Air Strut	stations	{'Number of Workstations Screwing-Technology Compressed Air up to 25 Nm Strut', 'Number of Workstations Manual Screwing-Technology Compressed Air 25 to 150 Nm at Manual Workstations Strut', 'Number of Workstations Screwing-Technology Compressed Air over 150 Nm Strut'}
1110	Number of Workstations Screwing-Technology Compressed Air up to 25 Nm Strut	stations	20
1111	Number of Workstations Screwing-Technology Compressed Air up to 25 Nm Wheel Hub	stations	20

#	Name of Element (KPI)	Unit	Definition
1112	Number of Workstations Screwing-Technology Compressed Air Wheel Hub	stations	{'Number of Workstations Screwing-Technology Compressed Air up to 25 Nm Wheel Hub', 'Number of Workstations Manual Screwing-Technology Compressed Air 25 to 150 Nm at Manual Workstations Wheel Hub', 'Number of Workstations Screwing-Technology Compressed Air over 150 Nm Wheel Hub'}
1113	Number of Workstations Screwing-Technology Electrical 25 to 150 Nm Strut	stations	80
1114	Number of Workstations Screwing-Technology Electrical 25 to 150 Nm Wheel Hub	stations	80
1115	Number of Workstations Screwing-Technology Electrical over 150 Nm Strut	stations	80
1116	Number of Workstations Screwing-Technology Electrical over 150 Nm Wheel Hub	stations	80
1117	Number of Workstations Screwing-Technology Electrical Strut		{'Number of Workstations Screwing-Technology Electrical up to 25 Nm Strut', 'Number of Workstations Screwing-Technology Electrical 25 to 150 Nm Strut', 'Number of Workstations Screwing-Technology Electrical over 150 Nm Strut'}
1118	Number of Workstations Screwing-Technology Electrical up to 25 Nm Strut		20
1119	Number of Workstations Screwing-Technology Electrical up to 25 Nm Wheel Hub		20
1120	Number of Workstations Screwing-Technology Electrical Wheel Hub		{'Number of Workstations Screwing-Technology Electrical up to 25 Nm Wheel Hub', 'Number of Workstations Screwing-Technology Electrical 25 to 150 Nm Wheel Hub', 'Number of Workstations Screwing-Technology Electrical over 150 Nm Wheel Hub'}
1121	Office Area per Employee	meter²/worker	3
1122	Office Area per Employee	meter²/worker	Parent~'Office Area per Employee'
1123	Output Invest MAT Storage	EUR	IF('MAT Storage'=TRUE, 'Invest MAT Storage', 0<<EUR>>)
1124	PA_1 F1 Daily Output_t	unit	Time Model_Daily Ouput'.Var_out_t
1125	Paintwork Rectification Rate	%	20%
1126	Paintwork Rectification Rate_t	%	Time Model Input'.'Paintwork Rectification Rate_t'
1127	Parts Carrier with Sealing Lip Line 1		1
1128	Parts Carrier with Sealing Lip Line 2		1
1129	Payed Breaks in Hours per Shift	hours/shift	0 <<Hours/Shift>>
1130	Per Year	unit	Units per Day*245
1131	Percentage Screwing Technology Compressed Air at Manual Working Stations Front Axle		{'Number of Workstations Manual Screwing-Technology Compressed Air up to 25 Nm Front Axle', 'Number of Workstations Manual Screwing-Technology Compressed Air 25 to 150 Nm Front Axle', 'Number of Workstations Manual Screwing-Technology Compressed Air over 150 Nm Front Axle'}
1132	Performance Related Wage Earners per Shift Synchronised	worker	ROUND('Workers Necessary Filling')
1133	Performance-Related Wage Earners	worker	ARRSUM('Workers Array'[FinishA..'F2-Lines'])
1134	Performance-Related Wage Earners at Engine-Gearbox-Line	worker	PRODUCT ('Manual Work Stations in Engine-Gearbox Line', 'KPI_74_G Average Employee Density in Engine-Gearbox Line')
1135	Performance-Related Wage Earners at Parallel Line Doors	worker	PRODUCT ('Manual Work Stations Doors', 'KPI_74_G Average Employee Density Doors')
1136	Performance-Related Wage Earners Pre-Assembly Axle	worker	PRODUCT ('Manual Work Stations Pre-Assembly Axle', 'KPI_74_G Average Employee Density Pre-Assembly Axle')
1137	Performance-Related Wage Earners Present	worker	Performance-Related Wage Earners*(1+'Supplement Additional Times')
1138	Personnel Costs Direct Year	EUR	Working Hours Volume Workers per Day*'Costs per Employee'*'KPI_36_C Assembly Production Days'/1 <<da>>
1139	Personnel Costs Prop	EUR	Workers Employed*'Hourly Wage Rate Worker'*'Assembly Planned Operating Time_t - Gross Line Operating Time'*'Working Stations per Year'/1<<da>>
1140	Personnel Costs Rectification Paintwork Rectification	EUR	Workers Rectification Paintwork Rectification' *'Hourly Wage Rate Worker'*'Assembly Planned Operating Time_t - Gross Line Operating Time'*'Working Stations per Year'/1<<da>>
1141	Pit Array	meter³	{'Pit Requirements Finish-Lines', 'Pit Requirements Test Rigs', 'Pit Requirements Finish-Lines', 'Pit Requirements F2-Lines', 'Pit Requirements Rectification', 'Pit Volume Paintwork Rectification'} *'Bin Total'

# Name of Element (KPI)	Unit	Definition
1142 Pit Cost Rate	EUR/meter³	0
1143 Pit Costs Paintwork Rectification	EUR	Pit Volume Paintwork Rectification'*'Pit Cost Rate'
1144 Pit Depth F2-Line	meter	1
1145 Pit Depth Finish-Line	meter	1
1146 Pit Requirements Complete Line	meter³	1200 <<meter^3>>
1147 Pit Requirements Finish-Lines	meter³	With of Pit Finish LIne'*'Pit Depth Finish-line'*'Station Length Finish Line' *'Number of Stations Finish Line'*'Number of Finish-Lines'
1148 Pit Requirements Rectification	meter³	Number of Rectification Stations'*'Pit Requirements Rectification Station'
1149 Pit Requirements Rectification Station	meter³	0 <<meter^3>>
1150 Pit Requirements Spotrepair	meter³	150 <<meter^3>>
1151 Pit Requirements Test Rigs	meter³	ARRSUM('Pit Requirements Testing Station'*'Test Rigs in Line')
1152 Pit Requirements Testing Station	meter³	{25,0,10,10,0,0}<<meter^3>>
1153 Pit Requirements Wax Station	meter³	50 <<meter^3>>
1154 Pit Volume Complete Line	meter³	ARRSUM('Number of Complete Lines')*'Pit Requirements Complete Line'
1155 Pit Volume Paintwork Rectification	meter³	Pit Volume Spot Repair'+'Pit Volume Complete Line'
1156 Pit Volume Spot Repair	meter³	Number of Spotrepair Lines'*'Pit Requirements Spotrepair'
1157 Pit Width F2-Line	meter/stations	4.2
1158 Planned Operating Times	minutes	{650,700,900,566,334,800,1000}
1159 Planned Time	*minutes/unit*	*500<<Minutes/Unit>>*
1160 Planned Time Finish Line Wax	min/unit	15 <<min/unit>>
1161 Planned Time Finish-Line A	min/unit	16 <<min/unit>>
1162 Planned Time Finish-Line B	min/unit	24 <<min/unit>>
1163 Planned Time Finish-Line_t	min/unit	Time Model Input'.'Planned Time Finish Line_t'
1164 Planned Time in F1-F2-Area	min	200
1165 Planned Time St 53 to F1 Related F1 to F2		KPI_126_M Planned Time on the Main Assembly Line'/'Planned Time in F1-F2-Area'
1166 Planning Time Spread	%	0%
1167 PopUp Automation Marriage		Parent~'PopUp Input Automation'

1168 PopUp Input Automation		FOR(i='Facilities Fully Automated'|
		FOR(j='Facilities Semi Automated'|
		FOR(k='Facilities Non Automated'|
		IF('Selection Semi-Automation'[j]=0 AND 'Selection Automation'[i]=0 AND
		'Selection Non-Automation'[k]=0,
		1,
		IF('Selection Semi-Automation'[j]=1 AND 'Selection Automation'[i]=1 AND
		'Selection Non-Automation'[k]=1,
		2,
		IF('Selection Semi-Automation'[j]=1 AND 'Selection Automation'[i]=1 AND
		'Selection Non-Automation'[k]=0,
		3,
		IF('Selection Semi-Automation'[j]=1 AND 'Selection Automation'[i]=0 AND
		'Selection Non-Automation'[k]=1,
		4,
		IF('Selection Semi-Automation'[j]=0 AND 'Selection Automation'[i]=1 AND
		'Selection Non-Automation'[k]=1,
		5,
		0))))))))

1169 Pre-Applied Sealing Bead Line 1		1
1170 Pre-Applied Sealing Bead Line 2		1
1171 Process Time	min/unit	{4,2,5.25,3.3,3,0} <<min/unit>>
1172 Process Time Rolling Road Rest Rig_t	min/unit	Time Model Input'.'Process Time Rolling Road Test Rig_t'
1173 Process Time St 53 to F1	min/unit	Main Assembly Line'.'Throughput Time 1 to F1'
1174 Process Time Transpack	min/unit	2 <<min/unit>>
1175 Process Time Wax Station	min/unit	0.7 <<min/unit>>
1176 Production Area Doors	meter²	Working Area Doors'+ 'Area Conveyor System Doors'+ 'KPI_17_A Gross Line-Side Presentation Areas Doors'
1177 Production Area Engine-Gearbox-Line	meter²	PRODUCT ('KPI_51_D Total Stations Engine-Gearbox-Line', 'Station Length Enginge-Gearbox-Line', 'Width of Production Area Engine-Gearbox-Line', 'Type of Line-Side Presentation Engine-Gearbox-Line') / 1 <<stations>>
1178 Production Area Front Axle	meter²	Working Area Front Axle'+ 'Area Conveyor System Front Axle'+ 'KPI_17_A Gross Line-Side Service Area Front Axle'

