



MICHELE ANGELO CECCHI

PROJECT-TO-PROJECT LEARNING IN GLOBAL NEW PRODUCT
DEVELOPMENT

SCHOOL OF MANAGEMENT
Leadership and Management

PhD
Academic Year: 2016 - 2017

Supervisors: Prof. Keith Goffin and Prof. Neil Turner
June 2023



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degree of PhD

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“Lessons learned database? Yeah, I’ve heard there are some.”

Interviewee 10, Project 1

ABSTRACT

This thesis deals with project-to-project learning in global new product development (NPD). Based on a Systematic Literature Review on knowledge management and NPD management, it shows that limited empirical research exists to explain the factors that influence project-to-project learning and that limited guidance is provided to NPD practitioners wanting to implement knowledge management initiatives in global NPD.

An in-depth case study is presented of three global NPD project teams in a large multinational organization active in the design and manufacture of complex systems for the automotive sector. Three research questions and five research propositions are built to guide empirical research on project-to-project learning. Case study methodology using data from observations, surveys, interviews and reviews of documents are used to uncover the project-to-project learning behaviour of global NDP teams. A three-step approach to data analysis is used to review the case study with the help of knowledge flow mapping, thematic coding and survey data analysis.

The research shows that radical, global NPD project teams need high volumes of both internal and external knowledge to be successful and that an intrinsic bias exists at different seniority levels, impacting on knowledge management. The research also shows that both social and structured knowledge management initiatives are effective and are used for project-to-project learning in global NPD. Finally, the implications of research findings for NPD practitioners and researchers are discussed.

Keywords: Radical innovation, dispersed teams, knowledge sharing, tacit knowledge

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LIST OF ABBREVIATIONS

APAC	Asia Pacific region
BU	Business unit
DUB	Business unit director
CoP	Communities of practice
CEO	Chief executive officer
CMO	Context, mechanisms, outcomes
COO	Chief operating officer
EMEA	Europe Middle East and Africa region
FRACAS	Failure reporting, analysis and corrective action system
GPL	Global product lines
GM	General manager
GMP	Global mentoring program
IT	Information technologies
ICT	Information and communications technologies
KMI	Knowledge management initiatives
KSI	Key strategy initiative
KSU	Knowledge sharing and use
LATAM	Latin America region
LRQ	Literature review question
MoM	Minutes of meeting
NA	North America region
NPD	New product development
NPI	New product introduction
NUDD	New, unique, different and difficult
OP	Oil pump
OTD	On time delivery
PBO	Project-based organizations
P&L	Profit and loss
PLD	Product line director
PMO	Project management office
PoC	Proof-of-concept
PPR	Post project reviews
RQ	Research question
QFD	Quality function deployment
R&D	Research and development
SRQ	Sub research question
SLR	Systematic literature review
VP/GM	Vice-president and general manager
WP	Water pump

CHAPTER 1 – INTRODUCTION

1.0 Background to the research

The aim of the Thesis is to investigate the dynamics of knowledge *sharing* and *use* (KSU) between global new product development (NPD) projects i.e., project-to-project learning in global NPD. The two constructs of KSU and global NPD are the foundation on which the research is built, therefore it is important to provide an initial definition for both.

As far as product launch and innovation are concerned, NPD projects play an important role in organizations. More and more organizations are relying on global NPD to achieve product innovation and NPD success (de Brentani and Kleinschmidt, 2015; Gemünden, 2015; Sivakumar and Roy, 2021; le Duc and Gammeltoft, 2023). In de Brentani and Kleinschmidt's (2015) global NPD model, two main characteristics define global NPD projects: (1) global NPD resources (i.e., innovation culture, resource commitment and senior management involvement) and (2) global NPD capabilities (global NPD strategy, process, team and communications). Based on the latter NPD model, in this Thesis, global NPD projects are defined as projects that leverage global capabilities and teams to develop new products or services for one or more regional markets. In practical terms, global NPD projects are defined as projects that resort to NPD teams in two or more geographical regions to leverage diversified local knowledge and capabilities, that do not

co-exist in a single geographical region¹ (e.g., customers, markets, suppliers, manufacturing operations or technical knowledge – McDonough *et al.*, 2001).

NPD is a knowledge-intense activity while diversified knowledge is a key to NPD success (Baxter *et al.*, 2010; Haug, 2022; Papa *et al.*, 2022): NPD projects use existing knowledge and create new knowledge. Organizations must identify ways for NPD projects to access existing knowledge, record newly created knowledge and make it available for future use: NPD teams that struggle to access existing knowledge can expect longer development cycles and repeat the same mistakes previous projects made. Different definitions and terminology are used in the knowledge management body of literature to describe how knowledge is managed in NPD projects and are discussed in Chapter 2 (e.g., knowledge transfer, knowledge sharing, knowledge integration, etc.). In this Thesis, the definition of knowledge sharing and use (KSU) by Holste and Fields' (2009) is preferred to knowledge transfer (commonly used as synonym of KSU), to emphasize the importance of both steps of knowledge sharing and knowledge using for an effective knowledge transfer to occur. In the context of project-to-project learning, KSU occurs only when (1) existing knowledge in a project is discovered and made available to other projects teams (i.e., sharing) and (2) the shared knowledge is acknowledged and considered by other project teams (i.e., use).

Knowledge management initiatives (KMI) exist to facilitate KSU. Yet, very limited guidance on which tools are best for KSU in global NPD is provided to global NPD teams. From an academic point of view, while literature acknowledges that KMI must be tailored to the context (Newell, 2005), little is known on which KMI work in global NPD project-

¹ In the context of this research four geographical regions are considered: Asia Pacific (APAC), Europe Middle East and Africa (EMEA), Latin America (LATAM) and North America (NA).

to-project learning and why. By contrast, understanding why some KMI are more effective than others in global NPD might provide guidance to practitioners implementing KMI for global NPD, fostering new knowledge management initiatives. Recent research confirms that open questions still exist and that investigation on knowledge management in NPD and global NPD is ongoing (Mathrani and Edwards, 2020; Gomo, Steyn and van Waveren, 2021; Teoh, Ling and Ibrahim, 2021; Cecchi *et al.*, 2022; Iftikhar and Ahola, 2022). The aim of this Thesis is to deal with these issues.

This Chapter introduces the research problem under investigation, the methodology used for the research, and the expected outcomes. Moreover, it presents the outline of the Thesis.

1.1 Gaps in literature on knowledge management in NPD

The research and development (R&D) function plays an important role in securing the competitive advantage of organizations (Richtnér *et al.*, 2013). *Product and process innovation* are usually obtained through NPD, with the work of R&D as well as other cross-functions (Baxter *et al.*, 2010). Bonanno and Haworth (1998) differentiated between product and process innovation, defining product innovation as “the creation of new goods and services” and process innovation as the development that “leads to a reduction in the cost of producing existing products” (p. 496): the main focus of the research is to investigate the learning dynamics in product innovation projects (i.e., NPD). The scope of the research is the analysis of the mechanisms that enhance KSU across NPD projects, with the whole focus on globally distributed innovation projects. NPD project teams must use and expand existing knowledge (e.g., product, process, customer, suppliers, organizational knowledge) to be successful and to generate product or process innovation. The ability of organizations to capture the knowledge created by project teams and to share it with other projects is critical to the success of new projects and to the growth of organizations (Ayas, 1998; Antoni and Sense, 2001). Williams (2008) observed that, to be successful, organizations must be able to capture the learning of their projects.

Boer *et al.* (2001) highlighted how a competitive environment drives shorter development intervals and mandate faster new product introductions (NPI). To achieve faster introductions, organizations must capture the knowledge created and present in NPD teams in order to avoid other NPD teams having to rediscover or recreate the same knowledge: knowledge created within NPD projects has relevance to other projects – i.e., component or technology re-use (Nonaka and Cusumano, 1997). Therefore, understanding how to enhance KSU across project teams is of paramount importance for managers and organizations (Goffin and Koners, 2011; Baxter *et al.*, 2013; Richtnér *et al.*, 2013).

While extensive research exists on understanding how knowledge develops in NPD projects, limited research was carried out on how knowledge is shared from project-to-project, especially in the case of global NPD projects (Baxter *et al.*, 2013). A recent literature review paper from Idrees *et al.* (2023) confirmed the highlighted gaps and recommends further research to be conducted on “knowledge-sharing practices”, “types of tools and sharing mechanisms” and “type and complexity of knowledge”. Global teams face further challenges as far as project-to-project learning is concerned. Pavanelli Stefanovitz and Jabbour (2022) indicated global NDP team dispersion as one of three key factors currently increasing NPD complexity. While NPD teams’ diversity and their access to local culture and practices are an advantage compared to local NPD, physical distance is a limitation to knowledge sharing.

In order to produce innovative products, access to knowledge is required – e.g., on customer needs and on technical knowledge (Grant, 1996; Nonaka and von Krogh, 2009). Two different sides of knowledge are often identified in literature: *explicit knowledge* and *tacit knowledge*. Explicit knowledge can be easily expressed in words and numbers and is easily communicated and shared. Tacit knowledge is difficult to reduce to writing and to share formally (Takeuchi, 2006; Holste and Fields, 2009; Baxter *et al.*, 2013). Tacit knowledge and the ability of organizations to capture and to share tacit knowledge between project team members are critical to the success of new projects and to the growth of firms and organizations (Grant, 1996; Baxter *et al.*, 2013). Many scholars observed that tacit knowledge sharing usually occurs in social contexts (Nonaka and von Krogh, 2009; Holste

and Fields, 2009; Baxter *et al.*, 2013). Trust is a key element for both tacit and explicit KSU (McAllister, 1995; Williams, 2008). If trust has not already been created between partners, forcing social dynamics may not help tacit knowledge transmission. While the literature shows that global projects do not necessarily perform worse than local projects, the limits for tacit knowledge sharing in the former are higher than in projects with co-located team members (Salomo *et al.*, 2010). If organizations fail to provide the right environment for tacit knowledge sharing, NPD teams will need to re-discover knowledge causing longer development cycles and potentially impacting on the success of NPD projects (e.g., on time delivery – OTD). Extensive research (Newell *et al.*, 2006; Oshri *et al.* 2006) covered the re-use of concepts, designs and technical knowledge. Limited research investigated the sharing and use of non-technical and tacit knowledge, especially in the case of global NPD.

Lessons learned databases and post-project reviews (PPRs) were investigated as a tool for capturing and transmitting tacit knowledge. PPRs are a commonly used KMI that rely on NPD teams to meet just before or after a project is closed to review and capture the knowledge the project teams learned. Extensive research exists on PPRs showing that, due to the limited time teams have between projects, PPRs can be either entirely missed or not completed with enough care to effectively capture project teams' knowledge (Kotnour, 1999; Williams, 2007; Goffin and Koners, 2011). Due to the importance that trust has in sharing tacit knowledge, lessons learnt may not be an ideal tool to capture it: lessons learnt can be identified as forced social interactions and are sometimes based on the assumption that mistakes were made and that the team has learnt from those mistakes. Lessons learnt might therefore not ensure capturing teams' knowledge and most importantly tacit knowledge. The aim of lessons learned can be intended for capturing mistakes, more than for increasing knowledge. The overall feeling of "looking for blame" is acting against the creation of trust and, therefore, other social interactions might be more suited to allow tacit knowledge sharing. Trust plays an important role in the willingness of NPD teams to re-use knowledge captured by other NPD teams (Holste and Fields, 2009): if NPD teams do not know and trust the technical competency of the teams that have captured the lessons

learned, they will hardly be willing to re-use it. The necessity for a better understanding of local customer needs together with the access to a global supply-base drive organizations to run NPD projects via global teams (Boer *et al.*, 2001; Salomo *et al.*, 2010) amplifying the issues of project-to-project KSU. Global teams lack the propinquity and offer fewer opportunities for social interactions, compared to local NPD projects. The competition between different sites also plays an important role in limiting the trust and the willingness to share between teams. Very limited research exists on which KMI are most effective in the case on global NPD and no recommendation is offered to practitioners and NPD managers on how to enhance KSU in global NPD.

1.2 The selected methodology

Following the systematic review of the literature presented in Chapter 2, five research propositions on the effectiveness of KMI in global NPD are developed to guide empirical research. Case study research is used to answer the research question that drives the investigation on project-to-project learning in global NPD. The systematic review of the literature shows that very limited studies exist that explore KMI in global NPD and that the few that do exist only cover specific types of knowledge (e.g., technical knowledge) or specific types of KMI (e.g., lessons learned databases).

Empirical research is needed in order to understand which KMI initiatives are effective and are considered most effective by NPD managers and practitioners. In particular, in-depth research is needed to understand KMI effectiveness in NPD as a function of (1) geographical distribution of the NPD resources (regional or global), (2) the degree of innovation of the NPD (incremental or radical) and (3) the type of knowledge that needs to be shared (explicit or tacit). Case study research is selected as the most appropriate research methodology to conduct investigation on project-to-project learning in global NPD. Case study research on three NPD projects at different stages of the development cycle and different degrees of innovations allows to explore the effectiveness of multiple KMI in the case of global NPD projects. In order to investigate multiple KMI at different

stages of three NPD projects, extensive access to the case organization's resources is needed. Three projects from a single company were selected to secure the needed access to company resources and teams. Multiple data sources were used in the case study as documents review, observations, surveys and interviews. Chapter 3 includes details on the selection of research methodology.

1.3 The Company to be studied

The host organization, *VehicleSystemsCo* is a large multinational organization operating in the development and manufacturing of complex systems and components for the automotive industry. Three global NPD projects from two business units were selected as project cases. The three global NPD projects are active across three regions (APAC, EMEA and NA), two projects are radical NPD projects while the third one is an incremental NPD project. Details on business and structure of the host organization are provided in Chapters 4 and 6.

Pre-existing ties with *VehicleSystemsCo* allowed extensive access to company procedures, interviews with project teams and observation of the three projects. While extensive access to the organization is a precondition for the selection of the company for the case study, *VehicleSystemsCo* was selected as they are very active in knowledge management – Chapter 5 includes details on the knowledge management process in *VehicleSystemsCo*.

While *VehicleSystemsCo* agreed to participate in the research and approved all the requests for access to personnel and data, the company is very concerned with protecting its intellectual property. *VehicleSystemsCo* intellectual property includes information about both their products and their processes. To guarantee anonymity and protect the confidentiality of *VehicleSystemsCo*, information and data through the thesis are disguised, when possible, or redacted (blacked out).

1.4 Contribution of the research

The research has implications for both knowledge management scholars and NPD practitioners. The research is contributing to the knowledge management field by investigating the effectiveness of KMI for global NPD. Social and informal KMI are expected to have limited effectiveness in the case of global NPD due to the limited face-to-face time between NPD practitioners and this is expected to impact on the creation of interpersonal trust between team members. The limited effectiveness of informal and social KMI is expected to have consequences on the ability to share tacit knowledge from project-to-project in global NPD. The research shows that social and informal KMI are effective and are used also in the case of global NPD. The research also highlights how the different knowledge needs of radical and incremental NPD project impact on the effectiveness of KMI initiatives in global NPD.

The contribution of the research to the knowledge management and to the body of literature on global NPD has implications for NPD practitioners and managers. One of the outcomes of the research is a framework for the application of KMI in global NPD. The framework is intended to provide guidance to NPD managers and practitioners wanting to implement KMI to facilitate knowledge sharing and use in global NPD projects. Finally, the research shows that misalignment exists between the expectations of NPD managers and the real-world application of KMI in global NPD projects, highlighting that bias exist at different seniority levels in global NPD organizations.

1.5 Summary and outline

This Thesis investigates project-to-project learning in global NPD and explores the behaviour of managers and practitioners in knowledge management. The aim is twofold: (1) to show that project-to-project learning happens also in the case of global NPD and (2) to understand the key factors that influence the process. To this aim, the Thesis is organized as follows.

Chapter 2 presents the outcome of a Systematic Literature Review on the empirical and theoretical research regarding KSU in global NPD. Then, based on this literature review, it introduces the research questions and defines five research propositions designed to guide the empirical research. Finally, it presents a preliminary framework for project-to-project learning in global NPD. Chapter 3 discusses the design of research. It starts with the philosophy that underlines the research to show, then, how research philosophy influences research strategy and case design. Chapter 4 focuses on the methodology employed to answer research questions. It also introduces *VehicleSystemsCo* providing details on the selected three cases. The Chapter also describes the selection criteria for the three projects. Chapter 5 introduces the context of the research and the key knowledge management process in *VehicleSystemsCo*. To this aim, it relies on company documentation. Chapter 6 proceeds with the observation of the three cases, providing a narrative of the projects and of the knowledge events occurred during the 12 months of the study cases. Chapter 7 reviews the survey and interview data by means of a three-steps approach: the knowledge flows between projects is analysed (Step 1); survey data is reviewed to assess the KMI on the basis of their effectiveness according to NPD managers and practitioners (Step 2); interview data is coded to understand the mechanisms underlying the perceived effectiveness of KMI (Step 3). Chapter 8 discusses the findings of the case study analysis and their implications for the research question. Chapter 9 concludes the Thesis, summarising the main results of the analysis, pointing out the main conclusions and discussing the implications for NPD practitioners and researchers. This Chapter also highlights the potential limitations of the research and the areas where further investigation is recommended.

CHAPTER 2 – LITERATURE REVIEW

2.0 Introduction

Chapter 1 introduced the research problem under investigation: knowledge sharing and use (KSU) in global new product development (NPD) in order to assess which knowledge management initiatives (KMI) are best suited for facilitating KSU in global NPD. This Chapter focuses on the thematic areas and theories that are relevant to address KSU in NPD. To this aim, it systematically explores the literature on the issue in the context of global teams. The final objective of this review is to summarise the available knowledge regarding project-to-project learning in global NPD and to examine the gaps between theory and empirical work. An initial map of the key areas is presented in Figure 2.1 by means of a Venn diagram.

Figure 2.1 highlights the three key areas of interest that were investigated in the literature review:

1. The available information about the NPD projects that are used by firm and organizations for R&D and about the knowledge needs of NPD projects (yellow bubble);
2. The available literature on knowledge in NPD, its components and knowledge sharing in organizations to point out the knowledge components that might be relevant to NPD (blue bubble);
3. The existing studies on how project learning works in the case of global NPD providing a key to identify the additional research that might be required to better understand project-to-project learning in global NPD (green bubble).

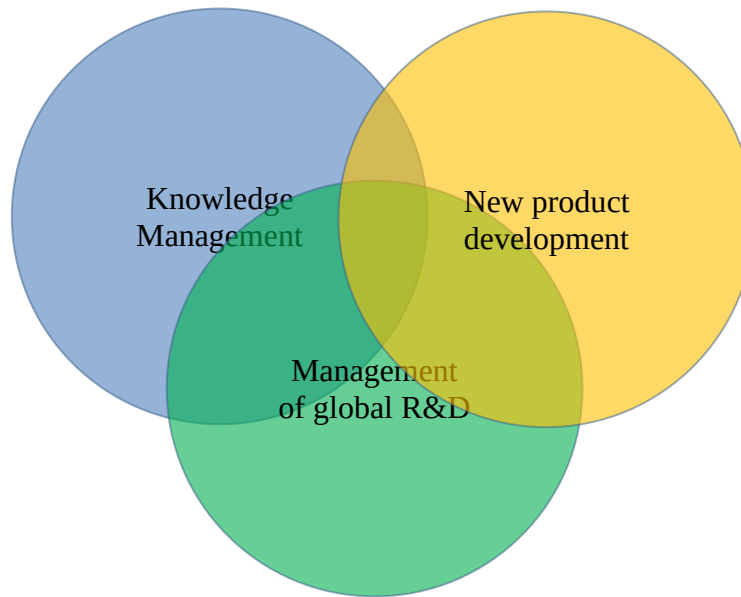


Figure 2.1 – Thematic areas of interest to the research

The following sections review the selected literature on these macro areas: Section 2.1 discusses the importance of NPD projects and reviews the categorizations of organizational knowledge useful for firms and organizations; Section 2.2 reviews the literature on the impact of organizational culture and geographical distribution of project teams on KSU in NPD; Section 2.3 reviews the selected literature on KMI used in NPD. Finally, Section 2.4 summarises the outcome of the Systematic Literature Review and highlights the main knowledges gaps.

2.0.1 Systematic Literature Review methodology

Based on the problem definition in Chapter 1 and the three thematic areas in Figure 2.1, two questions were selected to lead the Systematic Literature Review (SLR):

LRQ1: Which theories and which empirical research identify and explain the factors that represent roadblocks or incentives to knowledge sharing and use in global NPD?

LRQ2: What is known about which knowledge is shared and used in global NPD and which knowledge management initiatives are used for project-to-project learning in global NPD and why?

For the SLR, the ABI / ProQuest databases were searched using keywords derived from an initial review of literature which was necessary to define the problem and the search strings. The keywords for the search were the following: new product development, project learning, global teams. Alternative nomenclature and synonyms were also considered and tested (examples are reported below). Several trials led to the definition of the following search string which was used for the systematic literature review:

“new product development” AND (“project learning” OR “project knowledge”) AND (“international” OR “global” OR “distributed” OR “dispersed” OR “virtual”)

The use of the search string gave a total of 365 results by searching the “full text” of the papers. Figure 2.2 shows the three steps used to select the articles included in the literature review based on the review of the titles and abstracts. Appendix A includes the full list of the titles for the 365 papers identified by means of the search strings, together with their year of publication and their authors. Appendix A also includes details about whether the papers were included in the literature review or excluded on the basis of their title or abstract.

A review of the titles of the 365 articles led to the exclusion of 175 articles which were discarded being clearly related to a different body of knowledge. Examples of articles excluded by title are: “Diagnostic framework and health check tool for engineering and technology projects” or “Enhancing graduate employability through work-based learning in social entrepreneurship”. Works focused on construction projects or assessing project performance were also excluded: i.e., “The role of project management offices (PMOs) in IS project success and management satisfaction”.

After the exclusion of 175 articles on the basis of the title, the remaining 190 articles were reviewed on the basis of their abstract, resulting in the further exclusion of 103 articles. Finally, the articles on construction projects and the ones assessing project performance were excluded together with papers not written in English language.

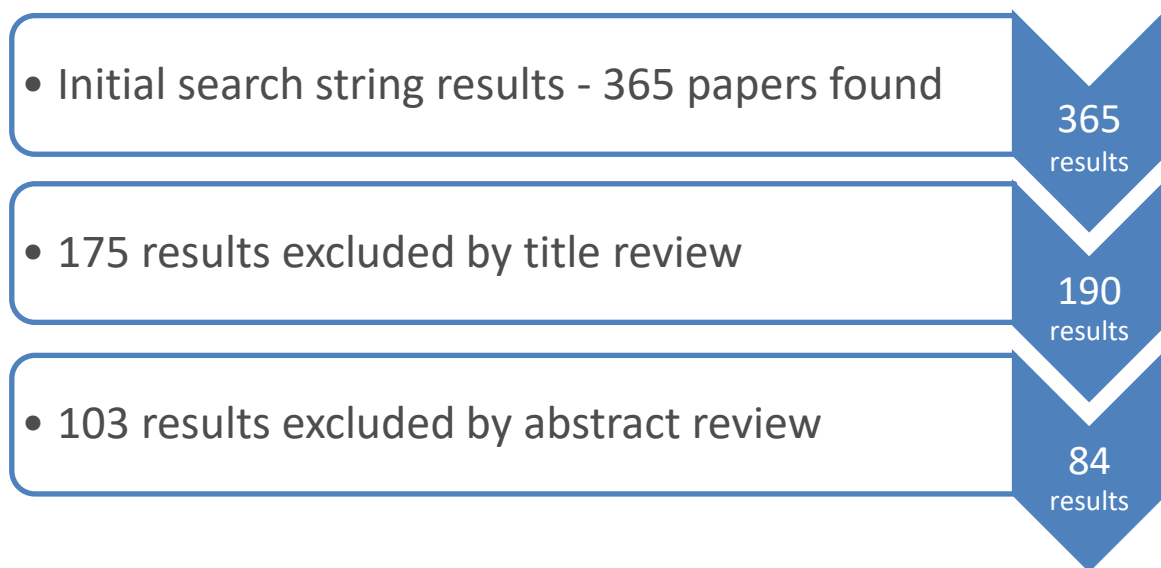


Figure 2.2 – Literature review paper selection steps

Here are some examples of the articles excluded by their abstract: “Lean leadership in major projects: from predict and provide to predict and prevent” or “Exploring Knowledge Management Models on Information Technology (IT) Projects”. The detailed

systematic literature extraction protocol is included in Appendix B which also accounts for the selection criteria used for both titles and abstracts.

The remaining 84 manuscripts were included in the SLR. 52 additional works, not discovered by the search string, were derived both from the citations of the 84 papers reviewed (i.e., snowballing) and following recommendations from the PhD review panel. Overall, 52 additional papers were included. A review of the search results obtained by replacing the key words “new product development” with “new product introduction”, or “project” with “program” did not provide additional relevant results.

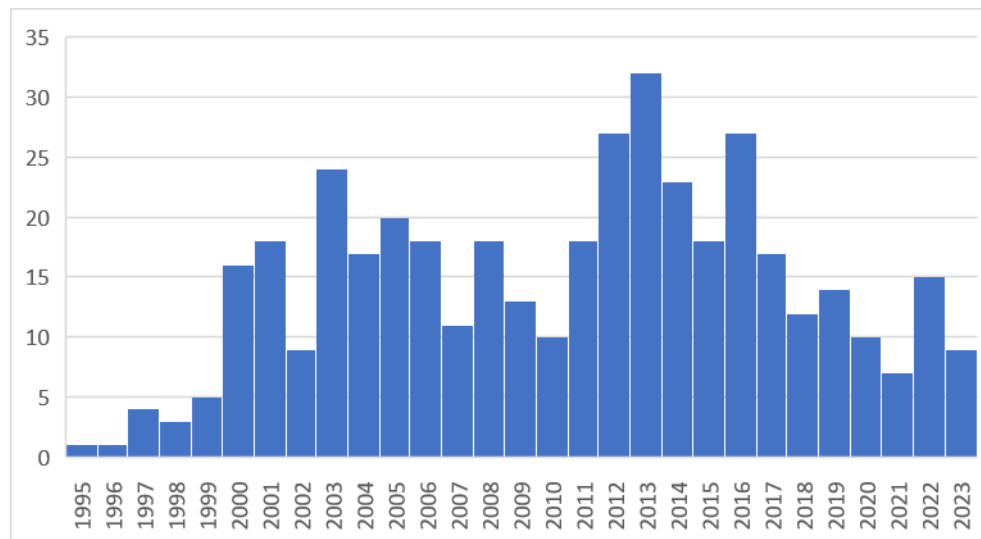


Figure 2.3 – SLR papers yearly distribution – total papers

The initial search (Figure 2.2) was completed between November 2018 and June 2019. The search was repeated in May 2023, using the same methodology as the one used in 2018 and 2019: 53 additional results were found and were reviewed following the same title and abstract review used for the 2018/2019 study. Repeating the search in 2023 showed that interest across academia and the industry on knowledge sharing within and across projects was still high. Figure 2.3 shows a histogram of total number of papers identified, plotted by the yearly number of papers published from 1995 to 2023. It also

shows that, while the number of yearly published papers peaked in the 2012-2016 period and showed a lower peak in the 2003-2006 period, interest was still high, with 15 papers published in 2022 and 9 papers published in the first months of 2023.

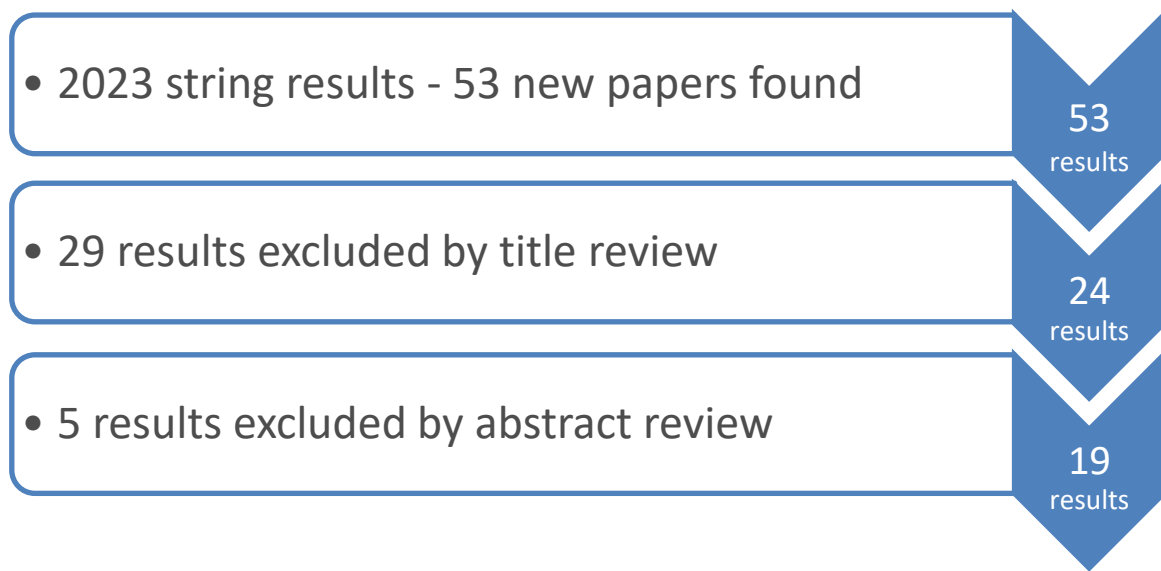


Figure 2.4 – Literature review paper selection steps – 2023 SLR additions

Re-running the literature review in 2023 showed that open questions remain to date on the mechanisms to share knowledge between projects while limited empirical evidence was available, as showed by Correa, Silva and Scafuto (2023). Out of the 53 new papers found by the 2023 re-run survey, 34 were excluded by title and abstract review – Figure 2.4. Appendix C includes the full list of the additional papers identified by the 2023 re-run survey, indicating which ones were excluded based on title or abstract review. Recently published papers, such as “Knowledge-sharing strategies in distributed collaborative product development” (Mathrani and Edwards, 2020), “The role of the project management office in knowledge transfer in a matrix structured organisation: a case study” (Gomo, Steyn and van Waveren, 2021) or “Globalized adoption of knowledge management in new product development: a conceptual framework”, were included in the review. Figure 2.5

shows a histogram of papers selected by title and abstract review for inclusion in the literature review, plotted by the yearly number of papers published from 1998 to 2023.

While recent papers exist that discuss knowledge management in new product development and were reviewed in the literature review, the major theories and research on the topic dated back to the early 2000s. The following sections focus on this early work and theories, as well as on more recent publications.

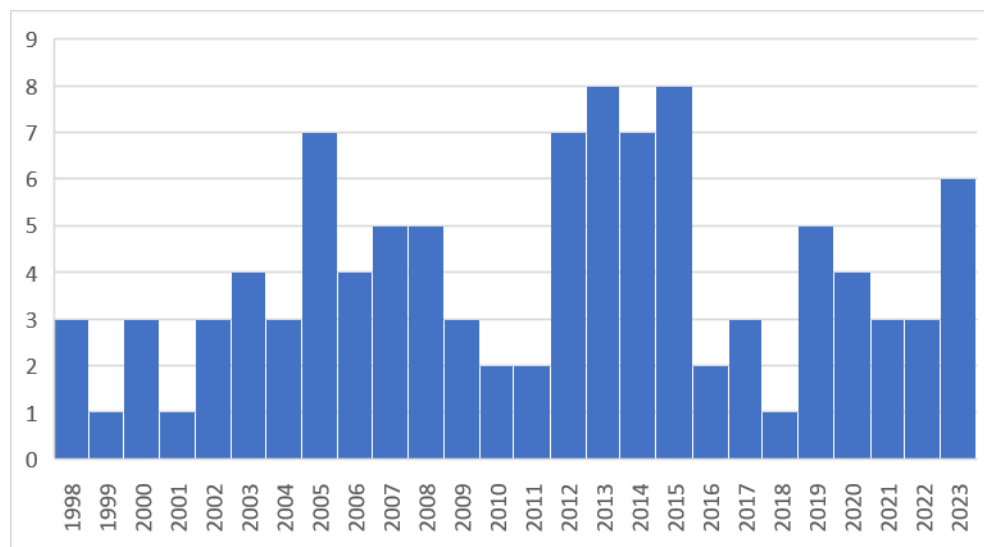


Figure 2.5 – SLR papers yearly distribution – filtered papers

2.0.2 Literature review assurance

The use of the SLR methodology is currently considered the golden standard as far as business and management research are concerned (Fish and Block, 2018; Mallett *et al.* 2012; Petticrew and Roberts, 2008). Fish and Block (2018) observe that while completing a literature review is an essential part of any research, still significant differences exist in the understanding of what a literature review should entail and how it should be conducted.

The use of the SLR was originally applied in the medical sciences in the 1970s and its use expanded to the social sciences (Mallett *et al.*, 2012). The main advantage of using a

systematic literature is that readers of the research are able to replicate the literature review, following the steps specified and (if the steps are followed correctly) they are able to replicate the results of the literature review. Mallett et al. (2012) summarize well the concept by saying that SLR are a rigorous and transparent form of literature review.

Fish and Block (2018) provide six practical recommendations for business and management researchers embarking on a literature review process and highlight how the use of the SLR can help with both focusing on the key concepts in literature and deriving meaningful conclusions. More importantly, the Authors highlight how using the SLR can help finding the right balance between “breadth and depth” of the literature review. This is particularly relevant in the context of the SLR presented in this Thesis. As the previous section showed, the topic of project-to-project learning in global NPD is at the centre of many different domains. The main goal of the literature review was, firstly, to identify the main theories developed in the field and relevant to the research and, secondly, to highlight the previous empirical research on the topic, to ensure the originality of the work completed. The use on the SLR is particularly suited for the latter – i.e. “depth”. Snowballing and frequent reviews with the PhD review panel were used to ensure sufficient “breadth” to the literature review.

2.1 NPD projects and knowledge

The literature showed that R&D, and in particular NPD, plays an important role in securing the competitive advantage of organizations and firms (Menke, 1997; Richtnér *et al.*, 2013; Distanont and Khongmalai, 2020; Tajaddini and Gholipour, 2021). NPD is a knowledge-intensive activity (Baxter *et al.*, 2010; Haug, 2022; Papa *et al.*, 2022) and, therefore, the ability of an organization to capture the knowledge developed by project teams throughout the project life cycle and to share it with other projects is critical to the success of new projects and to the growth of organizations (Goffin and Koners, 2011; Baxter *et al.*, 2013; Richtnér *et al.*, 2013). Accordingly, understanding how knowledge is created, shared and

used in NPD was seen as a key to identify what actions NPD team members and managers could take to improve knowledge sharing and use.

Antoni and Sense (2001) observed that projects are temporary organizations and tend not to “establish systems or frameworks to actively facilitate and optimize their learning within or between projects” (p. 4). Ayas (1998) developed the foundation for Antoni and Sense’s (2001) argument, observing that learning usually does not happen naturally, but needs to be managed and directed. Antoni and Sense (2001) also noted that improving learning in projects is not only extremely useful for long-term firm competitiveness but has also positive short-term (i.e., project) consequences. Kogut and Zander (1992) also observed that the ability of a firm to create and share knowledge effectively is a key to a competitive dimension, as technology transfer and replication are complex and costly, but crucial to the growth of the firm in terms of both size and profit. Recent studies confirmed the importance of knowledge creation, sharing and use in NPD to help building competitive advantage for firms and organizations (see the papers by Distanont and Khongmalai, 2020; Mathrani and Edwards, 2020; Tajaddini and Gholipour, 2021). Grant (1996) observed that NPD projects require the exploitation of a wide range of specialized knowledge and the reduction in knowledge breadth as individual knowledge becomes more specialized: this highlights the importance of integrating specialized knowledge. Baxter *et al.* (2013) argued that what really contributes to the performance of firms and organizations is knowledge *integration*, i.e., the “integration of specialist knowledge to perform a discrete productive task” (Grant, 1996). The need for knowledge integration and the integrating internal and external knowledge was also studied by Mathrani and Edwards (2020), that investigated the impact of knowledge integration for NPD project success, highlighting benefits of early-stage knowledge integration.

The literature reviewed in this paragraph showed that successful NPD is a key to securing the competitive advantage of firms and organizations. Many authors also highlighted the importance of diversified knowledge and of knowledge integration for the success of NPD projects, showing that it is important to understand key theories on

organizational knowledge and how the knowledge needs of NPD projects have been categorised.

2.1.1 Types of knowledge in NPD

The theory of organizational knowledge creation by Nonaka (1994) is one of the key theories to study knowledge in NPD.² This theory distinguishes two different aspects of knowledge useful for firms and organizations: *explicit* and *tacit knowledge*. Takeuchi (2006, p. 4) identified explicit knowledge as the “knowledge that can easily be expressed in words and numbers, and easily communicated and shared in the form of data, scientific formulas, or codified procedures”, while tacit knowledge (first introduced by Polanyi, 1966) is “highly personal and difficult to reduce to writing” (Holste and Fields, 2009, p. 128). Examples of tacit knowledge are knowledge on how to act and to solve problems and in general practical knowledge (Takeuchi, 2006; Baxter *et al.*, 2013; Hadjimichael and Tsoukas, 2019).

The importance of tacit knowledge for NPD is still extensively discussed (Newell, 2004; Holste and Fields, 2009; Goffin *et al.*, 2010; Sakellariou *et al.*, 2017) and recent studies (Zhang and Min, 2019; Sikombe and Phiri, 2019; Raudberget and Wlazlak, 2022; Idreesa *et al.*, 2023) showed that research on the importance of sharing tacit knowledge in NPD is still on-going. Salomo *et al.* (2010) observed how critical resources for firms “tend to be intangible” and “are developed over time and are not readily traded in the marketplace” (p. 957). Grant (1996) highlighted a very important aspect of tacit knowledge arguing that tacit knowledge is “acquired by – and stored in – individuals” (p. 377).

² For details see Huhtelin and Nenonen (2021).

Hedesstrom and Whitley (2000) pointed out that the concept of tacit knowledge is used in different and contrasting ways in knowledge management literature. The main controversy in the literature on the use of tacit knowledge relates to the ability of individuals and organizations to convert tacit knowledge into explicit knowledge: while some argued that tacit knowledge is not yet articulated in explicit form (Nonaka, 1996), other claimed that tacit knowledge cannot be articulated in explicit form (Polanyi, 1966). Nonaka and von Krogh (2009) summarized the different uses of the term and emphasized the advancement in the theory of organizational knowledge creation, pointing out that further work is required to assess “how leadership can motivate and enable individuals to contribute to organizational knowledge creation by transcending social practices” (p. 648). The sharing and use of tacit knowledge was debated and referred to in several ways in literature. While some agreed that tacit knowledge can be converted into explicit knowledge, and vice versa (Nonaka, 2006), others believed that, owing to its nature, tacit knowledge cannot be explicitly converted (Grant, 1996).

While the distinction between tacit and explicit knowledge is a key to explore the causal mechanisms behind the effectiveness of KMI and to assess how knowledge is shared and used across NPD projects, it is important to understand which *types* of knowledge are shared. Many scholars provided characterizations of the type of knowledge needed by NPD projects. Landaeta (2008) offered a categorization of the knowledge needed by NPD projects and defined three categories of project knowledge:

1. Technical knowledge;
2. Organizational knowledge (i.e., knowledge to solve crisis, issues, and problems);
3. Knowledge for the continuous improvement of project tasks (i.e., process).

Kotnour and Britton (2000) identified six projects knowledge needs:

1. Customer's project needs;
2. State of technology;
3. Internal capabilities and gaps;
4. External capabilities;
5. Potential partners;
6. Stakeholders needs.

Tell (2004) aimed at understanding and categorizing knowledge used and shared in NPD. This Author looked at characterizations of knowledge in NPD projects and built a theoretical, philosophically based model of what kind of knowledge exists in organizations and supports organizational knowledge. The purpose of Tell's typology was to evolve from the tacit/explicit knowledge dichotomy, to create a four-fold typology of knowledge, based on the context in which knowledge is created, shared and used. Focusing on knowledge justification, the Author (2004) defined four types of knowledge (Figure 2.6):

1. Objective knowledge;
2. Personal knowledge;
3. Subjective knowledge;
4. Organizational knowledge.

In Tell's definition (2004), personal knowledge included all elements of the widely used concept of tacit knowledge in which objective knowledge shared the same characteristics of explicit knowledge. The typology presented by Tell (2004) highlighted the importance of the context – performance and procedures – in the definition on knowledge.

	Internal justification	External justification
Justification by performance	Personal knowledge	Institutional knowledge
Justification by procedure	Subjective knowledge	Objective knowledge

Figure 2.6 - Knowledge typology based on knowledge justification - Tell (2004, p. 451)

While different categorizations of knowledge exist in literature, building on the concept of knowledge shared and used it is possible to summarize and define the five types of knowledge required in NPD (see Blackler, 1995; Sole and Edmondson, 2002; Landaeta (2008); Zhang and Min, 2021; Dastaki *et al.* 2022):

- *Technical knowledge* – knowledge on the physical and engineering foundations on which the products work.
- *Product knowledge* – defined as “product related information [...] such as information about brands, attributes [...] and usage situations” (Selnes and Grønhaug, 1986 p. 69).
- *Process knowledge* – intended as “knowledge about activities, steps, and procedures” required to complete a predetermined product development task (Ramesh and Tiwana, 1999 – p. 214).
- *Socio-political knowledge* – knowledge on the “social and political composition of the organization including its people, roles and responsibilities” (Evans and Easterby-Smith, 2011, p.12).
- *Knowledge on third parties* – intended as knowledge on performance, capability and reliability of partner suppliers, customers and competitors.

The above definitions of technical knowledge, product knowledge, process knowledge, socio-political knowledge and knowledge on suppliers will be used in the context of this thesis. NPD projects require team members to possess knowledge in all areas mentioned above and must be able to integrate it to complete projects and achieve successful product launches (Baxter *et al.*, 2013). Project teams failing to integrate product knowledge, process knowledge, socio-political knowledge and suppliers' knowledge might hinder successful product launch and NPD project performance.

2.1.2 Knowledge in incremental and radical projects

Kleinsmann and Valkenburg (2005) investigated the difficulties of combining different functions in integrated project teams (IPT) and investigated the barriers NPD project teams face when integrating knowledge. The authors argued that different knowledge backgrounds and conflicting requirements make it challenging to manage IPTs. Debate exists in literature if cross-functional integration always brings benefits to firms and organizations. Jugend *et al.* (2018) observed how limited information exists on whether cross-functional integration should be used in both incremental and radical NPD and provided the following definitions of incremental and radical NPD:

- Incremental NPD projects are new product development projects characterized by minor technological changes that lead to minor value differences for final customers;
- Radical NPD projects incorporate substantially different technology and answer new customer needs.

Jugend *et al.* (2018) also observed that radical and incremental NPD require different NPD management practices, skills and competencies. Rosell, Lakemond and Melander (2017) highlighted that the integration of external knowledge (e.g., supplier

knowledge) has been recently more and more emphasized in literature and is a key for innovation and radical NPD. Zhou and Li (2012) noted that different views exist on the role of internal and external knowledge in NPD and that, in particular, some scholars agree that in-depth internal knowledge is needed for product innovation (Zahra and George, 2002), while others believe that in-depth internal knowledge is useful for radical innovation only when coupled with external knowledge and inputs (Chesbrough, 2003; Katz and Du Preez, 2008). Zhou and Li (2012) observed that many scholars, as Ahuja and Katila (2001) and Laursen and Salter (2006), argue that many sources of external knowledge are required for radical innovation and are “necessary to trigger radical innovation and can be found only outside the firm, with customers, competitors, and suppliers” (p. 1091). However, while literature clearly showed that radical innovation favours external knowledge, caution must be used when thinking that external knowledge can fully replace in-depth internal knowledge.

2.1.3 Summary of the importance of NPD and knowledge

The literature reviewed in this section showed that firms and organizations resort to product innovation to secure competitive advantage in fast evolving, competitive environments. Product innovation is achieved by R&D and NPD projects. Understanding what kind of knowledge is required and created by NPD projects is essential to assess which knowledge must be shared and between which parties. Studies exist that defined and categorized what knowledge is needed and created by NPD projects (e.g., Kotnour and Britton, 2000; Kotnour and Landaeta, 2002; Tell, 2004; Zhang and Min, 2021; Dastaki *et al.* 2022). Knowledge is categorized by its content – customers, stakeholders, state of technology, suppliers’ capability, etc. – and by its form – explicit or tacit, personal or organizational, codified or social – (Tell, 2004; Enberg *et al.*, 2006). Knowledge (e.g., technical knowledge and knowledge of customer needs) is both a key input and a key output of product development. The literature reviewed in this section also highlighted that, in order to achieve innovation and successfully complete NPD projects, organizations must be able to store knowledge created by project teams and share it with others project teams. Learning

in project teams is therefore critical for the success of NPD projects as it secures the competitive advantage of firms and organizations.

The literature showed that incremental and radical NPD teams have very different knowledge needs, with radical NPD teams needing access to extensive external knowledge (e.g., customer and market trends, suppliers' knowledge) (Ahuja and Katila, 2001; Laursen and Salter, 2006; Zhou and Li, 2012). Different management practices are adopted for different types of innovation and KMI in large companies often focus on the knowledge creations processes (Jugend *et al.* 2018), while socio-political and technical needs of radical innovation projects and the use key of KMI are often not deployed in the case of incremental NPD projects. The literature also showed that incremental NPD projects have less need for multi-function integration than radical NPD teams (Jugend *et al.*, 2018).

In order to understand how to improve learning and knowledge sharing in NPD projects, it is crucial to understand what types of knowledge are important in NPD projects. The literature reviewed in this section showed that the interaction of both explicit (e.g., technical knowledge, scientific data) and tacit knowledge (e.g., know-how, practical knowledge) is required in NPD projects. The literature reviewed so far also showed that NPD projects need a high amount of specialized knowledge that needs to be integrated for NPD projects to be successful. While knowledge is an input to NPD projects, one of the outputs of NPD projects is “new” knowledge – both explicit and tacit. Using the definition by Goffin and Mitchell (2010), the literature showed that knowledge needs of NPD projects are influenced by the degree of innovation of the project. Definitions of product knowledge, process knowledge, socio-political knowledge and knowledge on suppliers were proposed in literature and can be used as a basis to investigate how knowledge is shared and used in NPD projects.

Table 2.1 summarizes the findings of the literature review on the importance of NPD and organizational knowledge as well as the questions that remain open after the review. The first column describes the domain under consideration; the second column introduces the key findings from the SLR; the third column shows key references for the findings in the second column; the four column points out the questions that remain open.

In particular, Table 2.1 summarizes three key findings of the SLR: (1) the selected categorization of knowledge needs; (2) the need of both explicit and tacit knowledge in NPD projects and (3) the impact that the degree of innovation has on project needs. The table also shows three unanswered questions: (1) are global NPD knowledge needs different from those of local NPD? (2) do global NPD projects have access to organizational tacit knowledge? And (3) are knowledge needs of global NPD projects also impacted by the degree of innovation.

Table 2.1 – Section 2.1 SLR findings and open questions

Domain	SLR findings	Reference	Open questions
Knowledge needs and knowledge generated in NPD projects.	Knowledge in NPD programs can be divided in four categories (product, process, socio-political and third-party knowledge).	Enberg <i>et al.</i> (2006); Marabelli <i>et al.</i> (2013); Bower (2007); Altman and Engberg (2016); Zhang and Min, (2021); Dastaki <i>et al.</i> (2022).	Do global NPD projects have different knowledge needs than co-located NPD projects?
Knowledge needs and knowledge generated in NPD projects.	NPD projects need access to both tacit and explicit knowledge to be successful.	Nonaka (1996); Grant (1996); Newell (2004); Holste and Fields (2009); Goffin <i>et al.</i> (2010); Zhang and Min, (2019); Sikombe and Phiri, (2019); Raudberget and Wlazlak, (2022); Idreesa <i>et al.</i> , (2023).	Do global NPD project have the same access to tacit knowledge as co-located NPD projects?
Knowledge needs and knowledge generated in NPD projects.	The types of knowledge needed and created by NPD projects are impacted by the degree of innovation of the NPD projects (radical vs incremental NPD).	Bartezzaghi <i>et al.</i> (1997); Nobeoka and Consumano (1997); Enberg <i>et al.</i> (2006); Jugend <i>et al.</i> (2018).	Are knowledge needs of global NPD projects also influenced by the degree of innovation of the project?

2.2 Trust, barriers and geographical distribution challenges

In order to understand how project-to-project learning works in global NPD, it is necessary to review what is known about the impact of organizational culture on NPD KSU.

To understand and to assess how knowledge can be shared and used in NPD projects, Takeuchi (2006) presented a knowledge generation and conversion process that shows how knowledge is created at an individual level, at a group level, and at an

organizational level. Baxter *et al.* (2013) identified two crucial components that affect KSU in NPD projects: *individual expertise* and *working together*. Baxter *et al.* (2013) developed a model which shows how individual expertise and working together affect learning in NPD, pointing out that further research is required to assess how the proposed model works in the case of “globally distributed innovation projects” (Baxter *et al.*, 2013, p. 417).