# Name of Element (KPI)	Unit	Definition
1179 Production Area PA Axles	meter²	Production Area Front Axle'+ 'Production Area Rear Axle'+ 'Production Area Wheel Hub'+ 'Production Area Strut'
1180 Production Area Rear Axle	meter²	Working Area Rear Axle'+ 'Area Conveyor System Rear Axle'+ 'KPI_17_A Gross Line-Side Service Area Rear Axle'
1181 Production Area Strut	meter²	Working Area Strut'+'Area Conveyor System Strut'+'KPI_17_A Gross Line-Side Service Area Strut'
1182 Production Area Train Area	meter²	Station Service Area Train Area'+'Area Conveyor Technology_Train Area'+'Copy of Area Conveyor Technology_Train Area'
1183 Production Area Wheel Hub	meter²	Working Area Wheel Hub'+ 'Area Conveyor System Wheel Hub'+ 'KPI_17_A Gross Line-Side Service Area Wheel Hub'
1184 Prop Costs Carrier Overhead Conveyor	EUR/meter	115
1185 Prop Costs Carrier Overhead Conveyor	EUR/meter	Parent~'Prop Costs Carrier Overhead Conveyor'
1186 Prop Costs Conveyor System Connecting Conveyor	EUR/meter	IF ('Selection Conveyor System Engine-Gearbox'['Connecting Conveyor']=1 AND 'Belt Width Conveyor System Engine-Gearbox'['Connecting Conveyor'] <= 1<<meter>>, DIVZX (LOOKUP ('Prop Costs Conveyor System Pre-Assembly-Lines', 'Selection Conveyor System Engine-Gearbox'['Connecting Conveyor']), 4, 0 <<EUR/meter>>), LOOKUP ('Prop Costs Conveyor System Pre-Assembly-Lines', 'Selection Conveyor System Engine-Gearbox'['Connecting Conveyor']))
1187 Prop Costs Conveyor System Engine-Gearbox-Line	EUR/meter	LOOKUP ('Prop Costs Conveyor System Pre-Assembly-Lines', 'Selection Conveyor System Engine-Gearbox'['Engine Line'])
1188 Prop Costs Conveyor System Front Axle	EUR/meter	LOOKUP ('Prop Costs Conveyor System Pre-Assemblies', 'Selection Conveyor System Axles'['Front Axle'])
1189 Prop Costs Conveyor System Gearbox-Line	EUR/meter	IF ('Selection Conveyor System Engine-Gearbox'['Gearbox Line']=1 AND 'Belt Width Conveyor System Engine-Gearbox'['Gearbox Line'] <= 1<<meter>>, DIVZX (LOOKUP ('Prop Costs Conveyor System Pre-Assembly-Lines', 'Selection Conveyor System Engine-Gearbox'['Gearbox Line']), 4, 0 <<EUR/meter>>), LOOKUP ('Prop Costs Conveyor System Pre-Assembly-Lines', 'Selection Conveyor System Engine-Gearbox'['Gearbox Line']))
1190 Prop Costs Conveyor System Pre-Assemblies	EUR/meter	Parent~'Prop Costs Material Handling Pre-Assembly'
1191 Prop Costs Conveyor System Rear Axle	EUR/meter	LOOKUP ('Prop Costs Conveyor System Pre-Assemblies', 'Selection Conveyor System Axles'['Rear Axle'])
1192 Prop Costs Conveyor System Strut	EUR/meter	IF ('Selection Conveyor System Axles'[Strut]=1 AND 'Belt Width Conveyor System Axles'[Strut]<= 1<<meter>>, DIVZX (LOOKUP ('Prop Costs Conveyor System Pre-Assemblies', 'Selection Conveyor System Axles'[Strut]), 2, 0 <<EUR/meter>>), LOOKUP ('Prop Costs Conveyor System Pre-Assemblies', 'Selection Conveyor System Axles'[Strut]))
1193 Prop Costs Conveyor System Wheel hub	EUR/meter	LOOKUP ('Prop Costs Conveyor System Pre-Assemblies', 'Selection Conveyor System Axles'['Wheel Hub'])
1194 Prop Costs Floor Transport System	EUR/meter	700
1195 Prop Costs Friciton Roller Track	EUR/meter	4000
1196 Prop Costs Material Handling Pre-Assembly	EUR/meter	{'Prop Costs Friciton Roller Track', 'Prop Costs Floor Transport System', 'Prop Costs Carrier Overhead Conveyor'}
1197 Proportion Complete Line	%	50 %//RAMP(5<<%/yr>>;STARTTIME)///50 %
1198 Proportion Non-Value Adding to Value Adding	%	Assembly Logistics'.Ratio
1199 Proportion of Availability Stations Complex Model	%	DIVZX('Additional Stations Sum'['Reserve Stations'], 'KPI_53_D Manual Work Stations in the Main Assembly Line Complex', 0%)
1200 Proportion of Availability Stations in Work Stations	%	DIVZX('KPI_53_D Availability Stations in the Main Assembly Line', 'KPI_53_D Manual Work Stations in the Main Assembly Line Simple', 0%)
1201 Proportion of Control Technique Body Assembly	%	0
1202 Proportion of Control Technique Filling	%	0
1203 Proportion of Control Technique Final Assembly	%	0
1204 Proportion of Control Technique Tilt Assembly	%	0
1205 Proportion of Control Technology	%	30%
1206 Proportion of Decoupling Stations Complex Model	%	DIVZX ('Additional Stations Sum'['Decoupling Stations'], 'KPI_53_D Manual Work Stations in the Main Assembly Line Complex', 0%)
1207 Proportion of Decoupling Stations in Work Stations	%	DIVZX ('KPI_58_D Decoupling Stations in the Main Assembly Line', 'KPI_53_D Manual Work Stations in the Main Assembly Line Simple', 0%)

#	Name of Element (KPI)	Unit	Definition
1208	Proportion of Engine-Line-Side Presentation in Assembly Daily Unit Output	%	10
1209	Proportion of Equipment Body Assembly	%	0
1210	Proportion of Equipment Filling	%	0
1211	Proportion of Equipment Final Assembly	%	0
1212	Proportion of Equipment Tilt Assembly	%	0
1213	Proportion of Foremen	%	17
1214	Proportion of Gearbox-Line-Side Presentation in Assembly Daily Output	%	10
1215	Proportion of Maintenance Access Area in Total Area Gearbox Store	%	100
1216	Proportion of Optional Equipment	%	10
1217	Proportion of Storage Area in Total Area Body Assembly	%	40
1218	Proportion of Storage Area in Total Area Doors	%	20
1219	Proportion of Storage Area in Total Area Doors Readout	meter²	ARRSUM(ROUND (PRODUCT ('Area Doors', 'Proportion of Storage Area in Total Area Doors'), 10 <<meter²>>))
1220	Proportion of Storage Area in Total Area Engine-Gearbox-Line	%	40
1221	Proportion of Storage Area in Total Area Filling	%	40
1222	Proportion of Storage Area in Total Area Final Assembly	%	40
1223	Proportion of Storage Area in Total Area Front Axle	%	40
1224	Proportion of Storage Area in Total Area Front Axle Readout	meter²	{PRODUCT ('Area Front-Axle', 'Proportion of Storage Area in Total Area Front Axle')}
1225	Proportion of Storage Area in Total Area Rear Axle	%	40
1226	Proportion of Storage Area in Total Area Rear Axle Read Out	meter²	PRODUCT ('Proportion of Storage Area in Total Area Rear Axle', 'Area Rear Axle')
1227	Proportion of Storage Area in Total Area Strut	%	40
1228	Proportion of Storage Area in Total Area Strut Readout	meter²	PRODUCT ('Area Strut', 'Proportion of Storage Area in Total Area Strut')
1229	Proportion of Storage Area in Total Area Tilt Assembly	%	40
1230	Proportion of Storage Area in Total Area Wheel Hub	meter²	PRODUCT ('Supplement Storage Area Wheel Hub', 'Area Wheel Hub')
1231	Proportion of Technical Stations Complex Model	%	DIVZX ('Additional Stations Sum'['Technical Stations'], 'KPI_53_D Manual Work Stations in the Main Assembly Line Complex', 0%)
1232	Proportion of Technical Stations in Work Stations	%	DIVZX ('KPI_56_D Technical Stations in the Main Assembly Line', 'KPI_53_D Manual Work Stations in the Main Assembly Line Simple', 0%)
1233	Proportion of Testing and Quality Stations Complex Model	%	DIVZX('Additional Stations Sum'['Testing and Quality Stations'], 'KPI_53_D Manual Work Stations in the Main Assembly Line Complex', 0%)
1234	Proportion of Testing and Quality Stations in Work Stations	%	DIVZX('KPI_54_D Testing and Quality Stations in the Main Assembly Line', 'KPI_53_D Manual Work Stations in the Main Assembly Line Simple', 0%)
1235	Proportions	%	{15,15,15,15,15,15,15}%
1236	Proportions of Units	unit	ROUND((Proportions*'KPI_41_C Assembly Agreed Daily Output'),1<<unit>>)
1237	Rate Daily Output Disproportionate	%	3%
1238	Rate Daily Output Linear	%	3%
1239	Rate Disproportionate	%	Parent~'Rate Daily Output Disproportionate'
1240	Rate Linear	%	Parent~'Rate Daily Output Linear'
1241	Rate Paintwork Rectification Rate Linear	%	5%
1242	Rate Paintwork Rectification Rate Overproportional	%	3%
1243	Rate Planned Time B Linear	%	5%
1244	Rate Planned Time B Overproportional	%	3%
1245	Rate Planned Time Disproportionate	%	3%
1246	Rate Planned Time Linear	%	5%
1247	Rate Rectification Rate Linear	%	5%
1248	Rate Rectification Rate Overproportional	%	3%
1249	Rate Time Rolling Road Test Rig	%	3%
1250	Rate Time Rolling Road Test Rig Linear	%	5%
1251	Rate Worker Costs Disproportionate	%	3%
1252	Rate Worker Costs Linear	%	5%

# Name of Element (KPI)	Unit	Definition
1253 Ratio Transpack	%	50
1254 Ratio Wax	%	50
1255 Ratio_OE	%	0%
1256 Ratio-Total	%	Ratio Transpack'+'Ratio Wax'
1257 Readout Auxiliary Space Installations Fully-Automated	meter²	{ARRSUM('Total Auxiliary Space Installations Fully Automated')}
1258 Readout Auxiliary Space Installations Semi-Automated	meter²	{ARRSUM('Total Auxiliary Space Installations Semi Automated')}
1259 Readout Invest Installations Filling	EUR	{ARRSUM('Total Invest Installations Filling')}
1260 Readout Invest Installations Fully-Automated	EUR	{ARRSUM('Total Invest Installations Fully-Automated')}
1261 Readout Invest Installations Non-Automated	EUR	{ARRSUM('Total Invest Installations Non-Automated')}
1262 Readout Invest Installations Semi-Automated	EUR	Facilities.'Readout Invest Installations Semi-Automated'
1263 Readout Stations Installations Fully-Automated	stations	{ARRSUM('Total Stations Installations Fully-Automated')}
1264 Rear Axle Assembly		1
1265 Rectification Rate	%	30%
1266 Rectification Rate Axle ACC	%	0%
1267 Rectification Rate Finish Line	%	{5,5} %
1268 Rectification Rate Rolling Road ABS Engine Test	%	0%
1269 Rectification Rate_t	%	Time Model Input'.'Rectification Rate_t'
1270 Rectification Volume	min	('Average Time Off-Line Rework'/1 <<unit>>*(1+'Waiting Rate')+'Handling Time per Vehicle') *'Agreed Daily Output'*'Rectification Rate_t'
1271 Required Area Buffer Stations Rectification	meter²	Area Buffer Station'*'Buffer Stations Rectification'
1272 Required Employees	worker	Total Number of Employees in Shift'+('Total Number of Employees in Shift'*'Addition Away')
1273 Required Employees	worker	Total Number of Employees in Shift'+('Total Number of Employees in Shift'*'Addition Away')
1274 Required Flow Rate	unit/hr	Required Flow Rate Complete Line'-'Minimum Requirements Complete Line'*'Flow Rate Complete Line'[2]
1275 Required Flow Rate Complete Line	unit/hr	Vehicles Complete Line'/'Assembly Planned Operating Time_t - Gross Line Operating Time'
1276 Required Flow Rate Spot Repair	unit/hr	Vehicles Spot Repair'/'Assembly Planned Operating Time_t - Gross Line Operating Time'

1277 Required Other Lines		IF('Required Flow Rate'=0 <<unit/min>>,0,
		IF ('Required Flow Rate'/'Flow Rate Complete line'[1]>1,
		{0,1},{1,0}))

1278 Required Workers Final Assembly	worker	ROUND('Required Workers Work Stations Final Assembly'+'Required Workers Testing and Quality Stations Final Assembly')
1279 Required Workers Rectification	worker	CEIL('Rectification Volume'/'Assembly Planned Operating Time_t - Gross Line Operating Time'* 1<<worker>>)
1280 Required Workers Testing and Quality Stations Final Assembly	worker	KPI_54_D Testing and Quality Stations Final Assembly'*'KPI_74_G Employee Density Testing and Quality Stations Final Assembly'
1281 Required Workers Work Stations Final Assembly	worker	'KPI_53_D Manual Work Stations Final Assembly'*'KPI_74_G Employee Density Final Assembly'
1282 Required WT per Station	minutes/(stations*unit)	'Planned Time'/'Number of Work Stations'
1283 Required WT per Station	minutes/(stations*unit)	Planned Time'/'Number of Work Stations'
1284 Requirements Filling Technology		IF('Number of Rectification Stations'<=0,0,1)
1285 Requirements Paintwork Rectification		IF('Vehicles Paintwork Rectification'<=0 <<unit>>,0,1)
1286 Sanitary Area per Employee	meter²/worker	2 <<meter^2/worker>>
1287 Sanitary Area per Employee	meter²/worker	Parent-'Sanitary Space per Employee'
1288 Scenario		Parent-'Scenario Daily Output'
1289 Scenario Daily Output		1
1290 Scenario Paintwork Rectification Rate		5
1291 Scenario Planned Time		5
1292 Scenario Planned Time Finish B		5
1293 Scenario Rectification Rate		5
1294 Scenario Rolling Road Test Rig		5
1295 Scenario Workers Costs		5
1296 Selecetion Breaks Yes No		TRUE
1297 Selection Area Connecting Conveyor	meter²	IF ('Selection of Line Engine-Gearbox['Connecting Conveyor'] = 1, 'Area Connecting Conveyor', 0 <<meter²>>)
1298 Selection Area Gearbox	meter²	IF ('Selection of Line Engine-Gearbox['Gearbox Line'] = 1, 'Area Gearbox-Line', 0 <<meter²>>)
1299 Selection Area Manual Work Stations Sub-Engine-Lines	meter²	IF (SUM ('Selection of Line Engine-Gearbox['Gearbox Line'], 'Selection of Line Engine-Gearbox['Connecting Conveyor']) > 0, SUM ('Area Manual Work Stations Sub-Engine-Lines', 'Additional Space Employees Sub-Engine-Line'), 0 <<meter²>>)
1300 Selection Automatic Stations		1

#	Name of Element (KPI)	Unit	Definition
1301	Selection Automation		{1,1,1,1,1,1,1,1,1,1,1,1,1}
1302	Selection Axle Assembly		{'Front Axle Assembly', 'Strut Assembly', 'Rear Axle Assembly', 'Wheel Hub Assembly'}
1303	Selection Axle Assembly		Parent~'Selection Axle Assembly'
1304	Selection Axles		1
1305	Selection Body Assembly		1
1306	Selection Breaks Yes No		TRUE
1307	Selection Calculation Model Cost Rate Pre-Assembly Area		1
1308	Selection Conveyer Engine-Gearbox		{'Gearbox-Line', 'Connecting Conveyor', 'Engine-Gearbox Line'}
1309	Selection Conveyor System		Parent~'Choice_Carrier Technology'
1310	Selection Conveyor System Axle		{'Conveyor System Front Axle', 'Conveyor System Strut', 'Conveyor System Rear Axle', 'Conveyor System Wheel Hub'}
1311	Selection Conveyor System Axles		Parent~'Selection Conveyor System Axle'
1312	Selection Conveyor System Engine-Gearbox		Parent~'Selection Materials Handling Technology Engine-Gearbox'
1313	Selection Conveyor Systems Body Assembly 1		Parent~'Selection Materials Handling Body Assembly 1'
1314	Selection Conveyor Systems Body Assembly 2		Parent~'Selection Materials Handling Body Assembly 2'
1315	Selection Conveyor Systems Filling		Parent~'Selection Materials Handling Filling'
1316	Selection Conveyor Systems Final Assembly		Parent~'Selection Materials Handling Final Assembly'
1317	Selection Conveyor Systems Tilt Assembly		Parent~'Selection Materials Handling Tilt Assembly'
1318	Selection Door Conveyors		{ARRSUM ('Selection Door Conveyors Line 1'), ARRSUM ('Selection Door Conveyors Line 2')}
1319	Selection Door Conveyors Line 1		{'Selection Line 1 Section 1', 'Selection Line 1 Section 2', 'Selection Line 1 Section 3', 'Selection Line 1 Section 4'}
1320	Selection Door Conveyors Line 2		{'Selection Line 2 Section 1', 'Selection Line 2 Section 2', 'Selection Line 2 Section 3', 'Selection Line 2 Section 4'}
1321	Selection Doors		1
1322	Selection Doors Lines		Parent~'Selection Door Conveyors'
1323	Selection Doors Lines Line 1		Parent~'Selection Door Conveyors Line 1'
1324	Selection Doors Lines Line 2		Parent~'Selection Door Conveyors Line 2'
1325	Selection Engine-Gearbox		1
1326	Selection Filling		1
1327	Selection Final Assembly		1
1328	Selection Fully-Automating		Parent~'Selection Automation'
1329	Selection Gearbox Store		1
1330	Selection Gearbox-Store		Parent~'Selection Gearbox Store'
1331	Selection Installations Filling		{0,1,1,1,1,1,1,1}
1332	Selection Installations Filling		Parent~'Selection Installations Filling'
1333	Selection Invest Connecting Conveyor	EUR	IF ('Selection of Line Engine-Gearbox'['Connecting Conveyor'] = 1, SUM ('Invest Conveyor System Connecting Conveyor', 'Invest Workpiece Carrier Connecting Conveyor'), 0 <<EUR>>)
1334	Selection Invest Gearbox-Line	EUR	IF ('Selection of Line Engine-Gearbox'['Gearbox Line'] = 1, SUM ('Invest Conveyor System Gearbox-Line', 'Invest Workpiece Carrier Gearbox-Line and -Store'), 0 <<EUR>>)
1335	Selection Invest Sub-Engine-Line	EUR	IF (SUM ('Selection of Line Engine-Gearbox'['Gearbox Line'], 'Selection of Line Engine-Gearbox'['Connecting Conveyor']) > 0, SUM ('Invest Logistic Sub-Engine-Line', 'Invest Production Control Sub-Engine-Line', 'Invest Facilities Sub-Engine-Line', 'Invest Equipment Manual Work Stations Sub-Engine-Lines'), 0 <<EUR>>)
1336	Selection Line 1 Section 1		1
1337	Selection Line 1 Section 2		1
1338	Selection Line 1 Section 3		1
1339	Selection Line 1 Section 4		1
1340	Selection Line 2 Section 1		1
1341	Selection Line 2 Section 2		1
1342	Selection Line 2 Section 3		1
1343	Selection Line 2 Section 4		1

#	Name of Element (KPI)	Unit	Definition
1344	Selection Main Line		{'Selection Automatic Stations', 'Selection Body Assembly', 'Selection Tilt Assembly', 'Selection Final Assembly', 'Selection Filling'}
1345	Selection Materials Handling Body Assembly 1		{1}
1346	Selection Materials Handling Body Assembly 2		{4}
1347	Selection Materials Handling Filling		{1}
1348	Selection Materials Handling Final Assembly		{1}
1349	Selection Materials Handling Tilt Assembly		{1}
1350	Selection Materials Handlling Technology Engine-Gearbox		{'Conveyor System Gearbox-Line', 'Conveyor System Connecting Conveyor', 'Conveyor System Engine-Gearbox-Line'}
1351	Selection Non-Automating		Parent~'Selection Non-Automation'
1352	Selection Non-Automation		{0,1,1,1,1,1,1,1,1,1,1,1,0,1,1,1}
1353	Selection of Carrier Technology Simple Model		{1}
1354	Selection of Line Engine-Gearbox		Parent~'Selection Conveyer Engine-Gearbox'
1355	Selection of Model Main Assembly Line		TRUE
1356	Selection Power Train		1
1357	Selection Pre-Assembly		{'Selection Engine-Gearbox', 'Selection Axles', 'Selection Power Train', 'Selection Doors'}
1358	Selection Semi-Automating		Parent~'Selection Semi-Automation'
1359	Selection Semi-Automation		{0,1,1,1,1,1,1,1,1,1,1}
1360	Selection Technical Area Doors		{'Selection Technical Area Line 1', 'Selection Technical Area Line 2'}
1361	Selection Technical Area Line 1		1
1362	Selection Technical Area Line 2		1
1363	Selection Technical Areas Doors		Parent~'Selection Technical Area Doors'
1364	Selection Tilt Assembly		1
1365	Selection Wax_Transpack		TRUE
1366	Selection_Mode of Drive		Parent~'Choice_Mode of Drive'

1367	Self Propelling Carrier Overhead Conveyor in Circulation Doors by Lines	pieces	{
			'Self Propelling Carrier Overhead Conveyor In Circulation Doors Line 1',
			IF(ARRSUM('Selection Doors Lines Line 2')=0,
			0<<pieces>>,
			'Self Propelling Carrier Overhead Conveyor in Circulation Doors Line 2')
			}

1368	Self Propelling Carrier Overhead Conveyor in Circulation Doors Line 1	pieces	100
1369	Self Propelling Carrier Overhead Conveyor in Circulation Doors Line 1	pieces	Parent~'Self Propelling Carrier Overhead Conveyor in Circulation Doors Line 1'
1370	Self Propelling Carrier Overhead Conveyor in Circulation Doors Line 2	pieces	100
1371	Self Propelling Carrier Overhead Conveyor in Circulation Doors Line 2	pieces	Parent~'Self Propelling Carrier Overhead Conveyor in Circulation Doors Line 2'
1372	Service Area	meter²	ARRSUM('Station Service Area Main Line')
1373	Share in the Costs Invest per Vehicle	EUR/unit	Amortisations.'Share in Costs Invest per Vehicle'
1374	Shared Technical Area Line 1		1
1375	Single Invest Assembly Carrier Doors	EUR	1
1376	Single Invest Electrical Screwing Technology Center-Lines	EUR	{'Invest Screwing Technology Electrical up to 25 Nm', 'Invest Screwing Technology Electrical 25 to 150 Nm', 'Invest Screwing Technology Electrical over 150 Nm'}
1377	Single Invest Facility Sound Insulation	EUR	{'Type of Production', 'Invest Sound Insulation Adhesive Layer Doors', 'Invest Sound Insulation Assembly Pressing Doors', 'Invest Sound Insulation Pre-Applicated Sealing Bead Doors', 'Invest Sound Insulation Parts Carrier Doors'}
1378	Single Invest Facility Toe-Camber-Adjustment Rear Axle	EUR	750000
1379	Single Invest Floor Transportation System Vehicle Front- and Rear Axle	EUR	1
1380	Single Invest Floor Transportation System Vehicle Strut	EUR	25000
1381	Single Invest Floor Transportation System Vehicle Wheel Hub	EUR	20000
1382	Single Invest Floor Transporting System Vehicle Engine-Gearbox-Line	EUR	25000

#	Name of Element (KPI)	Unit	Definition
1383	Single Invest Handling Assistor Axles	EUR	Parent~'Single Invest Handling Assistor Center-Lines'
1384	Single Invest Handling Assistor Center-Lines	EUR	{'Invest Handling Equipment Component Part Axles', 'Invest Handling Equipment Sub-Assembling Axles', 'Invest Handling Equipment Assembling Axles'}
1385	Single Invest Lifting Station	EUR	80000
1386	Single Invest Screwing Technology Compressed Air Center-Lines	EUR	{'Invest Screwing Technology Compressed Air up to 25 Nm', 'Invest Screwing Technology Compressed Air 25 to 150 Nm', 'Invest Screwing Technology Compressed Air over 150 Nm'}
1387	Single Invest Screwing-Facility Crash-Sensor Doors	EUR	40000
1388	Single Invest Screwing-Facility Crash-Strut Doors	EUR	40000
1389	Single Invest Self Propelling Carrier Overhead Conveyor Doors	EUR	1500
1390	Size Buffer Area	meter²	15
1391	Social Area per Employee	meter²/worker	Parent~'Social Space per Employee'
1392	Social Area per Employee	meter²/worker	Parent~'Employee Amenity Area per Employee'
1393	Social Area per Employee	meter²/worker	Parent~'Social Area per Employee'
1394	Social Space per Employee	meter²/worker	Parent~'Employee Amenity Area per Employee'
1395	Sound Insulation Doors Line 1		{'Type of Production Sound Insulation Line 1', 'Glazing Sound Insulation Door Line 1', 'Installation and Roll Sound Insulation Line 1', 'Pre-Applied Sealing Bead Line 1', 'Parts Carrier With Sealing Lip Line 1'}
1396	Sound Insulation Doors Line 1		Parent~'Sound Insulation Doors Line 1'
1397	Sound Insulation Doors Line 2		{'Type of Production Sound Insulation Line 2', 'Glazing Sound Insulation Door Line 2', 'Installation and Roll Sound Insulation Line 2', 'Pre-Applied Sealing Bead Line 2', 'Parts Carrier With Sealing Lip Line 2'}
1398	Sound Insulation Doors Line 2		Parent~'Sound Insulation Doors Line 2'
1399	Split-up Daily Output Door Lines	unit/days	IF ('KPI_41_D Assembly Agreed Daily Output Doors Line 1' > 'KPI_41_C Assembly Agreed Daily Output', {'KPI_41_C Assembly Agreed Daily Output',0 <<unit/days>>}, {'KPI_41_D Assembly Agreed Daily Output Doors Line 1', 'KPI_41_C Assembly Agreed Daily Output' -'KPI_41_D Assembly Agreed Daily Output Doors Line 1'})
1400	Stacking Factor Gearbox-Store		2
1401	Station Length Enginge-Gearbox-Line	meter	5
1402	Station Length Finish Line	meter/stations	6
1403	Station Service Area Main Assembly Line	meter²	Main Assembly Line'.'Station Service Area Main Line'

1404	Station Service Area Main Line	meter²	IF('Selection of Model Main Assembly Line'=TRUE,
			{
			{0<<meter²>>},
			'KPI_16_A Station Service Area Body Assembly',
			'KPI_16_A Station Service Area Tilt Assembly',
			'KPI_16_A Station Service Area Final Assembly',
			'KPI_16_A Station Service Area Filling'
			},
			{{0<<meter²>>},{0<<meter²>>},{0<<meter²>>},{0<<meter²>>},{0<<meter²>>}})

1405	Station Service Area per Manual Work Station Sub-Engine-Line	meter²	10
1406	Station Service Area Simple Model	meter²	Main Assembly Line'.'KPI_16_A Station Service Area Simple Model'
1407	Station Service Area Train Area	meter²	{'Method of Sevice'*'Width_Station Service Area'*'Length of Station'*'Number of Stations Service Area'}
1408	Stations Before Lifting Ramp	stations	Transpack Stations Before Lifting Ramp'+'Working Stations F2-Line'
1409	Stations Conveyors	stations	Sum Stations Finish Lines'*'Array Conveyor'[INDEX('Installation Conveyors'),Finish]
1410	Stations Facilities in Technical Areas	stations	FOR (i = 'Door Lines'| SUM ('Stations Sound Insulation in Technical Areas'[i], SUM ('Number of Facilities Door Seal Technical Areas'[i], 'Number of Facilities Glazing Door Glass -Triangular Glass - Technical Areas'[i]) * 1 <<stations>>))
1411	Stations Lifting Ramp	stations	1
1412	Stations per F2-Line Wax	stations	IF('Ratio Wax'>0%, CEIL('Stations Requirement F2-Line Wax'/'Number of Lines F2 Wax')+'Technical Stations Wax', 0<<stations>>)
1413	Stations Requirement F2-Line Wax	stations	CEIL('Daily Output Wax'/'Assembly Planned Operating Time_t - Gross Line Operating Time' *'Planned Time Finish Line Wax'/'Workers Density F2-Line' * 1 <<worker>>) +'Number of Lines F2 Wax'*'Stations Wax Station'
1414	Stations Service Area Line Section 1	meter	Type of Line-Side Presentation Body Assembly 1'*'Width Station Service Area Body Assembly 1'
1415	Stations Service Area Line Section 2	meter	Type of Line-Side Presentation Body Assembly 2'*'Width Station Service Area Body Assembly 2'