Mathrani and Edwards (2020) also investigated knowledge sharing in distributed NPD projects and proposed a knowledge-sharing framework to enhance knowledge sharing in early and late stages of distributed NPD projects, while highlighting that management style and organizational structure impact significantly on tacit and explicit knowledge sharing. The authors, however, argued that further research is needed to investigate knowledge sharing in distributed NPD projects across both large and small organizations. While the sharing and use of explicit knowledge can be enhanced by formal training, the transfer of tacit knowledge usually requires extensive personal contacts (Chen, 2005). Due to the very nature of tacit knowledge (i.e., the fact that tacit knowledge is personal), the level to which project team members share and use it is influenced by trust relationships (Holste and Fields, 2009).

2.2.1 Knowledge sharing and trust

McAllister (1995) argued that two forms of trust exist: *affect-based* trust and *cognition-based* trust. The affect-based trust develops from mutual care/concern between co-workers; the cognition-based trust develops from the competence and reputation (competence) of co-workers. Holste and Fields (2009) argued that the willingness of team members to share tacit knowledge is dependent on affect-based trust, while the willingness to use tacit knowledge is based on cognition-based trust. The importance of trust – or the lack of – as a potential obstacle to knowledge transfer was also highlighted by Paulin and Winroth (2013), pointing out that team members only share highly personal knowledge with team members they have “mutual care with” and only share tacit knowledge with team members

they consider reliable and competent (Lucas, 2005). Williams (2008) observed that the temporary nature of projects impacts the ability of project teams to develop trust.

While interpersonal trust was widely considered a key factor impacting on the knowledge-sharing end in a knowledge transfer, other authors (see, for instance, Von Krogh, 1998) focused their efforts on the receiving-end of knowledge (i.e., the use). Von Krogh (1998) studied the effects of organizational culture on KSU. Starting from Nonaka and Takeuchi's definition of knowledge as "justified true belief" (1995, p. 58), Von Krogh highlighted *justification* as a crucial step in KSU (1998). Von Krogh (1998) observed that using knowledge is as important as sharing knowledge; shared knowledge will not be used unless the receiving end does not consider this knowledge justified. *Care*, as defined by von Krogh (1998), is an enabler for knowledge justification and, therefore, for use. As a conclusion, one can say that, while many impacting factors exist, trust and care are the first ones that impact on KSU in NPD projects.

2.2.2 Barriers to knowledge sharing

Frank and Ribeiro (2014) identified four key categories of factors that influence project-to-project learning:

1. Personnel factors (e.g., work environment, staff development);
2. Technological factors (e.g., infrastructure);
3. Work design (e.g., management practice, procedures);
4. External environment (e.g., cultural context).

Landaeta (2008) also looked at the factors influencing KSU in NPD projects. This Author (2008) observed that the main difficulty organizations find when dealing with project learning is understanding the knowledge needs of a single project, based on the different nature of each project and including a comprehensive list of factors influencing KSU in projects:

1. Formal and informal networks;
2. Articulability and embeddedness of knowledge;
3. Knowledge distance;
4. Knowledge management processes and tools;
5. Perceived need for knowledge;
6. Organizational culture;
7. Cultural differences;
8. Organizational size;
9. Understanding of the cognitive style of individuals;
10. Senior management involvement;
11. Politics;
12. Knowledge transfer leadership;
13. Lack of standard work processes;
14. Learning mandate;
15. Geography;
16. Laws and technical regulations.

Both Landaeta (2008) and Frank and Ribeiro (2014) showed that many of the barriers for KSU are cultural. The importance of social contexts in knowledge sharing and use was also highlighted by many other studies in literature (Holste and Fields, 2009; Nonaka and von Krogh, 2009; Baxter *et al.*, 2013), which also showed that organizational culture plays an important role in organizational social dynamics.

Kleinsmann and Valkenburg (2005) studied enablers and disablers for shared understanding (defined as learning opportunities) in NPD programs by the means of a single project case study. Actors, projects and company are considered as the three key levels for categorizing learning opportunities in NPD. While Kleinsmann and Valkenburg (2005) initially argued that their study has identified enablers and disablers for learning in

NPD, the study only categorizes the kind of learning opportunities that were observed in the specific case study. Their conclusion was that actions taken at working-level are not enough to enhance learning in NPD, but actions at an organizational level must be taken to leverage the learning opportunities. Ajmal *et al.* (2009) investigated the impact of cultural barriers on KSU in project-based organizations. They argued that “the ability to create, share, and absorb knowledge among dispersed organisational members of varied cultural backgrounds is thus an essential requirement for success” (p. 340). Ajmal *et al.* (2009) dealt with the knowledge needs of projects with different complexity and argued that the “novelty and uniqueness” of the new product determine how much new knowledge is required. However, they also argued that, despite project complexity or product uniqueness, the NPD process is usually similar across projects. Using Taylor’s (1977) definition of culture as the “complex whole that includes the knowledge, beliefs, art, law, morals, customs, capabilities, and habits that are acquired by an individual as a member of society” (p. 346), they pointed out that effective knowledge management “requires the fostering of an organisational culture that encourages an awareness of the value of knowledge” (p. 348):

- Project-based organizations that want to encourage KSU must have a “no-blame” culture;
- They must allocate time and resources for project review and documentation of learning;
- They must establish easy to reference records.

The literature clearly showed that social interactions and interpersonal trust are key factors for successful KSU and that organizations must create “no-blame” culture and allocate NPD personnel’s time to document learning and projects record for future reference. Ajmal *et al.* (2009) proposed that organizations must create “easy to reference project records” (p. 349) but provided no recommendation on what information records should include or how easy to reference project records look like. Many other studies (Martini and Pellegrini, 2005; Paulin and Winroth, 2013; Chirumalla, 2014; Mathrani and

Edwards, 2020; Haug, 2022, and in particular, Chirumalla, 2014) analysed in detail the barriers and improvement opportunities in the case of complex product development projects. Compared to the research previously reviewed, this contribution is particularly interesting as it introduced for the first time the element of NPD complexity in the discussion on barriers and facilitators. The findings of the case study by Chirumalla (2014) are very similar to those available in literature for other product development projects and are summarised in Table 2.2.

Table 2.2 – Barriers and opportunities to KSU - Chirumalla (2014)

Barriers to effective lessons learned	Improvement opportunities
Lessons learned are not detailed enough	Lessons learned should be captured along the full life of the project
Lessons learned procedure is not clear enough	Lessons learned should assess the root cause of the problem and provide examples
Text based lessons learned have difficulties in capturing tacit knowledge	Standard procedures should be in place for capturing lessons learned
Lessons learned do not always capture context	Contextual details should be included
Dissemination of lessons learned captures is missing	Meta data should be stored in lessons learned
No clear procedure on how to identify relevant lessons learned	Networks of knowledge works should be developed
Information in lessons learned is not clear or necessarily relevant	Lessons learned should be integrated in business objectives

This research showed that the challenges related to the use of lessons learned in the case of complex product development are very similar to those traditionally highlighted in literature. The definition of “complex product development projects” presented by Chirumalla (2014) makes it difficult to understand if the complexity is related to the degree of innovation of the products (i.e., radical vs incremental product development) or to other NPD complexities (e.g., limited time, new team, new market, etc.).

2.2.3 Geographical distribution challenges

Organizations increasingly more often rely on dispersed teams to execute NPD projects (Gemünden, 2015, Sivakumar and Roy, 2021; le Duc and Gammeltoft, 2023). Globally distributed projects present a number of extra challenges compared to the projects with team members located in a single location: i.e., it is more difficult for distant team members to have as many frequent face-to-face interactions as co-located team members. Paulin and Winroth (2013) reported that geographical distance and linguistic distance can be considered examples of knowledge sharing inhibitors. Salomo *et al.* (2010) argued that firms tend to internationalize and run NPD programs with global organizations to better leverage market knowledge and create local content. In this context, team compositions and relationships play an important role as they impact on the capability of the firm to be successful in NPD.

Grant (1996, p. 377) argued that factors which influence knowledge integration are “stability, propinquity and social relationships”. Similarly, Baxter *et al.* (2013) observed that, as far as globally distributed projects are concerned, *stability, propinquity* and *social relationships* are a particular challenge for knowledge integration. Stability, propinquity and social relationships also played an important role in the work by Ali *et al.* (2018). Using the project *absorptive capacity* (ACAP) lens, Ali *et al.* (2018) investigated how macro-level KM practices in organizations stimulate micro-level knowledge sharing practices that generate higher level of project absorptive capacity that ultimately results in higher performance. Cohen and Levinthal (1990) defined absorptive capacity as the “ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends”. The concept of ACAP lends itself very well to NPD projects and project-to-project learning, defined as the ability of a project team to capture and use external knowledge. Examining the role that social relationships play in the creation of absorptive capacity, Ali *et al.* (2018) considered four key parameters:

1. Familiarity;
2. Communication;
3. Proximity;
4. Trust.

Bernstein and Waber (2019) observe that “[physical] propinquity, or proximity, predicts social interaction” (p. 83). Using global NPD teams (Salomo *et al.*, 2010), the difficulty in creating stability and social relationships in global NPD projects is partially balanced by the possibility of integrating “diverse talents, knowledge and cultures” (p. 965) and still making global NPD attractive for firms and organizations. Pavanelli Stefanovitz and Jabbour (2022) indicated global NDP team dispersion as one of the three key factors currently increasing NPD complexity. Case study research (Sole and Edmondson, 2002; Mathrani and Edwards, 2020) on project learning in globally dispersed NPD projects showed that NPD projects can be successful, and that learning can occur between remote team members; yet, little is known on how this knowledge transfer occurs. The success of globally dispersed NPD projects is attributed to the broader access that the global teams have to local experts, compared to similar NPD projects where the team members are all co-located. Local experts’ technical knowledge is referred to as *situated* knowledge: Sole and Edmondson (2001, p. 7) defined situated knowledge as “knowledge embedded in a physical site or location: for example, in a manufacturing facility, situated knowledge might include special knowledge about supplier reliability”. While the definition of situated knowledge is quite general, in Sole and Edmondson’s research (2002) the main learning considered in the study was technical (explicit) knowledge. Limited research is available on how non-technical or product knowledge (e.g., socio-political knowledge) can be shared in globally dispersed teams.

2.2.4 Summary of barriers and geographical distribution challenges

The importance of capturing and sharing knowledge between project team members and between different project teams, and the difficulties that go with it, are very clearly highlighted in literature. Many scholars created models to explain how knowledge is created and shared in project teams (i.e., Takeuchi, 2006; Baxter et al., 2013; Mathrani and Edwards, 2020). Section 2.2 showed the importance that organizational culture, social interactions, care and trust between co-workers play in the context of KSU (e.g., Von Krogh, 1998; Chen, 2005; Holste and Fileds, 2009; Frank and Ribeiro, 2014). In order to improve the performance of NPD projects and product innovation, it is very important to understand how NPD managers and practitioners can support social interactions and build a culture of trust between project team members and project teams (Mathrani and Edwards, 2020). As a major part of the knowledge created by NPD teams is tacit, it is extremely important to understand the role that social interaction plays in knowledge sharing in NPD projects.

The literature reviewed in Section 2.1 showed how the integration of different specialized knowledge is one of the key issues that NPD project face (Grant, 1996) and that the different knowledge backgrounds of NPD team members is a first barrier to NPD learning (Kleinsmann and Valkenburg, 2005). Cultural background is also identified as a key barrier for KSU in NPD (Ajmal *et al.*, 2009; Mathrani and Edwards, 2020). Ajmal *et al.* (2009) also observed that organizational culture can be a significant barrier to KSU and that “looking for blame” is a key blocker of knowledge sharing.

The SLR confirmed that time and resources availability for KSU in NPD is a clear factor that influences KSU: organizations that allocate more time for KSU and provide NPD teams with clear “learning mandates” are more successful in KSU (Ajmal *et al.*, 2009; Landaeta, 2008). Project’s absorptive capacity is also identified as a factor influencing KSU (Ali *et al.* 2018) and that trust, familiarity and propinquity are key factors that influence project-to-project learning in NPD (e.g., Ali *et al.* 2018; Grant, 1996). Building trust and

familiarity is more difficult in the case of globally distributed teams (Paulin and Winroth, 2013).

The literature reviewed in Section 2.3 showed that organizations rely on dispersed and global teams to execute NPD projects (Gemünden, 2015, Sivakumar and Roy, 2021; le Duc and Gammeltoft, 2023). Globally distributed projects present a number of extra challenges compared to the projects with team members located in a single location. Pavanelli Stefanovitz and Jabbour (2022) indicated global NDP team dispersion as one of three key factors currently increasing NPD complexity. However, global NPD teams have a broader access to local customer needs and global experts (Sole and Edmondson, 2001), but integration and use of local knowledge is more difficult compared to co-located teams.

The importance of social relationship and stability in sharing and using tacit knowledge is also highlighted in literature. The literature reviewed in this section showed that building trust between project team members and creating opportunities for sharing tacit knowledge is more difficult in the case of globally distributed projects. Understanding which managerial actions facilitate knowledge sharing in case of globally distributed projects is extremely interesting, considering that globally distributed projects are more and more employed by organizations. The literature also showed that globally dispersed teams have an advantage in terms of access to technical experts and knowledge situated in different location and are therefore attractive for firms and organizations. However, limited research is available on how non-technical knowledge can be shared in global teams and limited recommendation are available for NPD managers and practitioners wanting to improve knowledge sharing and use in global NPD teams.

Table 2.3 – Section 2.2 SLR findings and open questions

Domain	SLR findings	Reference	Open questions
Trust and barriers impacting KSU	Significant barriers exist to KSU in NPD, (cultural background social interactions, trust, communication, proximity, stability etc.)	Martini and Pellegrini (2005); Paulin and Winroth (2013); Frank <i>et al.</i> (2014); Chirumalla (2014); Mathrani and Edwards (2020); Haug (2022)	Which additional barriers do global NPD projects face, compared to co-located NPD projects?
Global NPD used and impact on KSU	The use of global NPD is continuing to increase. Global NPD projects do not show performance issues compared to local NPD.	Sole and Edmondson, 2002; Salomo <i>et al.</i> (2010); Pavanelli Stefanovitz and Jabbour (2022); le Duc and Gammeltoft, (2023).	

Table 2.3 summarizes the key findings of Section 2.2 and highlights how many barriers exist to knowledge sharing and use (cultural background social interactions, trust, communication, etc). The table also shows that, according to the literature, global NPD has a growing trend. The main open questions from Section 2.2 relates to which additional barriers that NPD project team face compared to local NPD.

2.3 Knowledge management initiatives

This Section reviews the KMI used in NPD with the aim of identifying what is known in literature on which KMI are used and proved effective for project-to-project learning in global NPD. Before discussing KMI, theoretical models for project KSU and project-to-project KSU are reviewed.

In order to understand the need for KSU in NPD, it is first important to understand the source of knowledge required, used, and shared in NPD. Kotnour (2000) highlighted how *Learning Organizations* develop a set of processes to allow “knowledge to be created from experience” (p. 393). This Author also investigated how well-structured project management methodologies integrate learning, and how learning in a project environment

improves project performance. He also created a good model to categorize the learning actions performed by project teams and distinguishes between those that involve:

- Inter project actors;
- Intra project actors;
- Learning support.

This model highlighted both inter-project learning and project-to-project learning and emphasized the importance of “learning support” functions, i.e. functions in organizations dedicated to supporting project learning (KMI). While the scope of Kotnour’s work was very vast and aimed at understanding “how [...] to learn from project experiences” (2000, p. 394), the actual research work only focused on what project managers learn. Kotnour concluded that the main facilitator for project-to-project learning is the ability of organizations to create environments that allow open discussions on mistakes made by previous teams. He continued to investigate the importance of organizational culture on KSU and in a later work (together with Landaeta, 2002) looked at knowledge management in the case of multi-project organizations. Multi-project organizations were defined as organizations where multiple projects are executed in parallel or subsequently to one another. Kotnour and Landaeta (2002) defined knowledge management as a “set of processes, tools and techniques for the most effective and efficient use of knowledge” (p. 1) and investigated how knowledge management works in the case of multi-project organizations, i.e., organizations where multiple projects are executed in parallel or subsequently to one another. They defined knowledge management as a “set of processes, tools and techniques for the most effective and efficient use of knowledge” (p. 1). Moreover, based on the six knowledge needs of project-based organizations identified by Kotnour and Britton (2000), they proposed a model of knowledge management across projects. Knowledge management was defined as “a set of proactive activities to support an organization in creating, assimilating, disseminating and applying its knowledge [...] to continually improve an organizations performance” (p. 2). Three key aspects impact on the

outcomes of knowledge management programs in the holistic model presented by Kotnour and Landaeta (2002):

1. The organizations' strategic context – e.g., organization's mission, vision and strategy;
2. The knowledge management program context – e.g., culture, reward and learning framework;
3. Knowledge management operations – e.g., processes, social networks and KM.

The model proposed by Kotnour and Landaeta (2002) highlighted the importance of factors like organizational culture and social networks for KSU, discussed types of knowledge required for NPD and introduced the need for KMI. Different categorizations exist of the type of knowledge required and generated by NPD projects (e.g., Tell, 2004). However, it is quite clear in literature that NPD projects need different kinds of knowledge to be successful. Enberg *et al.* (2006) investigated knowledge integration and proposed a multi-period model for knowledge integration based on different learning mechanisms. Starting from contrasting views on knowledge integration in the knowledge management body of literature, Enberg *et al.* (2006) proposed a model that combines the personalization strategy (Hansen *et al.*, 1999) with the codification strategy (Grant, 1996; Principe and Tell, 2001). Based on an empirical case study, Enberg *et al.* (2006) elaborated an interactive model of project learning; the peculiarity of the model is that it separates learning in two phases, based on whether interactions exist between project team members. Enberg *et al.* (2006) defined an *interaction* phase, when team members meet to agree on goals, share experiences and solve projects, and an *action* phase, when team members split and work independently on project tasks. In the model by Enberg *et al.* (2006), which supports the idea that knowledge creation, sharing and use is obtained with an alternation of individual and group efforts, the continued iteration between action and interaction is a key to project

learning. This model is very similar to Nonaka's SECI model (1991), in which group efforts (Socialization, Externalization) were combined with individual efforts (Combination, Internalization) and were associated with a continuous conversion of knowledge from tacit to explicit (Externalization) and from explicit to tacit (Internalization).

Based on Nonaka's (1991) SECI model, Oluikpe (2015) tried to create a unified model for KSU in NPD and used organizational knowledge creation theory as a basis for his research. Yet, the Author highlighted that the field of knowledge creation was nebulous and that the main organizational knowledge creation theories were widely criticized for the overly mechanical or simplistic models (see Nonaka and Takeuchi, 1995; Wenger, 2000). Based on the "social construction of knowledge" viewpoint, knowledge is a social – and not a personal – construction, Oluikpe (2015) developed the CRAI model, a theoretical model of "knowledge construction and appropriation enabled by social interaction in project teams and their relationship with project outcomes such as project success, innovation, operational efficiency, completion times and generation of new knowledge" (p. 354). The CRAI model provided an interpretation of the working of KSU in NPD. This is an iterative model very similar to Nonaka's SECI model (1991), where external knowledge (codified in CRAI) needs to be Interpreted and Assimilated by project team members before being Reproduced (Externalized in the SECI model).

Following the theoretical definition of the CRAI model, Oluikpe (2015) tested the model by assessing the impact on project performance. However, the empirical research of Oluikpe (2015) failed to show if the model succeeds in describing how KSU occurs in project teams. Frank and Ribeiro (2014) summarized, consolidated, and reviewed the 14 theoretical models regarding KSU available in literature. They categorized the 14 models in two groups and highlighted the key differences between them. They created a new summary model of the working of KSU in NPD combining the common elements of the 14 models. The summary model was made of five stages:

1. Phase 0: knowledge generation in the source;
2. Phase 1: knowledge identification;
3. Phase 2: knowledge processing;
4. Phase 3: knowledge dissemination;
5. Phase 4: knowledge application by the recipient.

While the review was very detailed and comprehensive, the summary model proposed by Frank and Ribeiro (2014) did not consider the difficulties and obstacles that project teams encounter in each phase – i.e., the lack of trust between project team members that limited the application of knowledge by knowledge recipients. Very little attention was paid to the additional challenge that global NPD face or how the proposed model would need to be adapted in the case of global NPD.

All the KSU theoretical models discussed, starting from Takeuchi's SECI models, assume that firms and organizations needed to share knowledge for NPD success, disregarding completely possible negative impacts of KSU. Oshri, Pan and Newell (2004) investigated the interaction between knowledge *exploration* and knowledge *exploitation*. Knowledge exploration was intended as the act of creating new organizational knowledge (e.g., creating new designs), while knowledge exploitation was intended as re-using existing knowledge in an organization, adapting it to new uses (e.g., component re-use). The Authors looked at the impact of a strategic initiative to enhance knowledge exploitation on an organization, therefore reducing the need to explore new knowledge. They observed how the competitive landscape in which many organizations operate forced them to re-use as much existing knowledge (and designs) from previous projects:

“In the past, the collective learning gained from a product development project was not systematically re-used in other potentially related projects. As a result, almost all new projects had to ‘reinvent the wheel’”

(Oshri, Pan and Newell, 2004 p. 10)

They also noted how the market push to create new products quickly brought organizations to re-use both designs and procedures, while their empirical work highlighted that the long-term personal development on NPD team members might be negatively impacted by over-emphasizing knowledge exploitation over knowledge exploration. However, they focused almost exclusively on the technical knowledge sharing – i.e., sharing designs – while, when assessing the negative impact of knowledge sharing on organizations, it is of paramount importance to consider different aspects of knowledge – not just technical knowledge.

Many studies were found to model the KSU in NPD and to identify barriers to KSU. Yet, limited studies investigated how these models were operationalized by firms and organizations in terms of KMI. Organizations commonly used more than one knowledge management initiative. These usually were including, among the others, the following (Prencipe and Tell, 2001; Frank and Echeveste, 2012; Van Waveren *et al.*, 2020):

- Action learning;
- Apprenticeships;
- Boundary / knowledge objects;
- Brainstorming sessions / team-work sessions;
- Communities of practice;
- Design / components re-use;

- E-mail, phone, instant messaging communications and informal chats;
- Expert yellow pages;
- Feedback loops
- Project reviews / gate reviews / post project reviews / debriefing meetings;
- Job rotations / job shadowing;
- Lessons learnt databases;
- Mentoring / training;
- Middle management knowledge brokering;
- Multi-media training;
- Network assessments;
- On the job training / job shadowing;
- Process maps;
- Professional networks;
- Project manager camps;
- Projects planning sessions;
- Relocation of offices or divisions;
- Re-use of experts;
- Seminar / conferences;
- Senior management reviews;
- Storytelling / metaphors and analogies;
- Templates / checklists / guidelines;
- Training / teaching;
- Wikis / repositories.

Table 2.4 – Quantitative mapping of papers on KMI and KSU in NPD and global NPD

Knowledge management initiative	Key references	Explicit KSU effectiveness		Tacit KSU effectiveness		Global NPD KSU effectiveness
		Project learning	P2P learning	Project learning	P2P learning	
Feedback loops	Chirumalla (2017)	●○○	●○○			
Boundary objects	Maaninen-Olsson <i>et al.</i> (2008), Di Maio (2013), Butters and Duryan (2019) +2	●●○		●○○		
Brainstorming sessions	Prencipe and Tell (2001), Van Waveren <i>et al.</i> (2020)					
Communities of practice	Wenger (2000), Sense (2003), Marabelli <i>et al.</i> (2013) +7	●●●	●●●	●●○	●●○	●○○
Design / components re-use	Nobeoka and Cusumano (1997), Oshri <i>et al.</i> (2004), Antoni <i>et al.</i> (2005) +1	●●○	●●○			
Expert yellow pages	Van Waveren <i>et al.</i> (2020) +1					
Informal / face-to-face communications	D'Armagnac (2015) +2	●○○	●○○	●○○	●○○	
Job rotations	Van Waveren <i>et al.</i> (2020), Ortega (2001)					
Lessons learnt databases	Chirumalla (2014), D'Armagnac (2015), Wiewiora and Murphy (2015) +2	●●○	●●○			
Mentoring / training	Prencipe and Tell (2001), Freyens and Martin (2007), D'Armagnac (2015) +1	●●○	●●○			
Middle management brokering	Prencipe and Tell (2001), Costanzo and Tzoumpa (2008)	●○○		●○○		
Post project reviews	Newell (2004), Williams (2007), Koners and Goffin (2007) +3	●●○		●●○		
Project manager camps	Prencipe and Tell (2001)		●○○		●○○	
Project reviews	Prencipe and Tell (2001), Antoni <i>et al.</i> (2005), Kotnour and Vergopia (2005) +3	●●○	●●○			
Relocation of offices	Prencipe and Tell (2001)					
Re-use of experts	Markus (2001), Edwards (2015), D'Armagnac (2015) +1	●●○	●○○	●○○	●○○	
Storytelling	Aramo-Iammonen and Jussila (2012); Sakellariou <i>et al.</i> (2017)	●○○	●○○	●○○	●○○	
Templates / guidelines	Prencipe and Tell (2001), Schulze <i>et al.</i> (2014)					
Wiki / repositories (ICT)	Martini and Pellegrini (2005), Wiewiora and Murphy (2015)	●○○	●○○			

●○○ <3 papers
 ●●○ 3 ≤ papers ≤ 5
 ●●● Papers > 5

An initial review of the SLR papers was used to build a quantitative map of works investigating the use of each KMI for either tacit or explicit KSU in project and project-to-project learning, in both local and global projects (see Table 2.4). The following scale, from one to three dots, was used to track the papers found for each KMI:

- – one dot indicates that fewer than three publications were found;
- – two dots indicate that three to five publications were found;
- – three dots indicate that more than five publications were found.

The list of KMI currently being used by firms and organizations running NPD projects is long and the theoretical analysis showed that these initiatives should help to mitigate the barriers to KSU. However, many authors observed that KMI are unfortunately not effective. D’Armagnac (2015) investigated why KSU in NPD was not as effective as expected, based on the systematic use of KMI recommended by literature. D’Armagnac (2015) noted that the relationship between projects and the organization was the foundation of project-based organizations (PBO): PBOs rely on projects to use pre-existing knowledge as basis to develop products and create new knowledge; organizations then used the newly created knowledge for subsequent activities (i.e., other projects). This Author also observed that projects often create new knowledge but struggle to re-use existing organizational knowledge, that they are a semi-autonomous entity inside a PBO, and that this autonomy can result in “voluntary distance” (p. 448) from the enterprise’s KMI: project participants might consider sharing or searching for knowledge as a waste of time that could be used for project activities. KMI could be expected to be more or less effective, depending on the type of organization and the type of knowledge used.

Based on existing knowledge categorizations, Martini and Pellegrini (2005) investigated the links between knowledge types and KMI used by organizations. They ran a comparison between two similar organizations, adopting different KMI and showing that

KMI implemented in organization were not aligned with the best practices prescribed by literature. They also used the available survey data from the two organizations to investigate key barriers for best practices to be introduced. Based on a review of literature, they categorized KMI in three types or configurations (p. 672):

1. Codified KMI;
2. Network-based KMI;
3. Traditional (or social) KMI.

Moreover, based on the results of the surveys, Martini and Pellegrini (2005) developed a model that assigns the best knowledge management configuration to an industry with specific reference to the type of business considered:

1. Companies manufacturing complex technological components used codified KMI;
2. Systems integrators tended to use network based KMI;
3. Manufacturing-to-order firms were more suitable for traditional KM initiatives.

2.3.1 Effectiveness of knowledge management initiatives

The effectiveness of KMI is extensively debated, and while some argued that firms and organizations need to implement the right KMI for their business and their knowledge needs (see for instance Martin and Pellegrini, 2005; Williams, 2008), others argued that the ability of NPD teams to share and use knowledge is independent of the type of KMI used. Williams (2008) observed that knowledge management developed over many years but noted that many scholars tend to overly focus on tools and information technologies to share knowledge, with this underlying assumption that “all knowledge is codifiable” (p.

251). Enberg *et al.* (2006) presented a case study on a single incremental NPD project that was considered very successful by the parent organization. They highlighted that the project used very few NPD best practices recommended in literature (i.e., clear project scope definition) and no explicit knowledge management initiative. Their results might suggest that knowledge management initiatives and NPD best practices were not effective or required in the case of incremental NPD projects. To the opposite, a more in-depth analysis of the interviews with the participants showed that the individual team members activities were guided by company's explicit/tacit knowledge related to the development of their product, referred by the authors as "foreknowledge". The Authors also referred that the project team was to be not "co-located" and that team members of different functions belonged to their parent functional organization for the full length of the project life. It is important to state that the definition of "co-located" used in this Thesis is different to the one used by Enberg *et al.* (2006): here "co-located" means physically located in the same geographical location as opposed to globally dispersed – i.e., co-located teams have opportunities for face-to-face meetings and social interactions, which is often limited in the case of globally dispersed teams. Enberg *et al.* (2006) also argued that, in the case of incremental NPD projects, tacit knowledge and individual work could be sufficient to complete the project successfully, without frequent interaction or communication among team members. However, very little information was given regarding the knowledge management initiatives used by the parent company and how the team members in the company might access the company's product tacit and explicit knowledge.

Ajmal *et al.* (2010) built a model to assess the effectiveness of KMI in NPD and identify critical success factors as the ones identified in literature and test the theoretical model empirically. This simple theoretical model considered six critical success factors:

1. Familiarity with KM;
2. Coordination among employees and departments;
3. Incentive for knowledge efforts;
4. Authority to perform knowledge activities;

5. System for handling knowledge;
6. Cultural support.

Ajmal *et al.* (2010) also investigated how to measure the effectiveness of KMI and identify four measures of the effectiveness of KMI:

1. Resources growth;
2. Knowledge content development;
3. Project survival;
4. Financial return.

While effective KMI were expected to provide short- and long-term competitive advantage to firms, leading to project success and financial returns for the organizations, directly measuring the financial impact of knowledge management initiatives was very complex and these measures provided little help in the assessment of the effectiveness of KSU. The conclusions of the empirical study was that all factors impact on KSU, as expected from literature.

Landaeta (2008) designed a survey to investigate the influence of KSU on project performance. This Author developed three hypotheses and tested them by means of data derived from a survey of 46 projects, focusing on the effectiveness of KMI on project performance. The results showed a positive impact of KMI on projects' body of knowledge, indicating that projects that use KMI tended to have an overall broader body of knowledge than projects that did not use it. They also showed that projects with broader body of knowledge tended to have better performance. The use of KMI showed to have little direct impact on projects' performance. The empirical work presented by Landaeta (2008) was one of the first empirical studies to investigate project-to-project learning and the impact of knowledge and knowledge management initiative on project performance.

The categories of knowledge considered in Landaeta's work did not consider the tacit or explicit nature of knowledge and little was discussed about the nature or effectiveness of the knowledge sharing initiatives used by the organizations surveyed. The assessment of project performance in Landaeta (2008) only took into account project cost, project schedule and the quality of project deliverables, while the long-term impact of the project on the organization (i.e., organizational knowledge, process improvements, etc.) was not considered. Finally, the focus was mostly on knowledge sharing, not investigating the actual use of knowledge by the knowledge receiving project.

While the debate on the effectiveness of KMI is still open, firms and organization invest many efforts in deploying KMI and studies exist that investigate their use and the effectiveness of KMI to capture either explicit or tacit knowledge. Costanzo and Tzoumpa (2008) observed that much of the existing literature focused on what project team learn, rather than on how learning occurred. Costanzo and Tzoumpa (2008) investigated the role of middle management for effective KSU in project-based organizations. They reviewed the existing literature on project-to-project learning and noted that many obstacles existed, either on the sharing end (fear of team members of losing their power) or on the receiving end. According to their conclusions, most of the existing research focused on tools and tasks (technology, routines) rather than on knowledge transfer between people. Moreover, they discussed the importance of the human aspect of knowledge sharing between project teams arguing that key people in the organization might significantly impact on project-to-project learning and that middle managers might perform as key organizational actors for project-to-project learning: while middle managers roles reduced with of downsizing and flat organizations, middle managers played a key role in ensuring team performance and project learning. Relaying on the work by Asllani and Luthans (2003), Costanzo and Tzoumpa (2008) identified two groups of middle managers: explicit knowledge middle manager and tacit knowledge middle managers. While explicit knowledge middle managers were technical experts who played directly a key role in knowledge generation and codification, tacit knowledge middle managers connected knowledge experts. Middle managers played a particularly important knowledge sharing role in cross-functional teams.

The role of middle managers in NPD KSU was not further discussed, while much of the focus was on KMI tools and tasks.

One of the first remarks that come to mind when discussing about re-using existing knowledge is re-using components or designs in their entirety. Nobeoka and Cusumano (1997) discussed multi-projects strategy and investigated rapid design transfer in NPD thanks to data on 210 projects from 17 firms in the automotive industry. They investigated the benefits and disadvantages of transferring technical knowledge (i.e., designs) from project to project introducing a framework for the assessment of the opportunity of enhancing project-to-project NSU based on the key distinction between radical innovation and incremental changes NPD. Moreover, they identified two parameters influencing the effectiveness of re-using of existing technical knowledge:

- Application: use existing technologies to replace existing products or to target new markets;
- Timing: the degree to which the transferred technology is still innovative (time between first invention and re-use).

Based on the application and timing parameters, these Authors presented a typology of multi project strategy based on three types of projects:

1. New design: NPD projects where no re-use is considered, no base design existed;
2. Rapid design transfer: NPD projects that re-use design from a previous project still on-going (the design of the first project might be impacted by the second);

3. Sub-sequential design transfer: NPD projects that re-use design from a previous project that is already finished (the first project's designs will not be impacted by the second);
4. Design modifications: NPD projects that re-use design from a previous project, replacing it (new generation product).

Nobeoka and Cusumano (1997) also investigated the benefits for projects and organizations of running multi-project NPD. The parameters to assess the benefits included: lead time, productivity, quality and market share. They expected a positive impact of running multiple projects in parallel and expected rapid design transfer and sub-sequential design transfer to positively impact sales and design modification NPD to negatively impact sales. Their data showed the correlation between use of rapid design transfer NPD and sales growth and the correlation of design modification NPD and reduced sales. The reliability of the correlation analysis was, however, dubious: the type of NPD was only one of the many variables that impact on sales' origin (this element is also highlighted by the Authors). Their results were very interesting and showed the potential benefit of KSU in NPD. This study, however, only looked at technical knowledge sharing (i.e., design re-use) and did not investigate which knowledge was shared in multi-project NPD or which KMI were used to achieve KSU.

Phased rollouts are a type of multi-project strategy that naturally lends itself to design / components re-use. Bower and Walker (2007) discussed how knowledge needs to be changed in phased rollout projects. Phased rollouts are projects where deliverables are released at different times – phased rollouts include phased location rollouts (different geographical markets or geographical facilities are addressed at different times), feature rollouts (different product feature are released at different times) or a combination of the two. Bower and Walker (2007) observed that both location and feature rollouts naturally represent a learning opportunity, as project learning could be shared from the first phase of the rollout to the subsequent phases. Bower and Walker (2007) described a theoretical model for planning knowledge management in the case of phased rollout projects.

While designs and components re-use are one of the first options for practitioners wanting to accelerate NPD project, re-using existing project knowledge and communities of practice are one of the most debated social – or traditional in Martini and Pellegrini (2005) definition – KMI in literature. Wenger (2000) recognised the importance of knowledge for the success of firms and organizations and observed that organizations must learn to be *social*. This Author revisited the concepts of knowledge, competencies and learning from a social perspective: the initial conflict between the personal experience of the participants in social interaction and the way competencies are understood by the community define how participants learn. For Wegner, communities of practice were “the basic building blocks of a social learning system because they are the social ‘containers’ of the competencies that make up such a system” (2000, p. 229). The concept of communities of practice (CoPs) is widely used in literature, Brown and Duguid (1991) explored the concept while studying how practitioners develop alternatives procedures to those recommended by their organization, to solve practical problems. In the context on non-canonical practice described by Brown and Duguid (1991), learning mostly occurred by the means of storytelling amongst practitioners. Since its original definition, the concept of CoPs has evolved. More recent studies (Bridwell-Mitchell, 2016) highlighted the importance of CoPs for peer-learning, while emphasising the potential negatives effects of strong CoPs as potential roadblocks for change and innovation. CoPs took advantage of the modern networking tools to increase knowledge sharing between peers in the case of global organizations, as observed by Lee *et al.* (2015). However, limited research is available on how web technologies and remote CoPs can help to share and use tacit knowledge.

Sense (2003) looked at the main differences between project teams and CoPs. Relying his studies on the situated learning theory (in contrast with psychological or cognitive learning theory), this Author observed that the main difference between project teams and CoPs was the temporary nature of project teams. In project teams, team members were focused on specific, individual and interlinked tasks that were time limited. On the other hand, CoPs focused on a knowledge domain and were commonly not impacted by time constraints. Sense (2003) argued that project teams can be considered an embryonal

CoP and that managerial actions (i.e., learning mandate / learning environment support) can enhance project team learning. Moreover, the Author (2003) presented a theoretical model on how learning in project teams could be improved, but little empirical evidence was provided to support the model. Sense's model identified four structural attributes that could facilitate learning across CoPs and projects (2003):

- Learning relationships: the relationships between persons, when one person is learning or teaching another;
- Understanding cognitive styles: understanding the way individuals process information and need information to be presented and to be fully understood;
- Knowledge management: the tools organizations use to manage knowledge (i.e., KMI);
- Learning mandate: how clearly learning is included in the scope of the work;
- Pyramid of authority: clear roles and responsible definition regarding project learning.

Sense (2003) argued that the importance of KMI is clear in literature and highlighted two additional organizational factors that play a key role in project-to-project learning: (i) how mature organizations were understanding the importance of learning in NPD (i.e., learning mandate) and how well this was communicated in organizations; and (ii) how open the organization was to learning diversity – an engineer would look at a problem differently compared to a finance analyst. The Author (2003) also highlighted two key focus areas for future research:

1. The sociological aspects of learning in project teams need to be addressed (social constructivist approach to project management practices, opposed to objectivist approach);
2. Little is known on what different forms of support for learning are required in different project types.

CoPs rely on storytelling an underlying mechanism for KSU. Aramo-Immonen and Jussila (2012) observed that storytelling plays an important role for learning and avoids errors repetition across the world. They hypothesized that storytelling could be expected to play an important role for learning in project-based organizations, also observing that little empirical evidence was available in literature on the role of storytelling to project-to-project learning in project-based organizations. The authors categorized project-based organizations storytelling in two groups:

1. Project company stories – stories about the history (e.g., foundations) or important events for the organization;
2. Project implementation stories – stories about successful or unsuccessful prior project endeavours.

While the claims presented by Aramo-Immonen and Jussila (2012) were logic and resonate with readers' personal experience, very little literature evidence and no empirical data were included to reinforce such claims. Sakellariou *et al.* (2017) also investigated the use of storytelling and metaphors, highlighting the importance of stories and metaphors for the creation of new knowledge in the front end of new product development projects and indicating that limited empirical studies existed that investigate the impact of storytelling on tacit knowledge sharing. The Authors, however, showed that the effectiveness of storytelling for the creation of new knowledge and transfer of tacit knowledge was

impacted by key factors such as the narrative skills of the storyteller, the nature and conciseness of the story, and the categories of knowledge involved.

2.3.2 Project-to-project learning

As organizations internationalize their operations and have offices in different locations, KMI adapt to the organizational structure: virtual CoPs are introduced when traditional CoPs cannot work due geographical or time zone constraints. Marabelli *et al.* (2013) explored how virtual communities of practice can support KSU in the case of distributed project teams. They focused on a multinational company replicating the implementation of an IT project in a new location. The goal of this company was to transfer the lessons learned from the first project implementation to the second project implementation. The implementation of virtual CoPs allowed to create interpersonal relationship between the project team members of the different projects. Marabelli *et al.* (2013) suggested that the successful implementation of the second project was a measure of effective KSU across the two projects.

The results presented by Marabelli *et al.* (2013) showed that it is possible to use virtual CoPs to increase KSU across projects. However, their research did not investigate if other knowledge management initiatives (i.e., re-use of experts) were used in the case study. Finally, their findings could be difficult to replicate in the case of radical product development when the second project to run is not a duplicate of the first project.

CoPs and storytelling are among the most used social KMI; however, many organizations rely on codified KMI for KSU. Lessons learned databases and post-project reviews are two of the most common codified KMI used by organizations and discussed in literature. Newell (2004) noted how organizations tend to use project reviews and information and communication technologies (ICT) to capture lessons learned from projects. While project reviews and post project reviews are often mandated and codified, debate exists in literature on whether many project are actually ever reviewed (Williams *et al.*, 2006). Newell's review of literature (2004) highlighted that PPR were considered a best

practice, while empirical evidence showed low effectiveness and low teams' satisfaction with the outcomes of PPRs. Based on the analysis of four cases studies, Newell (2004) showed that ICT-based KMI tend to be not effective, especially in the case of tacit knowledge. Three main drivers of the low effectiveness of ICT-based KMI were identified based on Newell's four-cases research (2004):

- ICT-based KSU of PPR lessons learned was generally not effective – teams did not use the databases to write or read;
- Learning occurred mostly when the knowledge receiving party had problems that could solve – i.e., learning occurred late, KMI were not able to avoid issues from arising;
- KSU usually happened within a function and not between projects.

All aspects observed by Newell have a very high importance for practitioners and show that knowledge management initiatives, traditionally designed to avoid repeating errors and encouraging knowledge sharing between projects, fail as they are only useful to share knowledge once a problem occurs, while they are not particularly effective in preventing errors repetition. Newell (2004) also observed that a key issue was the nature of knowledge teams were trying to share: teams tended to share the results of their efforts (explicit knowledge, technical solutions) and not the way (process, procedures) that allowed them to reach the results. Newell's work, however, only focused on PPR and not on other knowledge management initiatives implemented by organizations.

Antoni *et al.* (2005) focused their research on project-to-project learning (inter-project) and on the actions that an organization could take to increase project-to-project learning other than PPRs. They observed that the more complex the NPD project were, the least likely would be learning from previous projects: NPD projects were innovation projects and must supersede previous ideas and solutions to provide new products. In the

case of NPD, “previous experiences simultaneously enhance and inhibit present and future performance” (Antoni *et al.*, 2005 – p. 877). Antoni *et al.* (2005) defined *inter-project improvement* as a “systematic approach adopted to facilitate knowledge sharing across projects to result in systematic and cumulative improvement in the process and the deliverables of a project” (p. 878). They summarized the recommendations for practitioners aiming at improving project-to-project learning, including (i) the use of multiple KMI (i.e., not only PPRs); (ii) the use of a defined product development process combined with the use of a project manager; (iii) the modularization of products (i.e., braking the product down in re-usable sub-components) to maximize designs re-use and (iv) the use of all project gate reviews as learning points (not just the final gate as in the case of PPRs).

Kotnour and Vergopia (2005) focussed their research on learning-based project reviews. The key task of learning-based project reviews was to capture lessons learned *during* the execution of a project, instead of at the end of the project. PPR are very common in NPD and the literature shows that most of the lessons learned are captured after the completion of the project, when most NPD teams are often moved to a new endeavour and have limited time to dedicated to lessons learned. Capturing lessons learned during the execution of a project should help removing the time and resources availability barriers to KSU. Kotnour and Vergopia (2005) identified four levels of learning in NPD:

- Level I: project’s facts sharing;
- Level II: project’s action adjustments;
- Level III: project’s practice adjustment (at the project level);
- Level IV: organization practice adjustments.

Moreover, Kotnour and Vergopia (2005) highlighted barriers and enablers to KSU in learning-based project reviews presenting also a detailed analysis of how they worked. According to the Authors, the following six areas could be both an enabler and a barrier: (1) Learning intent; (2) People; (3) Process; (4) Tools; (5) Relationships; and (6) Projects.

Yet, while setting-up a good framework for assessing enablers and barriers to learning, they paid very little attention to which kind of learning must happen in NPD for projects to be successful. The final conclusion of their research was that NPD project teams needed to understand the barriers and enablers and calibrate the reviews, so that project learning could be maximised. The Authors' final remark was that further research is required to understand what kind of learning could occur and which tools were best suited to facilitate learning.

Relying on Takeuchi's (2006) SECI model, Goffin and Koners (2011) suggested that knowledge creation in NPD is based on a 3-step process: (1) individual learning; (2) project team learning; (3) project-to-project learning. The approach proposed by Goffin and Koners (2011) considered the use of PPRs as a tool to identify and capture the knowledge created by project teams. *Stage-gate project management* is a commonly used tool in organizations to develop a product or process and "move an idea to launch" (Cooper, 1990, p.44). Aimed at reducing the idea-to-launch time, phase-gate project management is a set of standard activities (stage) that companies have developed to complete NPD projects; the quality of the work completed at each stage is assessed by the company experts at the end of each stage (gates) (Cooper, 1990). PPRs are used at the end of each stage or project as a tool to capture learning in projects – PPRs can be considered as basic social contexts mandated by standard project management methodology. In their research, Goffin and Koners (2011) highlighted the most important learnings that project teams and individuals could get from NPD projects and the importance of tacit knowledge in many of the lessons learnt captured.

Koners and Goffin (2007) also focussed on PPRs and investigated the perception of PPRs by NPD professionals and the nature of knowledge shared in PPRs. By means of empirical research, they investigated whether PPRs could capture tacit knowledge, highlighting the importance of social interactions for KSU and showing in detail that the dissemination of lessons learned was more effective when it took place by social interaction and by co-located social networks (e.g., presentation, information discussion) rather than by formal documents and action points.

The case studies presented by Koners and Goffin (2007) showed that tacit knowledge emerged during PPRs but was hardly captured in formal documents. The Authors correlated the presence of tacit knowledge to the use of metaphors during the PPR discussions. While many occurrences of stories and metaphors were noticed during the observation PPRs, very few of these were effectively captured in written documents, indicating that tacit knowledge was potentially lost when capturing learning in written documents. While the literature shows that PPRs are an important tool for KSU, more research is required to investigate the impact and the use of other KMI. The contribution by Koners and Goffin (2007) only looked at the sharing end of knowledge sharing, not reviewing the importance of the receiving end, as also highlighted by the respondents to the structured interviews presented (p. 60):

“[...] only the results of future projects would really show whether PPRs had results in lessons learned within the organization.”

This aspect was analysed by Goffin *et al.* (2010) focusing on how teams learned in NPD projects and what knowledge was captured in PPR. This research contributed a clear definition of the difference between tacit and explicit knowledge (p. 40):

“Explicit knowledge, sometimes referred to as know-that, is knowledge that can be readily identified, explained, documented, captured in databases, and shared. Explicit knowledge is synonymous with information. Tacit knowledge, or know-how, is difficult to articulate, hard to record, based on experience, and intimately connected to the way we carry out tasks and solve problems.”

The Authors also pointed out several other KMI (i.e., mentoring) and focussed their research on PPR and on which typical lessons NPD team could learn. Moreover, they observed that eight categories of lessons learned could be identified, three of which related to tacit knowledge (2010, p. 45):

1. Budget and cost;
2. Ability to apply learning;
3. Organizational complexity;
4. Problem solving;
5. Product specifications;
6. Project objectives;
7. Project resources;
8. Project schedule.

Moreover, they identified a set of recommendation on how to run effective PPR and on how to improve the learning that was captured and codified:

1. Reinforcing the importance of lessons learned (Senior Leadership sponsorship);
2. Selecting the appropriate timing, location and duration of PPR (run PPR immediately after project closure);
3. Selecting the right participants, including as a minimum the core project team;
4. Using a facilitator (possibly external to the team);
5. Stimulating the use of stories and metaphors;
6. Linking the PPR with a social event;
7. Disseminating the results of the PPR.

The model proposed by Goffin *et al.* (2010) showed to be potentially able to improve tacit knowledge and to improve the effectiveness of PPR, also introducing the role of knowledge brokers to facilitate the transfer of knowledge from project-to-project. However, no empirical evidence that the recommendation provided alone could help to improve project-to-project learning was available. Limited information was available on how the recommendations provided might work in the case of global NPD.

The literature reviewed in the previous paragraphs showed that many Authors agreed on the importance of lessons learned from NPD project-to-project learning. Wiewiora and Murphy (2015) observed that lessons learned had a high potential for effective KSU, but the best practice lessons learned KMI were sub-optimal. They argued that empirical evidence showed that “projects rarely learn from each other, and thus tend to repeat the same mistakes resulting in unnecessary rework, errors and time overrun” (2015, p. 2). Turner *et al.* (2000) showed that, while many organizations prescribed capturing lessons learned in the closing phase of a project, often this process was only considered as a “ticking the box” activity. Moreover, Wiewiora and Murphy (2015) designed an empirical study of the root cause of poor lessons learned use in organization and to test if simplified and easy-to-use web-based software could help to improve the use of lessons learned. They took into account alternatives to lessons learned reviews, such as company intranet sites and forums, organizational directories to locate experts, etc. However, the KMI listed by them only allowed project participants to locate knowledge when needed (knowledge pull, reactive) instead of being provided with access to organizational knowledge upfront (knowledge push, proactive). They also argued that internet web tools were especially important in the case of global NPD, where opportunities for face-to-face collaborations are limited. Finally, while assessing the alternatives options to lessons learned review, they did not consider many other kinds of the knowledge management initiatives existing in literature.

While the debate is still on-going on whether tacit knowledge could be captured in written form in lessons learned databases or PPRs, if lessons learned databases and PPR transcript included more details about stories told, other KMI were shown to be better

suited for tacit knowledge sharing. Fuller *et al.* (2011) introduced the concept of *boundary objects* in the context of project learning and lessons learned. In their original definition (Star and Griesemer, 1989) boundary objects were defined as objects (p. 393):

“[...] plastic enough to adapt to local needs and the constraints of the parties using them; robust enough to maintain a common identity across sites; weakly structured in common use; abstract or concrete; given different meanings in different worlds; commonly structured making them recognisable to actors in more than one world; capable of acting as a means of translation.”