# Name of Element (KPI)	Unit	Definition
1416 Stations Sound Insulation in Technical Areas	stations	{PRODUCT ('Number of Facilities Sound Insulation Technical Areas'['Line 1'], IF ('Sound Insulation Doors Line 1'[1] = 1, 2 <<stations>>, 1 <<stations>>)), PRODUCT ('Number of Facilities Sound Insulation Technical Areas'['Line 2'], IF ('Sound Insulation Doors Line 2'[1] = 1, 2 <<stations>>, 1 <<stations>>))}
1417 Stations Wax Station	stations	4 <<stations>>
1418 Stations with Platform after Doorline per Section	stations	{'Stations with Platform Doorline 1 per Section', 'Stations with Platform Doorline 2 per Section'}
1419 Stations with Platform Doorline 1 per Section	stations	20
1420 Stations with Platform Doorline 2 per Section	stations	10
1421 Stations with Platforms by Door Lines per Track	stations	Parent-'Stations With Platform After Doorline per Section'
1422 Step Increase Paintwork Rectification Rate	%	20%
1423 Step Increase Planned Time B	min/unit	30 <<min/unit>>
1424 Step Increase Rectification Rate	%	20%
1425 Step Increase Time Rolling Road Test Rig	min/unit	1 <<min/unit>>
1426 Step Increasing	unit	300
1427 Step Increasing Planned Time	hours	5<<hours>>
1428 Step Increasing Workers Costs	EUR/hours	5 <<EUR/hours>>
1429 Step Time	yr	Parent-'Step Time'
1430 Step Time	yr	1
1431 Step Time Paintwork Rectification Rate	yr	8
1432 Step Time Planned Time	yr	8
1433 Step Time Planned Time B	yr	8
1434 Step Time Rectification Rate	yr	8
1435 Step Time Time Rolling Road Test Rig	yr	8
1436 Step Time Workers Costs	yr	8
1437 Storage Area	meter²	PRODUCT ('Total Area Body Assembly Excluding Storage Area', 'Proportion of Storage Area in Total Area Body Assembly')
1438 Storage Area	meter²	PRODUCT ('Total Area Filling Excluding Storage Area', 'Proportion of Storage Area in Total Area Filling')
1439 Storage Area	meter²	PRODUCT ('Total Area Final Assembly Excluding Storage Area', 'Proportion of Storage Area in Total Area Final Assembly')
1440 Storage Area	meter²	PRODUCT ('Total Area Tilt Assembly Excluding Storage Area', 'Proportion of Storage Area in Total Area Tilt Assembly')
1441 Storage Area Engine-Gearbox-Line	meter²	PRODUCT ('Total Area Engine-Gearbox', 'Proportion of Storage Area in Total Area Engine-Gearbox-Line')
1442 Storage Area Engine-Gearbox-Line Readout	meter²	ROUND ({'Storage Area Engine-Gearbox-Line'}, 10 <<meter²>>)
1443 Strut Assembly		1
1444 Sum Additional Production per Day	unit/days	ARRSUM('Additional Production per Day')
1445 Sum Additional Production per Year	unit/year	ARRSUM('Additional Production per Year')+'Additional Production without Breaks per Year'
1446 Sum Amortisation Over All	EUR	Time Model Output'.'Sum Amortisation Total'
1447 Sum of Depreciation Buildings	EUR/year	Amortisations.'Sum Amortisation Buildings'
1448 Sum of Depreciation Technology	EUR/year	Amortisations.'Sum Amortisation Technology'
1449 Sum of Units	unit	ARRSUM('Proportions of Units')
1450 Sum Stations Finish Lines	Stations	Number of Finish-Lines'*'Number of Stations Finish Line'
1451 Sum Total Output	unit	'KPI_40_C Agreed Annual Capacity'+'Sum Additional Produciton Per Year'
1452 Sum Total Output	unit	KPI_40_C Agreed Annual Capacity'+'Sum Additional Produciton per Year'
1453 Sum Work Stations Finish Lines	Stations	Number of Finish-Lines'*'Working Stations Finish-Line'
1454 Sum Workers Test Rigs	worker	ARRSUM(PRODUCT ('Test Rigs in Line','Workers Permanent'))
1455 Sum_Invest	EUR	ARRSUM('Invest Installations Fully-Automated 1')
1456 Supplement Absence	%	40%
1457 Supplement Additional Times	%	38%
1458 Supplement Caused by Absence	%	20%
1459 Supplement Fixed Personnel Costs	%	29%

# Name of Element (KPI)	Unit	Definition
1493 Technical Invest F2-Lines	EUR	//IF('Selection Wax_Transpack'=TRUE; 'Number of Lines F2 Wax'*'F2 Line Invest Facilities Wax'+ 'Number of Lines F2 Transpack'*'F2 Line Invest Facilities Transpack'
1494 Technical Invest Facilities Total	EUR	SUM('Readout Invest Installations Semi-Automated', 'Invest Installations Fully-Automated', 'Costs Conveyor System Changes', 'Readout Invest Installations Filling', 'Costs Converters', 'Costs Carrier')
1495 Technical Invest Filling	EUR	Invest Conveyor System Filling'+'Invest Tool Kit Filling'
1496 Technical Invest Final Assembly	EUR	Invest Conveyor System Final Assembly'+'Invest Tool Kit Final Assembly'
1497 Technical Invest Finish-Lines	EUR	Number of Finish-Lines'*'Invest Control Engeneering per Line'+ 'Station Length Finish Line'*'Costs per Meter Finish-Line'*'Sum Stations Finish Lines'/ 1<<meter>> +'Invest Prop Conveyor'+'Invest Conveyor Fixed'
1498 Technical Invest Front Axle	EUR	IF ('Selection Axle Assembly'['Front Axle'] = 1, SUM ('Invest Facilities Front Axle', 'Invest Process Control Front Axle', 'Invest Conveyor System Front Axle', 'Invest Manual Screwing Technology Front Axle', 'Invest Handling Assistors Front Axle', 'Invest Rework Area Front Axle', 'Invest Screwing- and Clamping Technology Front Axle', 'Invest Workpiece Carrier Front Axle', 'Invest Tool Kit Manual Work Stations Front Axle', 'Logistics Invest Front Axle'), 0 <<EUR>>)
1499 Technical Invest Gearbox-Store	EUR	IF ('Selection Gearbox-Store'=1, SUM ('Invest Automatic Gearbox Store-Shuttles', 'Invest Rack', 'Invest Production Control Gearbox-Store'), 0 <<EUR>>)
1500 Technical Invest incl Basic Equipment Doors	EUR	PRODUCT ('Technical Invest Doors', SUM ('Supplement for Replacement Basic Equipment Doors', 100 %))
1501 Technical Invest incl Basic Equipment Doors Readout	EUR	ROUND ({ARRSUM ('Technical Invest incl Basic Equipment Doors')}, 1000 <<EUR>>)
1502 Technical Invest incl Basic Equipment Engine-Gearbox Readout	EUR	SUM ('Technical Invest incl Basic Equipment Engine-Gearbox-Line Readout', 'Technical Invest incl Basic Equipment Sub-Engine-Line Readout', 'Technical Invest incl Basic Equipment Gearbox-Store Readout')
1503 Technical Invest incl Basic Equipment Engine-Gearbox-Line	EUR	PRODUCT ('Technical Invest Engine-Gearbox-Line', SUM ('Supplement for Replacement Basic Equipment Engine-Gearbox-Line', 100 %))
1504 Technical Invest incl Basic Equipment Engine-Gearbox-Line Readout	EUR	ROUND ({'Technical Invest incl Basic Equipment Engine-Gearbox-Line'}, 1000 <<EUR>>)
1505 Technical Invest incl Basic Equipment Front Axle	EUR	PRODUCT ('Technical Invest Front Axle', SUM ('Supplement for Replacement Basic Equipment Front Axle', 100 %))
1506 Technical Invest incl Basic Equipment Front Axle Readout	EUR	ROUND ({'Technical Invest incl Basic Equipment Front Axle'}, 1000 <<EUR>>)
1507 Technical Invest incl Basic Equipment Gearbox-Store	EUR	PRODUCT ('Technical Invest Gearbox-Store', SUM ('Supplement for Replacement Basic Equipment Gearbox-Store', 100 %))
1508 Technical Invest incl Basic Equipment Gearbox-Store Readout	EUR	ROUND ({'Technical Invest incl Basic Equipment Gearbox-Store'}, 1000 <<EUR>>)
1509 Technical Invest incl Basic Equipment Rear Axle	EUR	PRODUCT ('Technical Invest Rear Axle', SUM ('Supplement for Replacement Basic Equipment Rear Axle', 100 %))
1510 Technical Invest incl Basic Equipment Rear Axle Readout	EUR	ROUND ({'Technical Invest incl Basic Equipment Rear Axle'}, 1000 <<EUR>>)
1511 Technical Invest incl Basic Equipment Strut	EUR	PRODUCT ('Technical Invest Strut', SUM ('Supplement for Replacement Basic Equipment Strut', 100 %))
1512 Technical Invest incl Basic Equipment Strut Readout	EUR	ROUND ({'Technical Invest incl Basic Equipment Strut'}, 1000 <<EUR>>)
1513 Technical Invest incl Basic Equipment Sub-Engine-Line	EUR	PRODUCT ('Technical Invest Sub-Engine-Lines', SUM ('Supplement for Replacement Basic Equipment Sub-Engine-Line', 100 %))
1514 Technical Invest incl Basic Equipment Sub-Engine-Line Readout	EUR	ROUND ({'Technical Invest incl Basic Equipment Sub-Engine-Line'}, 1000 <<EUR>>)
1515 Technical Invest incl Basic Equipment Wheel Hub	EUR	PRODUCT ('Technical Invest Wheel Hub', SUM ('Supplement for Replacement Basic Equipment Wheel Hub', 100 %))
1516 Technical Invest incl Basic Equipment Wheel Hub Readout	EUR	ROUND (PRODUCT ({'Technical Invest incl Basic Equipment Wheel Hub'}, 'Number of Lines Wheel Hub'), 1000 <<EUR>>)
1517 Technical Invest incl Original Equipment Axles Readout	EUR	SUM (Axles.'Technical Invest incl Basic Equipment Front Axle Readout', Axles.'Technical Invest incl Basic Equipment Strut Readout', Axles.'Technical Invest incl Basic Equipment Rear Axle Readout', Axles.'Technical Invest incl Basic Equipment Wheel Hub Readout')

#	Name of Element (KPI)	Unit	Definition
1518	Technical Invest incl Original Equipment Doors Readout	EUR	Doors Lines'.'Technical Invest incl Basic Equipment Doors Readout'
1519	Technical Invest incl Original Equipment Engine-Gearbox Readout	EUR	Engine-Gearbox'.'Technical Invest incl Basic Equipment Engine-Gearbox Readout'
1520	Technical Invest incl Original Equipment Power Train Readout	EUR	Train Area'.'Total Invest_Train Area'

1521	Technical Invest Main Assembly	EUR	{
			'Technical Invest Simple Model',
			'Technical Invest Main Assembly Line Complex Model'
			}

1522	Technical Invest Main Assembly Line Complex Model	EUR	IF ('Selection of Model Main Assembly Line'=TRUE, (PRODUCT('Selection Main Line'['Body Assembly'],'Technical Invest Body Assembly')+ PRODUCT('Selection Main Line'['Tilt Assembly'],'Technical Invest Tilt Assembly')+ PRODUCT('Selection Main Line'['Final Assembly'],'Technical Invest Final Assembly')+ PRODUCT('Selection Main Line'[Filling],'Technical Invest Filling')+ PRODUCT('Selection Main Line'['Automatic Stations'],'Technical Invest Facilities Total')), 0<<EUR>>)
1523	Technical Invest Paintwork Rectification	EUR	('Invest Paint Mix Facility'+'Invest Extra Working Stations')*'Requirements Paintwork Rectification' +'Technical Invest Spotrepair'+'Technical Invest Complete Line'
1524	Technical Invest per Rework Station Front Axle	EUR	100000
1525	Technical Invest per Rework Station Rear Axle	EUR	100000
1526	Technical Invest Pre-Assembly Readout	EUR	SUM (PRODUCT ('Selection Pre-Assembly'['PA Engine_Gearbox'], 'Technical Invest incl Original Equipment Engine-Gearbox Readout'), PRODUCT ('Selection Pre-Assembly'['PA Axles'], 'Technical Invest incl Original Equipment Axles Readout'), PRODUCT ('Selection Pre-Assembly'['PA Doors'], 'Technical Invest incl Original Equipment Doors Readout'), PRODUCT ('Selection Pre-Assembly'['PA Power Train'], 'Technical Invest incl Original Equipment Power Train Readout'))
1527	Technical Invest Rear Axle	EUR	IF ('Selection Axle Assembly'['Rear Axle'] = 1, SUM ('Invest Facilities Rear Axle', 'Invest Process Control Rear Axle', 'Invest Conveyor System Rear Axle', 'Invest Manual Screwing Technology Rear Axle', 'Invest Handling Assistor Rear Axle', 'Invest Rework Area Rear Axle', 'Invest Screwing- and Clamping Technology Rear Axle', 'Invest Toe-Camber-Adjustment Rear Axle', 'Invest Workpiece Carrier Rear Axle', 'Logistics Invest Rear Axle', 'Invest Tool Kit Manual Work Stations Rear Axle'), 0 <<EUR>>)
1528	Technical Invest Rectification	EUR	Number of Rectification Stations'*'Technical Invest Rectification Station' +'Invest Filling'*'Requirements Filling Technology'
1529	Technical Invest Rectification Station	EUR	42000 <<EUR>>
1530	Technical Invest Simple Model	EUR	IF('Selection of Model Main Assembly Line'=FALSE, ('Cost Rate Technology per Automated Station Simple Model'* 'KPI_57_D Fully Automated Stations Simple' / 1<<stations>>+ 'Invest Conveyor System Simple'+'Invest Tool-Kits Body Assembly'), 0<<EUR>>)
1531	Technical Invest Spotrepair	EUR	Number of Spotrepair Lines'*'Invest Spotrepair Line'
1532	Technical Invest Strut	EUR	IF ('Selection Axle Assembly'[Strut] = 1, SUM ('Invest Facilities Strut', 'Invest Process Control Strut', 'Invest Conveyor System Strut', 'Invest Manual Screwing Technology Strut', 'Invest Handling Assistors Strut', 'Invest Screwing- and Clamping Technology Strut', 'Invest Confirmation of Variants Strut', 'Invest Workpiece Carrier Strut', 'Invest Tool Kit Manual Work Stations Strut', 'Logistics Invest Strut'), 0 <<EUR>>)
1533	Technical Invest Sub-Engine-Lines	EUR	IF (ARRSUM ('Selection of Line Engine-Gearbox') > 0, SUM ('Selection Invest Gearbox-Line', 'Selection Invest Connecting Conveyor', 'Invest Semiautomatic Machines Engine-Gearbox', 'Selection Invest Sub-Engine-Line'), 0 <<EUR>>)
1534	Technical Invest Tilt Assembly	EUR	Invest Conveyor System'+'Invest Tool Kit Tilt Assembly'

# Name of Element (KPI)	Unit	Definition
1535 Technical Invest Wheel Hub	EUR	IF ('Selection Axle Assembly['Wheel Hub'] = 1, SUM ('Invest Automatical Station Wheelbearing Press Unlinked Wheel Hub', 'Invest Brake Test Wheel Hub', 'Invest Conveyor System Wheel Hub', 'Invest Screwing- and Clamping Technology Wheel Hub', 'Invest Workpiece Carrier Wheel Hub', 'Invest Tool Kit Manual Work Stations Wheel Hub', 'Invest Process Control Wheel Hub', 'Invest Facilities Wheel Hub', 'Invest Handling Assistor Wheel Hub', 'Invest Manual Screwing Technology Wheel Hub', 'Logistics Invest Wheel Hub'), 0 <<EUR>>)
1536 Technical Stations in the Pre-Assembly Line	stations	0
1537 Technical Stations per Finish Line	stations	2
1538 Technical Stations Wax	stations	2

1539 Test Rigs in Line		CEIL(
		FOR(i='Test Rigs'|
		IF(NUMERICAL(i)<=5 AND NOT('Number of Test Rigs Unlinked'[i]=0),ARRMAX('Number of Test Rigs Unlinked'[Trail..'Engine Test']),0)))

1540 Test Rigs Technical Invest	EUR	Testing Line Technical Invest*ARRMAX('Test Rigs in Line')
1541 Testing and Quality Stations in the Pre-Assembly Line	stations	0
1542 Testing Line Technical Invest	EUR	ARRSUM(FOR(i='Test Rigs'|SIGN('Test Rigs in Line'[i])*'Invest Test Rig'[i])) +'Invest Headlights Integrated'
1543 Throughput Time 1 to F1	minutes/unit	'KPI_49_D Cycle Time'*'Total Stations on the Main Assembly Line'*1<<1/stations>>
1544 Time for Station Change_BTS	seconds/stations	25
1545 Time for Station Change_Roll Conveyer	seconds/stations	15
1546 Time Requirement Driver	min	(('Lead Time Axle-ACC'*(1+'Total Rectification Rate'[Trail])+'Lead Time Rolling Road-Eninge-Test'*(1+'Total Rectification Rate'['Rolling Road']) +'Driving Time Track Rolling Road'*(1+'Total Rectification Rate'[Trail])+'Walking Time Workers'*(1+'Total Rectification Rate'['Rolling Road']+'Total Rectification Rate'[Trail])) +'Driving Time') *'Agreed Daily Output'
1547 Time Requirement Test Rigs	min	Sum Workers Test Rigs'*'Working Time Worker'+'Time Requirement Driver'
1548 Time Way Back	s	80
1549 Total Amortisations per Year	EUR/year	Main Assembly Line'.'Total Amortisations per Year'
1550 Total Area	meter²	ARRSUM('Array Area')
1551 Total Area Axles Readout	meter²	SUM (Axles.'Total Area Front Axle Readout', Axles.'Total Area Strut Readout', Axles.'Total Area Rear Axle Readout', Axles.'Total Area Wheel Hub Readout')
1552 Total Area Body Assembly	meter²	Body Assembly'.'Total Area Body Assembly'
1553 Total Area Body Assembly	meter²	PRODUCT ('Total Area Body Assembly Excluding Storage Area', SUM (100 %, 'Proportion of Storage Area in Total Area Body Assembly'))
1554 Total Area Body Assembly Excluding Storage Area	meter²	SUM('Area Conveyor Systems Body Assembly', 'KPI_16_A Station Service Area Body Assembly 1', 'KPI_16_A Station Service Area Body Assembly 2', 'Additional Area Employee Body Assembly')
1555 Total Area Doors	meter²	ROUND (PRODUCT ('Area Doors', SUM ('Proportion of Storage Area in Total Area Doors', 100 %)), 10 <<meter²>>)
1556 Total Area Doors Readout	meter²	Doors Lines'.'Total Area Doors Readout'
1557 Total Area Doors Readout	meter²	ROUND ({ARRSUM ('Total Area Doors')}, 10 <<meter²>>)
1558 Total Area Engine-Gearbox	meter²	PRODUCT (SUM ('Total Area Gearbox-Store', 'Total Area Engine-Gearbox-Line', 'Total Area Sub-Engine-Lines'), SUM ('Proportion of Storage Area in Total Area Engine-Gearbox-Line', 100%))
1559 Total Area Engine-Gearbox Readout	meter²	Engine-Gearbox'.'Total Area Engine-Gearbox Readout'
1560 Total Area Engine-Gearbox Readout	meter²	ROUND ({'Total Area Engine-Gearbox'}, 10 <<meter²>>)

# Name of Element (KPI)	Unit	Definition
1561 Total Area Engine-Gearbox-Line	meter²	IF ('Selection of Line Engine-Gearbox'['Engine Line']=1, SUM ('Production Area Engine-Gearbox-Line', 'Area Conveyor System Engine-Gearbox-Line', 'Additional Space Employees Engine-Gearbox-Line', 'Traffic Area Engine-Gearbox-Line', 'KPI_17_A Gross Station Service Area next to Engine-Gearbox-Line', 'Area Line-Side Presentation Gearbox', 'Area Line-Side-Presentation Engine'), 0 <<meter²>>)
1562 Total Area Engine-Gearbox-Line Readout	meter²	ROUND ({'Total Area Engine-Gearbox-Line'}, 10 <<meter²>>)
1563 Total Area F1 to F2	meter ²	F1_F2-Area'.'Total Area'
1564 Total Area Filling	meter²	Filling.'Total Area Filling'
1565 Total Area Filling	meter²	PRODUCT ('Total Area Filling Excluding Storage Area', SUM (100 %, 'Proportion of Storage Area in Total Area Filling'))
1566 Total Area Filling Excluding Storage Area	meter²	SUM('Area Conveyor Systems Filling', 'KPI_16_A Station Service Area Filling', 'KPI_6_A Traffic Area Filling', 'Additional Area Employee Filling')
1567 Total Area Final Assembly	meter²	Final Assembly'.'Total Area Final Assembly'
1568 Total Area Final Assembly	meter²	PRODUCT ('Total Area Final Assembly Excluding Storage Area', SUM (100 %, 'Proportion of Storage Area in Total Area Final Assembly'))
1569 Total Area Final Assembly Excluding Storage Area	meter²	SUM('Area Conveyor Systems Final Assembly', 'KPI_16_A Gross Station Service Area Final Assembly', 'KPI_6_A Traffic Area Final Assembly', 'Additional Area Employee Final Assembly')
1570 Total Area Front Axle	meter²	PRODUCT ('Area Front-Axle', SUM (100 %, 'Proportion of Storage Area in Total Area Front Axle'))
1571 Total Area Front Axle Readout	meter²	ROUND ({'Total Area Front Axle'}, 10 <<meter²>>)
1572 Total Area Gearbox-Store	meter²	IF ('Selection Gearbox-Store' = 1, PRODUCT (SUM ('Area Gearbox-Store Net', 'Area Gearbox Store Shuttles'), SUM (100 %, 'Proportion of Maintenance Access Area in Total Area Gearbox Store')), 0 <<meter²>>)
1573 Total Area Gearbox-Store Readout	meter²	ROUND ({'Total Area Gearbox-Store'}, 10 <<meter²>>)
1574 Total Area Installations	meter²	SUM('Auxiliary Space Installations Semi-Automated', 'Area Installations Fully-Automated')
1575 Total Area Main Assembly Line	meter ²	Main Assembly Line'.'Total Area Main Line'
1576 Total Area Main Line	meter²	FLOOR(ARRSUM('Area Main Line Completely'))
1577 Total Area Main Line Complex Model	meter²	IF ('Selection of Model Main Assembly Line'=TRUE, (PRODUCT('Selection Main Line'['Body Assembly'],'Total Area Body Assembly')+ PRODUCT('Selection Main Line'['Tilt Assembly'],'Total Area Tilt Assembly')+ PRODUCT('Selection Main Line'['Final Assembly'],'Total Area Final Assembly')+ PRODUCT('Selection Main Line'[Filling],'Total Area Filling')+ PRODUCT('Selection Main Line'['Automatic Stations'],'Total Area Installations')), 0<<meter²>>)
1578 Total Area Main Line Simple Model	meter²	Area Convoyer System Simple Model'+ 'KPI_6_A Traffic Area Simple Model'+ 'KPI_16_A Station Service Area Simple Model'+ 'Additional Space Employees Main Assembly Line Simple Model'
1579 Total Area Power Train Readout	meter²	Train Area'.'Total Area_Train Area'
1580 Total Area Pre-Assemblies	meter ²	ARRSUM ('Pre-Assemblies'.'Total Area Pre-Assembly Readout')
1581 Total Area Pre-Assembly Readout	meter²	SUM (PRODUCT ('Selection Pre-Assembly'['PA Engine_Gearbox'], 'Total Area Engine-Gearbox Readout'), PRODUCT ('Selection Pre-Assembly'['PA Axles'], 'Total Area Axles Readout'), PRODUCT ('Selection Pre-Assembly'['PA Doors'], 'Total Area Doors Readout'), PRODUCT ('Selection Pre-Assembly'['PA Power Train'], 'Total Area Power Train Readout'))
1582 Total Area Rear Axle	meter²	PRODUCT ('Area Rear Axle', SUM (100%, 'Proportion of Storage Area in Total Area Rear Axle'))