Fuller *et al.* (2011) adapted the concept of boundary object to the context of organizational learning and hypothesised that lessons learned could be considered boundary objects that “mediate information across key boundaries which exist amongst actors, in projects, across organizations and in supply chains” (p. 124). They also highlighted the issue of measuring the effectiveness of knowledge management initiatives and argued that the matter has not been covered compressively in literature: project performance was the most commonly used measure in literature, but project performance was impacted by several different factors other than project learning, which made it difficult the discovering of the causal links between knowledge governance and project learning. Following a similar approach to the one presented by Goffin *et al.* (2010), Fuller *et al.* (2011) proposed their recipe for conducting lessons learned workshop, however limited empirical evidence was provided on the effectiveness of these improved lessons learned workshops and on which type of NPD projects.

2.3.3 Summary of the literature on knowledge management initiatives

Theoretical models of knowledge sharing and learning in NPD teams highlight the importance of both personal reflection and socialization (Takeuchi, 2006; Enberg *et al.*

2006). Theoretical models like Takeuchi's SECI and subsequent evolutions showed that NPD learning occurs at individual level, project-level, and organizational level (e.g., project-to-project). NPD projects learning includes both existing organizational knowledge and new knowledge. The conflict between exploration of new knowledge and exploitation of existing knowledge was discussed in literature (Oshri, Pan and Newell, 2004; D'Armagnac, 2015). Existing theoretical models highlighted the importance of organizational structures and activities aimed at facilitating knowledge sharing (Kotnour and Landaeta, 2002). Organizational activities aimed at facilitating KUS were referred to as KMI.

Many different KMI exist and are used depending on the type of knowledge required by NPD teams and on the structure of the organization running NPD projects (Prencipe and Tell, 2001; Frank and Echeveste, 2012; Van Waveren *et al.*, 2020). While different categorizations of KMI exist, a clear distinction must be made between codified and social KMI. This distinction depends on whether KMI rely on databases and IT system to share knowledge or are based on social interaction among NPD professionals. Codified KMI initiatives were shown to be well suited for capturing explicit technical knowledge but less effective for capturing tacit knowledge. Martini and Pellegrini (2005) argued that KMI should be selected depending on the type of business organizations – for instance, codified KMI are well-suited for organizations operating in complex manufacturing environments. Other scholars argued that the effectiveness of KSU is independent on the KMI used (Enberg *et al.*, 2006). However, the empirical evidence provided was limited. Many authors empirically investigated the effectiveness of KSU and KMI in NPD (for instance Landaeta, 2008, and Ajmal *et al.*, 2010). Yet, empirical research only measured KSU indirectly either in terms of projects success or financial returns, as knowledge transfer was seen as very difficult to measure directly (Fuller *et al.*, 2011).

KMI were identified as factors influencing KSU in NPD. The literature discussed the importance of both social and codified (IT based) KMI. Empirical evidence showed that poor quality IT based on KMI negatively impacted on KSU. However, little empirical work investigated the role of social KMI as facilitators to KSU, especially in global NPD. The

influence of both social and codified (for instance, IT based) KMI on KSU was identified in literature (Kotnour and Vergopia, 2005; Frank and Ribeiro, 2014); however, none of the works reviewed in this chapter discussed how the barriers and enablers created by KMI might change in global NPD, even though global NPD experience lower trust, familiarity and propinquity compared to local NPD projects and therefore might experience stronger barriers to KSU.

The influence of NPD complexity on KMI was highlighted by literature (Chirumalla, 2014), but very limited work was done that discussed how KMI should change as the NPD project complexity changes. Limited research exists to understand if the higher need for knowledge of radical innovation NPD projects (compared to incremental NPD) translates in a higher use of KMI; or if, on the contrary, KMI were less used in more complex projects, as NPD teams working on radical innovation projects need knowledge that is not found in the organizations and needed to create new knowledge.

Among the KMI discussed in literature, lessons learned databases were amongst the most discussed codified KMI (Chirumalla, 2014). Project reviews and CoPs were the most discussed social KMI. Project reviews were investigated, and the literature showed that different type had different KSU potential (Antoni *et al.*, 2005); Kotnour and Vergopia, 2005; Goffin and Koners, 2011). However, empirical research showed that the lesson learned captured and codified in the project review focused mostly on explicit knowledge. Little research investigated how the knowledge captured in project reviews was used by other projects.

CoPs were the most studied social KMI (see for instance Wenger, 2000; Sense, 2003; Marabelli *et al.*, 2013; Wiewiora and Murphy, 2015). Some research was done on virtual CoPs (Marabelli *et al.*, 2013) showing that they were effective for project-to-project KSU. However, the empirical evidence was limited to local incremental NPD.

Existing studies also investigated different configurations of multi-project NPD in PBO organizations (for instance Nobeoka and Cusumano, 1997), focusing on component and design re-use (i.e., explicit knowledge). The available studies showed that

organizations resorted to parallel, subsequent NPD or phased rollouts (Bower and Walker, 2007). The literature also showed that knowledge needs and KSU change, depending on the NPD configuration selected by the organization and the degrees of innovation of the NPD projects. Yet, very limited empirical research was done on the changes in categorized NPD configurations in the case of global NPD.

Table 2.5 – Section 2.3 SLR findings and open questions

Sub-domain	SLR findings	Reference questions	Open
Tools and methodologies for KSU.	19 KMI are described in literature for KSU in NPD.	Prencipe and Tell (2001); Van Waveren <i>et al.</i> (2020).	Which KMI are used in the case of global NPD?
			Which KMI are most effective for KSU in global NPD?
Tools and methodologies for KSU.	KMI can be categorized in social and codified KMI.	Martini and Pellegrini (2005); Williams (2008); Iftikhar and Ahola (2020).	Are social KMI effective in the case of global NPD?
Tools and methodologies for KSU.	Each KMI category is more effective for a specific type of knowledge.	Newell (2005); Williams (2008) Frank and Echeveste (2012); Mathrani, and Edwards (2020)	Which KMI are most effective for technical and non-technical KSU in global NPD?

Table 2.5 uses the same format used in Sections 2.2.1 and 2.3.1 to summarize the findings and the open questions from Section 2.3. It shows that few authors have listed and analysed knowledge management initiatives as methods for facilitating project-to-project learning showing that different categories of knowledge management initiatives are more effective for specific types of knowledge. Table 2.5 shows that very little information exists in literature about the use of KMI in global NPD and that four questions remain unanswered by the SLR.

Section 2.4 discusses the findings of SLR and translates the findings and open questions from Sections 2.1 to 2.3 into a research question.

2.4 Discussion of the Systematic Literature Review

A SLR was set up with the main goal of answering the two literature review questions LRQ1 and LRQ2, presented at the beginning of Chapter 2. LRQ1 and LRQ2 were designed to shed light on the available information on how knowledge is shared and used in global NPD. The review showed that, while little is known and very little empirical studies exist on KSU in global NPD, three main sub-domains clearly emerged from the reviewed literature:

- The types of knowledge needed and created by NPD projects and how these are impacted by the degree of innovation of the NPD projects;
- The impact that cultural and social factors have on KSU;
- The mechanisms and tools developed for facilitating KSU in NPD (i.e., knowledge management initiatives).

This section summarized the findings in each of the three sub-domains, highlighting what is known and which gaps remain in the case of global NPD. The SLR presented in this chapter showed that four main theories are relevant and used in the context of global project to project learning :

- Nonaka and Takeuchi's (1995) organizational knowledge creation theory;
- Lave and Wenger's (1991) learning theory on situated knowledge;
- Szulanski's (2003) theory on the stickiness of knowledge;
- Cohen and Levinthal's (1990) absorptive capacity theory.

It is important to highlight the key theories that underpin the research to help better design the research and to build the framework of the analysis and understand to the outcomes of the research. In particular, the organizational knowledge creation theory (Nonaka and Takeuchi, 1995) is essential to understanding the importance of tacit and explicit knowledge, the role they play through SECI and the different ontological levels in knowledge sharing between individuals and projects (individual, group, organization levels). Similarly, the situated knowledge theory (Lave and Wenger, 1991) is the key to understanding the group learning dynamics in professional environments. The four features of learning highlighted by the situated learning theory (learning is situated in practice, is social, is a “process of becoming” and is a dynamic process) are needed to understand learning in NPD projects.

The previous sections highlighted how many barriers exist to knowledge sharing. The main theory used to explain these barriers is the theory on the stickiness of knowledge (Szulanski, 2003). Understanding the motivational, cognitive and structural barrier to knowledge sharing is needed when studying knowledge sharing in global NPD: the motivational, cognitive and structural barriers present in NPD projects are further amplified in the case of global projects. Finally, the absorptive capacity theory is useful to understand how, despite the challenges presented by the stickiness of knowledge, organizations manage to learn: it is possible to understand this process by assessing the acquisition and assimilation capacity of an organization and their ability to exploit the knowledge they acquired. This is particularly important when discussing about the knowledge needs of global NPD projects.

These four theories are used to develop the project-to-project learning framework that underlies the research presented in this Thesis.

The review of the literature in Sections 2.1 to 2.3 showed the importance of NPD and knowledge for firms and organizations (Antoni and Sense, 2001; Ayas, 1998, Baxter *et al.*, 2013). This follows from the important role played by NPD projects in securing competitive advantage (Richtnér *et al.*, 2013). Therefore, the ability of an organization to capture the knowledge created by project teams throughout the project life cycle and to

share it with other projects is critical to the success of new projects and to the growth of organizations (Goffin and Koners, 2011; Baxter *et al.*, 2013; Richtnér *et al.*, 2013).

Knowledge is widely identified in literature as one of the most important assets for firms and organizations (Goffin and Koners, 2011; Baxter *et al.*, 2013). The importance of both explicit and tacit components of knowledge for NPD projects was also discussed extensively (Takeuchi, 1996; Holste and Fields, 2009; Grant, 1996). Knowledge can be categorized by its content (customers, stakeholders, the state of technology, suppliers' capability, etc.) or by its form (explicit or tacit, personal or organizational, codified or social – Tell, 2004 and Enberg *et al.*, 2006). The literature showed that knowledge is both a key input and an output of product development. Four categories of knowledge were selected as basis for the research and definition of product knowledge, process knowledge, socio-political knowledge and knowledge of suppliers were introduced.

Different models exist that explain how NPD teams and organizations learn. Antoni and Sense (2001) observed that projects are temporary endeavours and tend not to “establish systems or frameworks to actively facilitate and optimize their learning within or between projects” (p. 4): the lack of formal frameworks for facilitating learning in projects requires the implementation of alternative KMI. Prencipe and Tell (2001) observed that firms and organizations use different ways to create, share and use knowledge in NPD projects. The importance of organizational culture (such as care and trust relationships, and social interactions among project team members) for KSU was also discussed and analysed in literature (Holste and Fields, 2009; Lucas, 2005).

As a major part of the knowledge created by NPD teams is tacit, it is extremely important to understand the role that social interaction plays in knowledge sharing in NPD projects. NPD practitioners and managers need to integrate different specialized knowledge for NPD projects to be successful (Grant, 1996), therefore NPD project team are cross-functional. The cultural and knowledge background of NPD team members is a potential barrier for KSU (Kleinsmann and Valkenburg, 2005). Trust, familiarity and propinquity are key factors that influence project-to-project learning in NPD (see for instance Ali *et al.* 2018, and Grant, 1996) and building trust and familiarity is more difficult in the case of

globally distributed teams (Paulin and Winroth, 2013). However, as global NPD teams have a broader access to local customer needs and global experts (Sole and Edmondson, 2001), global NPD team more and more used firms and organizations to run NPD projects. Due to the limited face-to-face time, transfer of tacit knowledge is particularly challenging for global NPD projects. Limited research is available on how non-technical knowledge can be shared in global teams and limited recommendation are available for NPD managers and practitioners wanting to improve knowledge sharing and use in global NPD teams and more research is required (Baxter *et al.*, 2013).

The review of literature showed that, to date, there is still an open controversy on tacit knowledge and knowledge transfer, mostly focused on whether tacit knowledge can be converted into explicit knowledge (Nonaka and von Krogh, 2009). Hedesstrom and Whitley (2000) pointed out that the concept of tacit knowledge was used in many different and contrasting ways in knowledge management literature. While Nonaka (1996) argued that tacit knowledge can be translated into explicit knowledge, others (Polanyi, 1966) suggested that, due to its very nature, tacit knowledge cannot be transferred. Tacit knowledge was often defined as knowledge that cannot be captured into written form or shows many difficulties in being captured into written form (Polanyi, 1966, Holste and Fields, 2009). The potential conflict between exploration of new knowledge and exploitation of existing knowledge was also discussed in literature (Oshri, Pan and Newell, 2004; D'Armagnac, 2015) and the literature highlighted that organizations must balance the risk of constantly rediscovering or reinventing knowledge with the risk of blocking innovation if they rely too heavily on knowledge re-use.

2.4.1 Summary of KMI studies

The reviewed theoretical models highlighted the importance of organizational structures and activities aimed at facilitating knowledge sharing (Kotnour and Landaeta, 2002). Firms and organizations employ KMI to facilitate knowledge sharing in NPD projects. Table 2.6 lists the key management initiatives. It includes only KMI that are most discussed either in

theoretical or empirical studies related to KSU in global NPD. KMI that are only mentioned in literature (such as apprenticeships, brainstorming sessions, e-mail communications), but not thoroughly investigated in NPD, are not included.

The type of supporting evidence available to substantiate the impact of each KMI on tacit / explicit KSU for project learning, project-to-project learning and global NPD is rated using the following scale, from one to three squares:

- □ □ – one square indicates that the impact of the KMI was briefly discussed in literature;
- ■ □ – two squares indicate that the impact of the KMI was extensively discussed;
- ■ E – the letter “E” indicates that the impact of the KMI was shown in empirical studies.

A single square is awarded to KMI that were only briefly mentioned in literature, but no theoretical or empirical evidence was available to show the effectiveness of either tacit or explicit knowledge sharing and use. “Project management camps” offer a good example of KMI awarded with a single square: Prencipe and Tell (2001) listed Project manager camps as one of the existing “learning process” for project-to-project learning but did not detail why and how they could be useful for KSU.

Table 2.6 – Summary of depth theoretical and empirical works on KMI and their effect on KSU in NPD and global NPD

Knowledge management initiative	Key references	Explicit KSU effectiveness		Tacit KSU effectiveness		Global NPD KSU effectiveness
		Project learning	P2P learning	Project learning	P2P learning	
Feedback loops	Chirumalla (2017)	■ ■ □	■ ■ □			
Boundary objects	Maaninen-Olsson <i>et al.</i> (2008), Di Maio (2013), Butters and Duryan (2019) +2	■ ■ □		■ □ □		
Brainstorming sessions	Prencipe and Tell (2001), Van Waveren <i>et al.</i> (2020)					
Communities of practice	Wenger (2000), Sense (2003), Marabelli <i>et al.</i> (2013) +7	■ ■ E	■ ■ E	■ ■ E	■ ■ E	■ ■ E
Design / components re-use	Nobeoka and Cusumano (1997), Oshri <i>et al.</i> (2004), Antoni <i>et al.</i> (2005) +1	■ ■ E	■ ■ E			
Expert yellow pages	Van Waveren <i>et al.</i> (2020) +1					
Informal / face-to-face communications	D'Armagnac (2015) +2	■ ■ E	■ ■ E	■ ■ E	■ ■ E	
Job rotations	Van Waveren <i>et al.</i> (2020), Ortega (2001)					
Lessons learnt databases	Chirumalla (2014), D'Armagnac (2015), Wiewiora and Murphy (2015) +2	■ ■ E	■ ■ E			
Mentoring / training	Prencipe and Tell (2001), Freyens and Martin (2007), D'Armagnac (2015) +1	■ ■ E	■ ■ E			
Middle management brokering	Prencipe and Tell (2001), Costanzo and Tzoumpa (2008)	■ ■ E		■ ■ □		
Post project reviews	Newell (2004), Williams (2007), Koners and Goffin (2007) +3	■ ■ E		■ ■ E		
Project manager camps	Prencipe and Tell (2001)		■ □ □		■ □ □	
Project reviews	Prencipe and Tell (2001), Antoni <i>et al.</i> (2005), Kotnour and Vergopia (2005) +3	■ ■ □	■ ■ □			
Relocation of offices	Prencipe and Tell (2001)					
Re-use of experts	Markus (2001), Edwards (2015), D'Armagnac (2015) +1	■ ■ E	■ ■ E	■ ■ ■	■ ■ ■	
Storytelling	Aramo-Iammonen and Jussila (2012), Sakellariou <i>et al.</i> (2017)	■ ■ □	■ ■ □	■ ■ ■	■ ■ □	
Templates / guidelines	Prencipe and Tell (2001), Schulze <i>et al.</i> (2014)					
Wiki / repositories (ICT)	Martini and Pellegrini (2005), Wiewiora and Murphy (2015)	■ ■ ■	■ ■ ■			

■ □ □ Limited theoretical discussion
 ■ ■ □ Extensive theoretical discussion
 ■ ■ E Empirical studies

Three squares are awarded when empirical evidence showed that the KMI is impacting KSU for either explicit or tacit KSU. “Components and design re-use” are a good example of a KMI awarded with an “E”: Oshri, Pan and Newell (2004) ran a case study investigating the impact of components and design re-use in a firm operating in the aerospace sector, by interviewing NPD practitioners and observing dynamics of multiple NPD teams.

Table 2.7 summarise the qualitative and quantitative assessments provided in Table 2.4 and Table 2.6. Moreover, it helps to identify those KMI that were investigated by empirical studies and KMI that lack empirical research. Compared to the work of previous authors that reviews existing KMI for NPD projects (e.g., Van Waveren et al., 2020), Table 2.7 details if theoretical or empirical evidence exists in literature regarding the effectiveness of each KMI on explicit or tacit knowledge sharing within projects or from project to project. It also tracks if theoretical or empirical evidence exists on the impact of each KMI for KSU in global NPD.

Practitioners and academics clearly highlighted a distinction between radical and incremental NPD, depending on the degree of innovation required to develop the products. The SLR showed that scholars pointed out that knowledge sharing needs of incremental and radical NPD projects might be different (Nobeoka and Cusumao. 1997; Newell, 2005, Enberg et al., 2006). While some argued that KMI is not needed in the case on incremental NPD (Enberg et al., 2006), little empirical evidence is available on the knowledge sharing needs and inhibitors to address deepening on the degree of innovation of the project.

Table 2.7 – Summary of the assessment of literature on KMI and their effect on KSU in NPD and global NPD

Knowledge management initiative	Key references	Explicit KSU effectiveness		Tacit KSU effectiveness		Global NPD KSU effectiveness
		Project learning	P2P learning	Project learning	P2P learning	
Feedback loops	Chirumalla (2017)	●○○ ■□□	●○○ ■□□			
Boundary objects	Maaninen-Olsson <i>et al.</i> (2008), Di Maio (2013), Butters and Duryan (2019) +2	●●○ ■□□		●○○ ■□□		
Brainstorming sessions	Prencipe and Tell (2001), Van Waveren <i>et al.</i> (2020)					
Communities of practice	Wenger (2000), Sense (2003), Marabelli <i>et al.</i> (2013) +7	●●● ■□ E	●●● ■□ E	●●○ ■□□	●●○ ■□□	●○○ ■□ E
Design / components re-use	Nobeoka and Cusumano (1997), Oshri <i>et al.</i> (2004), Antoni <i>et al.</i> (2005) +1	●●○ ■□ E	●●○ ■□ E			
Expert yellow pages	Van Waveren <i>et al.</i> (2020) +1					
Informal / face-to-face communications	D’Armagnac (2015) +2	●○○ ■□ E	●○○ ■□ E	●○○ ■□ E	●○○ ■□ E	
Job rotations	Van Waveren <i>et al.</i> (2020), Ortega (2001)					
Lessons learnt databases	Chirumalla (2014), D’Armagnac (2015), Wiewiora and Murphy (2015) +2	●●○ ■□ E	●●○ ■□ E			
Mentoring / training	Prencipe and Tell (2001), Freyens and Martin (2007), D’Armagnac (2015) +1	●●○ ■□ E	●●○ ■□ E			
Middle management brokering	Prencipe and Tell (2001), Costanzo and Tzoumpa (2008)	●○○ ■□□		●○○ ■□□		
Post project reviews	Newell (2004), Williams (2007), Koners and Goffin (2007) +3	●●○ ■□ E		●●○ ■□ E		
Project manager camps	Prencipe and Tell (2001)		●○○ ■□□		●○○ ■□□	
Project reviews	Prencipe and Tell (2001), Antoni <i>et al.</i> (2005), Kotnour and Vergopia (2005) +3	●●○ ■□□	●●○ ■□□			
Relocation of offices	Prencipe and Tell (2001)					
Re-use of experts	Markus (2001), Edwards (2015), D’Armagnac (2015) +1	●●○ ■□ E	●○○ ■□ E	●○○ ■□ E	●○○ ■□ E	
Storytelling	Aramo-Iammonen and Jussila (2012), Sakellariou <i>et al.</i> (2017)	●○○ ■□□	●○○ ■□□	●○○ ■□ E	●○○ ■□□	
Templates / guidelines	Prencipe and Tell (2001), Schulze <i>et al.</i> (2014)					
Wiki / repositories (ICT)	Martini and Pellegrini (2005), Wiewiora and Murphy (2015)	●○○ ■□ E	●○○ ■□ E			

●○○ <3 papers
●●○ 3 ≤ papers ≤ 5
●●● Papers > 5

■□□ Limited theoretical discussion
■□□ Extensive theoretical discussion
■□ E Empirical studies

Finally, the review showed that no agreed method for measuring knowledge transfer existed in literature and most of the research relied on project teams' assessment of what degree of KSU occurred in the project lifecycle. In some cases (Nobeoka and Cusumano, 1997; Marabelli et al. 2013) project success or sales were considered as a measure of effective project-to-project KSU, however, as several authors suggested, many factors other than project learning might include impact project success and sales. Two different categorizations of KMI were proposed and will be employed in this thesis:

- KMI might be structured or social, depending on how many KMI rely on unstructured, interpersonal communication for their effectiveness. So, informal, face-to-face communication and storytelling are social KMI, while formal project reviews and lessons learned databases are structured KMI;
- KMI might be employee-led or company-led, depending on the level of effort organizations need to employ in terms of process, tools and procedures to facilitate KMI. Job rotations and project reviews are good examples of company-led KMI; informal/face-to-face communications and brainstorming sessions are employee-led KMI.

2.4.2 Empirical research on KMI

While Table 2.7 helped understanding the empirical evidence available on each KMI, it did not help providing a full picture of the empirical research on the use of KMI by KMI categories (social vs codified) or project degree of innovation (radical vs incremental NPD). Figure 2.7 offers a summary of the content of the papers identified by the SLR and shows how the majority of the papers only looked at technical knowledge sharing (37 papers), while only 26 analyse both technical and know-how (tacit) knowledge sharing and use. Similarly, most of the works identified by the SLR focus about codified KMI (28

papers), while 23 papers explore social KMI used for sharing technical knowledge and only 9 papers took into account social KMI employed to share technical and know-how knowledge.

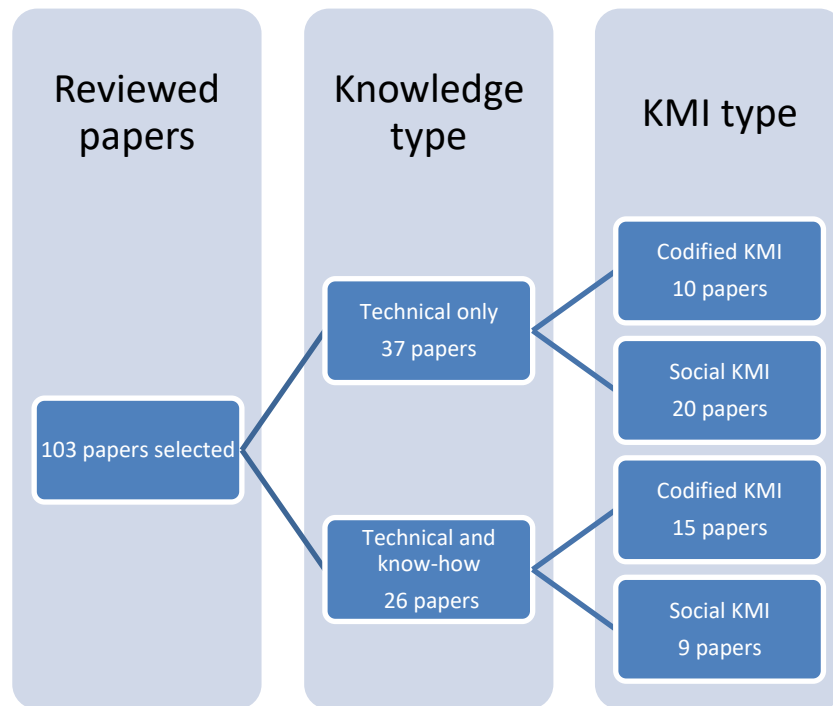


Figure 2.7 - Breakdown of the SLR papers by type of knowledge

Building on the breakdown presented in Figure 2.7, Figure 2.8 and Figure 2.9 detail the empirical or theoretical nature of the papers.

Figure 2.8 confirms the findings of Table 2.7 that the research on the use of KMI in global NPD projects is limited: only two empirical works were found covering only codified KMI, and of the two only one looked at both technical and know-how knowledge. No empirical research on the impact of social KMI for global NPD was found. Similarly, Figure 2.9 shows that very limited empirical research explores the impact of running radical innovation or incremental on KMI for KSU in NPD.

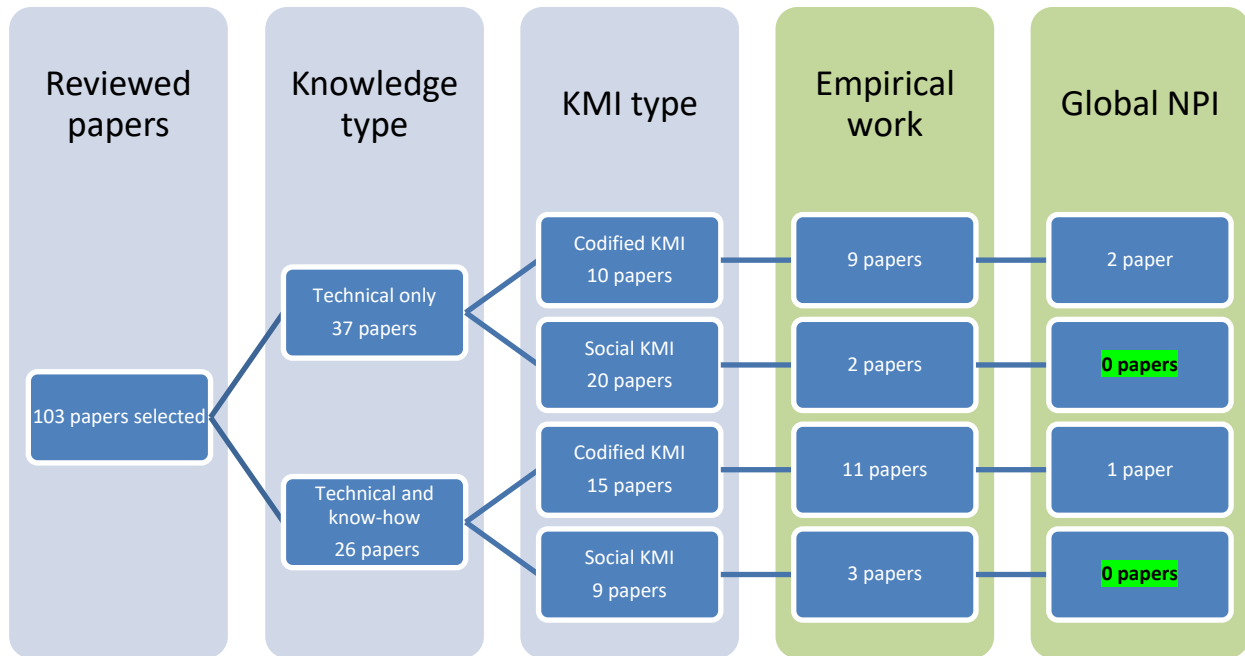


Figure 2.8 – Breakdown of empirical research in the SLR papers discussing global NPD

The SLR showed that many theoretical models described the potential interactions of different factors (inhibitors, barriers and facilitators) impacting on KSU. It also showed that tools (i.e., knowledge management initiative or knowledge governance) exist to reduce the barriers or to improve the effectiveness of KSU, while very limited research exists that investigates barriers and facilitators to KSU in the case of global NPD. The research on global NPD projects is particularly interesting considering that it is expected that global NPD will have lower trust, familiarity and propinquity compared to local NPD projects – all facilitators of KSU identified in literature.

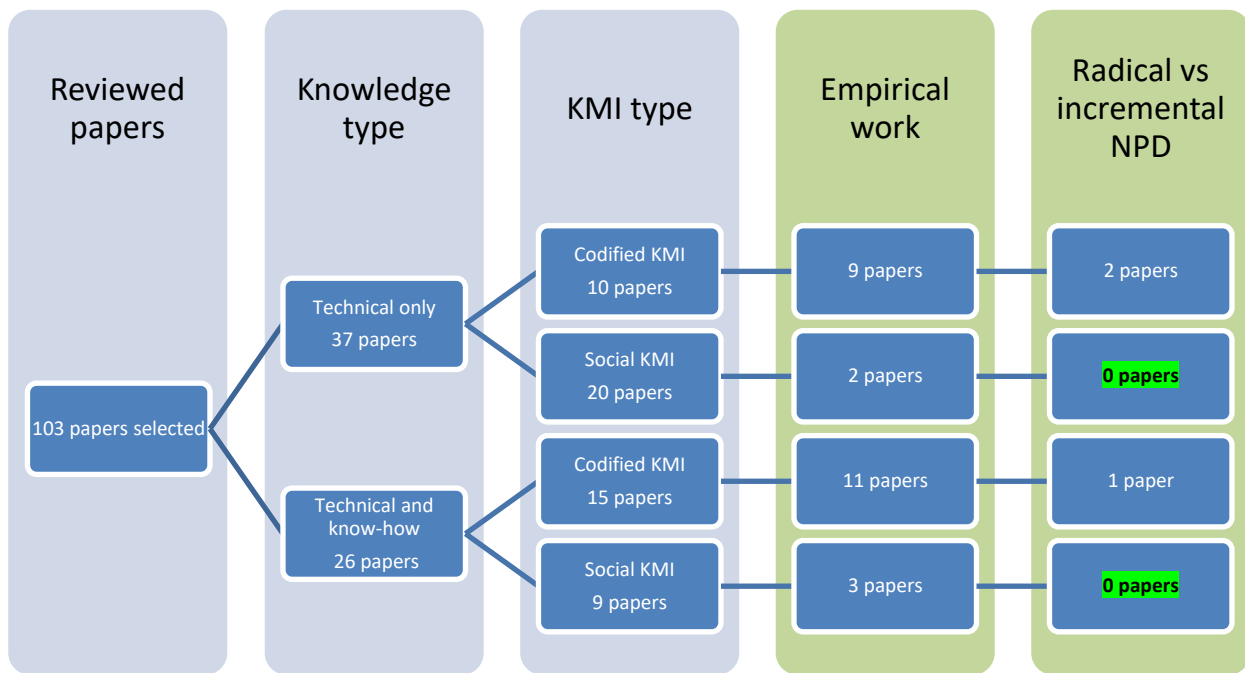


Figure 2.9 – Breakdown of empirical research in the SLR papers discussing radical NPD

2.4.3 From SLR to research questions

The results of the SLR showed that gaps exist and little guidance is given to practitioners and managers of global NPD projects on when to invest on KMI and on which KMI can help to reduce barriers or enhance KSU in case of radical global NPD projects. Table 2.8 and Table 2.9 were designed to summarize the findings of the SLR and NPD and the gaps in the understanding of KSU in global NPD. Table 2.8 summarizes the key findings from the SLR, based on the three subdomains introduced at the beginning of Section 2.4. Table 2.8 is directly derived by combining the contents of the “findings” columns of Table 2.1, Table 2.3 and Table 2.5.

Table 2.8 – Summary of SLR findings

Sec.	Domain	SLR findings	Reference
2.1	Knowledge needs and knowledge generated in NPD projects.	Knowledge in NPD programs can be divided in four categories (product, process, socio-political and third-party knowledge).	Enberg <i>et al.</i> (2006); Marabelli <i>et al.</i> (2013); Bower (2007); Altman and Engberg (2016); Zhang and Min, (2021); Dastaki <i>et al.</i> (2022).
		NPD projects need access to both tacit and explicit knowledge to be successful.	Nonaka (1996); Grant (1996); Newell (2004); Holste and Fields (2009); Goffin <i>et al.</i> (2010); Zhang and Min, (2019); Sikombe and Phiri, (2019); Raudberget and Wlazlak, (2022); Idreesa <i>et al.</i> , (2023).
		The types of knowledge needed and created by NPD projects are impacted by the degree of innovation of the NPD projects (radical vs incremental NPD).	Bartezzaghi <i>et al.</i> (1997); Nobeoka and Consumano (1997); Enberg <i>et al.</i> (2006); Jugend <i>et al.</i> (2018).
2.2	Trust, barriers and geographical distribution challenges.	Significant barriers exist to KSU in NPD, (cultural background social interactions, trust, communication, proximity, stability etc.)	Paulin and Winroth (2013); Frank <i>et al.</i> (2014); Chirumalla (2014); Butters and Duryan (2019); Mathrani and Edwards (2020); Haug (2022).
		The use of global NPD is continuing to increase. Global NPD projects do not show performance issues compared to local NPD.	Sole and Edmondson, 2002; Salomo <i>et al.</i> (2010); Pavanelli Stefanovitz and Jabbour (2022); le Duc and Gammeltoft, (2023).
2.3	Tools and methodologies for KSU.	19 KMI are described in literature for KSU in NPD.	Prencipe and Tell (2001); Van Waveren <i>et al.</i> (2020).
		KMI can be categorized in social and codified KMI.	Martini and Pellegrini (2005); Williams (2008); Iftikhar and Ahola (2020).
		Each KMI category is more effective for a specific type of knowledge.	Martini and Pellegrini (2005); Williams (2008); Iftikhar and Ahola (2020).

Similarly, Table 2.9 summarizes the open questions from the literature review which are directly derived by combining the contents of the “open questions” columns of Table 2.1, Table 2.3 and Table 2.5.

Table 2.9 – Summary of SLR open questions

Sec.	Domain	SLR open questions	SLR Q	Addressed?
2.1	Knowledge needs and knowledge generated in NPD projects.	Do global NPD projects have different knowledge needs than co-located NPD projects?	2.1.1	
		Do global NPD project have the same access to tacit knowledge as co-located NPD projects?	2.1.2	
		Are knowledge needs of global NPD programs also impacted the degree of innovation of the project?	2.1.3	✓
2.2	Organizational culture and social factors impact on KSU.	What additional barriers do global NPD projects face, compared to co-located NPD projects?	2.2.1	
2.3	Tools and methodologies for KSU.	Which KMI are used in the case of global NPD?	2.3.1	✓
		Which KMI are most effective for KSU in global NPD?	2.3.2	✓
		Are social KMI effective in the case of global NPD?	2.3.3	✓
		Which KMI are most effective for technical non-technical KSU in global NPD?	2.3.4	✓

A total of eight open questions pertaining global NPD remain unanswered from the SLR. The empirical research proposed in this Thesis intends to contribute to closing the knowledge gap on project-to-project learning in global NPD as summarized in Table 2.9. Out of the eight open questions, the research will only address five. A “tick” sign in the fourth column of Table 2.9 signals that the research will tackle the open question from the literature review. While the research methodology and designs will be introduced in Chapters 3 and 4, it is important to anticipate that the research will focus exclusively on global NPD projects and will not be able to answer comparative questions on local NPD (i.e., SLR question 2.1.1, 2.1.2 and 2.2.1).

The following research and sub-research questions will guide the empirical research:

RQ: In the context of global NPD, which knowledge management initiatives are most often utilised / considered by practitioners to be the most effective and why?

In particular, SRQ1 considers SLR questions 2.3.1, 2.3.2 and 2.3.4, while SRQ1 considers SLR questions 2.3.1, 2.3.2 and 2.1.3.

SRQ1: Which knowledge management initiatives are most used and considered most effective for **tacit knowledge** sharing and which for **explicit knowledge** sharing?

SRQ2: Which knowledge management initiatives are most used and considered most effective for **incremental NPD** and which for **radical NPD** project-to-project learning?

Table 2.9 shows how open questions arise from the SLR on project-to-project learning in global NPD. Table 2.4, Figure 2.8 and Figure 2.9 point out the limited empirical research around the open question listed in Table 2.9. Figure 2.10 visually represents how the research questions directly link to empirical research gaps. Arrows are used in Figure 2.10 to highlight how findings and gaps in literature are translated into research questions.

Overall, these are exploratory research questions that aim at investigating which KMI are commonly used by NPD practitioners in the case of globally dispersed NPD. Table 2.4 shows that the effectiveness of only one KMI in global NPD is discussed in literature and Figure 2.8 shows that only one study empirically investigated KSU in global NPD.

SRQ1 aims to investigate which KMI NPD practitioners consider most effective for tacit and explicit KSU in global NPD for project-to-project learning. Table 2.4 shows that limited research exists covering only few KMI in the case of explicit knowledge, while very limited research investigates the effectiveness of KMI for tacit knowledge: most of the existing research tends to cover technical knowledge.

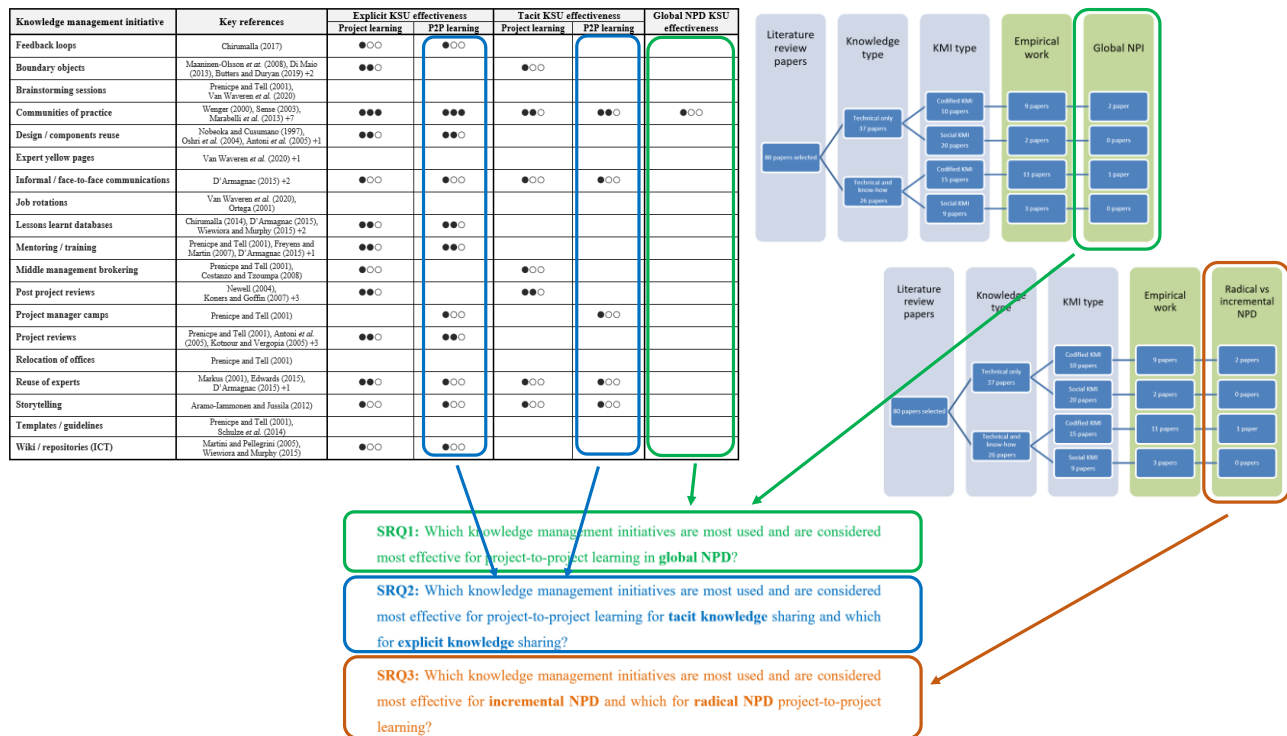


Figure 2.10 – Further research focus domain and SLR links

Finally, SRQ2 investigates the differences between KMI used for incremental and radical NPD. Figure 2.9 shows that very few empirical studies exist that cover the differences of KMI for radical and incremental NPD. This is a particularly interesting finding, as key KM literature highlights that KMI need to be tailored for the degree of innovation of the NPD projects and that significant differences exist between incremental and radical NPD projects (Nobeoka and Consumano, 1997; Newell, 2005).

2.4.4 Project-to-project learning – local NPD

A 2x2 framework of project-to-project learning in global NPD was created in order to guide the empirical research for answering the RQ and sub-research questions. The 2x2 framework of the project-to-project learning in global NPD will be used to derive

propositions on project-to-project learning in global NPD that the empirical research will confirm or refute. The first step needed for the creation of a global NPD project-to-project learning framework is the creation of a 2x2 framework of project-to-project learning in local NPD: the SLR shows that the learning dynamics of local project-to-project learning are better known than those of global NPD; so building a framework of local NPD based on literature evidence is easier, compared to building directly a framework of global NPD project-to-project learning. Project degree of innovation and tacit or explicit nature of knowledge were selected as the two key dimensions of the framework.

- Project degree of innovation dimension: radical vs local NPD;
- Knowledge type dimensions: explicit vs tacit knowledge.

The NPD project degree of innovation was selected as first dimension of the framework (horizontal dimension) because the SLR and the Author's professional experience showed that the knowledge needs and KMI of radical and incremental NPD projects are significantly different. The knowledge type was selected as the second dimension of the framework (vertical dimension) as the SLR showed that KMI target specific kind of knowledge and are more effective for specific kind of knowledge (e.g., some KMI, like lessons learned databases, are not effective for transferring tacit knowledge). The 2x2 framework presented in Table 2.10 shows what is the key knowledge source and the type of KMI used for the four combinations of project degree of innovation and knowledge types, based on the literature finding reported in Table 2.7. The following definitions are used in this Thesis for KMI structure (structured vs social) and formality (company-led vs informal):

- **Structured KMI:** are KMI that extensively rely on written documents, data and drawings to store knowledge. A good example of structure KMI are lessons learned databases, design re-use, templates, guidelines, etc.
- **Social KMI:** are KMI that mostly rely on interpersonal interactions as a means to transfer knowledge between individuals or groups of individuals. Examples of social KMI are experts re-use, communities of practice, brainstorming sessions, etc.
- **Company-led KMI:** are KMI that are formally designed and implemented by the organization. Company-led KMI are prescribed by company procedures and rely on enforcement by company management. Without company enforcement, the use of the KMI would be abandoned.
- **Informal KMI:** are KMI that are spontaneously or semi-spontaneously run by NPD practitioners in the organization. The key drivers for informal KMI are not company procedures or requirements, but the real knowledge need of the NPD practitioners. Informal KMI are not dictated by managers of the companies and self-sustaining but are by definition less structured and predictable than company-led KMI.

Table 2.10 highlights how the different needs of incremental and radical NPD drive the deployment of different KMI to address internal or external knowledge needs, respectively. Incremental NPD projects, where new projects only have minor product and project differences compared to previous projects, extensively rely on existing organizational knowledge. To leverage existing organizational knowledge, limited company-led formal and social KMI are used to encourage KSU of explicit and tacit knowledge, respectively.

Table 2.10 also includes a reminder of empirical evidence available in literature to support the use of KMI following the summary presented in Table 2.7. This is included in brackets for each KMI type.

Table 2.10 – Project-to-project in local NPD learning 2x2 framework

Local NPD projects		
	Incremental NPD	Radical NPD
	Explicit knowledge	Radical NPD
Explicit knowledge	Key K. source Internal	Key K. source External
	KMI focus Structured; company-led (discussed and in use)	KMI focus Structured/social; company-led (discussed and in use)
Tacit knowledge	Key K. source Internal	Key K. source Internal
	KMI focus Social; company-led (discussed and in use)	KMI focus Social; company-led/informal (discussed and in use)

Radical NPD projects are expected to need extensive knowledge external to the organization. The explicit knowledge these projects need can either be on a newly developed technological process, on new customer needs and market trends or on complete products. Company-led structured KMI are used to facilitate the acquisition of the required knowledge. In the case of tacit knowledge, the knowledge needs of local, radical NPD projects are very similar to those of local incremental NPD projects and tend to use social, company- or employee-led KMI.

2.4.5 Project-to-project learning framework – global NPD

Table 2.4 showed how very little is known about KMI in global NPD. This is reflected in Table 2.11: when adapting the project-to-project learning framework to global NPD, it is impossible to complete the framework based on the outcomes of the SLR. A question mark in Table 2.11 indicates a knowledge gap in literature and an area of the project-to-project learning framework undefined in the case of global NPD.

Table 2.11 – Project-to-project in global NPD learning 2x2 framework

Global NPD projects		Incremental NPD	Radical NPD
Explicit knowledge	Key K. source	Internal	?
	KMI focus	Structured; company-led (briefly discussed)	?
Tacit knowledge	Key K. source	?	?
	KMI focus	?	?

Assumptions must be made to fill the project-to-project learning framework for global NPD projects, in the form of propositions.

2.4.6 Research propositions

While extensive gaps exist on the KSU dynamics of global NPD projects, and especially on radical global NPD projects, some initial propositions can be derived, based on the existing literature on local NPD KSU and global NPD. In particular the following five proposition can be made (P1 – P5):

- P1:** In **radical** global NPD, the key **explicit** knowledge sources are external to the organization running the project;
- P2:** In **radical** global NPD, formal and company-led KMI are expected to be most used and effective for knowledge sharing;
- P3:** In **radical** global NPD, social KMI are expected to show limited effectiveness due to the geographical dispersion of the teams;
- P4:** In both **incremental** and **radical** global NPD, the key source for **tacit** knowledge is internal to the organization running the project;
- P5:** However, social and employee-led KMI are expected to be less used and effective in the case of global NPD, compared to local NPD.

The above propositions on KMI for global NPD projects are used in Table 2.12 to populate gaps in the project-to-project learning in global framework presented in Table 2.11, following the 2x2 framework initially introduced in Table 2.10.

Table 2.12 – Project-to-project in global NPD learning 2x2 framework updated with propositions

Global NPD projects		
	Incremental NPD	Radical NPD
Explicit knowledge	Key K. source Internal	Key K. source External
	KMI focus Structured; company-led (briefly discussed)	KMI focus Structured; company-led
Tacit knowledge	Key K. source Internal	Key K. source Internal
	KMI focus Structured; company-led	KMI focus Structured; company-led

2.5 Summary

With the help of a SLR, Chapter 2 reviewed the existing knowledge on project-to-project learning in NPD and global NPD in particular. It also highlighted that gaps exist in the understanding of knowledge needs and knowledge sharing and use in the case of global NPD. A research question and two sub research questions were introduced to contribute to increase the understanding of project-to-project learning in global NPD. A project-to-project learning framework was introduced and applied to both local and global NPD, showing that the project-to-project learning framework for global NPD cannot be completed relying only on the findings from the SLR (Table 2.11). Five research propositions were developed, based on the existing literature for global and local NPD

projects. A tentative project-to-project learning framework for global NPD was completed with the assumptions derived from the five research propositions (Table 2.12).

Chapter 3 details the research design of the empirical research developed to answer the research questions and validate the project-to-project learning framework for global NPD.

CHAPTER 3 – RESEARCH DESIGN

3.0 Introduction

The aim of this Chapter is to introduce the design and the strategy of the research carried out for this Thesis. This is done in three steps. First, the philosophical foundations are described, paying specific attention to the influence of the views and experiences of the researcher on research strategy. Second, the analysis focuses on the methodological aspects of the research revealing the theoretical framework that will drive the empirical investigation and that has been selected with the support of the SLR conducted in Chapter 2. Third, the host organization that will provide the support for the empirical exercise will be introduced and analysed. The organizational structure and key processes of the organization are described together with the advantages and risks of the choice. The overall aim of the chapter is to contribute to answer the research questions and to test the five propositions introduced in Chapter 2.

3.1 Research philosophy

This section illustrates and explains the methodological and theoretical underpinning of the research presented in this Thesis. When performing empirical studies, researchers need to select methods for collecting and analysing data. The decisions on the methods for collecting and analysing data define the overall approach to the research and the data analysis strategy. Blaikie (2007) points out that, while the key objective of research is the creation of new knowledge on the investigated phenomena, the choice of the theoretical and methodological background of the research is driven by the nature of the observed phenomena. Saunders, Lewis and Thornhill (2009) created the “research onion” to offer a visual representation of the key decisions a researcher must face to define research strategy and methodology and the chronological order in which the decisions need to be made (from

the outermost circle to the inner circle) (Figure 3.1). Six key dimensions – the layers in the onion model – guide the definition of the research:

- The philosophy guiding the research: positivisms, realism, interpretivism or pragmatism;
- The approach of the research: deductive or inductive;
- The research strategy: experiment, survey, case study, action research, etc.;
- The choice of methods: mono method, mixed method or multi-methods;
- The time horizon: cross-sectional or longitudinal;
- The data collection and analytical tools and techniques.
-

The personal belief of the researcher on the nature of reality and on the objectives of the research impacts on the positioning of the research in regard to research philosophy and approach. Two branches of philosophy discuss this matter, *ontology* and *epistemology*. Ontology discusses the nature of existence and the implication of personal beliefs on the researcher's ability to produce new knowledge, while epistemology focuses on the implication that the researcher's personal values have on research objectives. It follows that an ontological and epistemological assessment is needed to proceed to the definition of research philosophy and strategy.