# Name of Element (KPI)	Unit	Definition
1583 Total Area Rear Axle Readout	meter²	ROUND ({'Total Area Rear Axle'}, 10 <<meter²>>)
1584 Total Area Requirements Spotrepair-Line	meter²	Area Spotrepair Assembly'+'Area Spotrepair'
1585 Total Area Strut	meter²	PRODUCT ('Area Strut', SUM (100 %, 'Proportion of Storage Area in Total Area Strut'))
1586 Total Area Strut Readout	meter²	ROUND ({'Total Area Strut'}, 10 <<meter²>>)
1587 Total Area Sub-Engine-Lines	meter²	IF (ARRSUM ('Selection of Line Engine-Gearbox') > 0, SUM ('Selection Area Gearbox', 'Selection Area Connecting Conveyor', 'Selection Area Manual Work Stations Sub-Engine-Lines'), 0 <<meter²>>)
1588 Total Area Sub-Engine-Lines Readout	meter²	ROUND ({'Total Area Sub-Engine-Lines'}, 10 <<meter²>>)
1589 Total Area Tilt Assembly	meter²	Tilt Assembly'.'Total Area Tilt Assembly'
1590 Total Area Tilt Assembly	meter²	PRODUCT ('Total Area Tilt Assembly Excluding Storage Area', SUM (100 %, 'Proportion of Storage Area in Total Area Tilt Assembly'))
1591 Total Area Tilt Assembly Excluding Storage Area	meter²	SUM('Area Conveyor Systems Tilt Assembly', 'KPI_16_A Station Service Area Tilt Assembly', 'KPI_6_A Traffic Area Tilt Assembly', 'Additional Area Employee Tilt Assembly')
1592 Total Area Wheel Hub	meter²	PRODUCT ('Area Wheel Hub', SUM (100 %, 'Supplement Storage Area Wheel Hub'))
1593 Total Area Wheel Hub Readout	meter²	ROUND ({'Total Area Wheel Hub'}, 10 <<meter²>>)
1594 Total Auxiliary Space Installations Fully Automated	meter²	IF('Selection Fully-Automating'=1, { 'Auxiliary Space Installations Fully Automated'['Marriage FA'], 'Auxiliary Space Installations Fully Automated'['Glazing Glasses FA'], 'Auxiliary Space Installations Fully Automated'['Seat Assembly FA'], 'Auxiliary Space Installations Fully Automated'['Wire Harness Insertion FA'], 'Auxiliary Space Installations Fully Automated'['Sun Roof FA'], 'Auxiliary Space Installations Fully Automated'['Spare Wheel FA'], 'Auxiliary Space Installations Fully Automated'['Built Card FA'], 'Auxiliary Space Installations Fully Automated'['Cockpit Installation FA'], 'Auxiliary Space Installations Fully Automated'['VIN Scribing FA'], 'Auxiliary Space Installations Fully Automated'['Glazing Glasses - Side Window FA'], 'Auxiliary Space Installations Fully Automated'['Sealing Panoramic Sun Roof FA'], 'Auxiliary Space Installations Fully Automated'['Changing Bar FA'], 'Auxiliary Space Installations Fully Automated'['Defit Station FA'] }, 0<<meter²>>)
1595 Total Auxiliary Space Installations Semi Automated	meter²	IF('Selection Semi-Automating'=1, { 'Auxiliary Space Installations Semi Automated'['Marriage SA'], 'Auxiliary Space Installations Semi Automated'['Sun Roof SA'], 'Auxiliary Space Installations Semi Automated'['Sealing Panoramic Sun Roof SA'], 'Auxiliary Space Installations Semi Automated'['VIN Scribing SA'], 'Auxiliary Space Installations Semi Automated'['Wheels SA'], 'Auxiliary Space Installations Semi Automated'['Glazing Glasses - Side Window SA'], 'Auxiliary Space Installations Semi Automated'['Glazing Glasses SA'], 'Auxiliary Space Installations Semi Automated'['Cockpit Installation SA'], 'Auxiliary Space Installations Semi Automated'['Frontend SA'], 'Auxiliary Space Installations Semi Automated'['Changing Bar SA'], 'Auxiliary Space Installations Semi Automated'['Defit Station SA'] }, 0<<meter²>>)
1596 Total Budget	EUR	'Personnel Costs Direct Year'*(1+'Supplement Fix Personnel Costs'+'Supplement Inputed Costs'+'Supplement Material Costs')
1597 Total Costs	EUR/unit	Costs Non-Value Adding Time per Unit'+'Total Logistic Costs per Unit'+'Invest per Vehicle'
1598 Total Invest	EUR	ARRSUM('All Investments')
1599 Total Invest	EUR	ARRSUM('Total Invest Array')
1600 Total Invest Array	EUR	Array Invest of Buildings'+'Technical Invest Array'
1601 Total Invest Axles Readout	EUR	SUM (Axles.'Total Invest Front Axle Readout', Axles.'Total Invest Strut Readout', Axles.'Total Invest Rear Axle Readout', Axles.'Total Invest Wheel Hub Readout')
1602 Total Invest Body Assembly	EUR	Invest Buildings Body Assembly'+'Technical Invest Body Assembly'
1603 Total Invest Buildings	EUR	ARRSUM('Array Invest of Buildings')
1604 Total Invest Doors Readout	EUR	Doors Lines'.'Total Invest Doors Readout'
1605 Total Invest Doors Readout	EUR	SUM ('Invest Buildings Doors Readout', 'Technical Invest incl Basic Equipment Doors Readout')

# Name of Element (KPI)	Unit	Definition
1606 Total Invest Engine-Gearbox Line Readout	EUR	SUM ('Total Invest Engine-Gearbox Readout', 'Total Invest Sub-Engine-Lines Readout', 'Total Invest Gearbox-Store Readout','Invest of Buildings Storage Area Engine-Gearbox')
1607 Total Invest Engine-Gearbox Readout	EUR	Engine-Gearbox'.'Total Invest Engine-Gearbox Line Readout'
1608 Total Invest Engine-Gearbox Readout	EUR	SUM ('Invest of Buildings Engine-Gearbox-Line', 'Technical Invest incl Basic Equipment Engine-Gearbox-Line Readout')
1609 Total Invest Equipment	EUR	PRODUCT ('Invest Tool-Kits per Manual Work Station Filling', ARRSUM('Employees Needed Train Area')) / 1 <<worker>>
1610 Total Invest F1 to F2	EUR	F1_F2-Area'.'Total Invest'
1611 Total Invest F2-Lines	EUR	Invest of Buildings'+'Technical Invest F2-Lines'
1612 Total Invest Facilities	EUR	Invest Buildings Fully-Automated Stations'+'Technical Invest Facilities Total'
1613 Total Invest Filling	EUR	Invest Buildings Filling'+'Technical Invest Filling'
1614 Total Invest Final Assembly	EUR	Invest Buildings Final Assembly'+'Technical Invest Final Assembly'
1615 Total Invest Finish-Lines	EUR	Invest of Buildings Finish-Lines'+'Technical Invest Finish-Lines'
1616 Total Invest Front Axle Readout	EUR	SUM ('Invest Buildings Front Axle Readout', 'Technical Invest incl Basic Equipment Front Axle Readout')
1617 Total Invest Gearbox-Store Readout	EUR	SUM ('Invest of Buildings Gearbox-Store Readout', 'Technical Invest incl Basic Equipment Gearbox-Store Readout')

1618 Total Invest Installations Filling	EUR	IF('Selection Installations Filling'=1,
		{
		'Invest Installations Filling'['Filling Tank'],
		'Invest Installations Filling'['Filling Air-Conditioning'],
		'Invest Installations Filling'['Filling Cooling System'],
		'Invest Installations Filling'['Filling Brakes'],
		'Invest Installations Filling'['Filling Oil'],
		'Invest Installations Filling'['Filling Fountain Solution Servo and Others'],
		'Invest Installations Filling'['All Cascade-Testings and Codings'],
		'Invest Installations Filling'['Testing Facility Brake Pressure']
		},
		0<<EUR>>)

1619 Total Invest Installations Fully-Automated	EUR	IF('Selection Fully-Automating'=1,
		{
		'Invest Installations Fully-Automated 1'['Marriage FA'],
		'Invest Installations Fully-Automated 1'['Glazing Glasses FA'],
		'Invest Installations Fully-Automated 1'['Seat Assembly FA'],
		'Invest Installations Fully-Automated 1'['Wire Harness Insertion FA'],
		'Invest Installations Fully-Automated 1'['Sun Roof FA'],
		'Invest Installations Fully-Automated 1'['Spare Wheel FA'],
		'Invest Installations Fully-Automated 1'['Built Card FA'],
		'Invest Installations Fully-Automated 1'['Cockpit Installation FA'],
		'Invest Installations Fully-Automated 1'['VIN Scribing FA'],
		'Invest Installations Fully-Automated 1'['Glazing Glasses - Side Window - FA'],
		'Invest Installations Fully-Automated 1'['Sealing Panoramic Sun Roof FA'],
		'Invest Installations Fully-Automated 1'['Changing Bar FA'],
		'Invest Installations Fully-Automated 1'['Defit Station FA']
		},
		0<<EUR>>)

1620 Total Invest Installations Non-Automated	EUR	IF('Selection Non-Automating'=1,
		{
		'Invest Installations Non-Automated'['Marriage NA'],
		'Invest Installations Non-Automated'['Glazing Glasses NA'],
		'Invest Installations Non-Automated'['Seat Assembly NA'],
		'Invest Installations Non-Automated'['Wire Harness Insertion NA'],
		'Invest Installations Non-Automated'['Sun Roof NA'],
		'Invest Installations Non-Automated'['Sealing Panoramic Sun Roof NA'],
		'Invest Installations Non-Automated'['Convertible Soft Top NA'],
		'Invest Installations Non-Automated'['Spare Wheel NA'],
		'Invest Installations Non-Automated'['Door Disassembly NA'],
		'Invest Installations Non-Automated'['Cockpit Installation NA'],
		'Invest Installations Non-Automated'['Glazing Glasses - Side Window-NA'],
		'Invest Installations Non-Automated'['Wheel Assembly NA'],
		'Invest Installations Non-Automated'['Frontend NA'],
		'Invest Installations Non-Automated'['Door Assembly NA'],
		'Invest Installations Non-Automated'['Battery NA'],
		'Invest Installations Non-Automated'['Exhaust System NA']
		},
		0<<EUR>>)

1621 Total Invest Installations Semi-Automated	EUR	IF('Selection Semi-Automating'=1,
		{
		'Invest Installations Semi-Automated'['Marriage SA'],
		'Invest Installations Semi-Automated'['Sun Roof SA'],
		'Invest Installations Semi-Automated'['Sealing Panoramic Sun Roof SA'],
		'Invest Installations Semi-Automated'['VIN Scribing SA'],
		'Invest Installations Semi-Automated'['Wheels SA'],
		'Invest Installations Semi-Automated'['Glazing Glasses - Side Window - SA'],
		'Invest Installations Semi-Automated'['Glazing Glasses SA'],
		'Invest Installations Semi-Automated'['Cockpit Installation SA'],
		'Invest Installations Semi-Automated'['Frontend SA'],
		'Invest Installations Semi-Automated'['Changing Bar SA'],
		'Invest Installations Semi-Automated'['Defit Station SA']
		},
		0<<EUR>>)