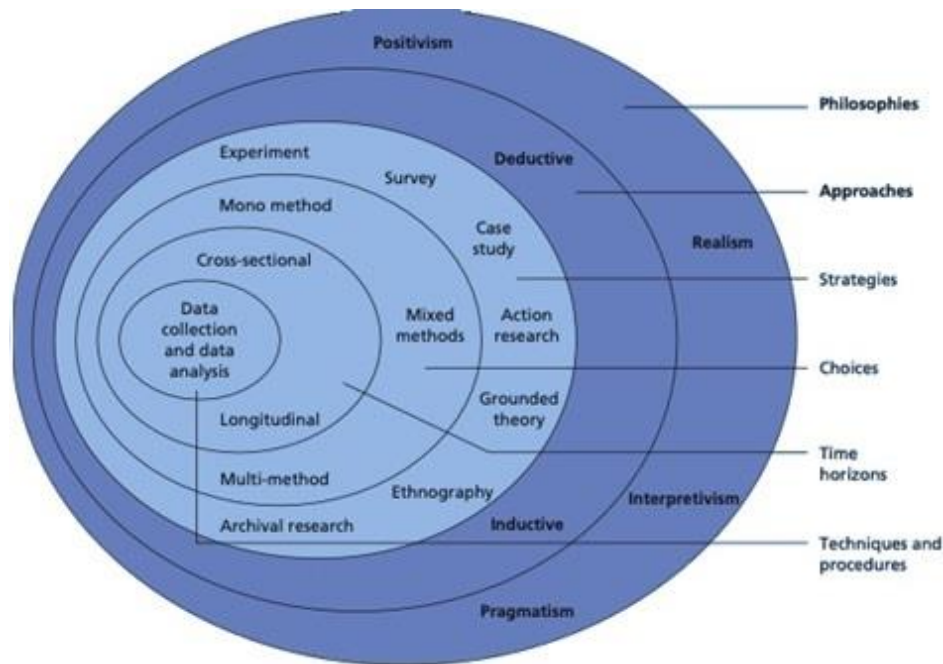


Figure 3.1 – The research “onion” – Saunders, Lewis and Thornhill (2009, p. 108)

This section is organized as follows. First, key philosophical concepts for scientific research are reviewed. The abstract concepts of ontology and epistemology, as used in social sciences and empirical research, provide the basis for this review. Then, the section continues to discuss the practical implications of the ontological and epistemological assumptions adopted, both in terms of philosophical and strategical implications. Finally, based on the outlined research philosophy, the section discusses the feasibility of the research and its potential effectiveness in answering the research questions and in identifying potential ethical issues.

3.1.1 Philosophical foundations

The main objective of the research presented in this thesis is to study knowledge sharing (in broad sense: technological, organizational and social) in global NPD projects. This section discusses the ontological and epistemological assumptions that underline research

methodology to highlight how the research contributes to create new knowledge on the phenomena under investigation.

Ontology and epistemology are two branches of philosophy that show that different approaches can be adopted to the analysis of reality and in order to create new knowledge. Ontology is defined as the branch of philosophy “that deals with the nature of being, or what exists; the area of philosophy that asks what reality is and what the fundamental categories of reality are” (Newman, 2014: p. 94). When talking about empirical research, ontology discussed the assumptions on the nature and on the way the real world operates, specifically related to the phenomena under investigation. While the concept of ontology may seem abstract, it captures many key aspects of the investigated phenomena – both in social science and natural science – and of the researcher. Discussing ontology brings the researcher to answer questions on the nature of the real world and on the objective of the research that are a key to define an effective research strategy. When designing empirical research, the first step is to clarify the assumptions on the nature of reality that underpin the research. Two main views exist on the nature of reality: *realisms* and *nominalism*³. Realists believe that the real world has an objective reality that is possible to be captured and does not need to be interpreted by human beings. Starting from the constructs of realisms, *critical realists*, revisit the key assumption of realisms (Sanders, Lewis and Thornill, 2009). They believe that the objective reality cannot be observed being studied through the subjective lenses of the researcher. The personal beliefs and views (i.e., subjectivity) of the researcher can influence and sometimes distort the observed reality with cultural interpretations and personal ideas. Critical realists argue that controls might sometimes be

³ The fundamentals of ontology for social science and management studies are discussed by Newman (2014); Sanders, Lewis, Thornill (2009); Blaikie (2007). See also Denscombe (2010).

needed to track the effective reality hidden under the contamination driven by the observer (Newman, 2014).

Critical realism is a midpoint between pure realism and nominalism. In contrast to realists, nominalists assume that the external reality is never really “external” to agents and observers (Denscombe, 2010; Bhattacharjee, 2012). Nominalists believe that a clear and unavoidable difference exists between external reality and the reality perceived by human beings, that are never able of really receiving the real world as truly external. Nominalists believe that researchers only observe the world through the lenses of their subjectivity, that defines the way they interpret reality. Based on the nominalist approach, the individual perception of reality is profoundly impacted by cultural and social influences. The impact of cultural and social influences may vary depending on the circumstances but can never be truly removed. The profound implication of nominalism is that the analyses of the real world made by human beings are always limited by their cultural background and subjectivity, i.e., by the way they see the world. Similarly, the values of a researcher directly impact on the way they conduct research (Sanders, Lewis and Thornhill, 2009). Newman (2014, p. 95) shows the ontological positions of the research along a continuum, between the extreme realist and the extreme nominalist (Figure 3.2).

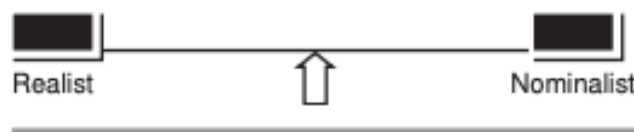


Figure 3.2 – The ontological continuum – Newman (2014, p. 9)

A researcher's personal ontological position will be somewhere along the ontological continuum. The pure realist bases their research on the assumption that they can "see" the real world and "read" reality as it appears to them; on the opposite end, the pure nominalist is fully aware that the contamination determined by socio-cultural influences and personal values cannot be removed.⁴ Lastly, it is important to point out that a researcher position along the ontological continuum is often influenced by opportunist considerations connected to the viability of research designs and resources available to run the empirical research. Therefore, the ontological positioning can also vary from *objectivism* – when social entities (phenomena and institutions) are considered fully independent from social actors – to *subjectivism* – when social entities are considered as a social construct, and it is assumed that they must be interpreted exploring the behaviour of the social agents. The "research onion" presented in Figure 3.1 summarises the main points of the argument, showing in the first outer ring the different ontological stance that a researcher can select (Newman, 2014):

- **Positivism:** for the positivist, social reality can be observed from an objective point of view and general law can be established, similarly to those of natural science;
- **Pure realism:** for the realist, social reality is considered objective and not influenced by the observer's social relationships;

⁴ Researchers find themselves somewhere in between the two extremes and their position along the ontological continuum is largely based on their personal believes.

- **Interpretivism:** for the interpretivist the real world needs to be interpreted and agent actions must be investigated from pre-existing theoretical schemes;
- **Pragmatism:** the pragmatist believes that in empirical research, research questions drive directly the ontological stance, as it would be otherwise impossible for the researcher to select an ontological position.

While choosing a positivist ontological position might seem a practical position, to avoid debating complex theoretical and philosophical discussions, it is also clear that it is hard to defend a pure positivist stance in social science and management studies. In social science and management studies data collection is often times contaminated – directly or indirectly – by the researcher (Drucker-Godard, Ehlinger and Grenier, 2011). This is often the case in field research and case study research that involve at some point interviews (Holmes, 2020).

As anticipated, the second branch of philosophy that plays a critical role in the research definition is epistemology. Defined as the “area of philosophy concerned with the creation of knowledge, epistemology focuses on how we know what we know or what are the most valid ways to reach truth” (Newman, 2014: p. 95). Epistemology deals with two key issues: 1) how knowledge is created and 2) how the knowledge created can be evaluated.

Epistemology and ontology are closely linked and a researcher’s answers to the questions posed by epistemology largely depends on their ontological position. For a realist, knowledge can be created by a careful investigation of reality independent of the observer’s point of view. By observing the world, the researcher can generate an idea of reality coherent with the observed reality. This idea can be validated or falsified by subsequent observations. Based on validation or disproven ideas, the researcher can *deduct* the general laws that explain in theoretical terms the real world, allowing the researcher to

create “objective” knowledge. For a nominalist, reality can only be observed from the researcher’s interpretative schemes. Therefore, an observation is described and interpreted by *induction* based on the researcher’s pre-existing interpretative schemes. However, the same reality can be interpreted from different schemes, creating different understanding of the same observation. For a nominalist, it is impossible to separate objective reality from interpretation. Similarly, it is impossible to compare different forms of knowledge if not comparing the different interpretation schemes that were used to create the knowledge.

Consequently, a nominalist and a realist also have very different understanding of how knowledge is created: in the realist approach, knowledge is created with a deductive logic, starting from the observation of reality that is used to develop hypotheses on agents behaviour; in the nominalist approach, knowledge is created with an inductive logic that compares observation with pre-existing theoretical schemes, as it is illustrated by the second outer layer in the “research onion” presented in Figure 3.1.

3.1.2 Philosophical approach

The researcher’s ontological view is therefore directly connected to their epistemological position, and both are a key for defining the research methodology in social and natural science. While key differences exist between social and natural science, the need for a rigorous *scientific* method is becoming more prevalent also in social science, starting from the definition of the base research philosophy (Drucker-Godard, Ehlinger and Grenier, 2011). The process of integrating the scientific method into social science dates back to the XIX century with neoclassical economists trying to imitate the research methods of natural science. This process led to the introduction of the “rational and optimizing” behavioural hypothesis in the agency theory and production theory (Volpi, 2013; Lunghini, 2013). In the course of the XX century the adoption of the scientific method expanded to other human and social sciences, including sociology, business economics and management studies (della Porta and Keating, 2008). Many differences exist between natural science and social science and using the scientific method in social science can prove very complex

(Newman, 2014). Nonetheless, the process of adopting scientific rigor in social science proved very effective, forcing researchers in social science to explicitly state their theoretical hypothesis and methodological choices.

Newman (2014) highlights the advantages and difficulties connected to the use of scientific methods in social science and propose ten questions about the nature of reality that researchers can answer to identify the suitable methodological approach. Newman proposes three approaches that differ for their position towards ontology and epistemology. The three approaches proposed by Newman are⁵:

- Positivist social science;
- Interpretative social science;
- Critical social science.

In the positivist analysis, phenomena are analysed and, when possible, measured in an objective way. For the positivist, reality is self-evident, social agents are rational and individualistic beings, human agency leads to determinism. Social science is not influenced by values and is always objective.

The differences between the positivist and the interpretive social science approach are clear and evident. The interpretive social science approach is based on the assumption that reality is a social construct, and that the main goal of social science is to understand

⁵ It is interesting to notice that the positivist analysis builds on causal laws that are derived from general theories. For details, see below Table 3.1.

social processes that generate from the interaction between individuals. In interpretive social science evidence gathered is always context-specific and inductive reasoning prevails on deductive reasoning. For social science interpretivists, human behaviour is driven by will.

Finally, in the critical social science approach, social reality is considered complex and social interplay influences behaviour and processes of change. The main goal of research is to explore changes in society and social science has an ethical dimension that aims at individual empowerment and the promotion of human freedom.

The previous Sections clearly show that the choice of a philosophical framework is a major key to the running of successful empirical research and understanding research findings. The Author of this Thesis strongly believes that the environmental and cultural background of the agent – including the researcher – directly impact on the behaviour of individuals, positioning the research much closer to the nominalist viewpoint along the ontological continuum (Figure 3.2). From an epistemology point of view, the researcher believes that propositions on the behaviour of agents can only be induced, and not directly deduced, from observation based on pre-existing schemes and that all propositions must be context-specific.

Table 3.1 – Key differences in the three approaches to social enquiry – adapted from Newman (2014, p. 120)

	Positivism	Interpretive social science	Critical social science
1. Reason for research	To discover natural laws so people can predict and control events	To understand and describe meaningful social action	To smash myths and empower people to change society
2. Nature of social reality	Stale pre-existing patterns or order that can be discovered	Fluid definitions of a situation created by human interaction	Multiple layers and governed by hidden, underlying structures
3. Human nature	Self-interested and rational individuals who are shaped by external forces	Social beings who create meaning and who constantly make sense of their words	Creative, adaptive people with unrealized potential, trapped by illusion
4. Human agency	Powerful external social pressures shape people's actions; free will is largely illusion	People have significant volition; they develop meanings and have freedom to make choices	Bounded autonomy and free choice structurally limited, but the limits can be moved
5. Rome of common sense	Clearly distinct from and less valid than science	Powerful everyday theories used by ordinary people	False beliefs that hide power and objective conditions
6. Theory looks like	A logical, deductive system of interconnected definitions, axioms and laws	A description of how a group's meaning system is generated and sustained	A critique that reveals true conditions and helps people to take action
7. An explanation that is true	Is logically connected to laws and based on facts	Resonates or feels right to those who are being studied	Supplies people with tools needed to change the world
8. Good evidence	Is based on precise observations that others can repeat	Is embedded in the context of fluid social interactions	Is informed by a theory that penetrates the surface level
9. Relevance of knowledge	An instrumental orientation is used; knowledge enables people to master and control events	A practical orientation is used; knowledge helps us to embrace/share empathetically others' life worlds and experiences	A dialectical orientation is used; knowledge lets people see and alter deeper structures
10. Place for values	Science is value free, and values have no place except when choosing a topic	Values are an integral part of social life: no group's values are wrong, only different	All science must begin with a value proposition; some positions are right, some are wrong

Pragmatically, the researcher also believes that the research question also drives directly the ontological position. In the case of this thesis, the answers to the research questions RQ and sub research questions SRQ1 and SRQ2 that the empirical research will uncover are only directly applicable in the specific context and under the specific conditions investigated. Therefore, an extensive space in this Thesis will be dedicated to explaining the context of the research.⁶

Summarizing, the research approach selected for the research presented in this Thesis is an interpretive social science approach.

3.1.3 From research philosophy to research strategy

The choices on research choices have direct implications on research strategy: they influence the research methodology and how the research is carried out. The research strategy is the action plan designed by the researcher to deliver the specific research objectives and has to be carefully selected to be suitable, feasible and ethical (Denscombe, 2010). The main research strategies include experiments, surveys, case study, action research, grounded theory, ethnography (*i.e.*, a research strategy that has the objective of studying process and situations starting from the point of view of social actors), phenomenology (*i.e.*, a research strategy that has the objective of exploring people's perceptions and meaning; people's attitudes and beliefs; people's feelings and emotions), and archival research (see the third outer layer of the research onion, Figure 3.1).

⁶ The risks and limitations of applying the findings of the research in different context and of deducing general laws for project-to-project learning are discussed in Chapter 9.

The research strategy selected for this Thesis is consistent with the research philosophy described above. As shown below in Section 3.2, the research strategy is a case study research consisting of three cases using data from multiple sources and a common source of data. It is necessary at this stage to discuss the philosophical implications of the selected research strategy.

The selection of case studies, with the use of surveys, interviews and observation, reveals the specific traits of the phenomenological approach. This approach is extensively used in health, education and management studies, when the objective is understanding the behaviour and perceptions of patients, students, employees and managers (Ehrich, 2005). Among the main characteristics of the phenomenological approach there are: subjectivity (rather than objectivity), description and interpretation (rather than measurement), agency (rather than structure). The main objective is to analyse the perceptions of the phenomena through people's attitudes, beliefs, feelings, and emotions. The specific characteristic of the phenomenological approach is the creation of qualitative data (and *not* of quantitative data) that are obtained asking open-ended questions. Finally, knowledge on the investigated phenomena is derived with an inductive and researcher-centred method, as researcher's values and experience are expected to directly influence the analysis, and the role and identity of the researcher have a clear role in the analysis (Denscombe, 2010). This is particularly true in the case of the research presented in the Thesis, as the Author has strong pre-existing ties with the host organization.

As a closing comment on translating the research philosophy in research strategy, it is important to discuss potential ethical concerns that might arise. The research presented in this Thesis is most certainly ethical research. Standard measures to ensure that no damage is done to participants in the research were taken: anonymity of all participants to the research is guaranteed at all stages; all data collected are treated as confidential; all participants in the research were informed about the nature of the research and about their role and accepted to participate freely. Finally, measures were taken to protect all business-confidential data of the host organization and, where possible, sufficient data is included to avoid negative impacts of the findings of the research while protecting data confidentiality.

3.2 Case design

The SLR clearly showed that important gaps exist in literature. Yet, these gaps are a hurdle for practitioners engaged in global NPD. Enterprises and organizations are relying more and more on globally dispersed teams to execute NPD projects (Gemünden, 2015, Sivakumar and Roy, 2021; le Duc and Gammeltoft, 2023). While the use of global and dispersed team has been observed since the 1980s (Ishikura, 1985), the 2020 Covid-19 pandemic and lockdowns have forced NPD teams to cooperate more remotely and therefore experienced significantly less face-to-face time, similarly to what happens in global NPD teams. Organizations and enterprises were forced to modify their knowledge management processes to adapt to a more remote or hybrid way of working (Cecchi *et al.*, 2022; Revoredo-Giha and Russo, 2022; Caccamo, Pittino, and Tell, 2022), very similar to those always experienced by global NPD teams. The selected organization for the empirical research employs knowledge management processes designed for remote working and global NPD and will provide an answer to the research question for this Thesis, by assessing the perceived effectiveness of KMI. In order to understand the most appropriate research methodology to answer the research question, Table 3.2 summarizes the approaches used by the key empirical papers reviewed in Chapter 2. Case study research is the most used one amongst the approaches investigating knowledge sharing and use in NPD.

From the research methodology point of view, the research question can be broken down in three parts: (1) *what* KMI are used, (2) *which* ones are considered most effective, and (3) *why*.

While case study research is the most used research methodology, it is also the most appropriate research method for investigating project-to-project learning in global NPD. No previous studies are available that were able to cover multiple KMI and both social and structured KMI, highlighting, at the same time, the complexity and value of conducting case study research on multiple KMI in global NPD. Surveys, ideally of multiple organizations, might seem initially the most appropriate research methodology to answer

parts 1 and 2 (i.e., “what”, “which”) of the research question (Yin, 2009) however, given the exploratory nature of the research, surveys would not be able to answer the “why” part. Moreover, given the exploratory nature of the research question and the duality of the three key variables (i.e., global vs local NPD, radical vs incremental NPD, explicit vs tacit knowledge), the “why” part of the research is the key enabler of the research, making the sole use of surveys insufficient to answer the research question.

The use of experiments and action research was discarded due to the very high number of factors impacting KSU in NPD (Section 2.2) most of which would be outside of the control of the researcher, making action research and experiments a non-viable option. Considering the pre-existing relationship of the Author with the host organization, the risks were high. While Zuber-Skerritt and Fletcher (2007) point out that action research is often used by part-time researchers conducting research in their organization, they also point out that the application of action research is particularly complex and not recommended in the cases in which organizational hierarchies can impact on the findings of the research.

Archival analysis, combined with the review of projects’ history and documentation, might be appropriate to answer the research questions, however, significant limitations exist with the use of archival analysis for the investigation of tacit knowledge, that is by definition difficult to be captured in writing. The confidentiality of the archives is also a hurdle to the research, with significant resistance expected from the host organization to publish confidential and proprietary data. The sole use of archival analysis to answer the research questions was also discarded.

Due to the exploratory nature of the research question and the importance of understanding the motivation that drive practitioners to use or neglect certain KMI (i.e., why?), the use of case study research is considered an appropriate methodology to (Yin, 2009; Goffin *et al.* 2019; Harwati, 2019). The case study evaluation template (CASET) proposed by Goffin *et al.* (2019) was used as guideline developing the case study and the review of the data, in particular, to ensure that the case study research quality standard was up to current research best practices and covered key aspects as research design.

Table 3.2 – Summary of methodologies previously used in key literature

	Literature reference	KMI	Sample / industry	Methodology
1	Ali <i>et al.</i> (2018)	-	Multiple organizations / Technology and software	Survey
2	Antoni <i>et al.</i> (2005)	Design / expert re-use	Two organizations / Transportation and software	Case study research + survey
3	Chirumalla (2014)	Lessons learned databases	Two organizations / Aerospace	Case study research
4	Costa <i>et al.</i> (2013)	-	Multiple organizations / Multiple industries	Case study research
5	D'Armagnac (2015)	Face to face interactions	Multiple organizational / Multiple industries	Case study research
6	Edwards (2015)	Expert re-use	Single organization / Telecommunications	Case study research
7	Fuller <i>et al.</i> (2010)	Lessons learned databases	Single organization / Support services	Action research
8	Goffin <i>et al.</i> (2011)	Post project reviews	Multiple organizations / Multiple industries	Case study research
9	Kleinsmann and Valkenburg (2005)	-	Single organization / Automotive	Case study research
10	Kotnour and Vergopia (2005)	Project reviews	Single organization / Aerospace	Action research
11	Landaeta (2008)	-	Multiple organizations / Multiple industries	Survey
12	Marabelli <i>et al.</i> (2013)	CoP	Single organization / Automotive	Case study research
13	Martini and Pellegrini (2004)	ICT	Two organizations / Oil & gas and hydraulics	Case study research
14	Newell (2004)	Post project reviews	Multiple organizations / Multiple industries	Case study research
15	Newell <i>et al.</i> (2006)	Project reviews / ICT	Multiple organizations / Multiple industries	Case study research
16	Nobeoka and Cusumano (1997)	Design re-use	Multiple organizations / Automotive	Case study research
17	Oluikpe (2015)	-	Multiple organizations / Multiple industries	Survey
18	Oshri, Pan and Newell (2004)	Design re-use	Single organization / Aerospace	Case study research
19	Paulin and Winroth (2013)	-	Multiple organizations / Multiple industries	Case study research
20	Wiewiora and Murphy (2015)	ICT	Multiple organizations / Multiple industries	Case study research
21	Wise (2016)	-	Multiple organizations / Multiple industries	Survey

3.2.1 Evaluation of case study quality

A CASET evaluation template was used to self-assess the quality of the case study and is reported in Appendix D. The results showed that the overall expected quality of the case study is targeted to be in line with high quality research published on major peer reviewed journals and the only two metrics where the research is expected not to be aligned with best practice are “validation of evidence” and “inter-coder agreement”. Both metrics would require multiple researchers involved in the interviews and coding of proprietary data of the host organization. This was not possible in the case of the research because of confidentiality requests from the host organization.

While some authors resort to investigating multiple organizations (e.g., Newell, 2004), longitudinal / single organization case studies are also often used to investigate NPD knowledge management dynamics (e.g., Oshri, Pan and Newell, 2004; Fuller *et al.*, 2010; Marabelli *et al.* 2013). Table 3.2 shows that multiple organizations and multiple industries are always preferred in the case of surveys; in-depth case studies often consider a smaller sample size and a limited number of industries (e.g., Kotnour and Vergopia, 2005). Table 3.2 shows that even in-depth case studies often face issues with having full access to the teams and project under investigation, limiting the researcher’s ability to fully understand the behaviour and practices under investigation (see Section 2.3).

Following the review of similar studies in literature and the review of alternative research methods, the use of case study was selected as research methodology. Chapter 4 will discuss the criteria used for the selection of the case study, but it is important to point out at this stage that three case studies of two business units of a single organization were selected. In line with best practices (Yin, 2009; Goffin *et al.* 2019), the case study used data from multiple sources as interviews of NPD teams, surveys, projects and organization documentation review and longitudinal observation of the projects through a 12-month period. The choice of longitudinal case study was driven by two factors: on one side, using longitudinal case study of three global NPD projects offered the unique possibility to access global project teams from multiple projects and to follow the project teams for an extended

period of time, observing first-hand the reactions of NPD team to key project events and studying the use (or the lack of use) of KMI. Access to the three global NPD projects was only possible due to personal links to a large multinational company, including access to proprietary data and confidential project events that would have been otherwise precluded to an external researcher. On the other side, as the organization resorted to remote or smart-working in an effort to react to the Covid-19 pandemic, more and more local NPD teams were experiencing the same challenges of global NPD team, with limited face-to-face time and few opportunities for social interaction. As companies adapted to running more and more NPD programs remotely, accessing multiple companies for multiple case study became a less viable option.

Deciding to limit the research to a single organization directly limited the generalization of the findings to other similar organizations and even more to NPD projects in general. To leverage as much as possible the large size of the host organization, the decision was made to study more than one project. While selecting a single case study would have allowed the Author to focus entirely on a single project, following it for a longer period of time and interviewing every single participant to the project, the results of the research were expected to be significantly impacted by the “health” of the project. As an example, if the project selected resulted to be a particularly successful (or unsuccessful) project, it is expected that the research would have been positively (or negatively) biased towards the knowledge management practices adopted on the project.

The decision was, therefore, to maximize the number of cases to be included in the research. The decision to limit the samples to three cases was driven by practical reasons on both the Author’s and the host organization side. Studying three projects, partially overlapped in time, allowed the Author to participate in all the key project events and interview the majority of the project teams in a limited amount of time. Selecting a higher number of projects, while maintaining the same depth of the research (i.e. the same number of interviews per project and the participation to key project events), would have implied running the empirical study for a significantly longer amount of time (two or three times as

long), not compatible with the timelines of the PhD and the availability granted by the host organization.

Particular attention was given to the selection of the cases, to increase the probability of observing unique and distinct project events (see Section 4.1).

3.2.2 Case host organization selection

The organization selected for the research is well-known to the researcher, due to pre-existing ties. The host organization is the automotive group of a large multinational corporation and in this document will be further referred to as *VehicleSystemsCo*. The group leadership team of *VehicleSystemsCo* expressed interest in the topic of the research and agreed to support the research, providing the Author with access to company resources, documentation, procedures and projects.

Limiting the research to *VehicleSystemsCo* only presents both advantages and limitations, due to the pre-existing ties with the researcher.⁷ The pre-existing ties of the Author with the host organization implies potential limitations. However, the advantages of having direct access to company employees, projects and procedures significantly outweigh the potential limitation offered by the proposed methodology. While the pre-existing relationships with the case study participants might influence the answers given by the participants in interviews and survey, the researcher's participation in key projects team events was not unexpected by the case study participants and therefore very limited interference of the researcher's presence on the behaviour of the project teams was

⁷ A list of advantages, risk and mitigation is provided in Table 3.3.

expected. As a confirmation that the benefits of the proposed cases selected in *VehicleSystemsCo* outweighed the potential limitations, a detailed review of the transcript of the interviews shows that the interviewees were happy to discuss both positive and negative aspects of the host company knowledge management processes and NPD processes.

3.2.3 Advantages, risks and risk mitigation of the selected host organization

The pre-existing researcher's knowledge of *VehicleSystemsCo* ensured an in-depth understanding of company culture, jargon and procedures. Moreover, owing to the pre-existing relationships with the case study participants, the Author was able to significantly reduce the introduction and explanation phases of the interviews and surveys and was able to grasp quickly references to previous company events and projects and to understand all the discussions that were happening. Case study participants did not need to explain in detail organizational structures, scope of the projects, projects status or failures/success, as these were well known to the researcher.

When probed about knowledge sharing with other teams and/or colleagues, the case study participants did not have to spend too much time in explaining roles and responsibilities as these details were already known to the researcher, allowing for very effective and content-rich discussions. The richness of details and frequent reference to project events or project activities were only shared in the context of the case study because the Author is familiar with the team – it is very hard to imagine that project team members would have accepted to share so many details and examples with a researcher not known by the employees of *VehicleSystemsCo*.

Table 3.3 – Advantages, risks and mitigation of the selected cases

Advantages	Risks	Mitigation
Extensive access to project meetings, project events and global NPD project teams	Access to the projects can be unilaterally interrupted by <i>VehicleSystemsCo</i>	Accept risk
Access to all NPD procedures and guidelines	Findings from documents review are not publishable in a thesis due to confidentiality reasons	Data disguised, thesis protection and prior agreements with <i>VehicleSystemsCo</i>
Case study participants are familiar with the Author and are not concerned about sharing confidential data or data potentially damaging <i>VehicleSystemsCo</i> reputation	Case study participants are reluctant to share information about malpractice and mistakes on projects for fear that the information might be disclosed with other employees	Multiple data sources and multiple participants are involved for each case. Direct observation of project events
Pre-existing knowledge of <i>VehicleSystemsCo</i> allows the Author to quickly understand reference to key company “historical” and project events and organizational jargon	Pre-existing knowledge of previous project events, professional responsibilities of the Author and personal views of the Author impact the data analysis and findings	Review findings and data analysis with <i>VehicleSystemsCo</i> team and PhD supervisors

While it is hard to believe that a researcher without any of the pre-existing relationships with *VehicleSystemsCo* could have had access to all the information shared, a researcher entering in contact with *VehicleSystemsCo* for the first time and without an in-depth knowledge of the organization (history and organizational culture) and projects would have most likely missed or misunderstood many examples that used company jargon or the full history associated to a name, project or initiative.

While confidentiality reasons prevent the Author to fully disclose their relationship with the host organization, pre-existing relationships exist that might impact on the findings of the research. This is a well-known issue in qualitative research, as the one presented in this thesis (e.g., Langley and Klag, 2019). Langley and Klag (2019) observe that while qualitative researchers highlight the importance of the direct proximity to the phenomena under observation, they also highlight that the researchers’ epistemological preferences

condition their understanding of it. These Authors refer to this as the involvement paradox. The involvement paradox is particularly relevant in the context of the research presented in this Thesis due to the pre-existing ties of the Author to the host organization.

Langley and Klag (2019) provide few recommendations to researchers trying to minimize the impact of their involvement in the research. These include clearly expressing and making visible to the reader their involvement in the research and in the activities under investigation. Additionally, the researchers are advised to select an appropriate stance when presenting the data, balancing between emphasising their involvement and the impact of the events and reporting the events as if they were observed fully detached from the events. Finally, these Authors highlight the importance for researchers to reflect openly in their research on the implications of their pre-existing epistemological preferences and their impact on the research.

Following a direct request from the host organization, details on the pre-existing relationship with the researcher were not included in the Thesis. However, the potential implications of the Authors epistemological preferences and of the pre-existing ties and involvement in the research are extensively discussed throughout the Thesis.

3.3 Validation of the selected project cases – RTM article

To validate the effectiveness of the selected case study projects to investigate knowledge management in NPD, the results of the pre-research were published in a feature article in *Research-Technology Management* in February 2022 titled “How COVID-19 Impacted the Tacit Knowledge and Social Interaction of Global NPD Project Teams” (Cecchi *et al.*, 2022). An investigation on how the Covid-19 pandemic impacted global NPD teams was conducted by interviewing 30 NPD professionals in three organizations operating in different industries. The investigation was conducted in June 2021 and included ten interviews from *VehicleSystemsCo* projects that were already selected for the research. Preliminary results of the research show that, in terms of NPD team’s ability to share knowledge, the additional challenges posed by the Covid-19 pandemic are very similar to

those experienced by global NPD, making an in-dept case study of NPD teams working on global programs very attractive. While the Covid-19 pandemic makes investigating the effectiveness of knowledge sharing and use in global NPD highly relevant and of broader interest for NPD practitioners, the results of the preliminary investigation also highlight practical limitations of conducting NPD research during the Covid-19 pandemic.⁸

3.4 The host organization of the case studies

This section introduces *VehicleSystemsCo*, its organizational structure and key processes. Each case study spanned a 12-month period commencing in January 2019 and finished in April 2022 with the last project interviews. The three case studies partially overlapped. *VehicleSystemsCo* approved the PhD research before January 2019 and granted the Author extensive access to company procedures. This prolonged and extensive access allowed the Author to have an advantage when answering the research questions. Before detailing the methodology of the research, it is important to discuss its context – i.e., *VehicleSystemsCo* – informing the reader about the organizational culture, the KMI used and the approach to KM. This is particularly important to understand the findings of the research, their applicability to other organizations and the potential limitations. This section introduces briefly *VehicleSystemsCo* based on the Author pre-existing knowledge and understanding of the organization, as well as on the information available in the public domain. All sales

⁸ For instance, NPD professionals were found to spend more time in meetings and to have limited time to participate in non-project activities as surveys or interviews.

number, patents numbers, financial information and position in rankings were anonymized and replaced with a range, to preserve confidentiality.

VehicleSystemsCo is a multinational organization that designs, sells and manufactures complex systems and components for many different end-markets (aerospace, automotive, industrial etc.). The two business units under investigation are active in the design and manufacturing of systems and components for the automotive industry. To protect the confidentiality, the real products designed and manufactured are disguised and the two business units are referred to as *water pumps* and *oil pumps* business units, respectively.⁹ *VehicleSystemsCo* has yearly sales that range in the \$10-50B, operating in more than 150 countries and occupying 50'000-100'000 full time employees. *VehicleSystemsCo* is a publicly traded company and is generally recognized as an innovative company and ranked multiple times in Thomson Reuters Top 100 innovators list in the period 2010-2020, being listed in the global 250 list of World's Largest Patent Holders (Intellectual Property Owners Association).

At the time of the writing of this Thesis, *VehicleSystemsCo* is a Fortune 500 company and was listed in Fortune's World's Most Admired Companies list for several years consecutively. *VehicleSystemsCo* is divided in 5 divisions, each structured into individual business units and product lines, each division with yearly sales in the \$1B-\$10B range. Knowledge management, knowledge transfer and knowledge retention were included in the organizations Key Strategic Initiatives (KSI) in 2020, 2021 and 2022.

⁹ Chapter 6 details why oil and water pumps were selected as examples of the products designed and industrialized in *VehicleSystemsCo* NPD projects.

The organization is an integrated operating company (i.e., not a holding) with a single Chief Executive Officer (CEO) leading all 5 divisions of the organization, each managed by a group global CEO or General Manager (GM). The five divisions of the organization, and the automotive division in particular, are managed with a matrix structure (Morgan, 1996). Reporting to the group's CEO are the regional presidents (one for each region in which the division is active e.g., Europe, North America, China, etc.) and the Global Business Unit Directors (BUD) or global Product Line Directors (PDL). BUDs and PLDs are responsible for the global profit and loss (P&L) of each business unit or product line, but not for the manufacturing operations; regional presidents are responsible for regional P&L and for the manufacturing operations.

Non-manufacturing departments (functions) report either to the regional or business unit leadership depending on their goal or local nature, hence the matrix structure of the organization (see Figure 3.3): e.g., the sales function, regional in nature, report into the regional presidents; the R&D and supply chain report into the group CEOs, GMs or directly at corporate level, when impacting multiple business units or divisions. The program management function is a special case, and in the context of this research it is important to highlight its peculiarity, as it is directly impacting on KM: low-risk, incremental NPD programs are program managed by the regional PMO team; high-risk radical NPD programs are program managed by global PMOs, reporting directly to the BUDs or PLDs.

In a similar way, NPD teams are split by the risk level of the programs they run: current programs and application engineering teams (mostly regional) lead low-risk, incremental NPD projects; high-risk, radical NPD programs are led by global, advanced engineering teams. Application engineering and advanced engineering teams are often split and have different reporting lines even in the case of the same division or business units. Finally, it is important to point out that both application engineering and advanced engineering teams report in the vice-president and general manager and do not report to the regional leadership.

Due to its global and innovative nature, the organization is very active on KM and many initiatives are in place to provide the team with the needed tool to share, access and use knowledge from the organization and other programs.

VehicleSystemsCo adopts a proprietary stage-gate project management process, where gates are established to ensure that all activities of a phase are completed before the project can proceed to the next phase. Due to confidentiality reasons, details of the proprietary stage-gate process cannot be disclosed here.

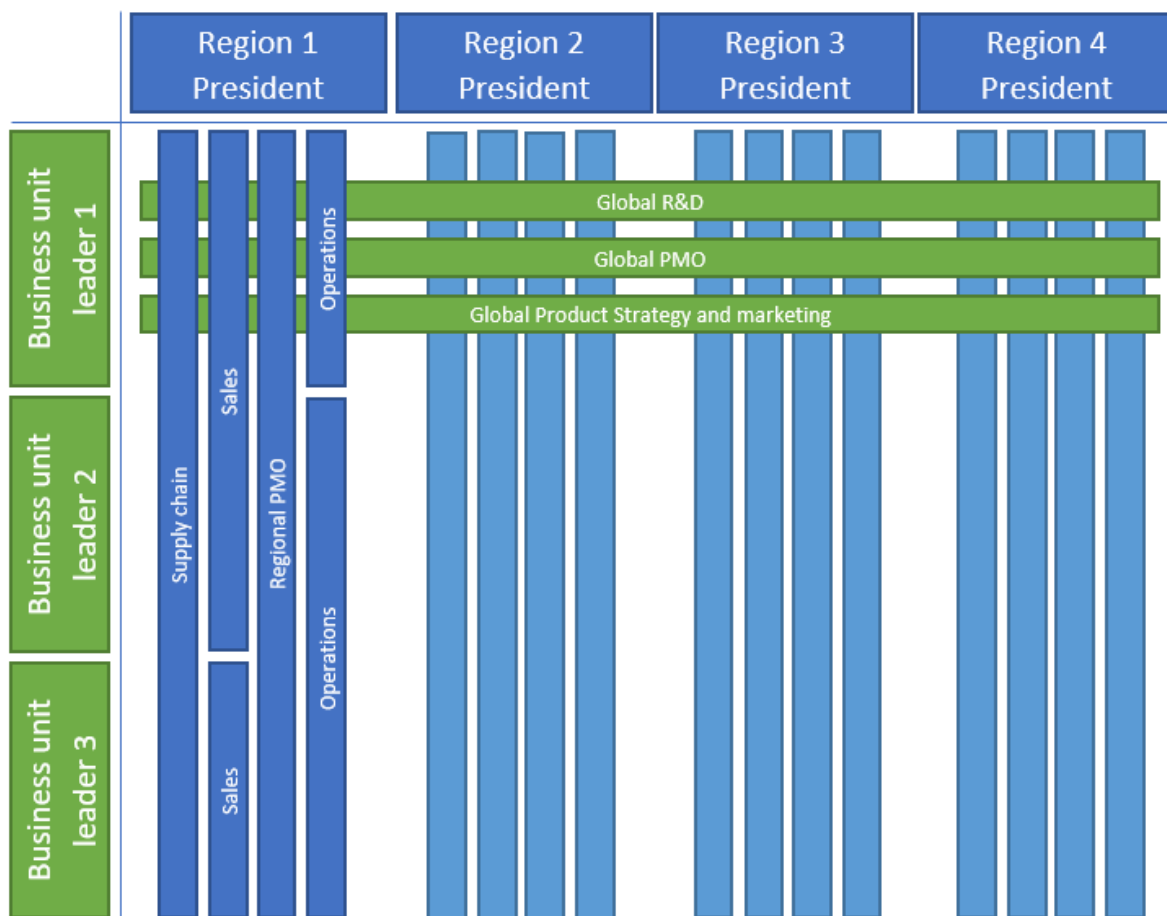


Figure 3.3 – Host organization’s matrix structure

The terms “pre-development”, “development” and “launch” are used to identify the stages of the projects at the time of the interviews. Projects in the *pre-development* stage are projects that require some R&D efforts to demonstrate proof-of-concept; this phase typically lasts 6 to 18 months. Incremental NPD projects have typically a very short pre-development stage or skip the pre-development stage entirely. Projects in the *development* stage are projects that have already completed proof-of-concept and are completing validation and verification of the technology on the final application – this phase typically lasts up to 12 months. Projects in the *launch* stage are projects that have completed validation and verification of the technology on the final application and industrialization is on-going – depending on the innovation content, the launch and execution phase can last from 6 to 30 months. Combining pre-development, development and launch stages gives a prospective on the standard total length of NPD projects: incremental NPD projects can be as short as 12 months from ideation to projects close, with larger radical NPD projects that can last as long as five years.

Three projects in two business units of *VehicleSystemsCo* with different degree of innovation and at different stages of development were selected as case study. Chapter 4 introduces the research methodology and the three case studies.

3.5 Summary

This Chapter introduced the research design and highlighted how the philosophical foundations of the research impact on research strategy and methodology. It has explained that an interpretive social science approach is the foundation of the research and has analysed the implications that selecting this approach has had both on the generalization of the research findings and on the impact that the views and personal experiences of the researcher have on research findings. Moreover, it has compared the research design and strategy with the empirical studies (identified with the support of the SLR), in which multiple cases were selected from a single host organization using multiple data sources. Finally, the host organization has been introduced.

CHAPTER 4 – THE RESEARCH METHODOLOGY

4.0 Introduction

Chapter 3 showed that different research methodologies are used to investigate knowledge sharing and use in NPD projects and pointed out the implications of the use of an interpretative social science approach on the research strategy. It also explained why multiple case studies in a single host organization were selected and looked at the research design in the literature on knowledge management in NPD. Relying on the reviewed literature, this Chapter builds the research on the case study using multiple data sources to investigate project-to-project learning in global NPD projects with the aim of answering the research question introduced in Chapter 2 and discussed in Chapter 3. The research methodology is designed to investigate how knowledge sharing and use occurs in NPD projects with globally dispersed team members. This Chapter first introduces the selection of three study cases, then it proceeds to detail the methodology and the plan for the research.

4.1 Selection of the study cases

With the help of *VehicleSystemsCo* business units' senior leadership teams, three project teams from the water and oil pumps business units were selected as case studies. The top ten projects managed by the two business units of *VehicleSystemsCo* under investigation were reviewed to select the three case study projects. Five parameters were considered when making the selection for each on the top ten projects (see Table 4.1):

- Project phase: pre-development, development or launch;
- Degree of innovation: radical or incremental NPD;
- Regions involved: regional or global NPD;

- Project team size: large (10+ participants) or small (less than 10);
- Business unit of ownership: water or oil pump business unit.

The goal of the selection was to identify three global projects representing the business units and all project phases and including at least one radical and one incremental NPD project. The first criteria used for the selection is to consider only projects involving the three regions in which the business units of *VehicleSystemsCo* are active (i.e., global NPD projects). Projects A, B, D, E were excluded following the regional selection criteria (see Table 4.1).

Table 4.1 – Case study projects selection

Project	Project phase	Degree of innovation	Regions involved	Project team size	Business unit
A	Development	Incremental NPD	Regional	Small	Water pumps
B	Launch	Incremental NPD	Regional	Large	Water pumps
C	Pre-dev	Radical NPD	Global	Small	Water pumps
D	Pre-dev	Radical NPD	Regional	Large	Oil pumps
E	Development	Incremental NPD	Regional	Small	Water pump
F	Launch	Radical NPD	Global	Large	Water pumps
G	Development	Incremental NPD	Global	Large	Oil pumps
H	Development	Radical NPD	Global	Small	Water pumps
I	Pre-dev	Incremental NPD	Global	Large	Oil pumps
J	Pre-dev	Radical NPD	Global	Large	Water pumps

Projects with large project teams were preferred to small project teams, as investigating larger project teams is expected to allow for the observation of more knowledge interactions between project team members due to the larger number of participants. Project C and H were excluded from the selection for reasons related to team size.

The third step in the selection process was based on the project phase: out of the four projects left, projects F and G are the only two projects in the *development* and *launch* phases respectively and were selected. The last project to be selected was the *pre-development* project. Projects I and J are both global pre-development projects with large teams. Project J was selected being a radical NPD project. As Chapter 5 will detail, KMI is applied more rigorously in *VehicleSystemsCo* in the case of radical NPD projects and therefore radical NPD projects were preferred, all other parameters considered.

The three selected projects F, G and J are highlighted in green in Table 4.1. For simplicity, in the following Chapters project F will be discussed as Project 1. Similarly, projects G and J will be discussed as Project 2 and Project 3.

4.2 Research phases and research plan

Multiple data sources were selected for the case study research, in line with case study theory (Yin, 2009) and with recent studies on case study research quality (Goffin *et al.*, 2019) that show that multiple data sources are needed for triangulation, for confirming the validity of the constructs generated by the research and to allow for more insights compared to a single data source. In line with recent recommendations (Shanks and Bekmamedova, 2018), four main data sources are used in the research:

- Review of projects and company relevant documents and procedures;
- Observations of NPD teams during project activities;

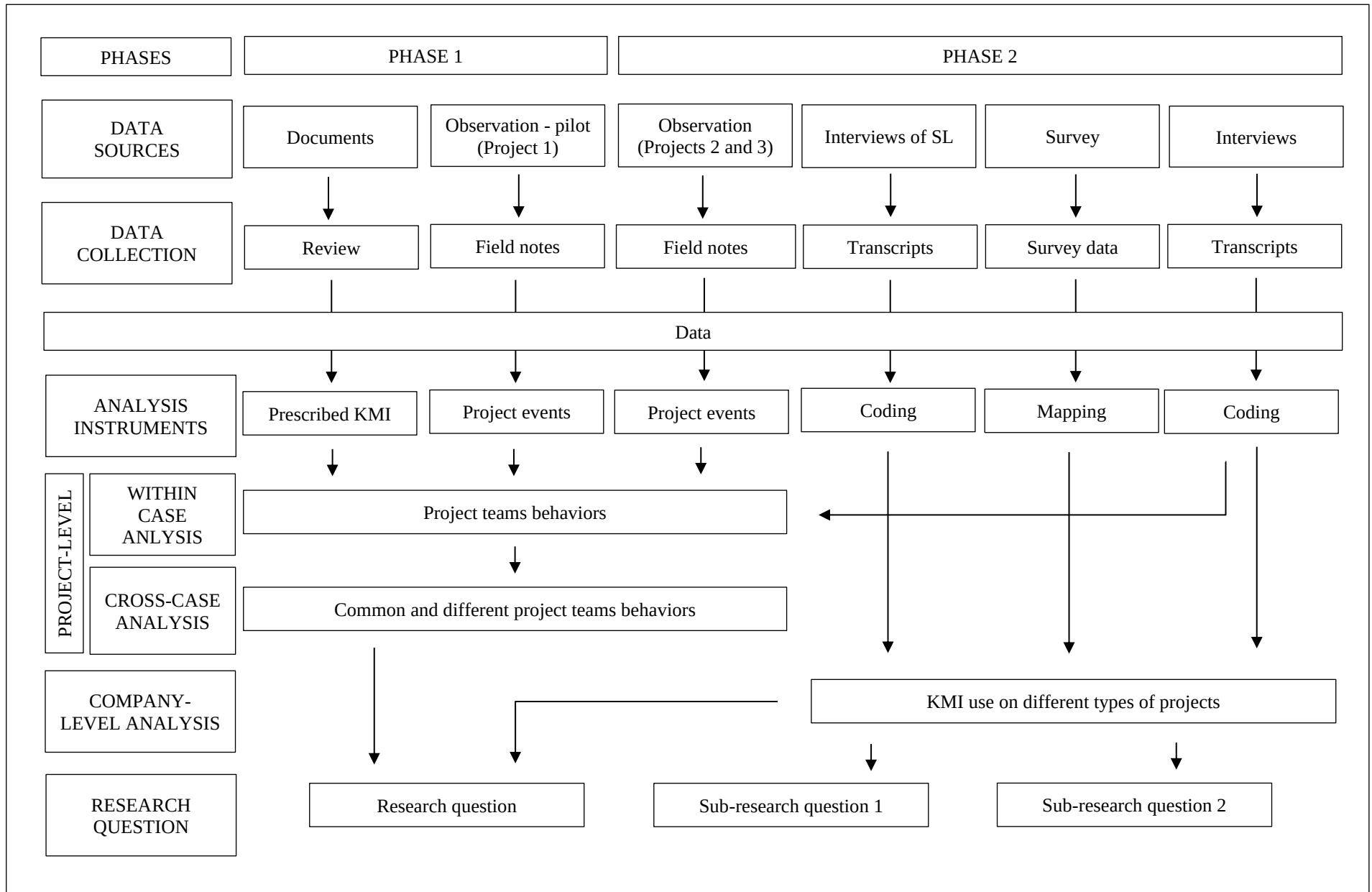
- Survey on the use and effectiveness of KMI;
- Interviews of NPD practitioners and managers.

Sections 4.2.1 to 4.2.4 review the structure and planning of the research as a function of the four data sources. Table 4.2 summarizes how the different data sources are to be used in Chapters 5, 6 and 7 for the data analysis from documents review, observation of NPD teams, surveys and interviews in three different steps. However, before detailing how data gathering from the different sources is planned, it is important to briefly discuss how the data is to be used to answer the research questions.

Table 4.2 – Summary of the use of data sources for research analysis

	STEP 1	STEP 2		STEP 3
	Research context analysis	Project-level analysis		Company-level analysis
		Within-case	Cross-case	
Documentation review	•			
NPD teams observation		•	•	
KMI survey				•
NPD teams interviews		•		•

The data analysis will be carried out in three steps. Step (1) is employed to contextualize the research by reviewing *VehicleSystemsCo* procedures and best practices for NPD and knowledge management. Step (2) is the project-level analysis. Step (3) is the company-level analysis.



Based on field notes and direct observation, Step (2) is structured in two parts: the first part is a within-case analysis and explores NPD project teams' reaction to key project events and to the use of KMI; the second part consists of a comparison between the behaviour of the three projects. While the first two steps start providing answers to the main research question by providing insights on the KMI mandated by *VehicleSystemsCo* and on the observed behaviour of the projects' teams, Step (3) is indeed required to fully answer the research question and sub-research questions. It combines the findings from the KMI survey and from the interview of NPD teams to provide insights on the used and perceived effectiveness of KMI.

Using the format introduced by Van Maldegem (2020), Figure 4.1 summarizes the empirical approach to the research and visually shows how the four data sources are linked with the three Steps of the data analysis. Figure 4.1 also introduces the tools that are employed for data analysis.

The four data sources are split in six blocks in the second row of Figure 4.1. The first block represents the review documents. The second and third blocks represent the observation of NPD teams. "Observation" is split in two separate blocks to highlight the split in the pilot and in the main research. Similarly, interviews are split in two blocks to highlight the importance of interviews to senior leaders (SL) compared to interviews to the rest of the project teams. The collected data is showed in the third row of Figure 4.1 and it shows how field notes, survey data and interview transcripts provide the data collected from observation, surveys and interviews. The fourth row in Figure 4.1 shows the analytical instruments used to explore the collected data. Finally, the last four rows show the project-level and company-level Steps of data analysis and explain how these will be used to answer the research questions. The summary information on the analytical instruments is provided for each data source and the arrows visually show how each step helps eventually answering the research questions.

the research question presented in Chapter 3 which refers to the perceived effectiveness and use of KMI for NPD managers and NPD practitioners:

RQ: In the context of global NPD, which knowledge management initiatives are most often utilised / considered by practitioners to be the most effective and why?

In order to be able to effectively compare and contrast the responses from NPD practitioner and managers, the interviews to senior leaders and to subject matter experts were deliberately kept separate from the other project interviews. Table 4.3 details the geographical location and role of NPD professionals participating in the research; a “check” mark (✓) in the column “Pilot” indicates the participation in pilot interviews.

The geographical distribution and sample size of the three projects are reported in Figure 4.3. Some team members work on multiple projects (i.e., experts re-use) and this is also stacked in the column “project” of Table 4.3. A check mark in the “SL interviews” column indicates the participation to the senior leaders’ interview part of the research. Job titles of the participants in the study are also included in Table 4.3.

As anticipated in Chapter 3, *VehicleSystemsCo* operates as an integrated company, i.e., not as a holding. Job titles and job responsibilities might differ to those in smaller companies or holdings.

To protect the confidentiality of *VehicleSystemsCo* and interviewed participants, and to explain the role of the interviewees to the readers, some job titles were modified to fit more common job titles for the equivalent responsibilities (Fadell, 2022). While the job responsibilities of a group CEO, Engineering director or program management director are clear and of universal meaning in the context of management research, further details are required to explain the responsibilities of product line and business unit directors in *VehicleSystemsCo*.

Table 4.3 – NPD professionals’ participation to the two Phases of the research

Role	Loc.	Project	Pilot	SL int.
VP/GM	US			✓
Global chief engineer	US	1	✓	✓
Global chief engineer	US	2,3	✓	✓
Engineering manager	CZ	3		
WP engineering manager	CN	1	✓	
OP Engineering manager	IT	2		
WP engineering supervisor	IT	3		
Global engineering director	US			✓
WP global engineering manager	IT			✓
OP global engineering manager	US			✓
Global engineering manager	US	2		
Global PMO director	UK			✓
Manufacturing engineer	PL	3		
PMO manager	IN	1,2	✓	
Product engineer	IT	1	✓	
Product engineer	CZ	1	✓	
Product engineer	IT	2		
Product engineer	IT	3		
Product engineer	IT	3		
Product engineer	CZ	3		
WP business unit director	IT			✓
Product strategy manager	IT			✓
Program manager	CN	1	✓	
Program manager	CN	2		
Program manager	IT	3		
Project leader	IT	1,3	✓	
Project leader	HK	1	✓	
Project leader	IT	2		
Project leader	CZ	3		
Project leader	IT	3		
Sales manager	CN	1,2	✓	
Sales manager	IT	3		
Supply chain manager	CN	1,2	✓	
Supply chain manager	PL	3		
Technical specialist	CN	1	✓	

In this Thesis, a product line director is intended as the Profit and Loss (P&L) owner for a particular line of products, while a business unit director is the P&L owner for a business unit composed of two or more product lines.

▼ Project 1

Radical NPD project, launch phase
Commercial vehicles group
6 Engineers, Program Manager, Supply Chain manager, Sales manager, Engineering manager, PMO manager, Chief engineer

■ Project 2

Incremental NPD project, launch phase
Light vehicles group
3 Engineers, Program Manager, Supply Chain manager, Sales manager, Engineering manager, PMO manager, Chief engineer

• Project 3

Radical NPD project, pursuit phase
Commercial vehicles group
7 Engineers, Program Manager, Manufacturing engineer, Supply Chain manager, Sales manager, Engineering manager, PMO manager, Chief engineer



Figure 4.3 – Data source and global dispersion of the cases

The following Sections will briefly review one by one the four data sources and how they are operationalized in the two phases of the research.

4.3 The review of relevant documentation

The review of relevant documentation was identified as the first source of data in the case study. It is intended to frame the context of the research and the NPD and knowledge management practices prescribed in *VehicleSystemsCo*. The procedures and guidelines are considered business confidential documents and therefore very few quotes and extracts are included in this Thesis, while coding of the documents is not used to protect confidentiality of business confidential information. The review of *VehicleSystemsCo* documents will help to understand the organization's expectations of NPD team and when particular procedures are deployed as a function of the degree of innovation of the projects.

An extensive review of *VehicleSystemsCo* KMI is also included in Chapter 5, to set the stage and context of the research. Special attention is given to failure reporting and corrective actions system (FRACAS). In *VehicleSystemsCo* FRACAS reports are used to track product failures and corrective actions during product development. *VehicleSystemsCo* has a reoccurring monthly FRACAS review meetings where team members from different global projects are invited to present and review FRACAS from the business units' projects. FRACAS logs and reports were reviewed as part of the search to identify the kind of knowledge captured (failure investigation process, failure diagnosis process, design weakness and improvements, customer knowledge, etc.). Access and use of FRACAS by team members was tracked with the use of interviews participants; interactions during the review meeting have also been observed (e.g., use of metaphors during the meeting, interest for the material discussed and interaction).

4.4 The observation of NPD teams

This section presents details of the organizational structure of *VehicleSystemsCo* and of the case study projects before introducing the planning of the observation of the three NPD projects. The three projects selected for participation in the research are projects at different stages of the NPD cycle and different degree of innovation. Using the NPD project stage nomenclature introduced in Section 3.3, Project 1 is a radical innovation NPD project in the launch stage; Project 2 is an incremental innovation NPD project in the launch stage; Project 3 is a radical innovation NPD project in the pre-development stage. Table 4.4 summarises the stage and innovation content of the three projects selected for the case study. NPD professionals participating in Phase 1 and Phase 2 are included in Table 4.3.

Table 4.4 – Case study projects phase and innovation content

	Project stage	Degree of innovation
Project 1	Launch	Radical NPD
Project 2	Development	Incremental NPD
Project 3	Pre-development	Radical NPD

The water pumps business unit was led from Europe with both the business unit director and global engineering manager based in EMEA; the oil pumps business unit was led from North America (NA), with both the business unit director and global engineering manager based in NA. The global engineering teams report into the NA-based global engineering director through the regional engineering managers.

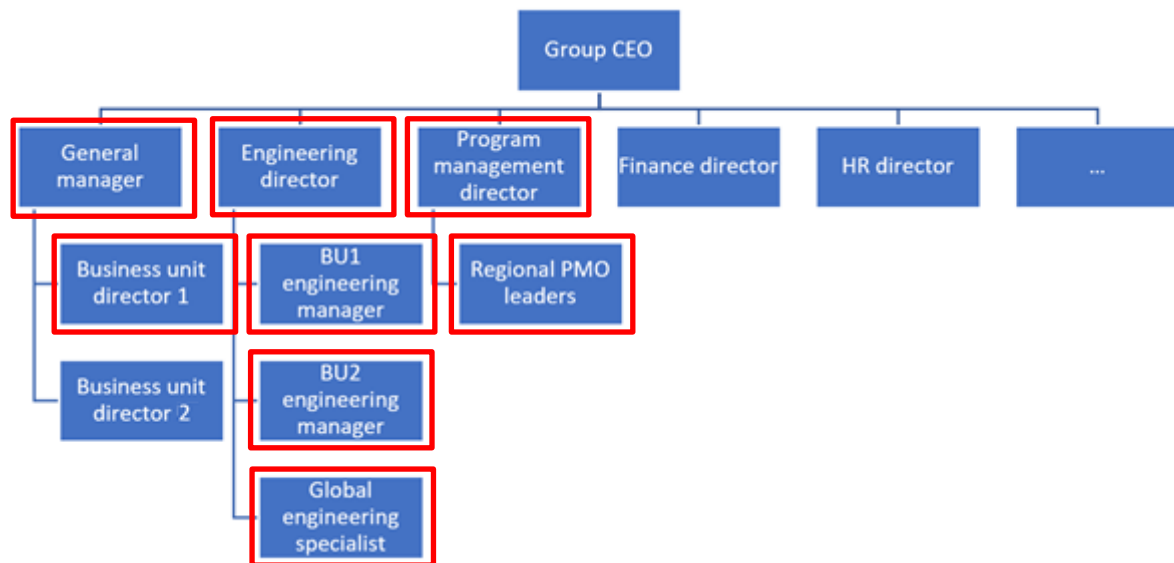


Figure 4.4 – automotive group organizational structure

Figure 4.4 shows a visual representation of the business unit and group organizational structure in *VehicleSystemsCo*¹⁰. The automotive group was made of multiple business units and manufacturing regions. The geographical footprint of manufacturing facilities and the business unit not included in the research are not showed in Figure 4.3 to focus the chart on the business unit under consideration. Additional business functions (e.g., advanced manufacturing, sales, etc.) are also not included in the chart, but were introduced in Chapter 3. Data gathering from project observations will be discussed in Chapter 6.

4.5 The survey on KMI

At the beginning of the second phase of the research a survey on KMI was administrated to the teams on a one-to-one basis with telephone or face-to-face interactions, when possible. KMI surveys were administrated independently from the participants' participation in case study projects.

The KMI list is presented in Table 2.4; it consists of three or four questions for each KMI, depending on the answers received. For each KMI, the first question is if the KMI name and mechanism is clear to the respondent. In case of a negative answer, the Author provides a brief explanation of the KMI. Once the KMI and mechanism is clear, two following questions are asked and adjusted, based on the answer to the previous questions, following the structure presented in Figure 4.5.

¹⁰Job titles were modified to fit more common job titles for the equivalent responsibilities and to protect interviews confidentiality as detailed at the beginning of Chapter 4.

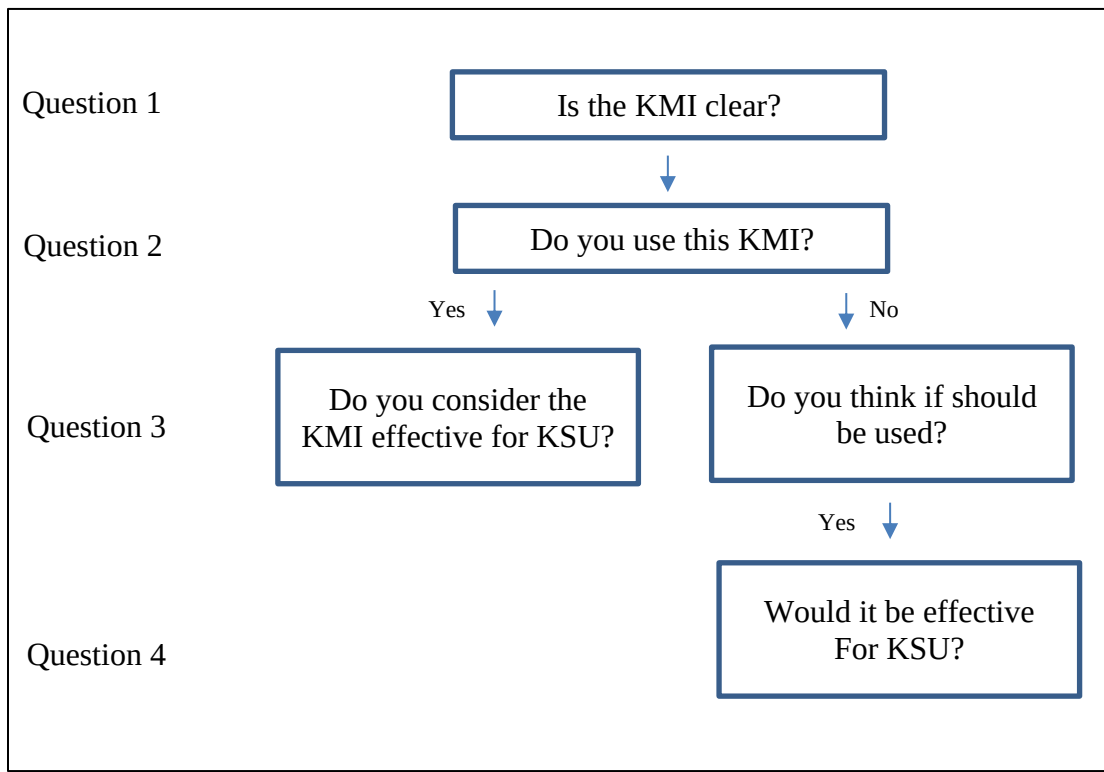


Figure 4.5 – KMI survey map

The KMI survey provides useful insights on the actual use of KMI from NPD practitioners in *VehicleSystemsCo* and the expected use of KMI from *VehicleSystemsCo* leaders. This information can then be compared with the *VehicleSystemsCo* procedures detailed in Chapter 5 to describe how NPD project teams operate compared to the expectation of the host organization and leadership team. As the survey are administrated independently of case project participation, the results of the survey are used in the company-level analysis, reported in Chapter 7.

4.6 The interviews

Interviews to project team members were conducted with the support of an interview protocol developed from the SLR presented in Chapter 2 and presented in Table 4.5. The pilot interview questions were intended to kick-off a conversation with the interviewee to create a rich dialogue on the project-to-project learning. An extract of Table 4.5, containing the interview questions, was provided to interview participants prior to the interview.

An information about the topics of the interview was provided to the participants with the meeting invitation (see Appendix F). A “prompt sheet”, with a list of KMI initiatives used in NPD (based on Table 2.3 – Appendix G) was provided to the interview participants the day before the interview. All interviews were recorded and fully transcribed for analysis. However, the transcripts are not available to the readers due to confidentiality reasons. A second interview questionnaire was updated from the preliminary results of the interviews conducted as part of the pilot case and additional key topics uncovered during the pilot interviews were added to the questionnaire presented in Table 4.5.

Semi-structured interviews to NPD managers and professionals working on global, radical and incremental innovations projects have helped understanding which KMI are considered most effective project-to-project tacit and explicit KSU and how such KMI are used and why. Preliminary results from the initial interviews showed the effectiveness of the selected methodology: all the interviews scheduled were completed in a timely manner, with very positive feedback from the project teams. Interviews at all levels in the organization were willing to openly discuss success and failures of the KMI adopted – all the potential interviewees accepted to participate in the study and accepted for the interviews to be recorded.

Table 4.5 – Initial interview questionnaire

	Interview questions	References
Intro	What is your role on the project? Can you tell me your story of the project?	NA
KMI	What did you do at the beginning of the project? Was it effective? Did you find it useful? Why? What did you do at the middle? Was it effective? Did you find it useful? Why? What did you do at the end? Was it effective? Did you find it useful? Why? Looking at the list of KMI shared, which one do you know? Which one do you use? Which one do you find useful? How did Covid impact your ability to share knowledge?	Prencipe and Tell (2001); Van Waveren <i>et al.</i> (2020).
K. needs	What interactions do you have with other projects? Get them to name the projects. How was your project influenced by previous projects? What did you do differently? What differences / similarities to the previous projects did you observe?	Enberg <i>et al.</i> (2006); Marabelli <i>et al.</i> (2013); Bower (200); Altman and Engberg (2016).

Table 4.6 – Senior leaders interview questionnaire

	Interview questions	References
KMI	What initiatives are you promoting to increase knowledge sharing in global NPD projects? What do you do in early-stage projects? What do you do for projects in the middle stage? Do you have an example of a project where good knowledge management was implemented? Was it effective and why? What impact do you think covid-19 had on project-to-project learning? Can you give me an example of a tool you are currently using that you consider effective for project-to-project learning?	Prencipe and Tell (2001); Van Waveren <i>et al.</i> (2020).
Radical v incremental	Which projects need more knowledge from other projects radical or incremental NPD? Why? Which projects benefit the most from knowledge sharing from other projects radical or incremental NPD? Why?	Bartezzaghi <i>et al.</i> (1997); Nobeoka and Consumano (1997); Enberg <i>et al.</i> (2006).

The interviews were designed to understand the global NPD framework of *VehicleSystemsCo*. A major goal was to identify the expectations of senior leaders in the organization, as far as project-to-project learning is concerned. Table 4.10 includes the list of the interviewed senior leaders and their job title, as well as date and duration of the interview. Participants to the interviews were carefully selected to ensure that as many as possible of the business unit's top leaders were included: key figures of the group president's staff were included and are highlighted in Figure 4.4 with a red box.

Understanding *VehicleSystemsCo* global NPD framework and senior leaders' expectations on project-to-project learning will help to understand the learning intent of *VehicleSystemsCo* and the focus that projects team have on project-to-project learning. In particular, interview questions were added to probe the following topics, that clearly emerged as key topics from the initial interviews and were not included in the initial questionnaire:

- Local versus global knowledge – “how do we get our teams to share local knowledge?”;
- Different knowledge needs of incremental and radical NPD projects – “In which projects is KM more important or useful, incremental or radical NPD?”.

4.6.1 Project 1 interviews – pilot

Table 4.7 includes the list of the interviewed team members and their job title, as well as date and duration of the interview.

Extracts from the interview transcripts, coding and analysis of the interviews are included in Chapter 6.

Table 4.7 – Project 1 interviews list

Role	Location	Interview date	Interview duration
Chief Engineer	US	08/07/21	33'21"
Engineering manager	CN	07/07/21	30'57"
PMO manager	IN	13/07/21	35'11"
Product engineer	IT	08/08/21	32'12"
Product engineer	CZ	30/06/21	31'26"
Program manager	CN	14/07/21	33'43"
Project leader	IT	07/07/21	31'38"
Project leader	HK	15/07/21	32'59"
Sales manager	CN	06/07/21	33'16"
SCM manager	CN	09/07/21	34'11"
Technical specialist	CN	06/07/21	27'37"

4.6.2 Project 2 interviews

Table 4.8 includes the list of the interviewed team members and their job title

Table 4.8 – Project 2 interviews list

Role	Location	Interview date	Interview duration
Chief engineer	US	21/07/21	47'42"
Engineering manager	IT	20/07/21	42'05"
Global engineering manager	US	21/07/21	32'47"
Product engineer	IT	26/07/21	32'50"
Program manager	CN	28/07/21	31'51"
Project leader	IT	28/07/21	39'50"
Sales manager	CN	06/07/21	33'16"
SCM manager	CN	09/07/21	34'11"

Extracts from the interview transcripts, coding and analysis of the interviews are included in Chapter 6.

4.6.3 Project 3 interviews

Table 4.9 includes the list of the interviewed team members and their job title, as well as date and duration of the interview.

Table 4.9 – Project 3 interviews list

Role	Location	Interview date	Interview duration
Chief engineer	US	15/06/21	29'33"
Engineering manager	CZ	12/06/21	26'43"
Engineering supervisor	IT	04/02/22	29'18"
Manufacturing engineer	PL	05/04/22	35'12"
Product engineer	IT	29/03/22	28'18"
Product engineer	IT	25/03/22	27'42"
Product engineer	CZ	30/11/21	30'09"
Program manager	IT	25/03/22	26'39"
Project leader	CZ	06/04/22	30'55"
Project leader	IT	04/04/22	30'32"
Sales manager	IT	04/04/22	26'49"
Supply chain manager	PL	11/03/22	31'29"

4.6.4 Interviews to senior leaders

Senior leaders and organizational interviews followed the first two project case interviews. Table 4.10 includes the list of the senior leaders interviewed and their job title, as well as date and duration of the interview.

Table 4.10 – Senior leaders interviews list

Role	Location	Interview date	Interview duration
VP/GM	US	31/08/21	27'17"
Global chief engineer	US	21/07/21	47'42"
Senior technical specialist	US	08/07/21	33'21"
Global engineering director	US	02/08/21	38'47"
Global engineering manager	IT	29/07/21	34'13"
Global engineering manager	US	02/08/21	30'21"
Global PMO director	UK	17/06/21	28'45"
WP business unit director	IT	10/06/21	33'25"
Product strategy manager	IT	29/07/21	38'45"

4.7 Considerations from Phase 1, Phase 2 and the three cases

Overall, very good participation from the case study and of the interviewees was observed across projects and regions. As Section 5.1 will detail, high engagement and passion for the topic confirmed that KM is a key topic for *VehicleSystemsCo*. All interviewees agreed to be recorded and it was possible to create full transcript of the interviews. No interviewee requested any material to be removed or cancelled from the transcript or asked to withdraw from the study after the interviews were completed. Interviews took place in both English and Italian. Italian interviews were not translated, and coding was completed on the Italian full transcript. Five interviewees were interviewed as both senior leaders and project interviewees for two projects, due to their extensive involvement in projects 1 and 2 respectively. In the case of three of those senior leaders it was decided to interview them once, in a single and longer interview, rather than interviewing them twice (once as senior leaders and once on a specific project). Overall, 35 interviews were completed, for a total of 19.5 hours of recorded interviews.

While a sample size of 35 interviews might seem limited, this number is considered satisfactory in the context of the research: the core team of each project (i.e., fully dedicated employees) were interviewed for each project, as well as the key decision makers at the

project gates. NPD project teams in *VehicleSystemsCo* tend to have a small core team (3-5 employees); the project team size typically increases to 8-10 people with the addition of shared, extended project team employees (e.g., technical experts). Similarly, the key functional and business leaders were interviewed in the interviews to senior leaders, together with key members of their first reporting line. A sufficient number of functional and business leaders (senior leaders and middle management) were interviewed to provide a full picture of the management expectation of knowledge sharing and KMI in *VehicleSystemsCo*. As showed in section 4.2, all key functional and business leaders of the business units under consideration were included in the research.

The decision to limit each interview to 30 min was driven by ensuring maximum participation from all levels of the organization in the research during the Covid-19 pandemic. The Covid-19 pandemic resulted in a significant increase in the numbers of meetings scheduled daily, compared to before the pandemic (Cecchi *et al.*, 2022). In the working environment at the time of the research, most current business meetings were limited to 30 minutes, with 1h or longer meetings reserved for extended reviews and customer meetings only. In such business context, limiting the interviews to 30 minutes was identified as the best compromise to ensure full participation of employees with busy schedules, whilst providing sufficient time to have an in-depth discussion about knowledge management. Extra time was always allocated at the end of the interviews, in case the Author felt extra time was needed and interviewees had the availability to continue the discussion: some interviews did extend well beyond the allotted time and were not interrupted by the researcher. The Author's pre-existing ties with the employees of *VehicleSystemsCo* were clearly a key enabler for the effectiveness of short, 30 minutes interviews. Most employees were already well aware of the research before the interviews were scheduled and very limited time was needed to bring the interviewees up to speed with the research. Similarly, the Author was well aware of the background of each project and the professional background of each interviewee, including previous projects and locations assignments. The combination of interviewee awareness of the research and the Author's knowledge of the organization and projects allowed to very quickly engage in

detail discussion about KM in NPD projects, as demonstrated by the data analysis reported in Chapter 6.

4.8 Summary

Chapter 4 introduced research methodology, the four phases of the research and the plan. The Chapter explained the selection criteria used for selecting the three case studies and gave a brief description of the three projects selected. The Chapter also explained the structure and objective of each phase starting from the review of the documentation, the observation of the three projects, the survey on knowledge management initiatives and the interview to the project teams and senior leaders, highlighting that good participation to the research was observed.

Chapter 5 further details the context of the research and *VehicleSystemsCo*'s approach to knowledge management, before reviewing the individual case studies in Chapter 6.

CHAPTER 5 – THE CONTEXT OF RESEARCH

5.0 Introduction

Chapters 3 and 4 introduced the research design and the methodology developed to answer the research questions. However, in order to better contextualize the contribution of the research, more information is necessary on the actions and processes in place for knowledge management in the *VehicleSystemsCo*. This is done in this Chapter.

This Chapter, mostly written before the completion of the interviews and before the analysis of the interview data, provides a sort of *ex-ante* picture of the environment in which the knowledge management takes place. Most of its content is derived from the Author's first-hand experience in his ten years tenure in *VehicleSystemsCo*, more than half of which after the PhD research was approved and kicked-off in October 2016. Special attention was paid to knowledge management since the research was initiated (including active involvement in organizational knowledge management activities), allowing an in-depth understanding of *VehicleSystemsCo* attitude towards knowledge management.

The case study research was conducted in the water and oil pumps business units of the automotive group of the organization, whereas the analysis of the organization's knowledge management initiatives (KMI) was conducted at an enterprise level (i.e., corporate) and the KMI described in the following paragraphs are deployed across the different groups and divisions of the organization. To reinforce and validate the Author's discussion of organizational culture and knowledge management, quotes from the research interviews were added to the Chapter, a sort of anticipation of the data analysis presented in

Chapter 6. Moreover, the Chapter includes a few quotes extracted for the interviews with NPD team members and senior leaders.¹¹

The Chapter shows that *VehicleSystemsCo* is quite advanced as far as KMI are concerned and most of the KMI prescribed by literature are implemented and encouraged. The following sections highlight the KMI that are prescribed by a procedure or for which an official company process or tool are in place. Sections 5.1 to 5.14 show which KMI are in place, prescribed and detailed in procedures revealing that *VehicleSystemsCo* is quite active and up to date in the field of KM. This strongly contrasts with the initial feeling perceived in conversations with NPD teams that KM is a pain point and that much more could be done to improve it:

“[...] we often have access to the knowledge we need after we realized we needed it, passively. Once we have a [technical] failure we quickly are told where to go and find the procedures we need to fix it. It’s very difficult that we hear of this knowledge before the failure happens.”

(P1-I7)

¹¹ The quotes are highlighted in the text by an italic font and quotation marks (“). Square brackets and blacked out text (■) highlight passages omitted for confidentiality reasons or because not relevant. Notes to improve the readability of the quotes are also added in square brackets. The author is included at the end of the quote, in brackets, using the following nomenclature: NPD teams: Project # - Interview #, abbreviated to P#-I#. E.g., Project 1 – Interview 1 is abbreviated as **P1-I1**.

Due to confidentiality reasons and to the role that best practices and business systems play in defining the competitive advantage of an organization over its peers and competitors, the following sections do not include details of *VehicleSystemsCo* process and procedures.

5.0.1 Trust, blame and organizational culture in *VehicleSystemsCo*

The review of the literature showed the importance of organizational culture (trust and blame in particular) for knowledge sharing in NPD. The host organization prides itself of having a “no blame” culture. As one of the managers in the organization commented, junior employees joining the organization are trusted early in their careers with important responsibilities on the NPD projects they work on and encouraged to learn on the job:

‘[...] as I always say when I hire new engineers, go out on the field and make mistakes!’

(VP/GM, 27 January 2020)

The organizational cultural elements of trust and no-blame is clear from the organizations documents and procedures (e.g., the organizations ethical procedures have a clear no retaliation policy). The no-blame culture is lived by the organization’s employees and is evident from both positive and negative lessons learned captured (see Section 5.7). Additionally, the lessons learned procedures directly ask the teams to capture all mistakes that occurred in the project, in order to understand the root causes and improve the process and procedures.

Elements of the “no blame” organizational culture are clearly recognizable in Chapter 6, however, given the importance of blame in knowledge sharing it is important at this stage to highlight how the culture is impacting the day to day activities of NPD project

teams. A good example of the no blame and transparent culture of *VehicleSystemsCo* can be recognised in their use of Key Performance Indicators (KPI) to assess and report the health of projects. When a number of KPI degrade, the overall health of the project becomes red and the project team is asked to provide regular updates to the leadership team, while investigating the root cause of the issues. Even though the process of turning the project KPIs to red drives a lot of attention and scrutiny to the project, there is limited reluctance in doing so, thanks to the focus of the organization on learning when issues happen, rather than looking for whom to blame. An executive from *VehicleSystemsCo* summarized well the concept in the following quote:

'I know it [turning the project red] is stressful, and I know some people want to be very careful with pushing the red button, but I say: the redder, the better.'

(VP/GM, 27 January 2020)

Chapter 2 also highlighted the dual importance of trust, on the sharing and receiving end of the knowledge flow. In particular, employees sharing knowledge must trust that the receiving party will not abuse the knowledge shared (e.g., taking improper ownership of new ideas and concepts) and the receiving party must trust the quality of the knowledge received, in order to apply it in their activities. The Author's pre-existing experience with *VehicleSystemsCo* showed that high levels of trust exist in the organization and is well summarised by a quote from one of the case study interviews:

"What really makes a difference is the culture. I think it might be generational but all the people I work with are very eager to share their knowledge and to teach me. [...] I never had an issue where someone

didn't want to teach me, to avoid sharing with me knowledge that would make his competency less valuable."

(P3-03)

5.1 Documents and procedures in *VehicleSystemsCo*

This section provides a summary of the organizational and project documents to understand the broader picture of knowledge management in *VehicleSystemsCo*. The NPD documents library is quite extensive, with over 200 procedures and templates for the different stages and types of NPD projects. All documents were reviewed as part of the case study, but only a fraction is discussed in this Thesis. Table 5.1 includes a selection of the reviewed documents and procedures which were selected amongst the mostly used documents in NPD projects and the documents most relevant for project-to-project learning (e.g., lessons learned procedures and project repository procedures are included). Group and corporate documents are discussed in Chapter 5, while project documents will be discussed in Chapter 6. The last two columns of Table 5.1 track if the documents are corporate guidelines or project documents, with the help of a "tick" sign. Project specific documents, as review presentation, technical reports, gate review documentation and customer documentation were also reviewed.

While the documents were not coded for key words due to confidentiality reasons, the following sections walk the reader through the key findings from the documents review for each KMI.

Table 5.1 – *VehicleSystemsCo* documents reviewed

Document number	Number of pages	Title of the document	Content of the document	Document reference	Group or corporate	Project document
1	14	<i>VehicleSystemsCo</i> leadership model	Corporate guideline detailing the leadership competencies in <i>VehicleSystemsCo</i> .	VLM	✓	
2	7	Project gate meeting guide	Corporate guideline detailing the NPD gate meeting format and decision framework.	NPDMTG	✓	
3	93	Ethics manual	Corporate manual detailing <i>VehicleSystemsCo</i> company values, ethics, quality and environmental and safety standards.	ETHICS	✓	
4	6	Prototype plan	Group guideline on preparation and control of prototypes, including minimum samples measurements and control plan.	PROTO	✓	
5	4	Lessons learned guide	Summary document including general guidelines on capturing lessons learned and lessons learned requirements at each gate. Examples of lessons learned captured are provided, as well as links to secondary guidelines for lessons learned tools.	LLGUIDE	✓	
6	3	Project document repository guideline	Guideline for minimum project repository requirements for NPD projects. The document includes a list of minimum documents that must be included in the repository at each stage.	REPGUIDE	✓	
7	9	Project final report guideline	Guideline for the use of the “final project report” template to be used upon completion of NPD projects. Key lessons learned and success factors for the project are included	S4REP	✓	
8	3	Change management guide	Guideline for the best practice and use of the template to track project changes.	CHANGE	✓	
9 – 12	10	Gate review checklists	Four documents providing the checklist for pre-work that needs to be completed before each gate review. Updating of lessons learned databases and project documentation repository is included at every gate.	CHECKLIST	✓	
13	11	Design review guideline	Corporate guideline detailing timing requirements and minimum content to be discussed at each	DESIGN	✓	
14	1	Minutes of meeting and action items list guide	Corporate guideline for the use of <i>VehicleSystemsCo</i> templates for minutes of meetings and action item list. The document includes a link to the latest templates and a short guide to the scope of the tools.	MoM	✓	
15	3	Feasibility assessment guideline	Corporate guideline to the use of the project feasibility templates. The templates include key lessons learned from previous projects, in the form of questions about the project being assessed.	FEAS	✓	

16	21	FRACAS guideline	Corporate guideline on the use of Failure reporting and corrective action systems in VehicleSystemsCo. The guideline includes links to templates and examples form previous projects.	FRACAS	✓	
17	7	Market launch plan	Corporate guideline on the preparation of the project market launch plan.	MARKET	✓	
18 – 32	100+	Project 1 project review and gate review presentations	-	-		✓
33 – 47	100+	Project 2 project review and gate review presentations	-	-		✓
48 – 56	100+	Project 3 project review and gate review presentations	-	-		✓

5.2 Feedback loops and brainstorming in *VehicleSystemsCo*

Feedback loops and brainstorming sections are deeply rooted in company culture. The organization's stage-gate NPD management process includes a number of tools and templates for comparing designs (e.g., Pugh matrix) and making collective decisions. Brainstorming sessions are formally mandated by the stage-gate methodology in the early stages of the project (i.e., concept definition stages) and for root cause investigation in case of failures. Feedback loops are also incorporated in company procedures and project teams are required to repeat the same activity in different stages of the project and to update and refresh documentation based on the feedback received during earlier reviews.

At each stage of the NPD process, NPD teams must submit evidence of completed brainstorming sessions and of development loops – the organization's procedure asks that teams document how the project and design details have evolved as a consequence of feedback loops. The quality of the evidence submitted prior to a stage-gate review determines if the stage will be cleared and the project allowed to proceed to the next development stage. When clearing a gate, three possible outcomes exist: (1) a gate is cleared successfully and the project team can proceed to the next stage; (2) a project fails completely the gate and is cancelled; or, more often, a project clears a gate with “further work required”. In this case, the project team is authorized to proceed to the next stage.

The observation of feedback loops in *VehicleSystemsCo* shows that the implementation of feedback loops is well aligned with the Class 2 feedback loops defined by Chirumalla (2017) – feedback loops related to NPD and product lifecycle. Other classes of feedback loops defined by the Author are not applicable to the research as they do not strictly relate to new product development. Similarly, brainstorming sessions used in *VehicleSystemsCo* fit the descriptions of both cross-function brainstorming sessions and specialized brainstorming sessions found in literature (Kavadias and Sommer, 2009). In line with literature, specialized brainstorming sessions are used for problem solving of complex technical issues; cross-functional brainstorming sessions are used for broader issues that need inputs of multiple functions: good examples of activities that in *VehicleSystemsCo* use cross-functional brainstorming sessions are the definition of manicuring strategies and product strategies, that require in-depth knowledge of multiple specialized subjects (e.g., manufacturing capacity, suppliers capability, customer footprints, etc.).

5.3 Communities of practices in *VehicleSystemsCo*

Structured and non-structured communities of practices (CoPs) exist in *VehicleSystemsCo*. Structured, or formal, CoPs are designed and led by the organization's leadership team and meet on a regular basis. These CoPs are often based on the organization's functions (e.g., Sales, Supply Chain), where colleagues working in similar types of roles across the enterprise meet to discuss yearly goals, projects status and specific challenges. Team building activities and events (e.g., Project Management Camps, Sales Yearly Meeting) are organized by *VehicleSystemsCo* to sustain the CoPs and encourage connections between CoPs members. Non structured CoPs also exist, where global colleagues working in the same function (e.g., R&D) and the same business unit meet virtually on a regular basis to discuss latest projects or customers news.

The use of CoPs observed in *VehicleSystemsCo* and the role that managers and senior leaders play in the creations and sustainment of CoPs are aligned with best practices

found in literature and both virtual and traditional CoPs exist (Dubé *et al.*, 2006; Ardichvili, 2008; Bridwell-Mitchell, 2016).

Two examples of CoPs in *VehicleSystemsCo* offer more insight into how the CoPs operate in the organization. The first one is the *water pumps global engineering team* CoP. Using Dubé's *et al.* (2006) descriptors, the Global engineering team CoP is a strategic CoP (intended to support the overall mission of *VehicleSystemsCo* within the boundaries of the water pumps business unit); a permanent CoP (opposed to temporary); an intentional CoP (led by the engineering management team of the business unit). It is operating with high boundary crossing (including only members of the engineering function, but across multiple countries) and its leadership is clearly assigned (the engineering managers lead it). Moreover, members selection is closed (only the engineering function), while enrolment is voluntary, but recommended and large in size. The second example is the EMEA regional sales CoP. The regional sales CoP is an operational CoP (focuses on the daily activities of the sales function), a permanent CoP and a spontaneous CoP, operating with low boundary crossing (includes only members of the sales function, only in EMEA). Its leadership is continuously negotiated (not clearly assigned), while members selection is closed (only the sales function) and enrolment is flu voluntary and small in size. Both the global engineering CoP and the EMEA sales CoP are intended to allow the sharing of best practices across employees working on similar tasks and facing similar problems, in line with literature.

5.4 Design and component re-use in *VehicleSystemsCo*

Design and component re-use is a key focus of the organization and very much encouraged by the group and by the corporate senior leadership. Prior to 2010 the organization invested in an intranet-based database of drawings and 3D models of all the components developed and in production. The online database is supported by a commercial software that allows product lifecycle management, including approval and release of changes and modifications – a notification system is also included that notifies all users subscribed to a single part number of any changes. The database is searchable, allowing users to find

existing part numbers and designs and is reviewed on a regular basis by the design to ensure the number of similar part numbers is kept as low as possible. These findings are in line with the recommendations by Sivaloganatha and Shahin (1999) that prescribe the structuring of databases with information on designs and the creation of databases to store the designs themselves. Recent computer aided design software (CAD) directly includes the capability to link with databases for the storage and sharing of designs in the so-called product lifecycle management (PLM) software (Zhang *et al.*, 2018).

In line with the observations of Shahin, Andrews and Sivaloganathan (1999), some of the interviewees in *VehicleSystemsCo* underline that design and component re-use also pose risks for the NPD project teams, especially when reusing new designs that are still in development. This is quite common in the case of projects running in parallel. One interviewee from Project 2 noted that reusing designs also implies carrying over the problems of the initial design:

“[...] I think the reason is that the information came too late. I mean, I personally never we knew we had this same problem on [REDACTED]. If we knew that, we would have started directly with a new component, not taking theirs”.

(P2-06)

While the risks and limitation of design re-use are well known both in the literature (Shahin, Andrews and Sivaloganathan, 1999) and to the practitioners, design re-use is strongly pursued and recommended in *VehicleSystemsCo* due to the potential benefits it brings in terms of development time and costs reduction.

5.5 Expert yellow pages and experts re-use in *VehicleSystemsCo*

Each business unit maintains in *VehicleSystemsCo* a list of subject matter experts (SME) that, each year, are deployed on the key programs. The list of the subject matter experts is stored on a shared network directory which is accessible to all employees of the business units. The SME list is searchable by employee name (i.e., the SME) and also by the expertise (i.e., the subject). The SME table includes both the name of the global expert and the name of local experts, one for each geographical area, if available. Including a local SME allows for smoother interaction, removing the burden of time zones and physical distance. As the expertise required is tailored to each individual division or business unit, SME lists are not deployed at an enterprise level – this is in line with what observed by Rao (2012) that surveys the use of knowledge management tools across multiple organizations. In 2015 *VehicleSystemsCo* purchased licences for a global “yellow pages” software, that allowed employees across all divisions and location to look up specialists in different locations, based on the expertise needed: e.g., searching for “aluminium welding” would return a short list of company-selected experts to contact for questions on aluminum welds. The software was quickly abandoned and has not been replaced with another similar enterprise tool at the time of the writing of this Thesis. The global software allowed employees across the globe and in different business units to search for a specific competency either technical or non-technical (e.g., project management or aluminium welding). However, maintaining the SME database up to date proved a difficult task and the activities were delegated to the individual business units.

5.6 Job rotations in *VehicleSystemsCo*

Job rotations are encouraged by *VehicleSystemsCo*. An intranet portal allows employees to access a list of internal vacancies across the locations and divisions of the business and apply for new roles. Movement across the business and locations is highly encouraged.

5.7 Lessons learned databases in *VehicleSystemsCo*

Databases of lessons learned exist both at a business unit and corporate level, with the business unit level ones preferred over the corporate ones. Trainings exist to provide accessibility and instruction on how to use the lessons learned databases. Since October 2016, *VehicleSystemsCo* has changed three times the tool for capturing and storing lessons learned, from simple Excel databased to complex commercial software – this is in line with literature findings (see Soltész and Berényi, 2021). The organizations stage-gate process requires that key lessons learned are captured at each stage and disseminated with similar projects on-going at the time of the review.

Lessons learned databases are the single knowledge management initiative that attracted the most controversy during the case study interviews. Middle managers especially are very sceptical about the effectiveness of lessons learned database:

“I think [lessons learned databases] are a gigantic waste of money, to be perfectly honest with you. Because I don’t think that’s how we learn right? I just don’t think that ties into the how people learn new things. It’s adding overhead, it adds to a rather large task list to an engineer, it’s not helping them get more efficient at learning. I think it’s flawed from the very beginning. In ■ years, I’ve never seen that work. And it’s been tried many, many times”.

(P2-02)

Senior leaders and other project team members in *VehicleSystemsCo* tend to be more optimistic about the use of lessons learned databases:

“We aspire to do better. It’s embedded in [REDACTED] and other processes and other things. And we use the word all the time ‘lessons learned, lessons learned’ but I think the formality is just not there. I think people use them, but I am not sure we are always so successful”.

(P2-01)

The use of lessons learned in *VehicleSystemsCo* is aligned with the best practices highlighted in literature and lessons learned are captured during the project lifecycle (see Kotnour and Vergopia, 2005) rather than just at the end of the project in post project reviews. While the management of lessons learned databases is led by the project management office (PMO) and the PMO is also responsible for ensuring lessons learned are captured, as indicated by best practices in literature (Barbalho *et al.*, 2016), many of the interviewees question the quality of the knowledge captured in the lessons learned databases:

“At the end of the day, if they [lessons learned] are not well written... [lessons learned are not useful] it depends on who’s writing them, right? But at the end of the day, a lot of times they are not well written. And if you don’t have a lot of experience with the project, you wouldn’t necessarily understand the issue or what’s trying to be conveyed.”

(P2-01)

“Of course, it’s faster to read [from a database] but if people don’t want to write their knowledge in a database, there is not much you can do.”

(P3-07)

While *VehicleSystemsCo* procedures mandate the use of lessons learned databases and the PMO offers the teams the tools and the support needed, the NPD teams in *VehicleSystemsCo* report to be struggling with the use of such tools, as showed by the above evidence. The teams identify the availability of limited time to capture and review lessons learned as one of the key reasons to object the use of these tools. This finding is not surprising, and it is well-known in literature (Newell, 2005; Williams, 2008).

5.8 Mentoring and training in *VehicleSystemsCo*

Mentoring and training are extensively used in *VehicleSystemsCo*. Divisional, functional and business unit training plans exist for each employee and are refreshed on a yearly basis. The organizational employs a tool called *VehicleSystemsCo University* that, with the support of a commercial software, allows registration and booking of face to face (instructor led) training.

Finally, *VehicleSystemsCo* hosts a *Global mentoring program* (GMP) where employees from different locations and business units are paired in a Mentor-Mentee partnership aimed at sharing best practices and lessons learned. The literature shows the impact that organizational culture has on knowledge sharing and use and on the willingness of employees to share knowledge with their peers and colleagues. Employees in *VehicleSystemsCo* commented positively on the impact of organizational culture and the willingness to mentor one another. As we will see in Chapter 6, middle managers extensively rely on mentoring and training for project-to-project learning:

“I mean, to me, learning is pretty much a very old skill set. Right? And how do we do it? And what's the most effective way? It's pretty much well thought out already. Right? So mentoring, mentoring and training to me are probably the most effective. Yeah, so you can think of, ah, if you think of a skilled trade, like, ah, you know, I love Italy, because of the masonry work great. So, there's people that do that, and are very, very good at that in Italy, right. And there's young people that probably train under very skilled trades, and that learn to do that, right. They just don't look at a piece of software and figure out how to lay down on a nice proper set of tiles, right?”

(P2-02)

5.9 Middle management knowledge brokering in *VehicleSystemsCo*

Middle management is active in knowledge brokering in *VehicleSystemsCo* and line managers are expected to be very involved on the technical and projects details of all projects on which their teams are active. Middle managers (e.g., engineering managers, supply chain managers) are involved in weekly review meetings on each active project and report-out to senior leadership on a weekly basis. Middle managers are exposed to success and failures on each project and are able to share what they observe with other projects and are therefore able to share knowledge across organizational boundaries Pitt and MacVaugh (2008).

As shown in Section 4.1, *VehicleSystemsCo* is structured in GPL; this also impacts middle on management reach and impact: some middle managers (e.g., engineering managers) have global responsibilities, with team members located in different geographical regions, while other managers (e.g., supply chains) have regional responsibilities, looking after projects impacting their region only. Due to the nature and reach of their roles, global managers are better positioned for global NPD project-to-project learning. In *VehicleSystemsCo* project reviews are a key tool that enables middle

management knowledge brokering. In project reviews, middle managers are able to both hear about issues and learning on several projects, not necessarily in the same business unit, and share the learnings with the project teams they supervise at a later stage. Similarly, middle managers used project reviews to direct the project teams towards specific subject matter experts or other project teams based on the issues that the teams are facing.

5.10 Post project reviews in *VehicleSystemsCo*

VehicleSystemsCo stage-gate process clearly identifies post-project reviews as pre-work for the final release gate of all projects. According to the formal procedure, no project can be closed – and its resources redeployed – if a final gate is not completed, including a post-project review. Post-project reviews are typically longer than lessons learned reviews that take place prior to the gate at the end of each phase in the project lifecycle. The extended project team is typically involved in post-project reviews, while only the core team typically participates to the other gate reviews.

In line with literature recommendation, the extended project team is invited to the post-project review as well as key external employees from other projects (Busby, 1999). During the post-project reviews, the core project team is invited to help to reconstruct the history of key project event that have significantly impacted, positively or negatively, on the project. While the teams are encouraged to discuss systemic issues (i.e., problems related to company procedures and practices), no specific checklist for lessons learned categories that should be covered in the post project reviews exists in *VehicleSystemsCo* (Goffin and Koners, 2011)

5.11 Relocation of offices in *VehicleSystemsCo*

Relocation of offices rarely takes place and it is usually related to manufacturing facilities. Not necessarily it impacts on R&D offices.

5.12 Storytelling in *VehicleSystemsCo*

Storytelling is used in *VehicleSystemsCo*, but it is not formalized in any procedure and not particularly encouraged by the senior leadership. Very senior, experienced and outgoing specialists tend to use storytelling as part as their training and mentoring strategy, but this is left to individual decisions and behaviour:

“[...] the issue is that a lot, or maybe not a lot but many, or our learnings happened involuntarily. What I mean is that often we start chatting with colleagues about a topic and we end up chatting about another topic and critical information comes up.”

(P1-01)

As for mentoring and training, interviewees report that the organizational culture in *VehicleSystemsCo* facilitates the use of storytelling of past mistakes to pass on lessons learned. However, *VehicleSystemsCo* employees observe that geographical dispersion of the team impacts on the ability to share knowledge via storytelling:

“A lot of the knowledge we have in the company, I think that’s where it gets tricky, is really embedded in the people we have. And that’s the one thing reason why I think global program are different. Because if you’re all collocated, it’s easier to get that information flowing, even just at the coffee machine talk, when you are global is different.”

(P2-01)

5.13 Templates and guidelines in *VehicleSystemsCo*

Templates and guidelines are extensively used by *VehicleSystemsCo*. Guidelines are periodically refreshed and updated. The yearly goals of senior leaders and middle managers often include the creation and refreshing of guidelines. Formal tools for capturing knowledge and revision-track templates and databases are used, new tools are experimented with to allow for better storing and control of procedures and documents. Online databases, accessible from each location are used to store and track revisions of the procedures. *VehicleSystemsCo* requires that specific procedures are formally called out on NPD project documentation (e.g., component drawing prints). Subject matter experts are required to review the project documentation to confirm the correct use of company guidelines. Managers and chief engineers are required to review the project work at the end of each gate to ensure the correct application of the standards on each project.

5.14 Summary

Chapter 5 showed that most of the KMI identified in literature are available to NPD team in *VehicleSystemsCo* and corporate process are developed to deploy them. The organization's senior leadership team is aware of the importance of KM and encourages KSU also by including goals related to KSU in yearly goals for middle management and working-level team, in line with recommendations found in literature (i.e., *learning mandate* and *learning environment support* – Sense, 2003).

Understanding *VehicleSystemsCo* knowledge management maturity is a key pre-activity required to validate the selection of the case study. Selecting a case study in a host organization where knowledge management is neglected or not up to date with current best practices would have severely limited the relevance of the research to a broader spectrum of organization and limited the contribution of the research to the academic knowledge base. Selecting an organization modern and mature as far as knowledge management is concerned was therefore a major key ensure research findings could contribute to the advancement of the NPD knowledge management field.