# Name of Element (KPI)	Unit	Definition
1622 Total Invest Main Assembly Line	EUR	Main Assembly Line'.'Total Invest Main Line'
1623 Total Invest Main Line	EUR	ARRSUM('Invest Main Line Completely')
1624 Total Invest Main Line Complex Model	EUR	Invest Buildings Main Line Complex Model'+'Technical Invest Main Assembly Line Complex Model'
1625 Total Invest Main Line Simple Model	EUR	Invest Buildings Main Line Simple Model'+'Technical Invest Simple Model'
1626 Total Invest Power Train Readout	EUR	Invest Buildings Power Train Readout'+'Technical Invest incl Original Equipment Power Train Readout'
1627 Total Invest Pre-assemblies	EUR	ARRSUM ('Pre-Assemblies'.'Total Invest Pre-Assembly Readout')
1628 Total Invest Pre-Assembly Readout	EUR	SUM (PRODUCT ('Selection Pre-Assembly'['PA Engine_Gearbox'], 'Total Invest Engine-Gearbox Readout'), PRODUCT ('Selection Pre-Assembly'['PA Axles'], 'Total Invest Axles Readout'), PRODUCT ('Selection Pre-Assembly'['PA Doors'], 'Total Invest Doors Readout'), PRODUCT ('Selection Pre-Assembly'['PA Power Train'], 'Total Invest Power Train Readout'))
1629 Total Invest Rear Axle Readout	EUR	SUM ('Invest Buildings Rear Axle Readout', 'Technical Invest incl Basic Equipment Rear Axle Readout')
1630 Total Invest Rectification	EUR	Invest of Buildings Rectification'+'Technical Invest Rectification'
1631 Total Invest Strut Readout	EUR	SUM ('Invest Buildings Strut Readout', 'Technical Invest incl Basic Equipment Strut Readout')
1632 Total Invest Sub-Engine-Lines Readout	EUR	SUM ('Invest of Buildings Sub-Engine-Lines Readout', 'Technical Invest incl Basic Equipment Sub-Engine-Line Readout')
1633 Total Invest Technology	EUR	ARRSUM('Technical Invest Array')
1634 Total Invest Test Rigs	EUR	Invest of Buildings Test Rigs'+'Test Rigs Technical Invest'
1635 Total Invest Tilt Assembly	EUR	'Invest Buildings Tilt Assembly'+'Technical Invest Tilt Assembly'
1636 Total Invest Wheel Hub Readout	EUR	SUM ('Invest Buildings Wheel Hub Readout', 'Technical Invest incl Basic Equipment Wheel Hub Readout')
1637 Total Invest_Train Area	EUR	Output Invest MAT Storage'+ 'Invest_Drive_Train Area'+ 'Invest Conveyor Technology'+ 'Invest MAT'+ 'Total Invest Equipment'+ 'Invest Automatic'
1638 Total Logistic Costs per Unit	EUR/unit	Assembly Logistics'.'Total Logistic Costs per Unit'
1639 Total Number of Employees	worker	{ 'Workers Required Main Assembly Line', 'Workers Required F1 to F2', 'Workers Required Pre-Assemblies', 0 <<worker>> }
1640 Total Number of Employees Final Assembly	worker	{ROUND('Required Workers Final Assembly'*(1+'Additional Non-Synchronised Employees Final Assembly'))}
1641 Total Number of Employees in Shift	worker	ARRSUM('Total Number of Employees')
1642 Total Number of Employees Main Line Complex Model	worker	IF ('Selection of Model Main Assembly Line'=TRUE, (PRODUCT('Selection Main Line'['Body Assembly'],'Number of Employees Body Assembly')+ PRODUCT('Selection Main Line'['Tilt Assembly'],'Number of Employees Tilt Assembly')+ PRODUCT('Selection Main Line'['Final Assembly'],'Total Number of Employees Final Assembly')+ PRODUCT('Selection Main Line'[Filling],'Number of Employees Filling')), 0<<worker>>)
1643 Total Number of Workers	worker	Foremen Requirements Main Assembly Line'+'Workers Required Main Assembly Line'
1644 Total Number of Workers	worker	ARRSUM('Workers Array')
1645 Total Planned Operating Time Complex Model	minutes/unit	IF('Selection of Model Main Assembly Line'=TRUE, ('KPI_103_M Planned Time Excluding OE Filling'+ 'KPI_103_M Planned Time Excluding OE Final Assembly'+ 'KPI_103_M Planned Time Excluding OE Body Assembly'+ 'KPI_103_M Planned Time Excluding OE Tilt Assembly'), 0<<minutes/unit>>)
1646 Total Rectification Rate	%	{'Rectification Rate Axle ACC', 'Rectification Rate Axle ACC', 'Rectification Rate Rolling Road ABS Engine Test', 'Rectification Rate Rolling Road ABS Engine Test', 'Rectification Rate Rolling Road ABS Engine Test', 0%}
1647 Total Stations F2-Line Wax	Stations	Stations Lifting Ramp'+'Transpack Stations After Lifting Ramp'+'Stations Before Lifting Ramp'
1648 Total Stations Installations Fully-Automated	stations	Facilities.'Total Stations Installations Fully-Automated'

# Name of Element (KPI)	Unit	Definition

1649 Total Stations Installations Fully-Automated	stations	IF('Selection Fully-Automating'=1,
		{
		'Work Stations Installations Fully-Automated'['Marriage FA'],
		'Work Stations Installations Fully-Automated'['Glazing Glasses FA'],
		'Work Stations Installations Fully-Automated'['Seat Assembly FA'],
		'Work Stations Installations Fully-Automated'['Wire Harness Insertion FA'],
		'Work Stations Installations Fully-Automated'['Sun Roof FA'],
		'Work Stations Installations Fully-Automated'['Spare Wheel FA'],
		'Work Stations Installations Fully-Automated'['Built Card FA'],
		'Work Stations Installations Fully-Automated'['Cockpit Installation FA'],
		'Work Stations Installations Fully-Automated'['VIN Scribing FA'],
		'Work Stations Installations Fully-Automated'['Glazing Glasses - Side Window - FA'],
		'Work Stations Installations Fully-Automated'['Sealing Panoramic Sun Roof FA'],
		'Work Stations Installations Fully-Automated'['Changing Bar FA']*0
		'Work Stations Installations Fully-Automated'['Defit Station FA']*0
		},
		0<<stations>>)

1650 Total Stations on the Main Assembly Line	stations	IF('Selection of Model Main Assembly Line'=TRUE, 'Total Stations on the Main Assembly Line Complex', 'Total Stations on the Main Assembly Line Simple')
1651 Total Stations on the Main Assembly Line Complex	stations	SUM(ARRSUM('Additional Stations Sum'), 'KPI_53_D Work Stations in the Main Assembly Line Complex')
1652 Total Stations on the Main Assembly Line Simple	stations	IF('Selection of Model Main Assembly Line'=FALSE, ('KPI_53_D Manual Work Stations in the Main Assembly Line Simple'+ 'KPI_54_D Testing and Quality Stations in the Main Assembly Line'+ 'KPI_56_D Technical Stations in the Main Assembly Line'+ 'KPI_58_D Decoupling Stations in the Main Assembly Line'+ 'KPI_53_D Availability Stations in the Main Assembly Line'+ 'KPI_57_D Fully Automated Stations Simple'), 0<<stations>>)
1653 Total Stations Train Area	stations	Total Stations_Pre-Assembly Line'[1]+'Total Stations_Pre-Assembly Line'[2]+'Total Stations_Pre-Assembly Line'[3]+'Total Stations_Pre-Assembly Line'[4]
1654 Total Stations_Pre-Assembly Line	stations	{'Manual Work Station_Pre-Assembly Line', 'Fully Automated Stations_Pre-Assembly Line', 'Technical Stations in the Pre-Assembly Line', 'Testing and Quality Stations in the Pre-Assembly Line'}
1655 Total Width of Line-Side Presentation Doors	meter	PRODUCT ('Type of Line-Side Presentation Doors', 'Width of Line-Side Presentation per Side Doors')
1656 Total Working Stations Finish Area	Stations	CEIL(('Planned Time Finish-Line_t'+'Additional Times Finish Line')*('Flow Rate of Finish-Lines'/'Workers Density Finish Line')*1<<worker>>)
1657 Traffic Area Doors	meter²	PRODUCT ('Lenght of Station Doors', 'Width Traffic Area Doors', 'Type of Line-Side Presentation Doors', SUM (PRODUCT ('KPI_51_D Stations Doors per Side', 'Selection Doors Lines'), 'KPI_51_D Total Stations Doors')) / 1 <<stations>>
1658 Traffic Area Engine-Gearbox-Line	meter²	PRODUCT ('Station Length Enginge-Gearbox-Line', 'KPI_51_D Total Stations Engine-Gearbox-Line', 'Width Traffic Way Engine-Gearbox', 'Type of Line-Side Presentation Engine-Gearbox-Line') / 1 <<stations>>
1659 Traffic Area Front Axle	meter²	PRODUCT ('KPI_51_D Total Stations Axle Pre-Assembly'['Front Axle'], 'Length of Station Front Axle', 'Width Traffic Way Axles', 'Type of Line-Side Presentation Front Axle') / 1 <<stations>>
1660 Traffic Area Rear Axle	meter²	PRODUCT ('KPI_51_D Total Stations Axle Pre-Assembly'['Rear Axle'], 'Length of Station Rear Axle', 'Width Traffic Way Axles', 'Type of Line-Side Presentation Rear Axle') / 1 <<stations>>
1661 Traffic Area Rectification	meter²	Number of Rectification Stations'*'Traffic Area Rectification Station'
1662 Traffic Area Rectification Station	meter²	24 <<meter^2>>
1663 Transfer Shift Model from Main Assembly Line		TRUE
1664 Transfer Time Vehicle	min	2 <<min>>
1665 Transpack Stations After Lifting Ramp	Stations	8
1666 Transpack Stations Before Lifting Ramp	Stations	4

# Name of Element (KPI)	Unit	Definition
1667 Type of Door Line 1		{'Type of Door Line 1 Section 1', 'Type of Door Line 1 Section 2', 'Type of Door Line 1 Section 3', 'Type of Door Line 1 Section 4'}
1668 Type of Door Line 1 Section 1		1
1669 Type of Door Line 1 Section 2		1
1670 Type of Door Line 1 Section 3		1
1671 Type of Door Line 1 Section 4		1
1672 Type of Door Line 2		{'Type of Door Line 2 Section 1', 'Type of Door Line 2 Section 2', 'Type of Door Line 2 Section 3', 'Type of Door Line 2 Section 4'}
1673 Type of Door Line 2 Section 1		1
1674 Type of Door Line 2 Section 2		1
1675 Type of Door Line 2 Section 3		1
1676 Type of Door Line 2 Section 4		1
1677 Type of Doors Line 1		Parent~'Type of Door Line 1'
1678 Type of Doors Line 2		Parent~'Type of Door Line 2'
1679 Type of Line-Side Presentation Body Assembly 1		1
1680 Type of Line-Side Presentation Body Assembly 2		1
1681 Type of Line-Side Presentation Doors		Parent~'Way of Line-Side Presentation Doors'
1682 Type of Line-Side Presentation Engine-Gearbox-Line		1
1683 Type of Line-Side Presentation Filling		1
1684 Type of Line-Side Presentation Final Assembly		1
1685 Type of Line-Side Presentation Front Axle		1
1686 Type of Line-Side Presentation Rear Axle		1
1687 Type of Line-Side Presentation Tilt Assembly		1
1688 Type of Line-Side Presentation Wheel Hub		1
1689 Type of Production		{0,0,0}
1690 Type of Production Sound Insulation Line 1		1
1691 Type of Production Sound Insulation Line 2		1
1692 Units per Area	unit/meter²	'KPI_40_C Agreed Annual Capacity'/'Total Area'
1693 Units per Day	unit/days	KPI_44_C Operating Time'/'Cycle Time'*1<<unit/stations>>
1694 Units per Worker	unit/worker	KPI_40_C Agreed Annual Capacity'/'Workers Employed'
1695 Unpayed Breaks in Hours per Shift	hours/shift	0
1696 Usage of Assembly Carrier by Door Lines		Parent~'Usage of Assembly Carrier by Door Lines'
1697 Usage of Assembly Carrier by Door Lines		{'Usage of Assembly Carrier Line 1', 'Usage of Assembly Carrier Line 2'}
1698 Usage of Assembly Carrier Line 1		1
1699 Usage of Assembly Carrier Line 2		1
1700 Value-Adding Time per Station	seconds/station	Assembly Logistics'.'Value-Adding Time per Station'
1701 Vehicles Buffer Area	meter²	Number of Buffer Stations'*'Size Buffer Area'*(1+'Supplement Proportional Traffic Area')
1702 Vehicles Complete Line	unit	Vehicles Paintwork Rectification'*('Proportion Complete Line')
1703 Vehicles Paintwork Rectification	unit	Paintwork Rectification Rate_t'*'Agreed Daily Output'*(1+'Internal Rectification Rate')
1704 Vehicles per Worker	unit/worker	Agreed Daily Output'/'Total Number of Workers'
1705 Vehicles Spot Repair	unit	(1-'Proportion Complete Line')*'Vehicles Paintwork Rectification'
1706 Waiting Rate	%	10%
1707 Walking Time Workers	s/unit	Time Way Back'*(1+'Total Rectification Rate'[Trail]+ 'Total Rectification Rate'['Rolling Road'])/ 1<< unit>>

1708 Way of Line-Side Presentation Doors		FOR (i='Door Lines']
		IF ('Gantry Systems Doors'[i]<3,
		1,
		2))

1709 Way of Production Sond Insulation Line 2		1
1710 Wheel Hub Assembly		1
1711 Width Conveyor Technology	meter	2
1712 Width Gearbox	meter	0.4
1713 Width of Delivery Area	meter	3
1714 Width of F2-Line	meter	7
1715 Width of Line-Side Presentation Area	meter	3