CHAPTER 6 – OVERVIEW OF THE CASES AND PROJECT-LEVEL ANALYSIS

6.0 Introduction

Three global NPD projects run by two different business units of *VehicleSystemsCo* were selected for the observation of the NPD project teams phase of the research. The projects were selected to ensure the Author the possibility to observe projects with different degrees of innovation and at different stages of the development cycle.

The Author joined as many project meetings as possible, joining meetings where participants would not expect his presence as part of normal working activities. Copious notes were taken to keep track of the project events and the Author had access to formal minutes of meetings (MoM) and project change logs¹² – approximately 180 pages of handwritten notes and e-mail MoMs.¹³ Altogether, the Author joined and had access to notes and minutes of meetings from approximately:

- 347 daily and weekly project team meetings (short working-level meetings, approximately 30-60 min long);
- 31 project and gate reviews (45-90 min review with senior leadership);

¹² Based on the *MoM* document introduced in Chapter 5.

¹³ An example of the Author's notes from project meetings is provided in Appendix E.

- 15 supplier, customers and *VehicleSystemsCo* manufacturing facilities visits;
- 63 formal one-to-one meetings with project participants and managers (30 min meetings).

6.0.1 Data gathering

The project meetings listed above are part of the standard project meetings planned from NPD project in *VehicleSystemsCo*. *VehicleSystemsCo* stage-gate program management methodologies¹⁴ prescribe frequent cross functional team meetings. For the case study projects, the cross functional project team meetings were scheduled with a weekly cadence. Additional team meetings were scheduled by each project-function team leader with their teams, also with a weekly cadence: *VehicleSystemsCo* project management methodologies prescribe that a “function team leader” is assigned for each function on every NPD project. Typically, radical NPD projects have one leader assigned for each NPD function: a radical NPD will typically have a product engineering leader, a manufacturing leader, a project finance leader, a project supply chain management leader, etc. The function leaders with larger teams normally host a sub-project team meeting, limited to project participants from their function. In line with NPD management and project management best practices (Cooper and Sommer, 2018), daily “stand-up” or “red alert” meetings were scheduled to keep track of urgent and time-sensitive activities. Regular reporting out sessions to senior leadership are scheduled for all projects of *VehicleSystemsCo*. The occurrence of reporting out sessions and the seniority levels of the participants (up to the business unit directors, the

¹⁴ Based on the *NPDMTG* guideline introduced in Chapter 5.

group CEO or higher) depends on the degree of innovation of the project and the project track of records, defined by time, quality and cost KPIs.

In addition to project meetings, one-to-one meetings between the Author and project team participants were scheduled. Relevant quotes from one-to-one meetings are included in this chapter.

Due to confidentiality reasons, the minutes of meetings and personal notes were not coded and are only used in this Thesis to guide the narrative of the three projects during the 12 months of observations and major project events. To ensure that the normal project operations were not excessively impacted by the researchers' presence, project meetings and project reviews were not recorded. Recording of meetings is very rare in *VehicleSystemsCo* and only limited to training and employee communications, where access to the recording is needed after the meetings for employees that were not able to join the meetings in real time. The quotes included in the following sections, derived from the author's personal notes or from minutes of meetings, are highlighted by single quotation marks (' '), to differentiate them from full transcripts quotes in double quotation marks (" "). Square brackets ([]) within quotes are used to highlights researchers notes to help the reader with the contextualization of the quotes (e.g., explaining if the quote is referred to a customer or supplier action). When outside of the context of quotes, square brackets ([]) are used in this Chapter to highlight relevant knowledge management initiatives (KMI) or types of knowledge connected to the project knowledge events.

Sections 6.1, 6.2 and 6.3 summarize the observations from 12 months of global NPD project activities for projects 1, 2 and 3, respectively. In addition to the observation of the three project teams, the Author had the opportunity to follow closely one community of practice (CoP) in one of the two business unit. Observations and findings from the CoP are reported in Section 6.4.

6.0.2 Addressing confidentiality issues in project observations

The following sections cover the 12 months of observations on each project in chronological order. Key focus was given to major project events (e.g., customer change requests, etc.) and knowledge-intensive activities (e.g., design sections, personnel changes, etc.). A brief introduction of the project and project events before the observation started is included at the beginning of each section. To maintain confidentiality of *VehicleSystemsCo* and its business units, the name of the products developed by the business units were changed. Also the discussion on actual vehicle systems could not be reported verbatim. To ensure the reader could understand the main project events and the related knowledge management issues, component systems with comparable degree of complexity to *VehicleSystemsCo*'s real products were chosen. The following sections will use internal combustion engine *water pumps* and *oil pumps* as examples of the core products of Business Unit 1 and Business Unit 2 respectively. When selecting two similar product families to represent the real products that *VehicleSystemsCo* designs and manufactures, five key parameters were considered:

- Systems operate in similar working conditions: only components and systems directly installed on internal combustion engines were considered. This is important for knowledge management as the working conditions of the component have an important impact on the relation with the customer, system level interactions and the design of the part.
- Systems have a high degree of complexity: only systems obtained by the assembly of several components were considered. This is important for knowledge management as key subsystem interactions are only possible when the component count is sufficiently high.

- Systems have to be mission critical: a failure of the system can result in a full engine system failure, leading the vehicle to enter “limp mode” (i.e., driving speed and range is limited) or coming to a full stop.
- The two product families are based on the same physics and engineering concepts, while facing specific technological challenges. This is important to knowledge management as engineers and technicians working in one business unit can easily transfer to the other.
- The two product families have significant margins for innovation and technical evolution. This is important for knowledge management as the research investigates both radical and incremental NPD.

Water pumps and oil pumps were selected to represent the two product families developed by *VehicleSystemsCo* as (1) both are sub-systems directly mounted on engines like the real products of *VehicleSystemsCo*; (2) both have a high degree of complexity; (3) both are mission-critical to the engine operation; (4) both share the same working principles (fluid pumping); and (5) innovation is still on-going in the industry on those products (Truong *et al.*, 2013) for example to reduce the energy they absorb and contribute to a reduction of fuel consumption of combustion engines.

Innovation projects involve complex problem-solving, often on an ongoing iterative basis, relying on existing and/or new knowledge. To understand knowledge flows in a company designing component systems, the reader requires an understanding of the typical problems involved. Therefore, to help the reader to better understand the learning dynamics of the NPD project teams, the following sections include references to the pump technology and components. Providing a basic explanation of the key sub-components of vane-type pumps is needed in order to be able to discuss component re-use and degrees of innovation. Truong *et al.* (2013) show a simplified schematics of a vane-type pump – Figure 6.1.

Readers well versed with or not interested in automotive engine systems might consider the next paragraphs trivial and can skip directly to Section 6.1 for the case study observation narrative.

In particular, the numbered components in Figure 6.1 are: (1) pump housing; (2) tapped holes; (3) cover; (4) drive shaft; (5) inlet port; (6) inlet port O-ring; (7) alignment pin; (8) main pump ring; (9) pump rotor; (10) rotor vanes; (11) secondary pump ring; (12) pivot pin; (13) outlet port; (14) discharge orifice; (15) oil seals; (16) biasing spring and (17) outlet O-ring.

The primary function of variable displacement oil and water pumps must be able to provide a variable, pressurized oil or water flow to the engine systems that require it based on engine conditions. Low pressure flow is provided to the pump through the inlet port (5); high-pressure flow is provided to engine systems through the outlet port (13). Inlet and outlet ports are connected to the other engine systems with sealing O-rings (6) and (17) respectively.

While O-rings are simple and well-known rubber rings, they provide the primary function of ensuring that the pressure in the ports and ducts is maintained and the flow is not leaking outside of the desired path. A complex system of spring and eccentric discs – components (8), (9), (11) and (13) – allows the pump to module the volume of flow it delivers, based on the requirements of engine systems. This Thesis will not include further details on the working principles of variable displacement vane-type pumps.¹⁵

¹⁵ Any further engineering detail needed to better understand the knowledge dynamics in the observed NPD teams are provided in Sections 6.1 – 6.3. For readers interested in understanding more about variable displacement vane-type pumps, please review the work by Truong *et al.* (2013).

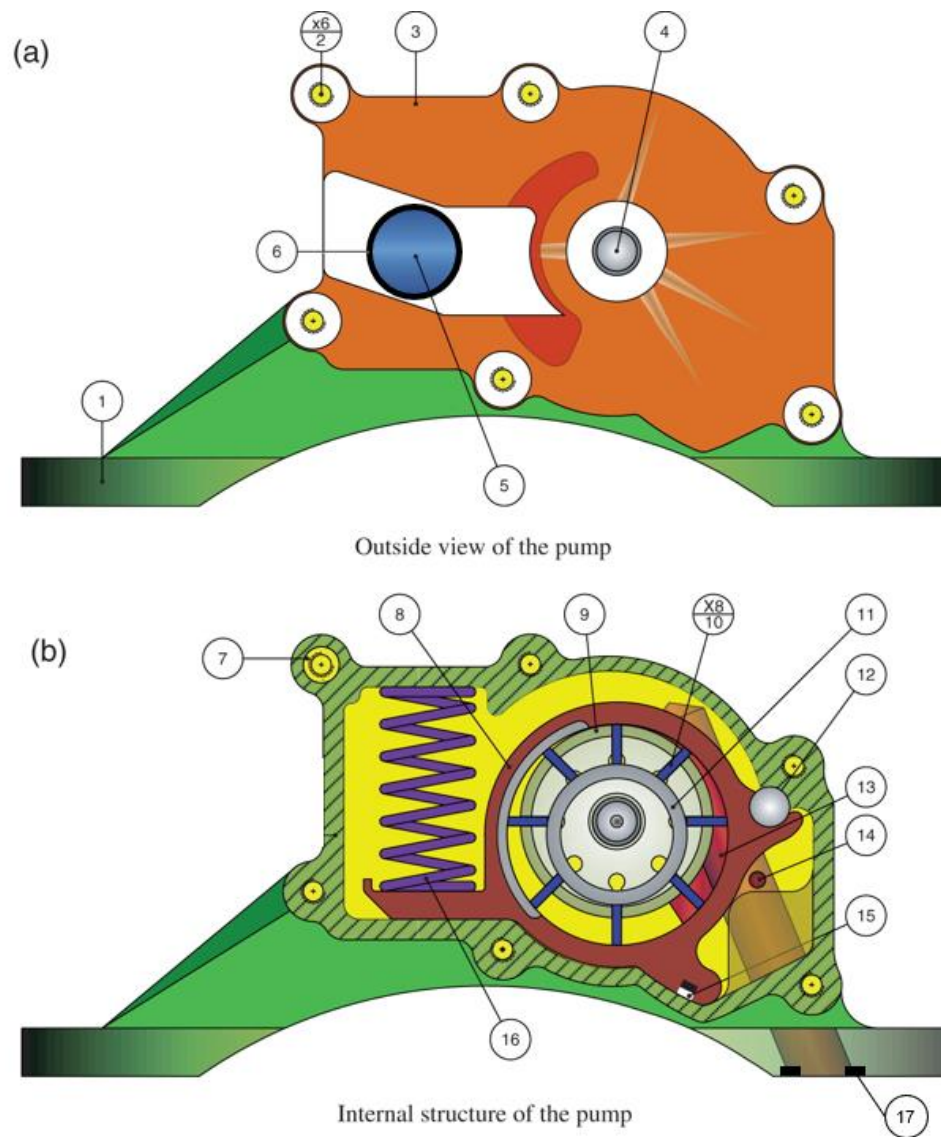


Figure 6.1 – Variable displacement vane-type pump diagram – adapter from Truong *et al.* (2013)

A number of different legacy and current *VehicleSystemsCo* projects are discussed in the case study narrative, as well as in the interviews and survey data analysis. For clarity, case studies are numbered (Projects 1, 2 and 3), while the other projects discussed are identified with alphabet letters, as in Table 4.4. Following the format presented in Table 4.4, Appendix H includes a full list of the projects discussed in this Thesis.

6.1 Project 1 case study

Project 1 is a radical, global NPD project. The project's team is geographically distributed, with team members located in all regions the organization is active in North America (NA), Europe Middle East and Africa (EMEA), and Asia Pacific (APAC). Project 1 was created to introduce a new *variable displacement* water pump technology to the APAC region, targeting a local (new) customer with the application of a new commercial vehicle for two customer platforms. The local APAC R&D team for the variable displacement water pumps business unit is newly created, so a major part of the NPD work is carried out by the EMEA team. Production is localized in APAC and the majority of the supply chain is APAC-based. Key NPD team members are APAC and EMEA based, with some involvement of the NA team.

When the project observations started, Project 1 was considered a 'trouble project', with significant delays to the original timeline, many product failures, supplier failures and extensive changes in the project team. Changes in the project team include the addition to the project roster of new resources, including newly hires in the organization. Project team roster changes also include a project manager change and technical lead changes. Due to its nature of radical innovation project, high scrutiny from the organization senior leadership is expected: Project 1 is frequently reporting progress to the group CEO and top-level global process experts were assigned to support the project team.

Project 1 was selected for the participation in the research due to its global reach, its complexity and its extended length: the project was kicked-off in 2016 and was still ongoing when Phase 1 of the research started –Figure 6.2 shows a milestone plan of Project 1. A dashed orange rectangle in Figure 6.2 shows the window of observation on Project 1 and the major project events discussed in the following sections. Orange circles and triangles are used in Figure 6.2 to highlight gate and project reviews. It is interesting to observe how the frequency of project reviews with the leadership team of *VehicleSystemsCo* increased as the project issues increased.

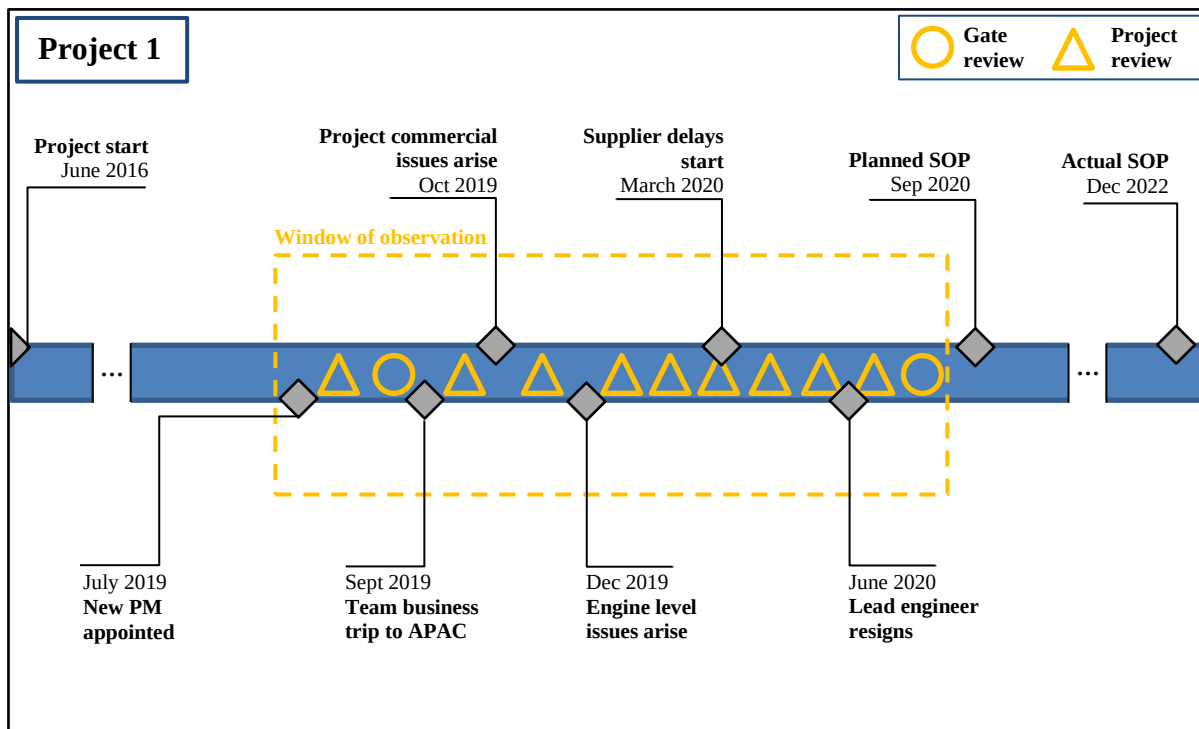


Figure 6.2 – Project 1 milestone plan and window of observation

The project complexity experienced by Project 1 includes technical complexity and, most interestingly, organizational and process complexity: *VehicleSystemsCo* project evaluation and ranking guidelines rank it as a high-risk project. The scope of Project 1 includes the development and technology transfer of partially known variable displacement water pump technologies in other regional areas of the organization and the knowledge transfer of the key processes needed to execute radical innovation projects. While other geographical areas of *VehicleSystemsCo* are used and have experience in leading radical innovation project, Project 1 is the first attempt to run a radical water pump innovation project in APAC. The non-technical and tacit knowledge required to execute the project make Project 1 a very interesting case study in the context on global NPD project to project learning.

The observations of Project 1 started in July 2019, when the program was already in its third year and the 12 months' observation followed the project in its planned final year, close to start of production (SOP).

6.1.1 Observations start as a new project manager is appointed

As anticipated, Project 1 was a 'trouble project' at the beginning of the observations and remained such for the whole duration of the case study. The initial assumption of the water pump business unit's leadership team was to have the full project managed by a local team, including a local project manager and a local lead engineer, with the oversight of the global engineering manager.

Following the struggles faced by the project, the business unit's leadership decided to reinforce the project team by adding to the project team a number of water pump experts from different locations. In the KMI terminology used in this Thesis, this action falls under the [experts re-use] category. The experts re-used, tasked with supporting and 'turning around' the project, included:

- One additional project manager, tasked with working with the local project manager;
- One additional supply chain or purchasing project manager, tasked with the coordination of the local suppliers and ensuring high quality of the process and the components delivered by the suppliers;
- One additional lead engineer, tasked with the leadership of all the technical aspects of the project;
- Two additional engineers, tasked with the day-to-day project activities.

These additional project resources are based in EMEA or NA. Most of the new resources applied to the project have pre-existing variable displacement water pumps development expertise, with sole (but important) exception of the project manager, that has an oil pump background – i.e., [Job rotations]. One of the first actions the new project team members were tasked with was to travel to APAC to meet the local team, assign clear responsibilities and make sure that a shared understanding of the project existed – i.e., [Face-to-face formal] and [informal communication].

Their first APAC trip was a very important event for the project team, as this was the first time in the APAC office for many of the new team members and the first time meeting the local team. Many stories of the trip were shared over the following months, to detail some of the key learnings of the team from the supplier visits and are still told today by the project team – i.e., [Storytelling].

The Author had the opportunity to join the first and subsequent visits to the local customer, suppliers and project teams. During the preparation of the first business trip, the newly appointed project manager commented:

‘I am very concerned about this project and my role. It’s the first time I have to work together with another project manager like this. I am not sure the idea of having a local “push” and a global “pull” project managers cooperating together is going to work. I am very concerned that the local project manager will feel like I want to steal his job. Aligning on the individual responsibilities is going to be super important.

Looking at how the project is going, I understand why they [the water pump business unit leadership team] are doing it, but I wonder if there is a better way... ’

(P1 project manager, July 2019)¹⁶

Section 6.1.2 includes details of the first APAC trip of the team, that included a visit to the customer premises and key suppliers’ visits.

6.1.2 Commercial issues arise

The water pump business unit’s leadership team accompanied the core project team in the first APAC visit. During the planning phases of the visit, it became immediately clear that the visit would become a key event for the project team in its new configuration. The visit had three main goals:

- To introduce the new team members to the regional project team;
- To visit the customer to understand better the project timing and technical requirements;
- To visit key suppliers and assess the suppliers’ capability.

¹⁶ This quote was captured as part of the notes from a one-to-one meeting between the Author and the Project 1 project manager. The July 2019 meeting was not scheduled as a dedicated PhD research interview but as a regular project execution review meeting.

Overall, the trip was considered a success, but two key findings from the trip would define the project activities for the months to come. From the side of the cooperation with the local project team, the visit was a full success. The worries of the EMEA and NA team members that the local teams would feel threatened by the addition of new, global team members proved wrong. The local teams welcomed the help, as many of them had extensive “core” water pump knowledge, but very limited variable displacement water pump knowledge. This was clearly discussed by the regional engineering manager, when directly asked about the risks and opportunities offered by the extended cooperation with the global team commented:

‘My team has never worked on a variable displacement water pump before and now I just have a few months to develop it. This customer is key for us, and we are trying to conquest new ground, but we don’t have all the skills to do by ourselves. [...] our customers also love when we bring westerners to the meetings. For them, the perfect way is that local language speakers do the work, but they know that there is someone from Europe or America in the background checking everything.’

(P1 local engineering manager, 24 Sept 2019)¹⁷

¹⁷ This quote was captured as part of the notes from a one-to-one meeting between the Author and the APAC local engineering manager. The September 2019 meeting was not scheduled as a dedicated PhD research interview but as a regular project execution review meeting.

The biggest findings for the newly established project team were from the customer's and suppliers' side. On the suppliers' side, the biggest findings were on the rotor supplier. The rotor – item 11, Figure 6.1 – is one of the key components of a water pump and the production process includes machining as well as special coating processes. The new members of the project team were very surprised to find out during a supplier visit that the ceramic epoxy coating commonly used for water pump rotor was not amongst the processes used by the local supplier selected for the project – i.e., [supplier knowledge], [process knowledge]. Previous project using different kind of alternative coatings had failed in the past, so the project team was very concerned about moving away from the known ceramic epoxy coating. Further investigation led by the supply chain project manager showed that ceramic epoxy coating was extremely hard to find in the manufacturing region and extremely expensive, so not a viable option for the project. The global team was quickly aware of the additional risks this implied for an already troubled project. The scope of the project now included training the local team on the risks of the new process – i.e., formal and informal [mentoring and training].

Additional project risks emerged from the customer visit. When a customer selects a variable displacement water pump supplier it is quite common for customers to work with multiple suppliers up to the supplier selection milestone. While dual-sourcing (i.e., sourcing the same component from two suppliers) is quite common in the automotive and water pump business, this is quite rare in the case of variable displacement water pump projects. Variable displacement water pumps are typically managed by customers as “advanced engineering” projects, as the pumps need to be customised for the specific engine application. Having a specific customized design implies that specific mouldings and manufacturing tooling have to be produced specifically for the customer application, making the re-use of the full system assembly very difficult. The need to fabricate specific mouldings and tooling drives high upfront investments on the customer and the supplier side, often making dual sourcing financially not a viable solution for these complex products. To the EMEA and NA teams' surprise, during the first meeting, the customer communicated the intention of using a dual-sourcing strategy for the variable displacement

water pump being developed in Project 1. This meant that, while the commercial negotiations were formally closed, the race with competitors was still open: between the two awarded suppliers, the fastest supplier and the supplier with better technical performance would be the first one to start production and the supplier with higher shares of the business, potentially significantly impacting the project financial performance.

These new findings painted a completely new picture for the project team and the project manager, and it significantly showed how the project would need to be managed in the following phases. Special attention was also needed on internal communications (i.e., [formal communication]): the local team was aware of the additional project risks, but these were not previously communicated to the group CEO or general manager, to avoid creating confusion.

6.1.3 Engine level interactions threaten the project

Customer requirements and the competitive landscape drove very fast development cycles. The team's ability to complete the development cycle on time was, however, slowed down by delays on the customer side. The performance of variable displacement water pumps is significantly influenced by engine-level systems interactions: the shape of the engine water ducts can significantly change the water flow compared to what *VehicleSystemsCo* bench tests show. For this reason, *VehicleSystemsCo* procedures mandate testing on full engine test benches – i.e., [process knowledge]. To run these tests, significant hardware components are required from the customer. Due to unexpected issues, the customer delayed significantly the delivery of the engine components.

Once the components were available, the team was finally able to kick-off the test campaign. To the surprise of the project team and the leadership team of the business unit, the test campaign completely failed. The system level testing was showing engine level interactions that the water pumps technical team had never seen before in any other pump testing campaign. The rotors were completely wearing out and damaging the customer mounting flanges on the engine. It was clear to the technical team that the pump design

could not go in service with so severe failure modes. The issue escalated quickly in *VehicleSystemsCo*, and a dedicated task force was created.

6.1.4 Panic and daily red alert meetings

Following the unexpected project failures, the group CEO tasked the general manager with forming a task force to solve the issue. Daily ‘red alert’ meetings were quickly introduced with the full project team to track daily the progress on the multiple open fronts: customer communication, suppliers’ parts procurements, testing and root cause analysis – i.e., [formal communication].

A structured root cause investigation process was led by the project lead engineer and was followed to help the team to identify the root cause – i.e., [process knowledge]. The lead engineer discussed the issue with his network of lead engineers across the organization, hoping to find similar cases and technical solutions – i.e., [informal communication]. During a discussion with a *VehicleSystemsCo* ducts supplier, the supplier and the lead engineer discussed the failure that was observed, and the duct supplier asked if the engine was using a special S-shaped water duct. The duct supplier explained that many customers use an S-shaped duct when they use a variable displacement water pump, while the supplier did not fully understand why S-shaped ducts were used, they recommend that the lead engineering checked if the engine was using that kind of ducts and if not, to test using an S-shaped duct – i.e., [tacit knowledge].

VehicleSystemsCo are typically not involved in the design and testing of the engine water ducts: this activity is normally left to the final customer, but variable displacement water ducts are not common in APAC, so the customer was also unaware of the details of water ducts design for variable displacement water pumps. A test was quickly organized to test the S-shaped introduction, proving that the introduction of an S-shaped duct reduced the rotor wear. The test campaign could restart.

At the next project gate review, the lead engineer and the project manager included a *lesson learned* item among system level interactions of variable displacement water pumps and of the risks of working with customers that were excessively relying on suppliers' knowledge of system integration. 'S-shaped ducts presence check' were added in the variable displacement water pump checklist, following Project 1 findings – i.e., [guidelines and procedures].

6.1.5 Validation of systems level solutions and fasteners failures

The definition and implementation of the S-shaped water duct on the customer engine allowed to restart validation testing on the water pump. Performance and durability testing are two key tests that need to be performed to validate the variable displacement water pump design. Variable displacement water pumps are characterized by a variable geometry rotor, that is designed to *change shape* in low flow conditions, to guarantee a high-pressure output. The design of the variable geometry rotor must be customized for the specific low flow conditions required by the customer. Low flow conditions are typically the most challenging operating conditions for the variable displacement water pumps and tests cycles focus extensively on these operating conditions.

While the rotor design and actuation systems are typically customized and subject to extensive design review as they can vary significantly from previous designs, other components as flanges, fasteners and bearing are standard components – i.e., [components re-use]. It is not uncommon for engineers to carryover entire sub-assembly designs, including fasteners and bearings from catalogue water pumps. Reusing existing components and sub-systems is highly recommended by *VehicleSystemsCo* procedures, as reusing components helps reducing the overall project costs and risks. Bearing, flanges and fasteners are part of the core knowledge of *VehicleSystemsCo*, and all employees are expected to know them well. Limited time is spent during design and project review discussing the design of core components.

Following the installation of the new S-shaped duct that the customer procured, the testing restarted. Low-flow performance and durability testing were completed successfully, and ‘green lights’ were given to customer vehicle testing. Customer vehicle testing is typically a major milestone for variable displacement water pump projects, as these happen very close to start of production and signal to the teams that the project is in good shape and ready to be closed.

During vehicle testing, both low- and high-flow testing was completed, as part of the normal working environment of the vehicle. Unfortunately, during the high-flow testing on a customer vehicle, the fasteners of the variable displacement pump failed. The failure highlighted two shortcomings of *VehicleSystemsCo* variable displacement water pump development process. On one side, most of the focus is on new and high-risk designs (e.g., the variable geometry rotor design) and the behaviour of low risk, carryover components is given for granted. On the other side, testing focuses mostly on the harshest conditions. The failure of a low-risk component in a low-risk test was considered as a key learning point for the water pump business unit leadership team.

6.1.6 Supplier issues delay start of production

Eight months in project observation, Project 1 looked to be back under control: the major technical hurdles were solved, the manufacturing and assembly line were installed and ready to begin manufacturing trials, so customer delivery milestones were respected. As a consequence, the frequency of red alert meetings was reduced from daily to weekly and the project status in *VehicleSystemsCo* tracking tool changed from red to yellow, and eventually to green.

As the project got closer to start of production (SOP), a key milestone in the automotive business, the production quantities that the suppliers had to manufacture gradually increased, testing the suppliers’ and *VehicleSystemsCo* production processes. *VehicleSystemsCo* procedure prescribe the use of reinforced control plans, in the case of projects with high degree of innovation and novelty, as in the case of Project 1. The project

manager of Project 1 had been carefully advised by the group's director of the project management office (PMO) on the implementation of a reinforced inspection plans – i.e., [process knowledge]. During one of the scheduled reinforced control plan inspections, significant levels of porosity were observed on the housing of the water pump – item 1 in Figure 6.1. Housing porosities are a well-known and high-risk issue on pump housings in *VehicleSystemsCo* because of learnings on legacy projects. Lessons learned from previous housing porosity issues are extensively discussed in [lessons learned databases] and [procedures].

Finding porosities on the pump housing was quickly identified as a significant project risk. The project risk level was immediately changed to red. Turning a project to red is a highly emotional moment for a project manager, as it often directly implies a much more frequent review scheduled and daily progress review meetings for the project team. These meetings directly increase the stress on the project teams and risk making the project manager not very popular with their teams. However, project managers and project teams in *VehicleSystemsCo* are encouraged by the leadership team to not hesitate turning projects to red, to ensure the projects get all help and support needed. When discussing about turning the project red, the vice president and general manager of the group commented:

'I know it [turning the project red] is stressful, and I know some people want to be very careful with pushing the red button, but I say: the redder, the better.'

(VP/GM, 27 January 2020)¹⁸

Daily meetings and frequent project reviews were quickly reinstated. Subject matter experts (SMEs) on housing casting porosities from other projects were brought in to help the project team – i.e., [experts re-use]. SMEs were sent to the supplier factories to review the production tooling and processes and extensive production flow simulation were requested. The SME visits and simulations showed that the production line and production tooling designed by the supplier were fundamentally flawed. New production tooling needed to be designed and manufactured. The production of new tooling directly implied a four to six months delay to the program timing.

The project manager worked closely with the local sales team to agree a containment plan with the customer, to ensure the deliveries to the customer could be maintained, based on parts sorting to ensure only porosity-free parts were shipped. Daily supplier meetings were scheduled, and frequent on-site visits were organized at the supplier site.

The new production tooling and the improved assembly line were completed according to plan.

¹⁸ This quote was captured as part of the meeting notes from a one-to-one meeting between the Author and the VP/GM. The January 2020 meeting was not scheduled as a dedicated PhD research interview but as a regular project execution review meeting.

6.1.7 The lead engineer resigns

Pump housing porosity were, unfortunately, not the last unexpected issue that would impact on the project. Close to the resolution of the pump housing porosity issue, the lead engineer on Project 1 announced that he had decided to leave *VehicleSystemsCo* to pursue different opportunities outside the company. Typically, employee turnover in *VehicleSystemsCo* is not particularly high and internal studies show it is lower than the average turnover experienced by other automotive companies in the same field. However, losing the lead engineer close to the start of production on a ‘trouble project’ was perceived as a high risk by the project manager and the business unit leadership team.

One of the team members of the engineering team of Project 1 was promoted to the role of lead engineer. Selecting an engineer internal to the team was considered the best way to ensure that the project team knowledge was maintained and to significantly reduce the time needed for the newly appointed lead engineer to get up to speed. To ensure that the project activities were not impacted by the lead engineer change, the engineering manager of the team was asked to closely monitor and supervise the activities of the new lead engineer.

The next two months proved very challenging for both the new lead engineer and the engineering manager. During the final long durability validation test a pivot pin of the pump (item 13 - Figure 6.1) was found broken. It was the first pivot pin in the history of variable water pumps in *VehicleSystemsCo* that this type of failure was observed. By the time the failure happened, the Covid-19 pandemic had made internal travel very challenging and the EMEA based lead engineer and engineering manager had to lead the APAC team remotely to the resolution of the issue.

A design change was needed to the pivot pin geometry, strengthening the part to ensure it would pass the durability test. The new design was validated, and the durability test passed. Combined with the completion of the new production line for the porosity-free pump housing, this meant that the project was technically ready to for start of production (SOP).

6.1.8 Commercial issues continue

At end of the 12 months' observation, the NPD team on Project 1 was ready for the starting of production, having solved commercial, staffing, technical and supply chain issues. However, the troubles of the program continued. By the end of observation of Project 1, the Covid-19 pandemic had impacted not only on the ability of the NPD teams to travel, but also on the customers of *VehicleSystemsCo*, on their demand of vehicles, their ability to sell their products and, therefore, their ability to purchase systems and components from their suppliers, including *VehicleSystemsCo*.

The reduced sales volume, combined with the higher project costs driven by the prolonged development cycle and extensive use of subject matter experts, impacted on project financials. The lower sales compared to initial forecast and the higher development costs resulted in a lower return on investment on the project and on the project missing significantly its financial targets. According to *VehicleSystemsCo* procedures, for the project to be completed and for the project team to clear the final gate, the project team must demonstrate successful start of production and deliver the project financials agreed at the beginning of the project.

A lessons learned review was organized by the project manager to capture the key lessons learned that led the project team to not delivering the project financials and to identify the key next actions to close the gap to project profitability. Among the key lessons learned captured the team identified (1) the frequent personnel change; (2) the focus on the major new technical challenges; (3) the low maturity of the local supply chain and (4) the weak commercial agreements signed with the customer.

The Project 1 team also defined key actions to improve the project's profitability, that included both supply chain and commercial actions: introducing lower cost suppliers, increasing the price to the customer and increasing the share of *VehicleSystemsCo* components compared to the second source suppliers.

6.1.9 Findings from the observation of Project 1

The observation of the Project 1 team has identified a few key knowledge events that have challenged the team and the reactions of the team to these challenges. Five kind of knowledge events can be distinguished:

- Personnel changes;
- Technical failures;
- Supplier issues;
- Commercial issues;
- Events outside of the team's control.

The Project 1 NPD team and *VehicleSystemsCo* used a number of different KMI to prepare for potential issues and react when those occurred. In the case of Project 1, personnel changes were both a knowledge event for the project team (e.g., the resignation of the lead engineer) and a KMI used to reinforce the project team (i.e., project manager [job rotation] to support Project 1). When faced with personnel changes, the Project 1 team resorted to extensive face-to-face and informal communication to rebuild the team. The team also relied extensively on written documentation, to offset the knowledge that was lost when the previous project manager and lead engineer left the project. Storytelling was also extensively observed, used both as a way to build the team, often sharing stories of key events withing the team, and as a way to share knowledge outside of the team. During the observations it was clear that the stories shared always included some peculiar fact, object or event, that acted as a catalyst for the story to be interesting and memorable – i.e., [boundary object]. When discussing with the lead engineer before he left *VehicleSystemsCo* he commented:

‘One of the best stories from that trip [the first team business trip to APAC] was when we visited [redacted] [external actuation supplier]. During that trip we realized that the spec we wrote for them was not clear, and a lot of work was needed to fix the assembly line they had just completed, but the real reason we tell the story and people still remember it is because during the car trip to the supplier site I was pushing all the buttons on the arm rest of that fancy car and almost got in a fight the sales director for it!’

(P1 lead engineer, 13 March 2020)

Mentoring and training were also extensively used by the project team to react to personnel changes, as well as experts re-use. The project team was also faced with a few key technical issues, both related to the maturity of the water pump as well as systems interactions. It is interesting to note that both the key failures that were observed were not related to the key innovative content of the project (i.e., the components allowing for variable displacement), but to core water pump components (e.g., fasteners, pivot pin) and system level interactions. To tackle the technical challenges, the NPD project team and the project manager relied extensively on their knowledge of *VehicleSystemsCo* processes, procedures and design guidelines. Dedicated task forces were formed, and red alert daily meetings were scheduled. The formation of dedicated task force allowed for a very effective sharing of knowledge between the team and subject matter experts.

Issues with customers and suppliers also occurred during the observation of Project 1. To tackle those issues, the NPD team resorted to the re-use of subject matter experts, lessons learned databases and procedures. Finally, some of the issues encountered by the project team were outside of the control of the project team, such as the Covid-19 pandemic and its impact on customer orders, travelling and suppliers’ shutdowns. The project team had to accept those issues and to develop containment actions to offset them later in the life of the project.

Using the service blueprint format introduced by Bitner, Ostrom and Morgan (2008), Figure 6.3 summarises the observation of the Project 1 case analysis and visually represents the role of the mayor events discussed in the project lifecycle. Text boxes in the central rows on the table are used to track the major events. In addition to the events, the first and last rows in the table are used to track the system design status and the KMI. Arrows are used to track the links between major project events, the system design status and the KMI the team used to react to knowledge events.

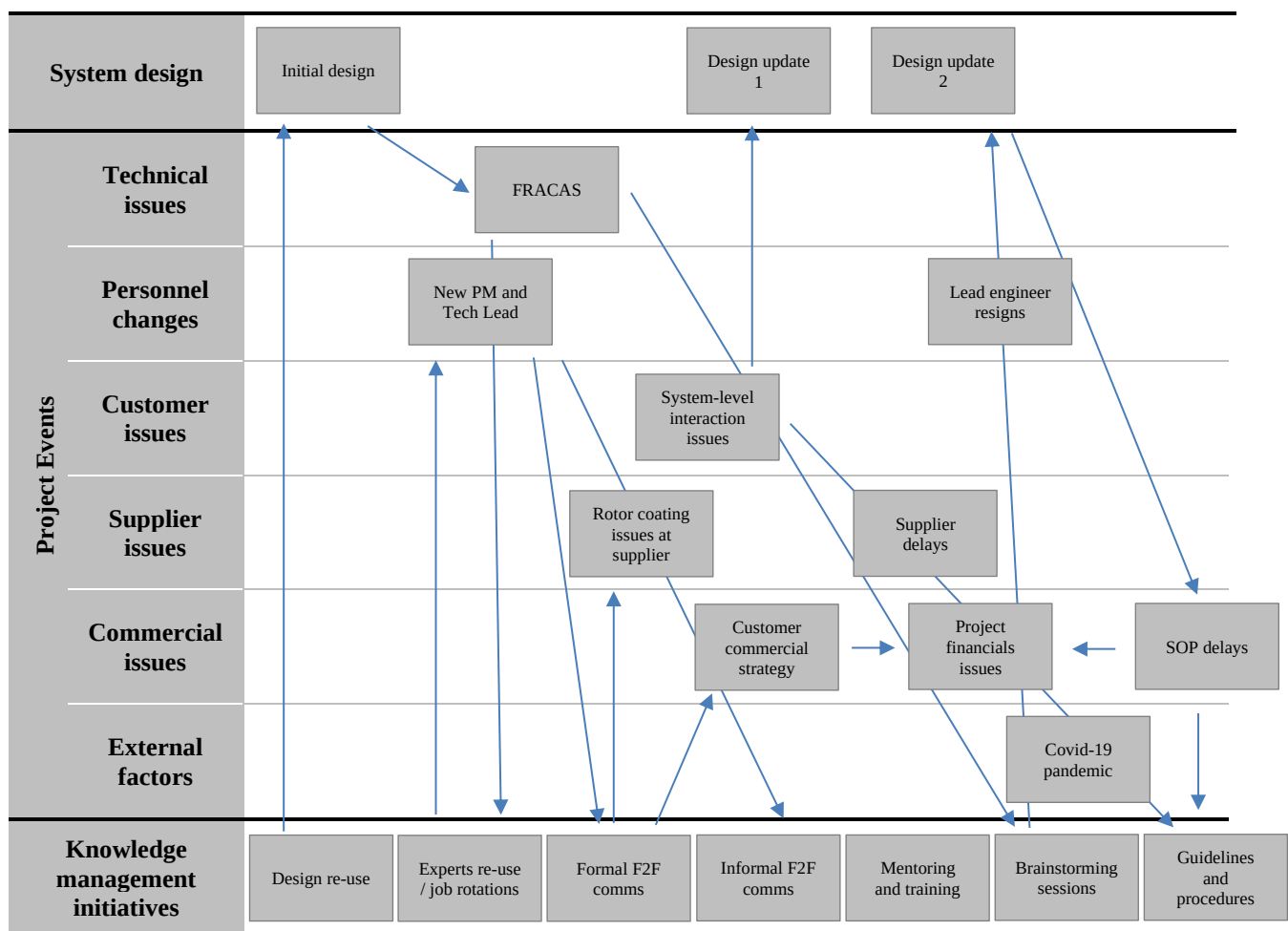


Figure 6.3 – Project 1 events and KMI blueprint

6.2 Project 2 case study

Project 2 is an incremental, global NPD project. The project's team is geographically distributed, with team members located in all regions the organization is active in North America (NA), Europe Middle East and Africa (EMEA), and Asia Pacific (APAC). Project 2 was created to introduce in the APAC region an electro-mechanical oil pump technology developed and validated in EMEA in 2016 for an EMEA customer. As the technology was developed in EMEA, the core of the NPD team was based in EMEA. The product team responsible for the oil pumps business unit was headed in NA, so a significant part of the NPD team was NA based. The production location, project manager, final customer and majority of the supply were APAC based.

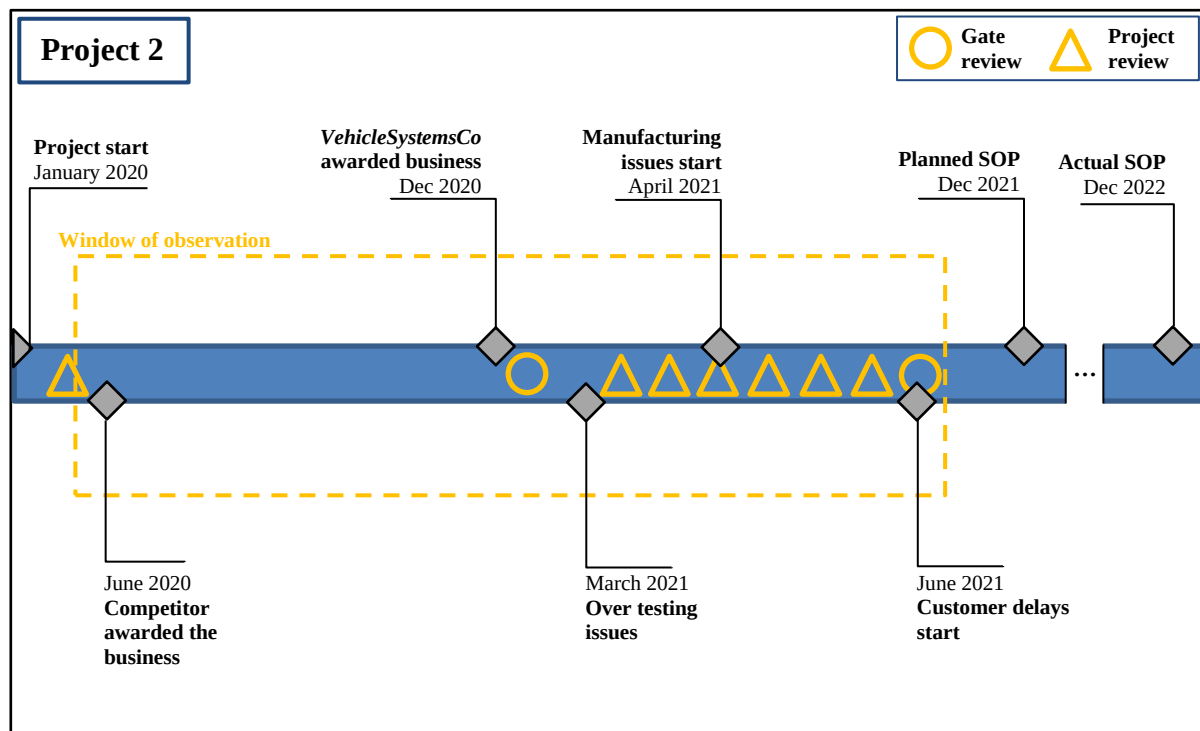


Figure 6.4 – Project 2 milestone plan and window of observation

When the project observations started, Project 2 was considered a successful project, running according to timelines and with limited product failures. A limited number of FRACAS (failure reporting and corrective action system) are expected to be identified in incremental NPD projects, as they are using fully validated technology from previous projects. In particular, the technology deployed in Project 2 was created in a EMEA radical innovation projects and fully validated in that program. The lead engineer of Project 2 was part of the 2016 project (Project N) where the technology was initially developed and is helping technical explicit and tacit knowledge transfer between the projects.

Global NPD projects in *VehicleSystemsCo* tend to be radical innovation projects, as these are the type of projects that can benefit more from the use of global teams. However, due to the regional technology transfer nature of the project, the leadership team of the oil pump business unit decided to manage the project with a global NPD team, making it an ideal case study.

Incremental NPD projects in *VehicleSystemsCo* are typically shorter than radical NPD projects, the observations of the Project 2 started in June 2020 and lasted for 12 months. The end of the observation coincided with the planned start of production of the project. Figure 6.4 illustrates the timeline of the main project events following the format used in Figure 6.2.

6.2.1 All hope is lost! The main competitor is selected as production supplier

The project observation started at the very beginning of the project, with the formation of the project team. When forming the Project 2 team the leadership team wanted to de-risk the project as much as possible, leveraging experts in the organization with knowledge on both the product and global teams. In particular (1) the sales manager for Project 1 was appointed as sales manager on Project 2; (2) the supply chain manager of Project 1 was appointed as supply chain manager of Project 2 and (3) the lead engineer of Project 2 was one of the senior engineers deployed on the project where the technology was initially

developed (Project N) and the co-author of many of the patents that created the foundation technology for Project 2. While the staffing choices the leadership team made of Project 2 are a clear example of the “experts re-use” KMI, it is important to point out that Project 1 and Project 2 belong to two different business units, the water pump business unit and oil pump business unit respectively.

The first activity managed by the newly created project team was the proof-of-concept (PoC). The PoC is typically one of the first activities that project teams run, to ensure that the selected architecture works effectively when adapted to the new customer application. Thanks to the high maturity of the electro-mechanical oil pump technology, the team was able to manufacture the PoC hardware and run PoC in a very short time. The customer PoC was successful, and the team had high hopes that *VehicleSystemsCo* was going to be selected as production supplier for the oil pump by the customer.

Unfortunately, due to a more competitive commercial offer, the customer selected one of *VehicleSystemsCo* competitors as the production supplier for the electro-mechanical oil pump. Losing a business is always an emotional moment for the project team as, normally and typically, after lessons learned are captured and on-going activities are completed, the project team is dissolved, and project team members released to be deployed on other projects.

This was not the case for the team on Project 2 as one of its goals was to transfer the technology to the APAC region to facilitate the pursuit of further electro-mechanical oil pump business. Therefore, the project team was given time and budget to finalize the technology transfer.

6.2.2 A change of heart – *VehicleSystemsCo* supplier selection

The decision of the business unit leadership team to keep the Project 2 alive (with limited resources, budget and focus) would prove a very good one. A couple of months following the decision to select a *VehicleSystemsCo* competitor as production supplier, the target

customer decided to revert their decision and award the business to *VehicleSystemsCo*. While limited information was available on the drivers for this sudden and unexpected change of heart, the information pointed at technical failures on the competitor's product. This had two main implications for the Project 2 team: first, they had to recover the time lost; and, second, with this customer any technical failure (quite common in oil pump NPD projects) could prove hard to recover from.

The full NPD project team was quickly reassembled and reinforced. As PoC was completed and the technology fully validated in a previous program, the leadership team of the business unit decided to appoint as project manager on Project 2 the industrialization leader of Project 1, based in APAC. To accelerate the project and reduce risk, some of the key suppliers that worked on the original technology development project (based in EMEA) were selected as suppliers also for Project 2. This decision was a key (and unpopular) decision as typically APAC suppliers are used for EMEA project, and not the other way around.

6.2.3 The rush to make up for lost time

The need not to delay the customer start of production mandated a number of key project decisions. The first one was the selection of the same, EMEA based, suppliers used in Project N and other legacy projects. This allowed to directly carry-over the components developed in the previous projects – i.e., [component re-use] – with minor changes needed, if any.

This decision allowed the program team to fully focus on the validation of the existing electro-mechanical application on the new customer engine. To speed up the validation project, the team made the decision to run multiple tests in parallel in multiple *VehicleSystemsCo* locations globally. To minimize the chances of customer failures, the project team decided to extend the duration of the internal tests and to add testing to failure – i.e., [NPD process knowledge]. Testing to failure, as opposite of testing to pass a codified test, is mandated by *VehicleSystemsCo* procedures, but this requirement is typically waived

for oil and water pump projects due to the impact it has on the project timing. The oil and water pumps business units' teams are therefore unfamiliar with test-to-fail campaigns.

6.2.4 Over-testing, and failing

As the team focused on the validation testing in parallel to executing the industrialization plan, a failure was observed in one of the test-to-fail tests.

The designed test-to-fail tests worked around either extending the duration of the test (e.g., a 500h test would run for 1000h, resulting in an additional safety factor of 2, if passed) or increasing the severity of the loading condition (e.g., a vibration test typically conducted up to 4G acceleration would run at 6G, resulting in an additional safety factor of 1.5x, if passed).

One of the bearings of the electro-mechanical oil pump (not visible in the diagram in Section 6.0), tested at 6G vibration levels, failed. The oil pump had passed several times the 4G vibration test, then a failure at 6G left the team puzzled on what to do next and how to assess the impact of this failure on the overall project.

Following the 'the redder, the better' approach, the project was quickly turned to red status in *VehicleSystemsCo* project tracking system and a dedicated task force was formed, including bearing and vibration experts from other projects – i.e., [experts re-use]. While oil pumps in service are expected to see vibration levels equivalent up to 6G acceleration, the pumps are expected to endure such harsh environments for very limited time. The team debated extensively on the validity of the test: based on the test results at 6G, significant redesign of the pump was needed if 6G endurance needed to be demonstrated, significantly delaying the project and SOP.

The task force reviewed the full "lessons learned database" and reviewed the requirement list of previous projects, trying to understand if any customer had previously asked for 6G endurance and if any legacy product was ever able to endure a 6G durability test. The task force was able to find a single, very niche application, that needed 6G

compatibility, but the finding confirmed that the pump would require significant redesign. The task force quickly converged on redesigning the test cycle, rather than redesigning the pump hardware. A revised vibration test was designed and passed, bringing the project back to green.

6.2.5 Manufacturing struggles

While the EMEA and NA portion of the team were busy assessing potential design changes needed by the oil pump, the APAC team was busy running the industrialization part of the project. The industrialization phase took place while traveling was still significantly constrained as a result of the Covid-19 pandemic and the APAC and the rest of the global team were communicating extensively remotely, relying on both [formal and informal communication].

The assembly process of electro-mechanical oil pumps includes a few very specific manufacturing and assembly steps that required the use of specifically designed production equipment. Local APAC suppliers were selected for the production of the manufacturing equipment. Only after the individual manufacturing and assembling pieces of equipment were developed, produced and tested at the supplier side they were transferred to *VehicleSystemsCo* premises for the installation in the final production location. In order to respect the low cycle time needed for high-volume automotive production, the different pieces of manufacturing equipment needed to work seamlessly together. The process of integration of different manufacturing equipment from different suppliers was in charge of the advanced manufacturing team. The global advanced manufacturing team is a small team of 5-10, globally dispersed, advanced manufacturing engineers that typically travel to the production sites at the time of final assembly line preparation. Discussing about the manufacturing issues experienced by Project 2, the manufacturing engineering manager commented:

'I'm really struggling to understand what issue with the equipment is. On paper, it looks like the issue we faced on [redacted] [project name], but I'm not convinced that's the real story here. It's very difficult to explain all the details, also the language barriers, over the phone. There is really only so much I can do without boots on the ground.'

(Manufacturing engineering manager, 4 May 2021)

The Covid-19 pandemic severely limited the ability of the advanced manufacturing engineering team to operate as they normally would do and travel to the local manufacturing facilities. For this reason, the advanced manufacturing team assigned to Project 2 was made of only APAC engineers, with the additional remote support of global teammates. During the final production trial runs, the local advanced manufacturing engineering team realized that an incompatibility between two assembly stations could result in the wrong assembly of the main pump rotor (item 11 - Figure 6.1). A wrong assembly of the rotor in the pump would result in a non-functional pump, that would be scrapped at the end-of-line quality controls. The wrong rotor assembly is a well-known potential assembly process failure mode for oil pumps: the “lessons learned databases” and dedicated manufacturing “procedures” clearly prescribe checks and design features that must be introduced to prevent it. In the rush to recover the time lost in the early phases of the project, the team skipped the review of key company documentation, and this was not caught in the regular [project progress reviews].

Following the discovery of the wrong rotor assembly failure mode, modifications to the pump final assembly lines were needed. The impact to the overall project timeline was limited to 1 month and temporary containment actions (i.e., 100% manual checks) were included, slowing down the cycle time but allowing the project team to respect the project start of production date.

6.2.6 Start of production and persisting uncertainty

As the project team quickly approached the start of production date on time, it started to become clear to the project team that customer project activities were not proceeding as smoothly as the *VehicleSystemsCo* project activities usually did.

The customer validation activities were also impacted by Covid-19 lockdowns, delaying the project activities. More importantly, during the Covid-19 pandemic, in an effort to reduce the impact of the pandemic on the automotive sector, the local APAC government started delaying the stricter emission requirements that forced carmakers to introduce advanced engine technology, including variable displacement oil pumps. A customer delay in start production directly impacts on project financials, as was described in the case of Project 1. Lessons learned on Project 1 showed that the uncertainty surrounding combustion engines development in Covid-19 times required stricter and more protective conditions to be included in the contract language. This Project 1 lesson learned was not transferred to Project 2, despite the two projects were sharing the same sales manager, putting the overall project profitability at risk.

6.2.7 Findings from Project 2 observations

The observation of Project 2 showed that, compared to radical innovation projects (e.g., Project 1), incremental projects showed significantly lower technical failures.¹⁹ The need to

¹⁹ Chapter 7 will show that, while this may appear logical given the higher maturity and lower risk of incremental NPD projects, the finding is not fully aligned with the expectations of the business unit leadership team.

accelerate significantly the project, combined with the additional challenges posed by the Covid-19 pandemic, forced the team to deploy extensively experts and component re-use. The high level of experts' re-use observed in Project 2 is in a way uncommon for projects in *VehicleSystemsCo* and is expected to have contributed positively to the project success. During an informal discussion with the lead engineer, he commented:

'Of course, the project went well, this is basically the exact same project we did for [REDACTED] [other customer name] and it was working very well for them! Why would it not work well for [REDACTED] [Project 2 customer name]?'

(P2 lead engineer, 22 June 2021)

While the re-use of experts and designs produced a positive impact on the project, Project 2 still experienced issues related to the lack of review of lessons learned databases and existing company procedures.

During the post project review, the project team attributed the miss to the limited time available to the team.

Using the format introduced with Figure 6.3, Figure 6.5 summarises the observations from the Project 2 case analysis and visually represents the role of the major project events discussed in the project lifecycle. Text boxes in the central rows on the table are used to track the major project events. In addition, the first and last rows in the table are used to track the system design status and the knowledge management initiatives (KMI), respectively. Arrows are used to track the links between major project events, the system design status and the KMI the team used to react to the knowledge events.

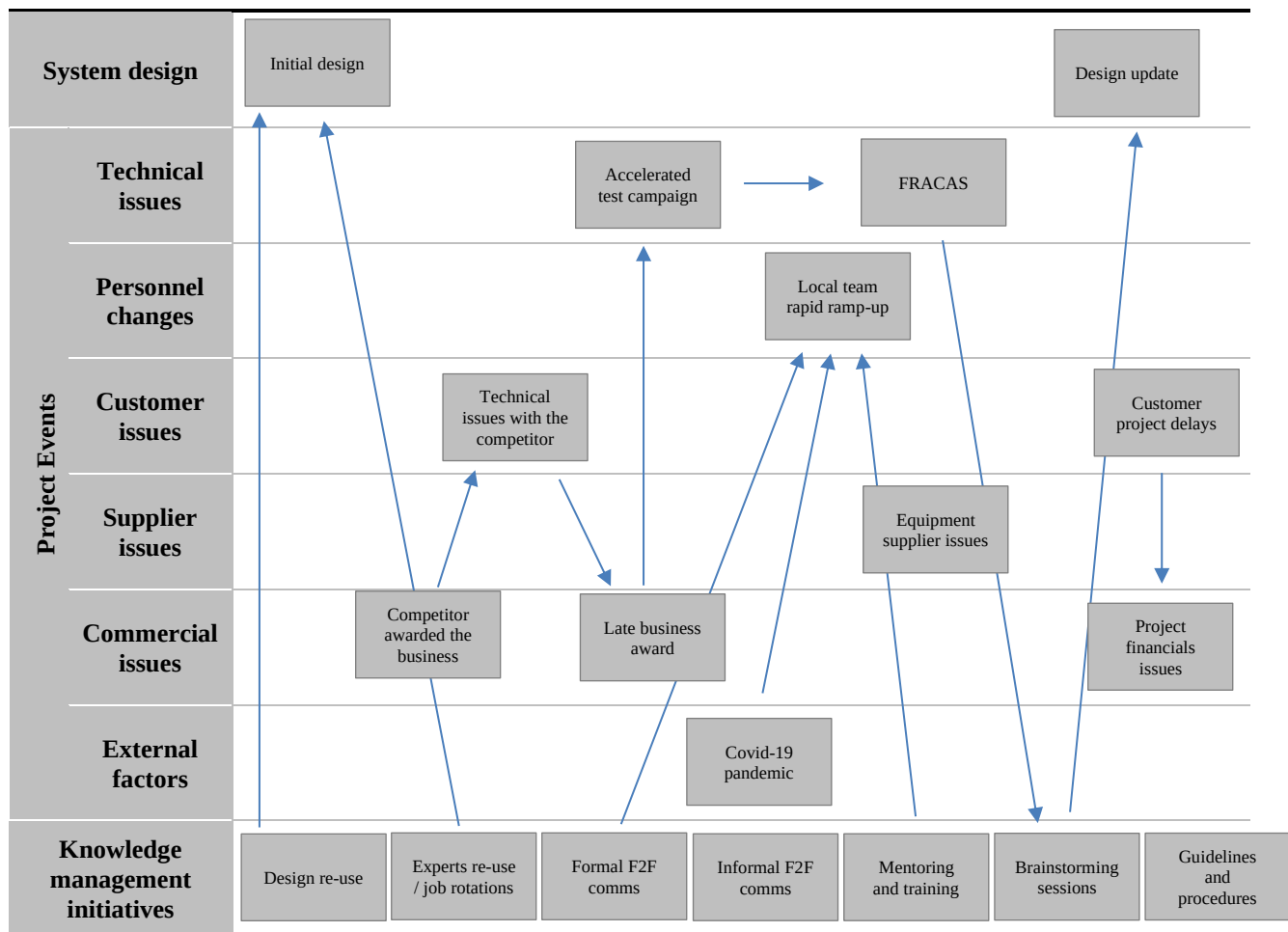


Figure 6.5 – Project 2 events and KMI blueprint

6.3 Project 3 case study

At the time of the start of the case study, Project 3 was an early-stage, radical, global NPD project. The scope of Project 3 was to develop a new water pump technology for the application with a specific customer in EMEA and APAC. The core R&D team was EMEA based, with support from the NA and APAC teams. Extensive virtual validation, including modelling of the variable displacement water pump in a simulation software for structural and dynamics analysis, was carried out in both NA and APAC and played a big role in the project activities.

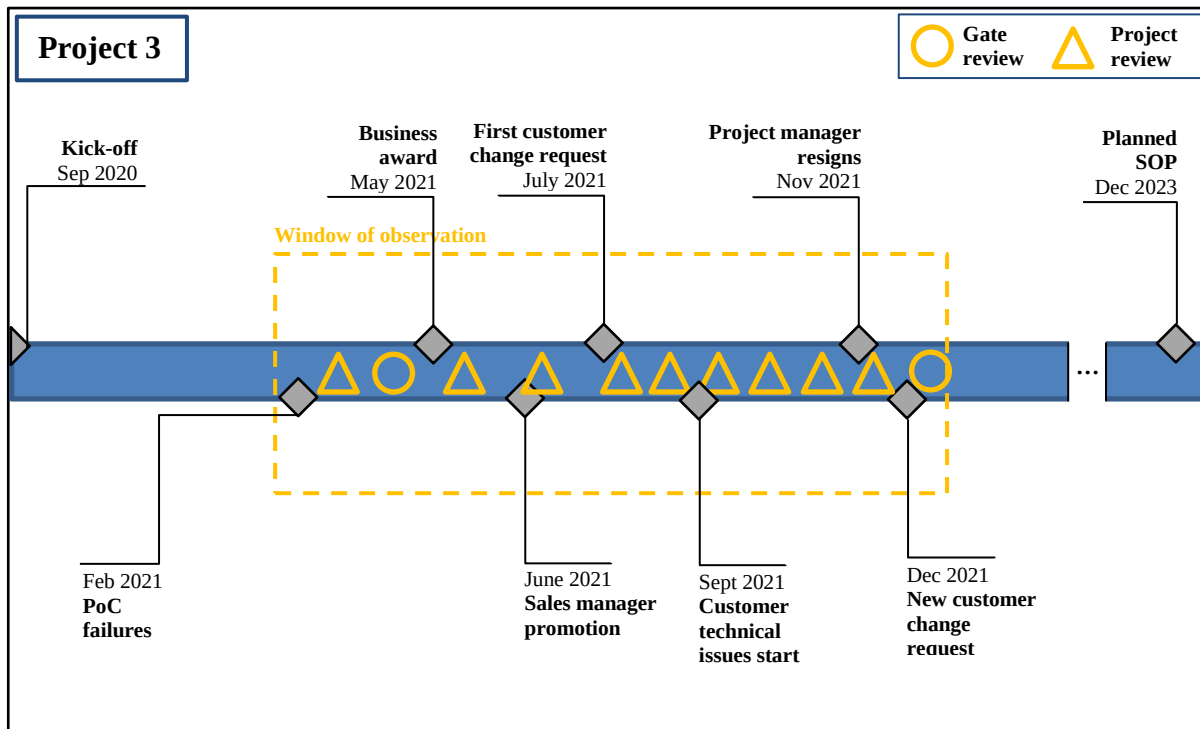


Figure 6.6 – Project 3 milestone plan and window of observation

Project 3 was considered a successful project at the time of writing of this Thesis. Nevertheless, because of the new technology development and implementation, product failures (FRACAS) were expected. Few had already been found and solved by the team. A clear team structure and goals were in place. Part of the scope of Project 3 was to pilot the latest KMI introduced by the automotive group and business unit. Key global experts were deployed to support the global team and technical leads with previous experience on similar projects were selected to lead the technical portion of the projects. In particular, one of the two technical leads of the project was previously the lead engineer of Project 1.

The 12 months' observation of Project started in the early stages in January 2021 and covered proof-of-concept activities (PoC) as well as commercial negotiations that eventually led to *VehicleSystemsCo* selection as production supplier and a number of

change requests from the customer. Figure 6.6 illustrates the timeline of the main project events following the format used in Figure 6.2.

6.3.1 Proof-of-concept – the component re-use ordeal

Shortly after Project 3 observations started, the project team embarked on the proof-of-concept (PoC) test campaign on the customer engine. The variable displacement water pump developed in Project 3 is based on oil pump technology that was never tested on water pump and that was never developed in large-size water pumps.

In line with *VehicleSystemsCo* procedures and best practices, and to minimize project risks and costs, the engineering team on Project 3 was tasked with maximizing the number of components re-used from previous projects. In particular, the external pump housing (item 1 – Figure 6.1) and connections (e.g., fasteners, O-rings – item 6 – Figure 6.1) were carried over from a previous project in the water pump business unit – i.e., “Design and component re-use”.

Before embarking in PoC testing at the customer premises, sub-system and component level testing was typically conducted in *VehicleSystemsCo* to reduce the likelihood of failures on the customer engines. These failures are typically perceived poorly by the customer and *VehicleSystemsCo* leadership team and negatively impact on the chances of *VehicleSystemsCo* of being selected as production supplier in the project bid phase. Internal testing was successful, and the prototype was shipped to the customer site for PoC. The Author had the opportunity to travel to the customer premises with the project team to witness the PoC test campaign. PoC testing on customer engines is always an important event for project teams. For the team on Project 3 in particular, this PoC testing was an important moment as it was the first real-world test on a brand-new product and an important business opportunity (i.e., the size of Project 3 potential sales compared with the total sales of the water pump business unit).

The first tests, designed to check the overall fit and function in standard mode, were successful so the team proceeded to testing the secondary mode – i.e., modulating the flow. Initial variable flow tests were also positive, so the team continued the test campaign, with gradually harsher tests. After a few days of testing, all of a sudden, the customer engine stopped in an unexpected way: the new variable displacement pump was clearly the first and main source of concern for both *VehicleSystemsCo* and the customer.

The Project 3 team quickly kicked-off a root cause investigation analysis, following *VehicleSystemsCo* procedure and tools – i.e., [NPD process and procedures]. Using standard templates, the project team quickly identified a long list of potential failure modes. The key failure modes hypostasised by the team involved mainly the new, unique, different and difficult components (NUDDs). NUDDs include all new technology or known technology used in a different environment. The team created a long list of components to be inspected and quickly replaced, if a failure was found. The focus of the project team was on all the complex components, like levers, springs and rotors (items 8, 11 and 16 – Figure 6.1). These are components that move and can have unpredictable dynamic behaviour and the teams invest significant amount of time designing and analysing them. NUDDs are oftentimes the elements that characterize the radical innovation elements in a *VehicleSystemsCo* product. Prior to disassembling the engine and the water pump, the team started brainstorming possible solutions, in order to have a convincing story and solution for the customer.

Once the engine and the water pump were disassembled, the team quickly realized that the complex components and NUDDs were in good operating condition. The teardown and disassembly confirmed that the engine failure was caused by the water pump, but the team struggled to immediately understand the root cause. The root cause analysis eventually showed that one of the O-rings that sealed the water pump housing towards the engine (item 6 – Figure 6.1) had slipped out of its position and caused the pump to leak. Replacing the O-ring was a very quick activity, and the testing campaign could restart and finish successfully. The root cause investigation analysis, however, did not end with the identification of the O-ring failure. The team needed to understand what had caused the O-

ring to fail. A detailed analysis showed that the wrong O-ring was prescribed on the inlet side of the pump. This was particularly puzzling, as the inlet and outlet O-rings were two of the few carryover components. When discussing this with the lead engineer he explained:

‘When I was designing the new pump housing, I copied the O-rings from [REDACTED] [Project K]. I just took the part number they had and used it. I saw they had different ones for inlet and outlet, but I thought it was more elegant to use the same part number on both sides. In the rush of the project, I didn’t think of asking [REDACTED] why he had different O-rings on inlet and outlet, I thought it was OK to reduce the part number count...’

(P3 lead engineer, 19 February 2021)²⁰

The re-use of a wrong part number was a very interesting finding for the water pump business unit leadership team of *VehicleSystemsCo*: they had pushed the team to re-use as much designs as possible but did not consider the risks associated with blindly reusing components, without the background knowledge (tacit and explicit) embedded in the designs. When discussing the O-ring failure with the engineering manager of the team he commented:

²⁰ This quote was captured as part of the meeting notes from Project 1 FRACAS review meeting held after the O-ring failure was observed.

‘This failure is crazy. I’ve looked at those [3D] models like a hundred times and I know the [REDACTED] models by heart. Why didn’t I see it? The O-rings have different colours for the very purpose of ensuring poka-yoke²¹. Was I really so focused and the all-new bells and whistles that I forgot to check the basics?’

(Engineering Manager, water pumps business unit, 13 May 2021)

After replacing the O-ring with the correct one, the PoC was completed successfully, with positive results for the customer.

6.3.2 Business award and project financials

After the successful completion of the proof-of-concept testing, the project team focused their energies on the commercial negotiations of the bid. While successful testing was minimum requirement for *VehicleSystemsCo* to be selected as a production supplier, much of the selection was based on the commercial offer and contractual conditions offered.

The water pump business unit leadership team learned the importance of a well-rounded commercial offering on a previous variable displacement water pump project (Project L). In the case of Project L, while the project team delivered a successful PoC and an attractive pricing model, the business opportunity was lost due to lack of agreement on

²¹ Poka-yoke is a Japanese word and design technique very commonly used in the automotive sector to define an assembly design that is engineered to make wrong assembly difficult, impossible, or easily detectable.

commercial terms and condition. To ensure that similar problems did not occur on Project 3, the water pump business unit leadership team ensured that a dedicated sales manager was entirely focused on managing the bid process for Project 3 – i.e., [Lessons learned], [Process knowledge].

The intervention of the sales manager immediately paid off. Frequent and close connections with the customer highlighted good alignment between *VehicleSystemsCo* and the customer on commercial terms and condition (i.e., Project L risk was avoided), but highlighted a gap in terms of price. While the project team was confident to have offered a competitive price, the price was still higher than the budget the customer had available for the water pump. In order to ensure a good profitable business for *VehicleSystemsCo* and an affordable price for the final customer, the project team had to propose some drastic cost-out designs on the product.

A few cost-out designs were included in the product offering, to make the final price more attractive, but two in particular were particularly aggressive designs, never tested in the water pump division. The first cost-out was the use of cheaper *aluminium* rather than the traditional *cast iron* for the pump housing (item 1 – Figure 6.1): while aluminium is a more expensive raw material, its material properties make it easier to machine (key cost driver for housings), but also make the housing weaker. Secondly, the use of *carbon filled plastic* rather than *steel* was proposed for the main pump ring (item 8 – Figure 6.1): while carbon filled plastic is an expensive and particularly strong material, the use of plastic allows for a net-shape²² moulding. As for aluminium, the use carbon filled

²² Net-shape moulding is a manufacturing process that allows the production of very precise components, without the need of secondary machining operations. While the mold tooling production is expensive, eliminating or reducing the secondary machining makes the overall process significantly cheaper.

plastic for main pump rings was introduced in production for water pumps in *VehicleSystemsCo*, adding risk to the project.

The assumptions of using aluminium and carbon filled plastic for the housing and main pump ring respectively made the overall price of the product more competitive and closer to the customer target price.

6.3.3 The job rotation issue: the sales manager is promoted

In the third month of observation of Project 3, the team was starting to feel more comfortable about the maturity level of the water pump and the attractiveness of the price offered. However, the commercial negotiations were not closed yet, eating time away from the project team that was waiting for a supplier selection decision to start the full project validation activities.

In the middle of the commercial negotiations, the sales manager received a job rotation offer from another business unit – i.e., [job rotations]. While the water pump business unit leadership team tried to resist and delay the transfer, the business needs of the other business unit were considered stronger, and the transfer was approved. This meant that Project 3 had to accept and bring up to speed a new sales manager. A new sales manager was quickly found and introduced to the project team.

After a short period of adjustments and commercial negotiations for *VehicleSystemsCo* and the customer, the negotiation was closed and *VehicleSystemsCo* was selected as the production supplier for the variable displacement water pump.

6.3.4 The first major customer change request

Following the supplier selection, validation testing proceeded fast to make up for the time lost during the commercial negotiations. The delays in finding a commercial agreement had delayed both *VehicleSystemsCo* and the customer testing activities: *VehicleSystemsCo*

could not invest significant time and money without the commitment of product sales in production, and the final customer could not continue engine validation without knowing what supplier to validate.

Once the validation campaign restarted, the customer quickly observed that the overall working conditions of the engine were quite different than anticipated: the vibration levels the engine experienced were much higher than simulations showed, and this meant that the loading on the water pump housing was significantly higher than expected. The use of aluminium for the pump housing was no longer an option.

Reverting back to cast iron for the pump housing had a number of drawbacks for the project team: all the component drawing had to be remade, the production tooling manufactured so far had to be scrapped, validation testing repeating with cast iron housing and either *VehicleSystemsCo* or the customer had to absorb the additional costs. This major project change meant that approximately three months of project activities had to be repeated, however, the start of production date did not change, meaning that the project team now had to work with much tougher timing constraints.

6.3.5 Major customer failures delay project activities

As the project team scrambled to adjust to the pump housing material change and to recover the time lost in commercial negotiations, the customer experienced a major engine level failure that would stop customer engine and vehicle testing²³.

²³ The typical validation program of a *VehicleSystemsCo* customer is made of three steps of increasing representativeness of the final working environment: (1) sub-system testing, (2) engine testing and (3) vehicle testing.

Concerns over the variable displacement water pump being the root cause of the engine failures were immediately raised. The team started immediately a structured root cause investigation – i.e., [process knowledge] – consuming the time of the full project team for two weeks. The *VehicleSystemsCo* root cause investigation confirmed that a water pump issue causing the engine failure observed was a highly unlikely event. The finding was later confirmed by the customer's own root cause analysis.

While root cause investigations showed that the water pump was not the cause of the failure, the confidence on the water pump and engine overall maturity was shaken, but the start of production date remained unchanged, adding stress on the project team.

6.3.6 The project manager resigns

As the Project 3 team worked its way towards start of production, managing design changes, supplier delays and customer delays, the project manager of Project 3 communicated their intention to resign from *VehicleSystemsCo*, to pursue another professional opportunity outside of the company. While personnel turnover is not uncommon in the automotive industry, as the case of the sales manager change in Section 6.3.3 shows, personnel changes can impact on the project activities.

The water pump business unit leadership team reacted quickly to the change and decided to promote a member of the Project 3 team to the role of project manager. Shortly after the first project manager resigned, the lead engineer was appointed as project manager – i.e., [job rotations]. As a consequence, the lead engineer role on the project became vacant and a senior engineer on the team was appointed as lead engineer for the project.

While selecting internal project team members for promotion has many benefits for the business unit (e.g., personnel retention) and the project continuity, it is also a test for the organization's knowledge management system. The incumbents for the roles of project manager and lead engineer were facilitated by knowing the project history and main project events, but in their previous roles they did not need to have access to significant amount of

information they would need in their new roles. The following serve as examples of the additional information that the new project manager and lead engineer needed:

- Project manager: project reviews presentation and templates, financial models, supplier and customer contracts, etc.
- Lead engineer: all suppliers technical point of contacts, all customer point of contacts, project reviews presentation and templates, etc.

Accessing the documents and information needed was relatively straight forward for the new lead engineer, as their predecessor was still in the organization and the project. The project manager faced more difficulties and commented:

‘I really struggled to find all the project financials. The folder structure on [redacted] [project repository tool] was not very clear to me. I quickly realized that [redacted] [previous project manager] had never updated [redacted] [project status reporting tool]. I had never used that tool before, so I had to rely on my network inside the company to teach me how to do it and how to fix all the problems I found in zero time...’

(P3 project manager, 19 October 2021)

Following a few weeks of adjustment period, the project team and project activities were back to normal.

6.3.7 A new key customer change request

Towards the end of the observation of Project 3 the validation and industrialization activities were proceeding well and according to plan. Until, unfortunately, another customer change request impacted once again on the project team.

One of the initial assumptions of Project 3 was that the water pump to be developed and validated was a variable displacement water pump. Engine testing at the customer showed that the performance improvement delivered by the variable displacement pump were minimal compared to a fixed displacement pump and that it was going to be difficult to squeeze in the project timeline the time required to develop a control system for the variable displacement pump. As a consequence of this, *VehicleSystemsCo* were asked to change their pump design from variable displacement to fixed displacement.

While converting a variable displacement pump to a fixed displacement pump is technically feasible, the team had to assess the impact on both validation efforts and project timing. The project manager quickly called a project review meeting to kick-off change manage procedures – i.e., [process knowledge]. The lead engineer called a series of technical meeting to discuss design options and create a plan – i.e., [brainstorming sessions]. On top of the technical and scheduling issues, fixed displacement pumps are also cheaper than variable displacement pumps, so the change could also have impact on the project financial performance.

The final decision of changing the water pump design from fixed displacement to variable displacement was still open when the observations on the project came to an end.

6.3.8 Start of production closes in and uncertainty remains

At the end of the 12 months observation, many uncertainties exist on the project, from the limited testing time to the risk of new changes from the customer, driven by delays in their own development plan. With just over 12 months left to go before start of production, many

members of the *VehicleSystemsCo* project team started to wonder if significant delays were to be expected on the overall project timeline and start of production.

6.3.9 Findings from Project 3 observation

The observation of Project 3 offered a few very interesting examples of how NPD project teams reacted to project changes. Some of the changes experienced by the NPD team working on Project 3 included personnel change (e.g., sales manager promotion, project manager resignation) and scope changes (e.g., removing aluminium housing, moving to a fixed displacement architecture). Rodrigues, Dharmaraj and Shrinivasa (2006) and classical project management literature (PMI, 2021) identify project changes, and scope changes especially, as one of the key project risks with potential ripple effects on the overall project.

The observation of Project 3 showed how the project team relied extensively on structured KMI to address changes and project risks: the team accessed lessons learned databases, involved subject matter experts, used formal templates and company procedure, etc. On top of structured KMI, Project 3 teams members commented that they were extensively relying on their professional network inside the organization to seek for information needed and guidance.

Observing key technical failures in Project 3 showed how components and design re-use are highly considered by the water pump business unit's leadership team as a tool to reduce project risks and costs. However, Project 3 also showed the risks associated with reusing components and designs without having a full understanding of the background knowledge (tacit and/or explicit) that goes with it.

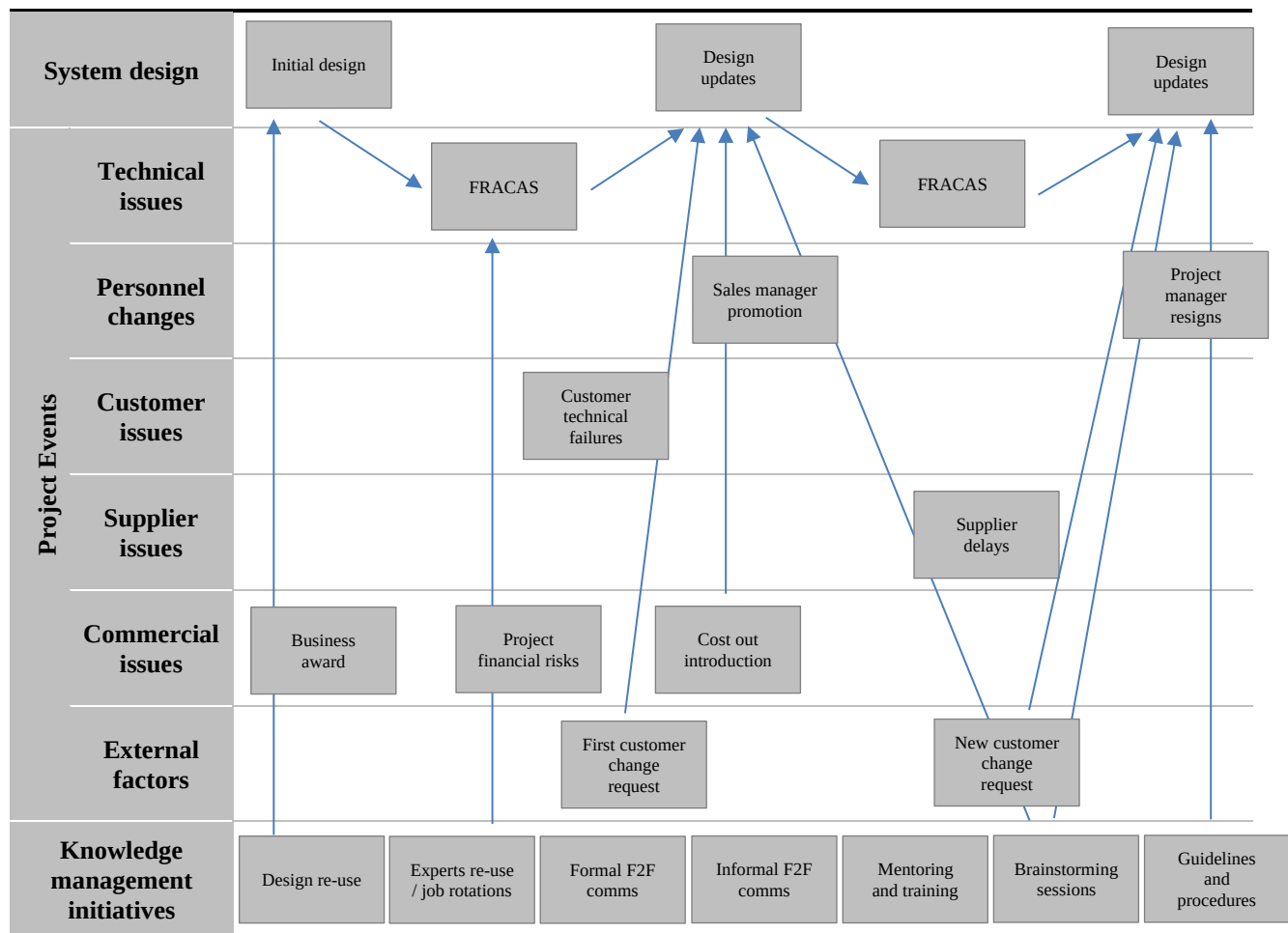


Figure 6.7 – Project 3 events and KMI blueprint

Using the format introduced with Figure 6.3, Figure 6.7 summarises the observations from the Project 3 case analysis and visually represents the role of the major project events discussed in the project lifecycle. Text boxes in the central rows on the table are used to track the major project events. In addition to project events, the first and last rows in the table are used to track the system design status and the knowledge management initiatives (KMI), respectively. Arrows are used to track the links between major project events, the system design status and the KMI the team used to react to knowledge events.

6.4 Water pump global engineering CoP and lessons learned databases

During the 12 months of the Project 3 observation, the Author had access to the lessons learned databases and the monthly business unit global engineering meetings of the water pump business unit: the global engineering team meeting is designed to increase project awareness across the global teams and improve knowledge sharing by strengthening the global engineering teams, effectively working as a CoP.

The information and the documents shared during monthly global engineering meetings are considered “business confidential” by *VehicleSystemsCo*: no recording of the meetings was allowed, and product and business details were excluded from reporting. While the hard data from CoP observations was limited, some interesting insights on project-to-project learning and learning behaviour on NPD projects teams in *VehicleSystemsCo* emerged.

FRACAS and lessons learned play an important role in global engineering CoP meetings. FRACAS are extensively used in the automotive and aerospace sectors and by many companies in general (Hallquist and Schick, 2004). FRACAS are typically reviewed in weekly FRACAS meetings, that are designed for the project technical team to report out on the testing status of the new systems and components and focus in particular on resolution of the failure modes observed, using a three steps approach that includes (1) containment action introduction; (2) root cause identification and (3) introduction of permanent corrective actions (Sahai *et al.*, 2011). FRACAS review meetings are the time when *middle management knowledge brokering* mostly occurs. Middle managers participate in bi-weekly reviews for all programs running at the same time in their business unit and are often able to identify similarities and trends between different project teams and to connect team leaders of different projects or the projects teams with subject matter experts. As an example of this, during a bi-monthly technical review for Project 2 one of the engineering middle managers commented:

'Project [REDACTED] had the same issues you guys are discussing today six months ago! They arrived at the conclusion that [REDACTED] [a technical solution] is not going to work. [REDACTED] [a separate technical solution from another vendor] could work, they are now working with [REDACTED] [supplier name] to assess feasibility. Please check with [REDACTED] where they are at and if you can do the same [on Project 2].'

(Water pumps engineering manager)

While weekly FRACAS meetings and senior leadership reports provide interesting insights in how middle management knowledge brokering works in *VehicleSystemsCo*, these meeting typically only involve the core team of one project and SME and, therefore, provide limited information on project-to-project learning and how project teams learn from other project teams.

To better understand how formal *VehicleSystemsCo* KMI work for project-to-project, the Author participated for 12 months in global engineering team meetings of the water pump business unit. The global engineering team meetings are typically made of three sections. The first section is intended as a general introduction and the regional engineering managers or the global engineering managers provide updates on business trends, business outlook organizational updates and NPD process updates. The first section of the meeting is typically limited to 15 minutes. The second section is dedicated to product design. In the second section, one or two project teams are invited each month to present the design highlights of their project and their development both in terms of peculiar customer requirements and analytical definition of the product. The second section is intended to inform all NPD teams globally about design details and foster design and component re-use. The second section of the meeting typically lasts 20 to 45 minutes. The third and last section of the meeting is dedicated to FRACAS. As for the second section, one or two project teams are asked each month to share with all global engineering teams

details of one FRACAS that they are working on. The objective of the third section of the meeting is to raise awareness of design flaws and, most importantly, of new NPD methodologies developed to solve the issues encountered. The third section of the meeting typically lasts 20 to 45 minutes.

The target audience of the global engineering meeting is over 50 engineers globally. The participation and engagement in the team meetings vary, depending on the phase of the projects, projects commitments, and month of the year. Table 6.1 includes details of the participation to global engineering meetings during the 12 months of the case study research. Lower participation to the team meetings was observed during the months of August and December, in line with local holidays. Table 6.1 also tracks the number of projects and the number of FRACAS reviewed in each team meeting.

Table 6.1 – FRACAS monthly meeting access data

	June 2021	July 2021	Aug 2021	Sept 2021	Oct 2021	Nov 2021	Dec 2021	Jan 2022	Feb 2022	Mar 2022	Apr 2022	May 2022
Meeting participants	32	41	18	23	34	43	19	22	33	38	32	28
Project teams represented	5	7	4	4	5	8	4	4	5	7	5	6
Designs presented	2	2	1	1	2	2	0	0	2	1	2	2
Design presentation downloads	7	8	3	5	6	11	-	-	10	12	9	7
FRACAS reviewed	2	2	3	2	2	1	2	2	1	2	1	2
FRACAS presentations downloads	9	10	7	8	9	15	7	8	12	9	11	9

The active engagement observed in the engineering team meetings is relatively limited, with approximately 5 to 10 individuals contributing to the discussion by asking questions or providing comments. The limited participation in these virtual global team meetings was in line with what previous studies on participation and engagement in virtual team meetings found (Anderson *et al.* 2007; Bal and Foster, 2000). While limited interactions were observed during the meetings, many interactions between the individual team members were observed after the meetings. While no information is available on the informal interactions generated by the team meetings, when probed one week to ten days after the reviews, the FRACAS or project designs reported that they were contacted by other project teams for further information on presented materials. The materials presented at the engineering team meetings are stored in the business unit shared repository, accessible to all participants to the monthly global engineering meetings. Table 6.1 also includes details of the number of downloads recorded for the FRACAS and design presentations of each monthly team meeting.

Large focus of the global engineering team meetings was on NUDDs product characteristics²⁴. NUDDs are extensively discussed in the global engineering team meetings and also extensively discussed in the reviews with middle management and senior leaders. *VehicleSystemsCo*'s focus on NUDDs is consistent with the high focus on radical NPD. As a follow-up to the interviews, when asked about the company's focus on NUDDs, a *VehicleSystemsCo* senior engineering leader commented:

²⁴ In the literature on NPD risk management and the quality function deployment (QFD), NUDDs are defined as New, Unique, Different and Difficult product characteristics (Olechowski, 2012).

'We have to focus on NUDDs, we've learned this is the hard way on [redacted] and [redacted] [project names]. When we have a new concept or we are using a concept we know well in a new environment, that's when things start to go wrong, we need to do a better job at highlighting our NUDDs early on and do as much analytics on them before we start cutting steel.'

(Water pump business unit director, 18 January 2021)

The last portion of the case study included a review of the lessons learned databases of the business unit of *VehicleSystemsCo* that participated in the case study. Different lessons learned databases exist in *VehicleSystemsCo*: as new, web-based tools are introduced, the older lessons learned databases are still supported and accessible, causing difficulties for the project team members trying to access the lessons learned. Capturing lessons learned before each gate is mandated by the stage-gate project management system used by *VehicleSystemsCo*. Project managers are required to submit evidence that lessons learned were captured before each gate is cleared. During the 12 months of the case study, a consistent update of the lessons learned databases before the gates was observed. However, the use of the lessons learned databases was most of the time led by the project managers; the project team members had limited awareness of the location of and access to the lessons learned database. Very limited access to the lessons learned databases outside of the mandated pre-gate updates was observed. A sampling review of 50+ lessons learned captured in both the legacy and the new system showed that the quality of the lessons learned captured varies significantly and, unsurprisingly, is strongly dependent on the focus the team used when writing the lessons learned. The majority of the lessons learned samples (26) focused on the timing aspects of the program. Technical and NPD process learnings were also found in a large portion of the lessons learned reviewed (18). The relevance of schedule learnings, product technical learnings and process learning is well aligned with the findings by Goffin *et al.* (2010). In line with *VehicleSystemsCo* guidelines, the lessons learned reviewed included both negative (i.e., mistakes made) and positive

learnings. Positive learnings were often focused on the timing of specific NPD activities, either anticipating or delaying key project activities (e.g., supplier sourcing selection) compared to the prescribed timelines.

Interestingly, the observation of the global engineering meeting showed that structured KMI work in *VehicleSystemsCo* is a catalyst for informal communication and informal project-to-project learning between NPD team members. While limited participation in structured KMI was observed, many informal communications started-off as an indirect consequence of the structured KMI, resulting in knowledge sharing and use between projects.

6.5 Findings from the project-level analysis

The observation of the three case study projects and the water pump CoP showed how NPD project teams react and manage key knowledge events during their project's lifecycle. Variable displacement water and oil pumps were selected as products representing the complexity and engine system level interactions actually experienced by *VehicleSystemsCo* products. The three projects were selected to represent both business units and different degrees of innovation.

Five types of knowledge events were observed on the three projects:

- Personnel changes;
- Technical failures;
- Supplier issues;
- Commercial issues;
- Events outside of the control of the team.

KMI were used to prepare for potential issues and react to project events. The 12 months observations of the three projects highlighted that project changes are a constant across them and that personnel changes were the most common change event, followed by scope change. Personnel changes on the projects occurred both in the form of a KMI (e.g., experts re-use) and a knowledge event for the project team (e.g., the resignation of the lead engineer or project manager). The three project teams reacted in similar ways to personnel changes, relying on hard documentation, procedures and guidelines to manage the transitions. Personal links and informal communications were also used to manage the shortcomings of formal documents and procedures. Storytelling was also observed within and across the three projects, used a way to build the team, sharing often stories of key project events within the team, and as a way to share knowledge outside of the project team. Mentoring and training were also extensively used by the project teams to react to personnel changes.

Commercial issues were also experienced by projects' teams, highlighting the importance of contract language for NPD projects. While *VehicleSystemsCo* procedures discuss the importance of contract language and prescribe minimum conditions that must be included, the observation of the three projects showed that these are often overlooked by the project teams.

As far as technical issues are concerned, the most common issues faced by the project teams were related to the interfaces and systems-level interactions on the customer engines. The observation of the three projects showed the difficulty *VehicleSystemsCo* have in capturing learning on systems level interactions, other than prescribing a thorough change tracker and customer requirements management system. Dedicated task forces were formed, and red alert daily meetings scheduled. The formation of dedicated task forces was also observed and allowed for effective sharing of knowledge between the team and subject matter experts.

Components, designs and experts re-use were also extensively observed across the three projects. However, observations of the failures of Project 3 in design re-use highlighted the risk of relying too heavily on design re-use to accelerate and de-risk the

projects, without having a full understanding of the background knowledge (tacit and/or explicit) that goes with the re-used designs. The observation of the three projects in *VehicleSystemsCo* also showed the perceived importance of respecting challenging and, at times, unrealistic timelines and the risks that these drive in terms of limited ability of the team to complete successfully standard project activities. The importance of customer timelines is, however, a constraint in the automotive industry (Staeblein and Aoki, 2015).

Different behaviour and reactions to knowledge events were observed in radical and incremental NPD projects. While, as expected, a lower number of failures were observed on incremental NPD projects, limited use of pre-existing lessons learned and company procedures was observed also in the case on Project 2 (incremental NPD). The observation of the three NPD projects highlighted the importance of differentiating the incremental and radical innovation components (i.e., NUDDs) of each project and the risks associated with focusing extensively the project team's efforts on NUDDs. Excessive focus on NUDDs can lead teams to underestimating the risks related to ignoring the explicit and tacit knowledge embedded in "well known" incremental content of radical NPD projects.

Issues with customers and suppliers also occurred during the observation on the three projects and the teams resorted to the re-use of subject matter experts, lessons learned databases and procedures. The analysis of the three projects showed how company procedures are applied consistently and systematically in the case of major project events. Root cause analysis, task forces and daily "red alert" meetings were deployed similarly on all three projects, when needed.

6.6 Summary

Chapter 6 included the narrative of the main project events during the 12 months of observations on the three projects. The observation showed how the teams reacted to major project events and how they relied on knowledge management initiatives (KMI) to solve and manage projects events (see Table 6.2). The observation highlighted the importance of the KMI for the global NPD projects in *VehicleSystemsCo*, but mostly helped to understand

the project-to-project learning at project level, having the projects (and therefore the project teams) as unit of analysis.

Table 6.2 – Findings from case studies observations

		Project events		
		Technical issues	Personnel changes	Customer issues
Knowledge management initiatives	Design re-use	Design re-use is both a solution (P1, P2) and a cause (P3) of technical failures.	-	Design re-use was observed as solution to customer issues in P1.
	Expert re-use	Re-use of experts was observed on all three projects to address FRACAS systematically.	Re-use of experts was used as a mitigation action to personnel change in P1 and P3.	Experts were consulted in Project 1 and 2 when customer issues started.
	Brainstorming sessions	Brainstorming sessions were used in P1 and P3 to involve fresh eyes on FRACAS resolution.	-	Brainstorming sessions were used in P1 and P3 to assess the customer issues and potential solutions.
	Formal comms	Formal communication was used in all three projects to share FRACAS status.	Formal communications were reinforced following personnel changes to maintain team alignment.	Red alert meetings were initiated following customer issues.
	Informal comms	Informal communication was observed to discuss FRACAS findings and potential actions in P2 and P3.	-	-
	Project reviews	The cadence of formal project reviews was increased following FRACAS events.	-	The cadence of formal project reviews was increased following customer issues.
	Mentoring and training	-	Mentoring and training was observed as a key success factor for new team members joining the project teams.	-
	Job rotations	-	Job rotations were both the cause of- and mitigation to- personnel changes.	-
	Procedures and guidelines	Procedures and guidelines were consulted as part of the root cause analysis.	Procedures and guidelines were consulted by the new team members.	-
	Storytelling	Storytelling was used to share knowledge of previous project FRACAS.	Project storytelling was used as means to bring new team members up to speed.	-
	Boundary objects	Failed components all three projects acted as boundary objects for the team.	-	-
	Lessons learned DB	Lessons learned databases were consulted at the start of FRACAS.	-	Lessons learned databases were consulted when customer issues started.

Table 6.2 (continued) – Findings from case studies observations

Project events				
Supplier issues	Commercial issues	External factors		
Comparison with similar components was used to assess supplier issues.	-	-	Design re-use	Knowledge management initiatives
Experts and SME were consulted after encountering supplier issues.	Experts from the sales and marketing team were consulted after commercial issues arose.	-	Expert re-use	
Brainstorming sessions were scheduled in response to supplier issues in P1 and P3.	-	Brainstorming sessions were scheduled in response to external events.	Brainstorming sessions	
Formal communications were extensively used to manage supplier issues.	Formal communications were extensively used to manage commercial issues.	Formal communications were extensively used to manage external factors.	Formal comms	
Informal communications were used extensively to discuss supplier issues.	Informal 1:1 discussions were observed amongst team members when faced with commercial issues.	Informal communications were observed to discuss the implication of external factors on P1 and P2.	Informal comms	
Supplier issues were extensively discussed in project reviews.	Commercial issues were extensively discussed in project reviews.	-	Project reviews	
-	-	-	Mentoring and training	
-	Job rotations negatively impacted commercial issues resolution on P1 and P3.	-	Job rotations	
Supplier quality management procedures were used extensively.	Sales and marketing best practices were used to manage commercial issues.	Company procedures were consulted to deal with external issues.	Procedures and guidelines	
Storytelling was used to share stories of previous supplier issues.	Storytelling was used to share stories of previous commercial issues.	-	Storytelling	
-	-	-	Boundary objects	
Lessons learned DB were consulted after supplier issues emerged.	Lessons learned DB were consulted before commercial issues emerged.	-	Lessons learned DB	

CHAPTER 7 – COMPANY-LEVEL ANALYSIS

7.0 Introduction

In this Chapter, a three-step approach to data analysis based on interview data and knowledge management surveys in *VehicleSystemsCo* is used to answer the research question and sub-research questions with the aim of understanding what KMI global NPD teams use for project-to-project learning and which approaches global NPD managers think are effective for project-to-project learning.

The three steps provide a map of knowledge management between projects based on interview data, an analysis of the survey data on KMI use, and finally a qualitative, coding-based analysis of the reoccurring themes emerging from the interviews. Figure 7.1 visualizes the three-step analysis, linking it to the relevant research questions.

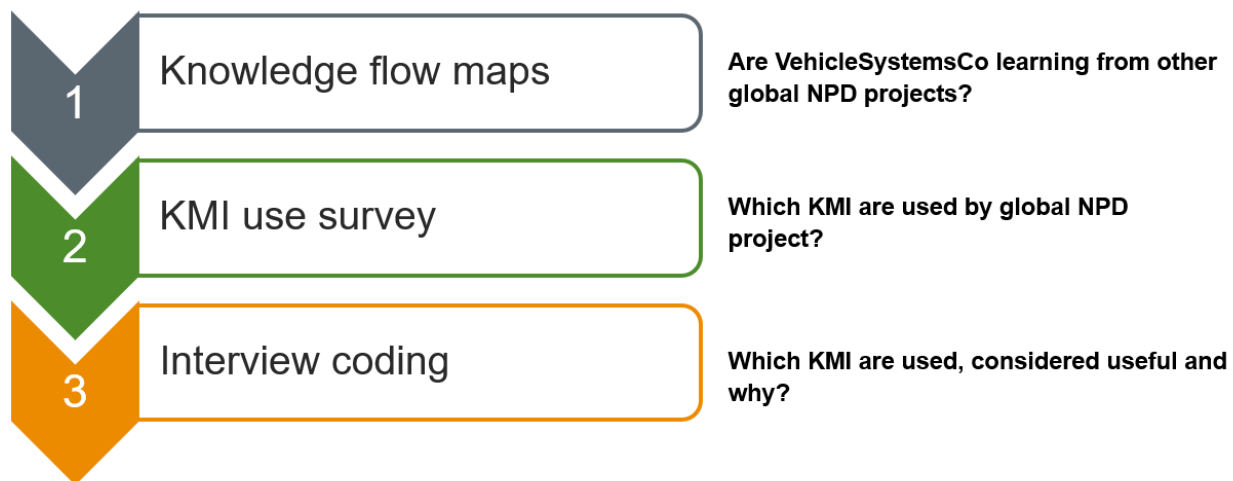


Figure 7.1 – Data analysis process flow

The first step to understand project-to-project learning in global NPD is to map knowledge flows between global NPD projects. This is an important step as the literature reviewed in Section 2.2 highlights that one of the key risks for global NPD (e.g., Salomo *et al*, 2010) is limited interpersonal communication and informal knowledge sharing that constrains the ability of sharing knowledge. The literature also shows that global NPD projects can be successful despite limited interpersonal communications. Mapping knowledge flows between global NPD projects helps to assess whether limited interpersonal and face-to-face communications cause limited knowledge flows. Knowledge flows between projects and KMI use are mapped based on interviews responses showing that extensive knowledge links exist between projects at a much higher extent than predicted for the use of KMI. Yet, while helping to understand if knowledge flows exist between global NPD projects, knowledge flow maps provide limited information on how project-to-project learning occurs. Figure 7.2 shows how Step 1 of the data analysis helps to answer the RQs and highlights which dimensions of the 2x2 framework are influenced by the analysis at Step 1. By investigating the extent of KSU in global NPD projects, Step 1 helps overall framing the effectiveness of KMI in *VehicleSystemsCo*.