#	Name of Element (KPI)	Unit	Definition
1716	Width of Line-Side Presentation Axles per Side	meter	Parent~'Width of Line-Side Presentation per Side Center-Lines'
1717	Width of Line-Side Presentation Engine-Gearbox-Line	meter	PRODUCT ('Type of Line-Side Presentation Engine-Gearbox-Line', 'Width of Line-Side Presentation per Side Engine-Gearbox-Line')
1718	Width of Line-Side Presentation Front Axle	meter	PRODUCT ('Type of Line-Side Presentation Front Axle', 'Width of Line-Side Presentation Axles per Side')
1719	Width of Line-Side Presentation per Side Center-Lines	meter	2
1720	Width of Line-Side Presentation per Side Doors	meter	{'Width of Line-Side Presentation per Side Doors Line 1', 'Width of Line-Side Presentation per Side Doors Line 2'}
1721	Width of Line-Side Presentation per Side Doors Line 1	meter	3
1722	Width of Line-Side Presentation per Side Doors Line 2	meter	2.5
1723	Width of Line-Side Presentation per Side Engine-Gearbox-Line	meter	3
1724	Width of Line-Side Presentation Rear Axle	meter	PRODUCT ('Type of Line-Side Presentation Rear Axle', 'Width of Line-Side Presentation Axles per Side')
1725	Width of Line-Side Presentation Wheel Hub	meter	PRODUCT ('Type of Line-Side Presentation Wheel Hub', 'Width of Line-Side Presentation Axles per Side')
1726	Width of Line-Side Presentation-Unit Engine	meter	2
1727	Width of Line-Side Presentation-Unit Gearbox	meter	0.8
1728	Width of Production Area Engine-Gearbox-Line	meter	1
1729	Width of Station Service Area Final Assembly	meter	3
1730	Width Station Service Area	meter	3.4
1731	Width Station Service Area Body Assembly 1	meter	3
1732	Width Station Service Area Body Assembly 2	meter	3
1733	Width Station Service Area Filling	meter	3
1734	Width Station Service Area Tilt Assembly	meter	3
1735	Width Testing Line	meter	7
1736	Width Traffic Area	meter	2
1737	Width Traffic Area Doors	meter	{'Width Traffic Area Doors Line 1', 'Width Traffic Area Doors Line 2'}
1738	Width Traffic Area Doors Line 1	meter	3
1739	Width Traffic Area Doors Line 2	meter	3
1740	Width Traffic Area Simple Model	meter	5
1741	Width Traffic Way Axles	meter	Parent~'Width Transportation Route Center-Lines'
1742	Width Traffic Way Engine-Gearbox	meter	Parent~'Width Transportation Route Engine-Gearbox'
1743	Width Transportation Route Center-Lines	meter	4
1744	Width Transportation Route Engine-Gearbox	meter	4
1745	Width Wax Station	meter	10
1746	Width Work Area Workmen Center-Lines	meter	2.5
1747	Width Working Area	meter	1
1748	Width Working Area Employee Axles	meter	Parent~'Width Work Area Workmen Center-Lines'
1749	Width Working Area Employee Doors	meter	{'Width Working Area Employee Doors Line 1', 'Width Working Area Employee Doors Line 2'}
1750	Width Working Area Employee Doors Line 1	meter	3
1751	Width Working Area Employee Doors Line 2	meter	2.5
1752	Width_Station Service Area	meter	1
1753	With of Pit Finish Line	meter	4.2
1754	Work Stations in Main Assembly Line	stations	Main Assembly Line'.'KPI_53_D Work Stations in the Main Assembly Line Simple'
1755	Work Stations Installations Fully-Automated	stations	2
1756	Workdays per Week Doors	days/week	{'Workdays per Week Doors Line 1', 'Workdays per Week Doors Line 2'}
1757	Workdays per Week Doors Line 1	days/week	5
1758	Workdays per Week Doors Line 2	days/week	4
1759	Worker Costs per Day	worker*EUR	'Net Operating Hours per Day - Main Assembly Line'*'Worker Costs per Hour'
1760	Worker Costs per Hour	worker*EUR/hours	'Costs per Employee'*'Total Number of Workers'
1761	Worker Density	worker	Required WT per Station'/'Cycle Time'*1<<Worker*Unit>>

# Name of Element (KPI)	Unit	Definition
1762 Workers Array	worker	{'Workers Finish', 'Workers Requirement Testing Line', 'Workers Finish', 'Workers Requirement F2-Lines', 'Required Workers Rectification', 'Workers Paintwork Rectification'} *'Bin Total'
1763 Workers Assembly Tasks	worker	1 <<worker>>
1764 Workers Complete Line	worker	{12,18} <<worker>>
1765 Workers Density F2-Line	worker/stations	1 <<worker/stations>>
1766 Workers Density Finish Line	worker/stations	{0.8,0.8} <<worker/stations>>
1767 Workers Efficiency	unit/worker	Agreed Daily Output'/'Workers Total'
1768 Workers Employed	worker	Total Number of Employees In Shift'*(1+'Supplement Additional Times')*(1+'Supplement Absence')
1769 Workers Employed	worker	('Performance-Related Wage Earners Present')*(1+'Supplement Absence')
1770 Workers Finish	worker	CEIL('Total Working Stations Finish Area'*'Workers Density Finish Line')
1771 Workers Necessary Filling	worker	('KPI_53_D Work Stations Filling'*'KPI_74_G Employee Density Filling')+ ('KPI_54_D Testing and Quality Stations in the Main Assembly Line Filling'*'Employee Density PQ-Cycles')
1772 Workers Necessary Main Assembly Line	worker	FLOOR(ARRSUM('Workers Necessary Main Assembly Line Allover'))
1773 Workers Necessary Main Assembly Line Allover	worker	IF('Selection of Model Main Assembly Line'=FALSE, 'Employees Main Assembly Line Overall Simple Model', 'Total Number of Employees Main Line Complex Model')
1774 Workers Necessary Testing and Quality Stations Body Assembly	worker	('KPI_54_D Testing and Quality Stations in the Main Assembly Line Body Assembly 1'+'KPI_54_D Testing and Quality Stations In the Main Assembly Line Body Assembly 2') *'KPI_74_G Employee Density Testing and Quality Stations Body Assembly'
1775 Workers Necessary Tilt Assembly	worker	SUM('KPI_53_D Work Stations Tilt Assembly', 'KPI_54_D Testing and Quality Stations In the Main Assembly Line Tilt Assembly')* 'KPI_74_G Employee Density Tilt Assembly'
1776 Workers Paintwork Rectification	worker	IF('Vehicles Paintwork Rectification'=0 <<unit>>, 0 <<worker>>, 'Additional Manpower Requirement'+'Workers Requirement Spotrepair'+'Workers Requirement Complete Line')
1777 Workers Payed per Shift	worker	K73_G Performance-Related Wage Earners per Shift Synchronised in the Main Assembly Line Simple Model'*(1+'Supplement Non-Synchronised Employees Main Assembly Line')
1778 Workers Permanent	worker	{1,0,0,0,0,0}<<worker>>
1779 Workers Rectification Paintwork Rectification	worker	ARRSUM('Workers Array'[Rectification..'Paintwork Rectification'])*'Supplement Absence'
1780 Workers Required F1 to F2	worker	F1_F2-Area'.'Total Number of Workers'
1781 Workers Required Main Assembly Line	worker	Main Assembly Line'.'Workers Necessary Main Assembly Line'
1782 Workers Required Pre-Assemblies	worker	ARRSUM ('Pre-Assemblies'.'Employees Requirement Pre-Assembly Areas Readout')
1783 Workers Requirement Complete Line	worker	ARRSUM('Number of Complete Lines'*'Workers Complete Line')
1784 Workers Requirement F2-line Transpack	worker	IF('Ratio Transpack'>0%, ('Workers Requirements Working Stations'+'Workers RequirementsTranspack')*'Number of Lines F2 Transpack', 0<<worker>>)
1785 Workers Requirement F2-Line Wax	worker	IF('Ratio Wax'>0%, CEIL('Daily Unit Output Wax'*'Planned Time Finish Line Wax'/'Assembly Planned Operating Time_t - Gross Line Operating Time' * 1<<worker>>) +'Manpower Requirements Wax Station', 0<<worker>>)
1786 Workers Requirement F2-Lines	worker	F2 Line Driver'+ //IF('Selection Wax_Transpack'=TRUE; 'Workers Requirement F2-Line Wax'+ 'Workers Requirement F2-Line Transpack'
1787 Workers Requirement Spotrepair	worker	Number of Spotrepair Lines'*('Workers Spotrepair'+'Workers Assembly Tasks')
1788 Workers Requirement Testing Line	worker	CEIL('Time Requirement Test Rigs'/'Assembly Planned Operating Time_t - Gross Line Operating Time'* 1 <<worker>>)
1789 Workers Requirement Total	worker	CEIL('Time Requirement Test Rigs'/'Assembly Planned Operating Time_t - Gross Line Operating Time') * 1 <<worker>>
1790 Workers Requirements Working Stations	worker	4 <<worker>>
1791 Workers RequirementsTranspack	worker	9 <<worker>>
1792 Workers Spotrepair	worker	1 <<worker>>
1793 Workers Total	worker	Workers Employed'+'Workers Rectification Paintwork Rectification'
1794 Working Area B	meter²	Number of Stations Station Service Areas Filling'*'Belt Width Conveyor Systems Filling'*'Length of Station Filling'

# Name of Element (KPI)	Unit	Definition
1795 Working Area Body Assembly	meter²	(('Belt Width Conveyor Systems Body Assembly 1'*'Length of Station Body Assembly 1')*'Number of Stations Body Assembly1')+ (('Belt Width Conveyor Systems Body Assembly 2'*'Length of Station Body Assembly 2')* 'Number of Stations Body Assembly2')
1796 Working Area Doors	meter²	PRODUCT ('Width Working Area Employee Doors', 'Lenght of Station Doors', SUM (PRODUCT ('KPI_51_D Stations Doors per Side', 'Selection Doors Lines'), 'KPI_51_D Total Stations Doors')) / 1 <<stations>>
1797 Working Area Final Assembly	meter²	Number of Stations Service Area Final Assembly'*'Belt Width Conveyor System Final Assembly'*'Length of Station Final Assembly'
1798 Working Area Front Axle	meter²	PRODUCT ('KPI_51_D Total Stations Axle Pre-Assembly['Front Axle'], 'Width Working Area Employee Axles', 'Length of Station Front Axle', 'Type of Line-Side Presentation Front Axle') / 1 <<stations>>
1799 Working Area per Manual Workstation Sub-Engine-Lines	meter²	5
1800 Working Area Rear Axle	meter²	PRODUCT ('KPI_51_D Total Stations Axle Pre-Assembly['Rear Axle'], 'Width Working Area Employee Axles', 'Length of Station Rear Axle', 'Type of Line-Side Presentation Rear Axle') / 1 <<stations>>
1801 Working Area Strut	meter²	PRODUCT ('KPI_51_D Total Stations Axle Pre-Assembly['Strut], 'Width Working Area Employee Axles', 'Length of Station Strut') / 1 <<stations>>
1802 Working Area Wheel Hub	meter²	PRODUCT ('KPI_51_D Total Stations Axle Pre-Assembly['Wheel Hub'], 'Width Working Area Employee Axles', 'Length of Station Wheel Hub', 'Type of Line-Side Presentation Wheel Hub') / 1 <<stations>>
1803 Working Hours Volume Workers per Day	hours	'Workers Employed'*'KPI_44_C Operating Time'/1<<worker>>
1804 Working Stations F2-line	Stations	4 <<stations>>
1805 Working Stations Finish-Line	Stations	Number of Stations Finish Line'-'Technical Stations per Finish Line'
1806 Working Stations per Year	da	250 <<da>>
1807 Working Time per Station	seconds/stations	KPI_49_D Cycle Time'*'KPI_74_G Average Employee Density Simple Model'*1<<unit/worker>>
1808 Working Time per Station Body Assembly	seconds/stations	KPI_49_D Cycle Time'*'KPI_74_G Employee Density Body Assembly'*1<<unit/worker>>
1809 Working Time per Station Filling	seconds/stations	'KPI_49_D Cycle Time'*'KPI_74_G Employee Density Filling'*1<<unit/worker>>
1810 Working Time per Station_Pre-Assembly	seconds/stations	IF('Choice_Carrier Technology'=1, ('KPI_49_D Cycle Time'*'Employee Density'*1<<unit/worker>>)-'Time for Station Change_BTS', ('KPI_49_D Cycle Time'*'Employee Density'*1<<unit/worker>>)-'Time for Station Change_Roll Conveyor')
1811 Working Time Worker	min/worker	Assembly Planned Operating Time_t - Gross Line Operating Time' * 1 <<1/worker>>
1812 Working Weeks per Year	week	49
1813 Workpiece Carrier in Circulation Engine-Gearbox-Line	%	50
1814 Workpiece Carrier in Circulation Front Axle	%	100
1815 Workpiece Carrier in Circulation Rear Axle	%	50
1816 Workpiece Carrier in Circulation Strut	%	50
1817 Workpiece Carrier in Circulation Wheel Hub	%	50

Appendix D – Certificate of Invention

BMW Group

Markus Grueneisl
TI-400

PERSÖNLICH

Kopie dieses Schreibens bitte unterschrieben zurück an

03.02.2005
Ihre Erfindungsmeldung 16114
Modellgestützte Planung von Montagestrukturen bei einem Auto mobilproduzenten: Entwicklung eines Powersimmodells...

Sehr geehrter Herr Grueneisl,

Ihre vollständige Erfindungsmeldung ist am **21.01.2005** bei uns eingegangen und wird unter der Nr. **16114** geführt.

Für Ihre Mitarbeit danken wir Ihnen und bitten Sie, uns den Empfang dieses Schreibens bis spätestens **24.02.2005** schriftlich zu bestätigen. Bitte verwenden Sie hierfür die beigefügte Kopie.

Mit freundlichen Grüßen
Bayerische Motoren Werke Aktiengesellschaft

ppa. i.V.

Anlage