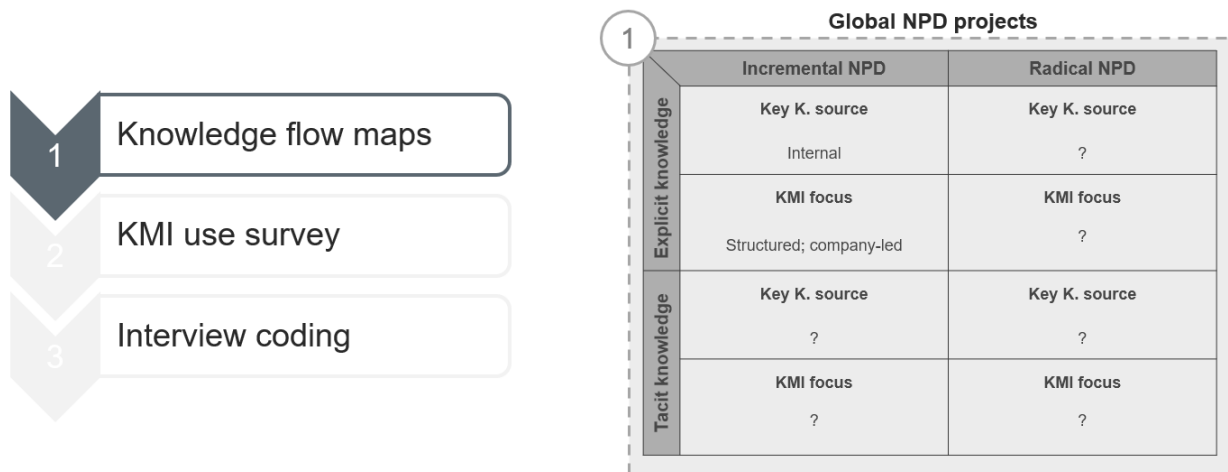


Figure 7.2 – Data analysis process flow – Step 1

The aim of Step 2 is to understand which KMI amongst or beyond those officially deployed by *VehicleSystemsCo* are actually used by global NPD teams to achieve the project-to-project learning mapped in Step 1: Chapter 5 showed that most of the KMI discussed in literature are used in *VehicleSystemsCo*, but not all are used in either Project 1, Project 2 and Project 3. Survey responses are plotted against each KMI for each interview participants, tracking KMI use and reported KMI effectiveness for each KMI under investigation. Figure 7.3 illustrates how Step 2 helps to answer the RQs and what dimensions on the project-to-project learning 2x2 framework are influenced by the KMI survey. Step 2 provides helpful information to answer the main research question (i.e., which KMI are used and considered most effective) but provides limited information to explain the mechanisms that make KMI effective (i.e., “why?”) and provides limited information to answer SRQ1 and RQ2 – which KMI are effective for which kind of knowledge and which KMI are effective as a function of the degree of innovation of the project.

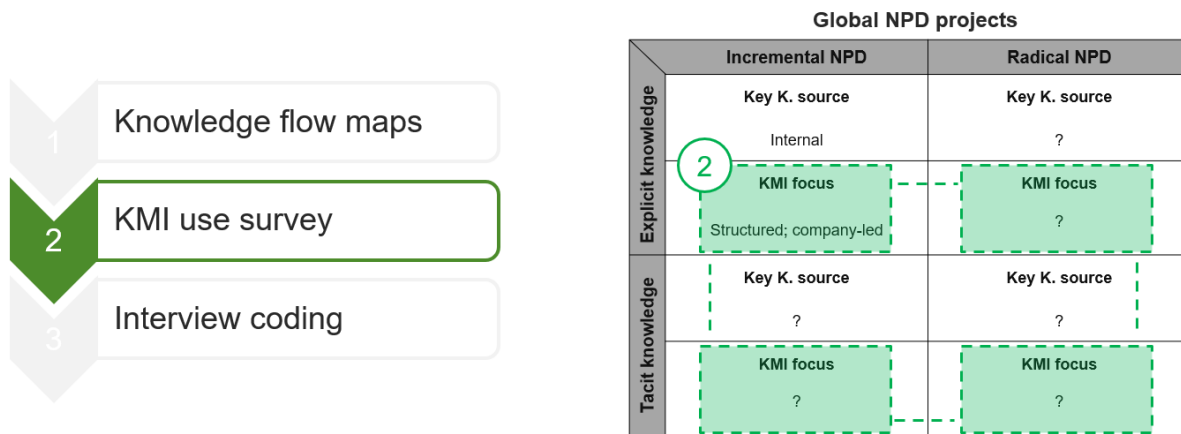


Figure 7.3 – Data analysis process flow – Step 2

The third step is designed to help answering SRQ1 and SRQ2 and in particular to help understanding which KMI are better suited for tacit or explicit knowledge and for different degrees of innovation. To this aim, full interview transcripts are coded for key themes. Multiple codes looking at project degree of innovation, project geographical distribution, KMI characteristic and types of knowledge are used to assess KMI effectiveness and help answering SRQ1 and SRQ2. Figure 7.4 shows which dimensions of the 2x2 project-to-project learning framework are influenced by step 2 of data analysis.

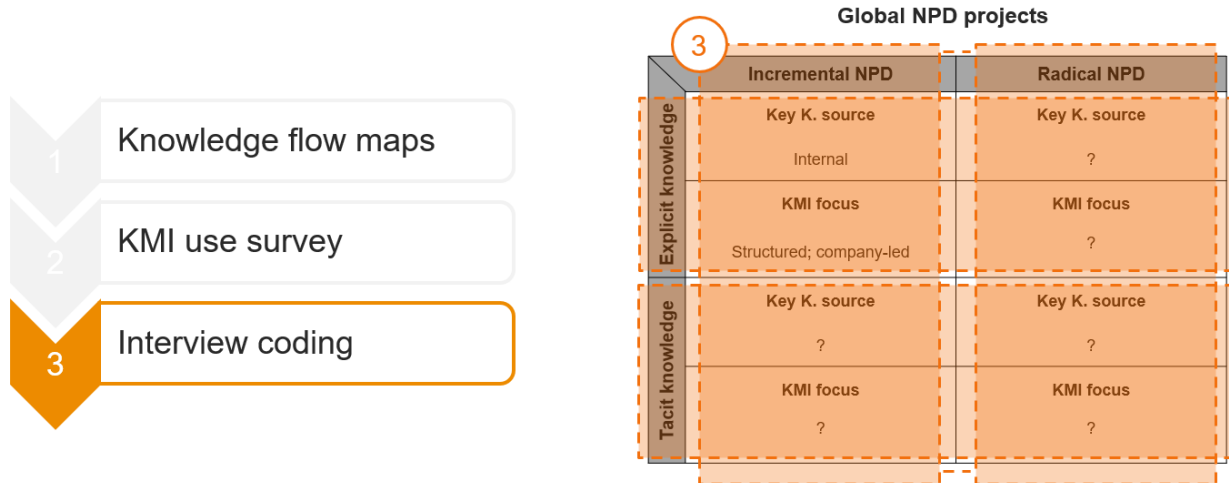


Figure 7.4 – Data analysis process flow – Step 3

Finally, the observations from the *VehicleSystemsCo* case study also allows to compare and contrast different views and practices on KMI in global NPD, at various organizational and sophistication levels (from theory to practice, from senior leadership and organizational design to working-level employees).

The Chapter is organized as follows. Section 7.1 includes details of the knowledge flow mapping; Section 7.2 includes the results of the survey on the use and usefulness of KMI in the project teams interviewed; Section 7.3 details the coding structure used to analyse the interview transcripts; Section 7.4 summarizes data analysis and findings.

Chapter 7 includes a few quotes from the interviews with NPD team members and senior leaders. The quotes are highlighted by an italic font and quotation marks (“”). Square brackets highlight passages omitted for confidentiality reasons or because not relevant. Researcher’s notes to improve the readability of the quotes are also added in square brackets. The author of the quote is included at the end of the quote, in brackets, using the following nomenclature:

- NPD teams: Project # - Interview #, abbreviated to P#-I#. E.g., Project 1 – Interview 1 is abbreviated as **P1-I1**;
- Middle managers: Middle manager #, abbreviated to MM#. E.g., Middle manager 1 is abbreviated as **MM1**.
- Senior meanders: Senior leader #, abbreviated to SL. E.g., Senior leader 1 is abbreviated as **SL1**.

7.1 Knowledge flow mapping

The first part of the data analysis intends to assess whether project-to-project knowledge flow exists between the three global NPD projects investigated. The main goal of the knowledge flow maps plotted in Figure 7.5, Figure 7.6 and Figure 7.7 is to show the extent of the knowledge links between the three projects and any other project explicitly discussed by the interviewees.

The three projects selected as case study are plotted in Figure 7.5: orange circles are employed to represent the projects. Project names (Project 1, 2 and 3) are reported above the project circle and the degree of innovation of the project are reported below the project circle. Project 1 and Project 3 are visually represented by two circles to show they are made up of 2 sub projects each, led by the same project team and targeting the same final customer or final applications. Structured KMI explicitly implemented by the *VehicleSystemsCo* in Projects 1, 2 and 3 are plotted in Figure 7.5: blue lines are employed to track design or component re-use and green line expert re-use amongst the three projects.

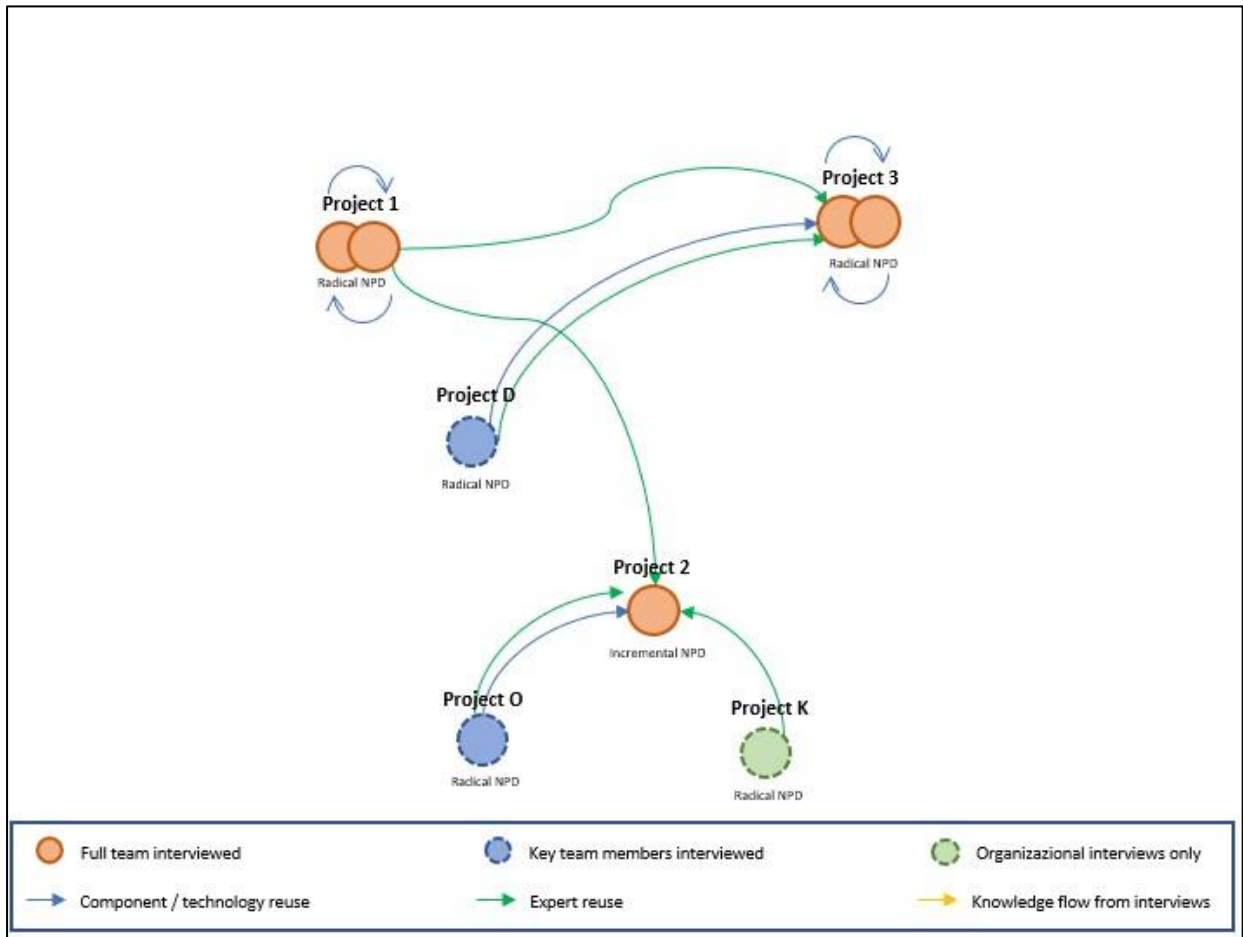


Figure 7.5 – Knowledge link between projects

Very little design re-use exists amongst the projects under investigation. Expert re-use from Project 1 to both Project 2 and Project 3 was introduced by *VehicleSystemsCo*. Project 1 was initiated in 2018 and is further along in the NPI lifecycle compared to Project 2 and Project 3, both kicked off in 2020 and key subject matter experts that learned in Project 1 were asked to support Project 2 and Project 3.

Looking at the boarder business unit picture more projects impact or are influenced by Project 1, 2 and 3. Based on the feedback from middle managers and senior leaders in the organization, a total of seven additional projects have formal ties with Project 1, 2 and 3,. Figure 7.6 plots the three projects and the connection to other projects in the business unit. As for Figure 7.5, blue lines in Figure 7.6 represent technology or component re-use and green line expert re-use between the projects. The additional seven projects that either share designs or experts with the case study projects are also plotted in Figure 7.6.

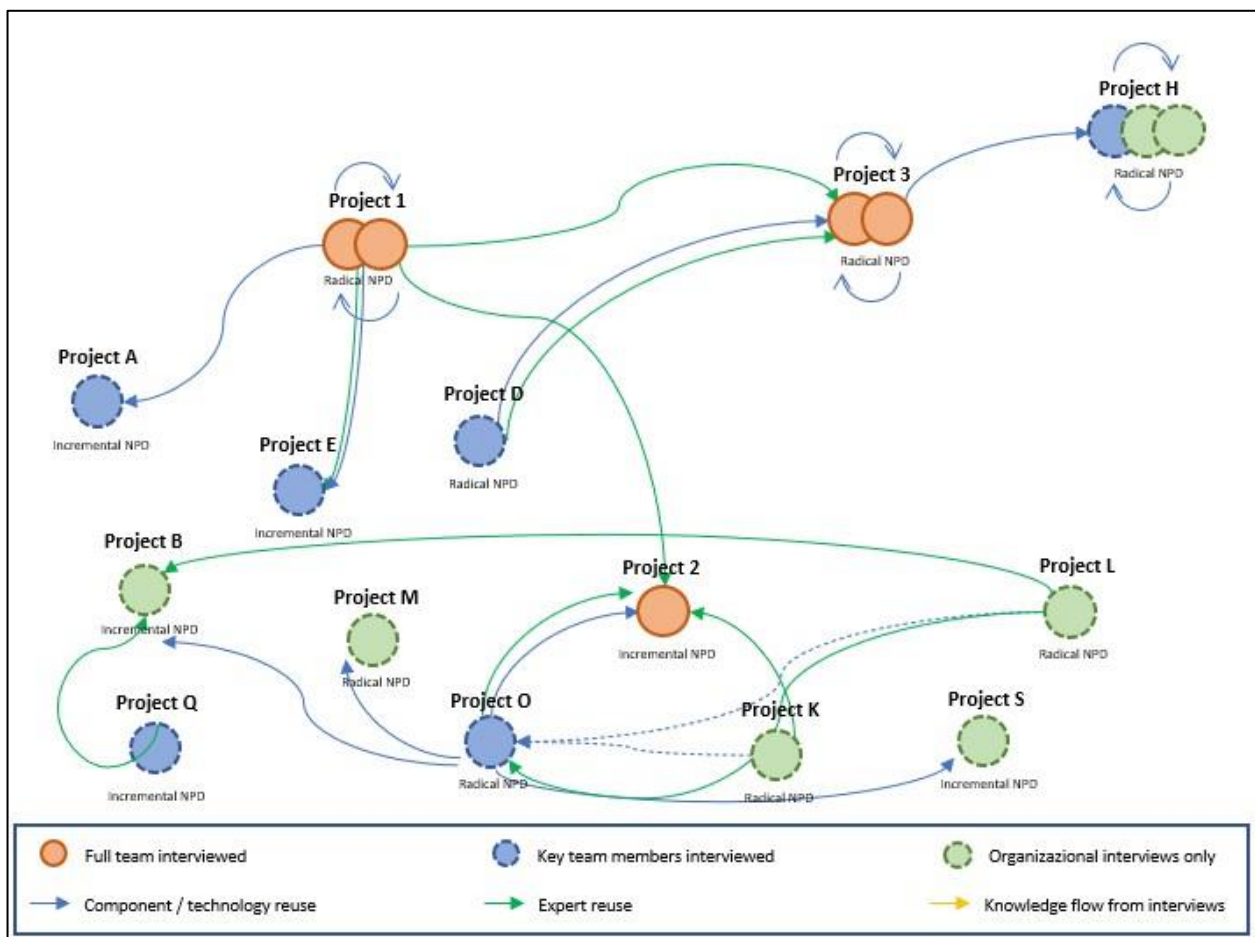


Figure 7.6 – Knowledge links to other projects

To distinguish the additional seven projects showed in Figure 7.6, capital letters instead of numbers are employed to differentiate each project. Colour coding is also employed to differentiate the projects reported in Figure 7.6: an orange circle highlights that the full NPI program was interviewed as part of the research (Projects 1, 2 and 3); the projects whose key team members were interviewed as part of the research are identified by a full blue circle (key team members from these projects were re-used in either Project 1, Project 2 or Project 3); in case of the projects with a green circle, no team members were interviewed as part of the research. The projects coloured in green share no team members with either Project 1, Project 2 or Project 3. Experts' re-use and components / design re-use are plotted with a green and blue arrow respectively.

Figure 7.5 and Figure 7.6 show that *VehicleSystemsCo* implemented experts and design re-use to formally share knowledge between key projects of the organization. One of the key outcomes of the case study was to understand if the team members of Projects 1, 2 and 3 were able to identify other projects that impacted on their project and therefore to identify project-to-project learning events. The feedback from case study interviews is included in the knowledge flow maps in Figure 7.7 and captures additional project-to-project learning instances, as reported by the interviewees. Interviewees were explicitly asked to name all projects that had influenced their activities or that had any learnings which they used in their activities. The additional projects are also plotted in Figure 7.7. It is interesting to see that the number of projects team members have named during the interviews is significantly higher than those plotted in Figure 7.6 which were predicted solely based on design / component re-use and experts' re-use. The decision to plot experts and design re-use is a core focus of *VehicleSystemsCo* when setting up a new project. Experts and design re-use are also KMI less influenced by the lack of face-to-face and interpersonal communication typical of global NPD projects.

Following the interviews, seven projects were additionally added to the knowledge flow map presented in Figure 7.6. Yellow arrows have also been added to show the knowledge flow described by team members during the interviews. When interview data allowed it, key KMI were indicated on top of the yellow arrows to highlight KMI explicitly

named during interviews. Project 1 and Project 2 belong to water pumps business unit, while Project 3 belongs to the oil pumps business unit. All three are part of the automotive group.

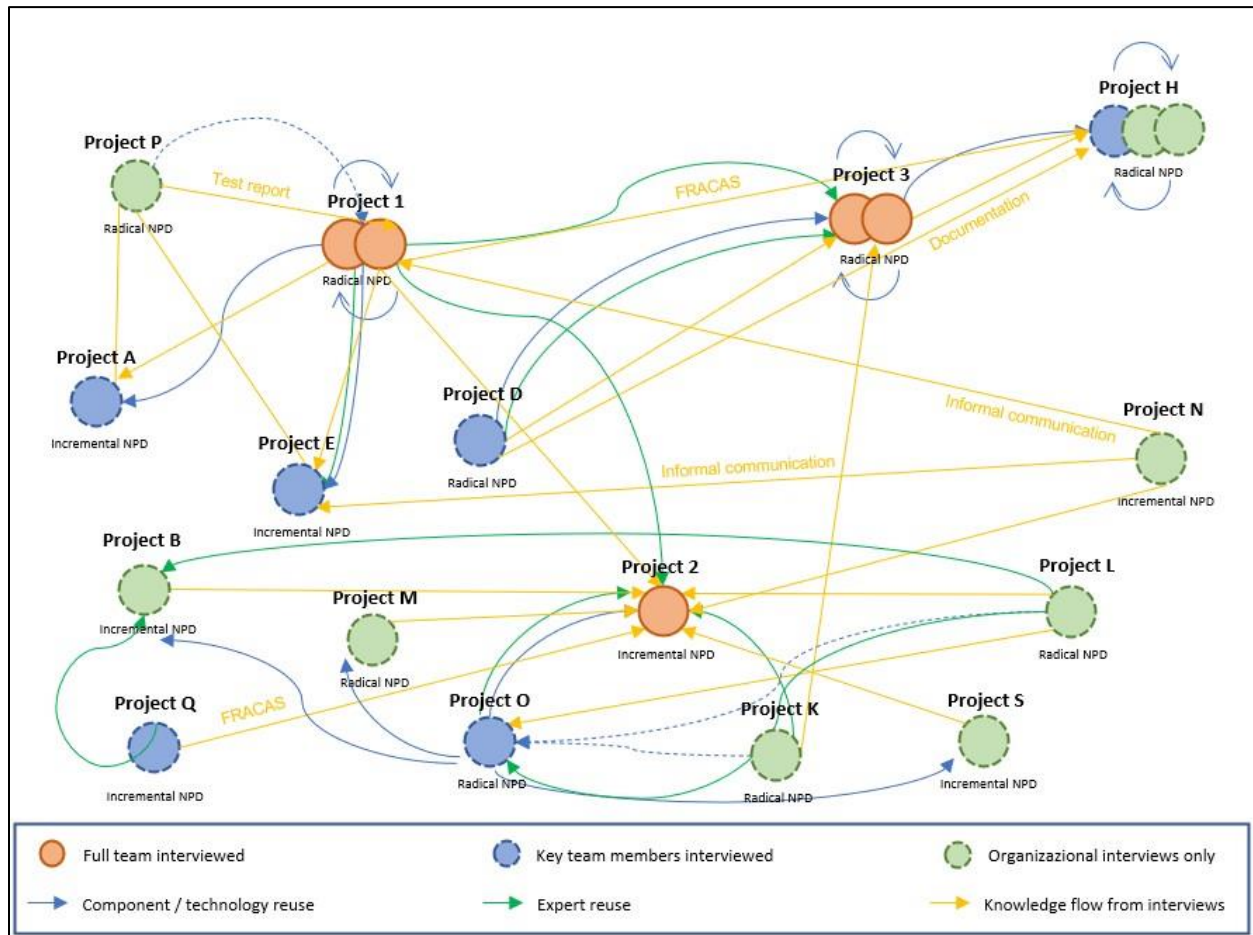


Figure 7.7 – Knowledge links discovered with interviews

The data collected in the knowledge flow maps helps to uncover the *knowledge behaviour* of global NPD teams: knowledge flow maps show that the flows occurring between global NPD projects are much higher than what could have been predicted based on the re-use of experts and of designs. The list of projects discussed by interview participants is extensive in the context of *VehicleSystemsCo* and includes all the main

projects the business unit ran in the last ten years. Comparing the average tenure length of the team members to completion date of the Projects A-S, it is quite clear that many of the latter were finished before most of the participants joined *VehicleSystemsCo*. Projects A-S were completed or entered into service between 2010 and 2017. The team members tenure length in *VehicleSystemsCo* is not included in this document due to confidentiality reasons. The high number of projects discussed by team members, many of which were long concluded before the interviewed team members joined *VehicleSystemsCo*, highlights how effective global NPD teams are in finding ways to access the knowledge they need around the prescribed knowledge paths – i.e., *knowledge finds its way to the teams!*

The finding that teams manage to access knowledge not easily available to them is particularly interesting and important for project-to-project learning in global NPD. Two trends are clearly visible when looking at the evolution of the knowledge flow maps, from Figure 7.5 to Figure 7.7: firstly, the number of projects included on the maps increases at each step and, secondly, the number of knowledge links between the projects increases significantly at each step. The fact that the number of projects increases at each step shows that the project teams manage to access the knowledge embedded in - a high number of projects, irrespectively of whether the projects were run by the same location they are based in (co-located) or by global locations. When reviewing the charts in Figure 7.7 with *VehicleSystemsCo* managers and subject matter experts, they were surprised to see some of the projects were even included on the chart: some of the projects included were very old projects, that were seldomly discussed in reviews and many of the employees that led those programs have either retired or left the organization.

The high number of knowledge links between the projects was also surprising for the *VehicleSystemsCo* managers. The knowledge links showed both the effectiveness (higher than anticipated) of formal KMI, but also the positive side effects of the formal KMI. The high number of unexpected knowledge flows between NPD projects is an indication that, when knowledge needs occur in a team, the awareness of knowledge external to the team itself is a sufficient trigger to go outside of the traditional channels to recover the knowledge needed, despite the existing barriers.

7.2 Survey of KMI use in the case study projects

To provide more information on how knowledge flows between project, a survey on the use of KMI was conducted as part of the case study interviews in *VehicleSystemsCo* with the aim of understanding how knowledge flows between global NPD projects. The day prior to each interview, a full list of KMI based on Table 2.4 (presented in Section 2.3) was sent to the interviewees. Most of them were familiar with the listed KMI, with the exception of *boundary objects* and *project manager camps*. Also, *expert yellow pages* often raised questions and after the initial interviews the name “Expert Yellow Pages” was replaced by the *VehicleSystemsCo* company specific term of “*Subject matter expert list*”.

During the interviews, participants were asked to go through the list line by line, commenting whether each KMI was used in their projects and it was considered useful. Table 7.1 summarizes the survey of KMI use and usefulness. KMI initiatives from the SLR are listed in the first column and additional columns are included to track the results of the survey on KMI, one for each completed interview. Each row is corresponding to the feedback of a participant – the columns are ordered randomly in Table 7.1. Cells colour coding is used to track interviewees’ responses, in particular for each interview (columns) the cell corresponding to each KMI (row) is coloured in green, yellow or red as follows:

- green cell if the interviewee reported that the KMI is in-use and considered effective;
- yellow cell if the KMI is in-use but not considered particularly effective (neutral);
- red cell if the KMI is used and considered ineffective or detrimental to knowledge sharing and use;
- cells are left blank if KMI are not used.

With the exclusion of “boundary objects” and “relocation of offices”, Table 7.1 shows that most of the KMI identified in literature are used by the global NPD interviewed teams. A high-level review suggests that no single KMI is recognized universally as key for project-to-project learning in global NPD.

Informal and face-to-face communication and *mentoring and training* are considered key to project-to-project learning in global NPD by the majority of the participants to the interviews, respectively with 28 and 23 participants out of 35 indicating that informal communication is effective for project-to-project learning in global NPD and no interview highlights potential detrimental effect on project-to-project learning. This finding is somehow in contrast with the limitation of global NPD projects highlighted by literature (e.g., lack of propinquity and contact) (Baxter *et al.*, 2013). *Experts re-use* (22 positive responses), *Brainstorming sessions* (21 positive responses), *feedback loops* (21 positive responses), *design re-use* (20 positive responses) and *project reviews* (20 positive responses) are also considered beneficial for project-to-project learning. However, few interviewees have highlighted potentials negative effects of these KMI for project-to-project learning in global NPD. The negative impacts highlighted by interviewees were further probed during the interviews (see below Section 7.5).

Similarly, no single KMI is considered ineffective or detrimental to project-to-project learning in global NPD with the single exception of *lessons learned databases* that are poorly ranked by the majority of the interviewees (see below Section 7.6). Additionally, Table 7.2 details the KMI that, while not currently in use, were highlighted as having high potential for KSU – the corresponding KMI cells are highlighted in blue: *experts yellow pages* (6 positive responses) and *jobs rotations* (6 positive responses) were identified as the two KMI not used but with highest expected effectiveness for knowledge sharing and use.

The data presented by the KMI survey helps understanding which KMI – highlighted by the knowledge flow maps presented in Section 7.1 – are used and contribute to the knowledge flow between projects. It also helps answering the portion of the RQ regarding “which KMI are used and considered effective for KMI” (see below Section 7.6).

Table 7.1 – Use and effectiveness of KMI in global NPD from case study interviews

KMI	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
Feedback loops																																				
Boundary objects																																				
Brainstorming sessions																																				
Communities of practice																																				
Design/components re-use																																				
Expert yellow pages																																				
Informal / F2F comms																																				
Job rotations																																				
Lessons learnt databases																																				
Mentoring / training																																				
Middle mgmt brokering																																				
Post project reviews																																				
Project manager camps																																				
Project reviews																																				
Relocation of offices																																				
Re-use of experts																																				
Storytelling																																				
Templates / guidelines																																				
Wiki / repositories (ICT)																																				

 Used and effective
  Used but limited effectiveness
  Ineffective or detrimental
  Not used

Table 7.2 – Use and effectiveness of KMI in global NPD from case study interviews and potentially useful KMI

KMI	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Feedback loops																																			
Boundary objects																																			
Brainstorming sessions																																			
Communities of practice																																			
Design/components re-use																																			
Expert yellow pages																																			
Informal / F2F comms																																			
Job rotations																																			
Lessons learnt databases																																			
Mentoring / training																																			
Middle mgmt brokering																																			
Post project reviews																																			
Project manager camps																																			
Project reviews																																			
Relocation of offices																																			
Re-use of experts																																			
Storytelling																																			
Templates / guidelines																																			
Wiki / repositories (ICT)																																			

 Not in use but potentially beneficial

Yet, KMI survey offers little insights to help answering SRQ1 and SRQ2, showing which KMI are better suited for tacit/explicit knowledge and different degrees of innovation in the case of project-to-project learning in global NPD projects. The coding analysis presented in Section 7.3 contributes to better understanding KMI effectiveness for different types of knowledge and projects degree of innovation.

7.3 Interview coding

Section 7.1 and 7.3 detail Step 1 and Step 2 of the data analysis from the case study interviews. While knowledge flow maps and KMI survey provide information on which KMI are used and considered effective, further steps are required to help to understand the mechanisms behind the perceived effectiveness. To help to understand why KMI are effective in global NPD, the full interview transcripts were coded for key words and key themes based on the SLR in Chapter 2. An initial coding structure was prepared based on the SLR and tested on the first interview. The themes and key words derived from the SLR are listed in Table 7.3, together with the selected codes and the relevant literature reference.

Table 7.3 – Initial coding structure

Theme	Sub-themes	Codes	Literature ref.
Geographical distribution	Local team	“Local”, “regional”, city names, country names	Enberg <i>et al.</i> (2006); Marabelli <i>et al.</i> (2013); Bower (2007); Altman and Engberg (2016).
	Global team	“Global”, “international”, city names, country names	
Types of knowledge	Technical knowledge	“Product”, “technical”, name of products	Nonaka (1996); Grant (1996); Holste and Fields (2009); Newell (2004); Goffin <i>et al.</i> (2010);
	Supplier knowledge	“Supplier”, name of supplier,	
	Process knowledge	Process names	
	Customer knowledge	Customer names, projects names	
	Local knowledge	City names, countries	
	Tacit	SECI, metaphors, storytelling	
Knowledge management initiatives / communication	Social KMI	“Mentor”, “training”, “shadowing”, “phone”, “expert”, “coach”, “call”, etc.	Prencipe and Tell (2001); Van Waveren <i>et al.</i> (2020).

	Formal KMI	“Databases”, “project review”, “lessons learned”, etc	
Degree of innovation	Radical innovation	Company specific project risk classification	Bartezzaghi <i>et al.</i> (1997); Nobeoka and Consumano (1997); Enberg <i>et al.</i> (2006).
	Incremental innovation	Company specific project risk classification	

Table 7.3 lists four themes and twelve sub-themes, for a total of more than 37 codes. The four themes selected for the coding (geographical distribution, types of knowledge, KMI and degree of innovation) are directly derived for them three key literature domains presented in Chapter 2 (see Table 7.4).

Table 7.4 – Coding themes and SLR domains

Coding themes	SLR domain
Types of knowledge	Knowledge needs and knowledge generated by NPD projects
Degree of innovation	
Geographical distribution	Organizational culture and social factors impact on KSU
KMI	Tools and methodologies for KSU

The coding structure presented in Table 7.3 is the initial coding structure and the codes included in the “codes” column were selected based on the reviewed literature and the nomenclature used in *VehicleSystemsCo* and well known to the Author (e.g., project names, facilities names). The development of the final coding structure was an iterative process and new codes were added, modified or expanded during the application on the interview transcripts. The final, expanded coding structure is presented in Table 7.5.

In addition to the codes listed in Table 7.5, particular care was taken when coding for KMI. Individual codes were created for each KMI from Table 2.4. Additionally, the following

codes were broken down in sub-codes to allow for better granularity during the analysis, based on re-occurring topics and themes identified in the interviews:

- **Informal communication:**
 - Core team informal communications;
 - Informal communications with other departments;
 - Informal communications with other projects;
 - Informal communications while travelling.
- **Formal communication:**
 - Core team formal communications;
 - Formal communications with other departments;
 - Formal communications with other projects;
- **Mentoring and training:**
 - Formal mentoring and training;
 - Informal mentoring and training.

A total of 41 codes was used in the final coding. The codes discussed above and the full list of KMI codes are not included in Table 7.5 in an effort to keep the table easy to read. The commercial software nVivo was used to code the interviews and track coding frequency. The number of different themes and sub-themes captured in each interview transcript ranged from 10 to 24 themes, with total codes references captured in each interview ranging from 20 to 60 references. Table 7.14 includes a summary of the codes' frequency by code type found in the interview transcripts. As expected, the number of references to different sub-themes is closely linked to the seniority of the interviewees: more senior employees and managers tend to engage with all sub-themes (around 20 different codes identified in the case of interviews of more senior employees); junior employees with total industrial seniority up to 5 years showed a tendency to engage in fewer sub-themes.

Table 7.5 – Final coding structure

Theme	Sub-themes	Codes	Literature ref.
Geographical distribution	Local team	“Local”, “regional”, city names, country names	Enberg <i>et al.</i> (2006); Marabelli <i>et al.</i> (2013); Bower (2007); Altman and Engberg (2016).
	Global team	“Global”, “international”, city names, country names	
Types of knowledge	Technical product knowledge	“Product”, “technical”, name of products, details on technical issues	Nonaka (1996); Grant (1996); Holste and Fields (2009); Newell (2004); Goffin <i>et al.</i> (2010);
	Supplier knowledge	“Supplier”, name of supplier,	
	NPD process knowledge	Process names, reference to procedural issues and learnings	
	Customer knowledge	Customer names, projects names, market trends	
	Local knowledge	City names, countries	
	Commercial strategy knowledge	Knowledge about product trends, product use	
	Competitors’ knowledge	Knowledge about regional / global competitors	
	Tacit knowledge	SECI, metaphors, storytelling	
Knowledge management initiatives / communication	Social KMI	“Mentor”, “training”, “shadowing”, “phone”, “expert”, “coach”, “call”, etc.	Prencipe and Tell (2001); Van Waveren <i>et al.</i> (2020).
	Formal communications	“Databases”, “project review”, “lessons learned”	
Degree of innovation	Radical innovation	Company specific project risk classification	Bartezzaghi <i>et al.</i> (1997); Nobeoka and Consumano (1997); Enberg <i>et al.</i> (2006).
	Incremental innovation	Company specific project risk classification	

As an example of the coding used, a two pages extract for the interview of a senior expert, is provided to give an example of the effectiveness of the coding in pages 238 and 239.

Dotted lines are used to highlight the text coded; colour coding and *code tags* are provided to highlight the codes captured. The transcript extract proposed in page 238 is from an interview of a water pump middle manager and the interviewee is answering a question about the use of KMI in the projects he is working on. The example provided was randomly selected amongst the transcripts available and shows the content richness of the interviews and transcripts available. The paragraphs reported as an example are related to a senior specialist with extensive industry experience. The example in page 238 also shows that the coding structure proposed works well and that the codes proposed are a good fit for the content of the interviews and will be expanded as the coding work progresses. Codes like the name of commercial software and new KMI as “observed” are not present in the original coding structure and were added. Coding for global and local knowledge is achieved considering both names of the locations, such as countries (e.g., Pune, Italy) and office location of the people mentioned. After the initial testing and the expansion of the codes list, coding was completed on all 35 transcripts. As Chapter 4 detailed, interviews were carried out in both English and Italian languages. Italian interviews were not translated, and coding was completed on the Italian full transcript, using the English codes for easier data analysis and to avoid code duplication.

Codes’ presence and *codes’ frequency* are used to analyse the interview coding data. The first parts of the analysis presented in this section was completed based on the codes’ presence in the interview transcripts. *Codes’ presence* is defined as a Boolean measure and intended to track if a particular theme, knowledge type or KMI is discussed in an interview.

On the other hand, *codes’ frequency* is a countable measure defined to track how often a particular theme, knowledge type or KMI is discussed in an interview. Sections 7.3.1 and 7.3.2 review the findings of the codes’ presence and frequency analysis, respectively.

“[...] Because we're trying to do a lot of these things, right? I mean, we're even trying to use like, Auros and, you know, all these databases, this is, you know, but I honestly, too often, I think we do that kind of stuff, thinking that there's some piece of software is going to fix everything, right. But I look at knowledge sharing a lot, like, you know, when we go through university to, to learn, say calculus, right? calculus is 1000s of years old. How do we learn calculus? And, you know, a semester in school? Right? We do that through mentoring and training. You, right? We have a textbook, right, which would fall into the templates and guidelines, right? Yeah. Yeah. I mean, to me, learning is pretty much a very old skill set. Right? And how do we do it? And what's the most effective way? is pretty much well thought out already. Right? So mentoring, mentoring and training to me are probably the most effective. Yeah, so you can think of a if you think of a skilled trade, like a, you know, I love Italy, because of the masonry work great. So there's people that do that, and are very, very good at that in Italy, right. And there's young people that probably train under very skilled trades, and that learn to do that, right. They just don't look at a piece of software and figure out how to lay down on a nice proper set of tiles, right? Yeah, yeah. And so these are the things that I look at this stuff. And we often look to a piece of software to solve our problems these days. But if I look back at learning and how what's effective is the mentoring and training. So, you know, when [redacted] was our [redacted] engineer, got on board of the [redacted] program and started talking to [redacted] and [redacted] and said, “Listen, I actually went through this laser welding

studies, and this is the things we learned” and you know, that just actually mentoring and training the guys is probably the most effective right? And getting together as a team and doing that, to me is the best. Right? You need mentoring and I personally feel that's the most effective anyways, I mean, I've done this for 29 years in the automotive industry, and I've had many mentors right. Many, many mentors. I mean, that's how I've learned one of the things

KMI, new-code¶ I've learned, I'd say, right, I've listened. And I observed and I, you know, I shadow people, right? [...] That's for sure. Right? I mean, I spend, I mean, just before this meaning almost every day, I'm on the phone with [REDACTED] Right? KMI, new-code¶

shadow people, right? [...] That's for sure. Right? I mean, I spend, I mean, just before this meaning almost every day, I'm on the phone with [REDACTED] Right?

mentoring and training those guys. Right? So it's a lot harder. But you know, with the technology that we have, you know, with it, it's effective, you can do it, but you got to spend a lot of time at it, which a lot of people don't want to do. Right. So again, my example with with [REDACTED] a real [REDACTED] and his team, right, is that I'm on the phone with them every morning. Almost every morning, right? It's just, it's time served, it's it's a lot more difficult. You've got to spend, you've got to go through a lot more repetition. So it would be something like, can you learn calculus online versus in person? Yeah, probably, but it's probably a lot harder. Right? I would say, you got to spend a little more time with it to be able to do that. Right? It's kind of like learning a foreign language versus with what do you call it? like one of those apps? Yeah. Versus, you know, in person training with someone that knows the language, right is probably not quite as effective, but it can be done. [...]”

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something like, can you learn calculus online versus in person? Yeah, probably, but it's probably a lot harder. Right? I would say, you got to spend a little more time with it to be able to do that. Right? It's kind of like learning a foreign language versus with what do you call it? like one of those apps? Yeah. Versus, you know, in person training with someone that knows the language, right is probably not quite as effective, but it can be done. [...]”

7.3.1 Analysis of the codes' presence in interview transcripts

This Section deals with the first analysis of the interview coding data. Table 7.6 tracks codes' presence of themes and sub-themes in each interview transcript. Each line in Table 7.6 represents an interview transcript and each column a sub-theme from the themes presented in Table 7.5. To facilitate the subsequent analysis, KMI are broken down into the individual KMI listed in Table 2.4. A full dot marks the codes, themes or sub-themes' presence in each interview transcript (rows) for each theme (column). For convenience and to facilitate the data analysis, Columns 1 to 4 in Table 7.6 track the seniority level of interview participants.

Table 7.14 is used to track codes' frequency of themes and sub-themes in each interview transcript. Each line in Table 7.14 represents an interview transcript and each column a sub-theme from the themes presented in Table 6.5. To facilitate the subsequent analysis, KMI are broken down into the individual KMI listed in Table 2.3. A first level of the analysis of the interview data was conducted based on the codes and themes' presence data presented in Table 7.6.

The codes' presence data presented in Table 7.6 was grouped in sub-themes and analysed based on the seniority levels of the participants to the case study and is reported in Table 7.7 to Table 7.13. Table 7.7 looks at the themes of geographical dispersion of the NPD projects. The results show that consistently more than 75% of the respondents discuss the difference between global and local projects teams while discussing about project-to-project learning. The coding presence shows that middle managers and subject matter experts are more aware of the impacts of geographical distribution of the project teams on project-to-project learning, with senior leaders and working-level teams discussing less frequently about the geographical nature of project teams while talking about project-to-project learning.

	Seniority				Geo distrib.		Degree of innovation		KMI																		Knowledge type																			
	Working team	SME	Middle management	Senior leadership	Global	Regional / local	Incremental	Radical	Brainstorming	Camps	CoP	Design reuse	Documentation / guidelines	Expert reuse	F2F comms	Feedback loops	Formal comms - core team	Formal comms - other dep	Formal comms - other projects	FRACAS	Informal - core team	Informal - other dept	Informal - other projects	Informal - travelling	Job rotations	Mentoring / training (Informal)	Mentoring / training (formal)	Middle management	Project reviews	Repositories / databases	Storytelling	Knowledge on competitors	Knowledge on customers	Lessons learned	NPD process knowledge	Product/commercial strategy	Product technical knowledge	Supplier knowledge	Tact knowledge	Testing and prototyping						
Interviewee 1	✓											•	•			•			•	•	•	•	•			•	•													•						
Interviewee 3	✓				•								•					•	•			•	•				•	•						•					•							
Interviewee 4	✓				•	•						•	•			•			•	•		•	•			•	•			•										•						
Interviewee 6	✓				•	•						•				•			•	•		•	•																		•					
Interviewee 9	✓				•	•	•					•		•					•	•		•	•				•			•										•						
Interviewee 10	✓				•	•					•	•				•	•	•	•			•	•				•					•								•		•				
Interviewee 11	✓				•	•	•					•					•		•	•			•						•					•						•		•				
Interviewee 13	✓				•	•			•				•	•			•	•	•			•	•				•					•									•		•			
Interviewee 14	✓				•														•	•		•	•																		•					
Interviewee 15	✓				•	•		•	•			•							•	•		•	•		•																	•				
Interviewee 16	✓				•	•		•			•	•		•			•		•	•		•	•							•											•		•			
Interviewee 17	✓				•	•	•	•				•		•				•	•			•	•						•					•							•		•			
Interviewee 18	✓				•		•	•			•			•			•		•	•			•				•			•											•		•			
Interviewee 19	✓				•	•							•				•		•	•		•	•																				•			
Interviewee 20	✓							•				•	•					•	•				•																			•		•		
Interviewee 21	✓				•							•	•	•					•	•		•	•						•														•		•	
Interviewee 27	✓					•						•	•	•						•	•		•	•			•																•		•	
Interviewee 28	✓				•	•							•	•			•				•	•							•														•		•	
Interviewee 34	✓				•	•		•	•			•							•	•		•	•				•																	•		•
Interviewee 35	✓				•	•									•		•		•	•						•	•	•		•												•		•		
Interviewee 2		✓			•	•		•				•	•	•					•	•			•			•	•	•							•							•		•		
Interviewee 22		✓			•	•	•					•	•	•					•	•			•				•	•	•														•		•	
Interviewee 25		✓			•	•	•	•														•										•												•		•
Interviewee 30		✓			•		•	•				•	•	•			•	•		•			•	•			•																•		•	
Interviewee 5			✓		•	•						•	•	•					•	•		•	•			•	•																•		•	
Interviewee 8			✓		•	•			•	•	•	•																				•												•		•
Interviewee 12			✓		•	•	•			•		•		•	•		•		•	•		•	•			•	•	•		•														•		•
Interviewee 24			✓		•	•	•	•					•	•						•	•		•	•			•			•														•		•
Interviewee 26			✓		•	•							•				•				•						•																	•		•
Interviewee 29			✓		•	•										•			•	•			•	•																				•		•
Interviewee 33			✓		•	•							•		•		•				•	•							•														•		•	
Interviewee 7				✓	•			•			•			•				•					•								•												•		•	
Interviewee 23				✓	•	•	•	•					•	•							•																						•		•	
Interviewee 31				✓		•	•	•	•			•		•		•					•		•				•																	•		•
Interviewee 32				✓	•	•	•	•	•		•	•	•	•				•	•		•					•																	•		•	

A thorough review of the transcripts as well as the data analysis presented below shows consistently that middle managers and SME are more aware of the additional challenges posed by the geographical dispersion of project teams.

All interviewees are active in global NPD projects and were directly asked about the differences between global and local NPD projects, so the high presence of the geographical dispersion codes is not surprising.

Four groups of seniority were defined and were employed in the data analysis. The four seniority groups are defined as follows:

- **Working-level teams:** in teams working level employees are defined as those employees' performing daily tasks on projects, and in *VehicleSystemsCo* include project functional leads and project managers. These employees are the ones that need access to knowledge and whose learning KMI initiatives should target.
- **Senior leadership team:** these employees are providing business, strategic, organizational and technical direction to the teams. Senior leaders are director-level employees and above. They decide the long-term strategy and the tools the organization employs.
- **Middle managers:** middle management tier sits in between senior leaders and working-level teams, providing technical leadership and line management to the teams. Middle manager, SME and Chief engineers often operate as knowledge brokers in global NPD.
- **SME and Chief engineers:** subject matter experts and chief engineers work in parallel to middle managers and are the gate keepers of project quality and deep-technical knowledge. Compared to middle managers, SME and Chief engineers are less concerned with project milestones and focus almost exclusively on technical risks.

Table 7.7 – Interviewees’ responses – project geographical distribution

	Global	Local
Working-level team	85%	70%
SME	100%	75%
Middle management	100%	100%
Senior leaders	75%	75%

Table 7.8 focuses on the projects’ degree of innovation and looks how many of the interviewees discuss explicitly about either incremental or radical innovation. As for geographical distribution, responses on degree of innovation are also analysed by seniority level. All interviewees were directly asked about the relative importance of the degree of innovation on project-to-project learning. Surprisingly, the Working-level teams discussed very little about incremental NPD. The degree of innovation is more discussed as the seniority of the interviewees increases, with the exception of middle management. All interviewed senior leaders discuss about radical innovation. The innovation of the projects will be further discussed in this section, after reviewing and commenting the coding frequency.

Table 7.8 – Interviewees’ responses – degree of innovation

	Incremental	Radical
Working-level team	20%	45%
SME	75%	75%
Middle management	29%	14%
Senior leaders	75%	100%

The 2x2 framework for project-to-project learning in global NPD presented in Table 2.11 in Chapter 2 identifies the knowledge source as one of the key factors that influence

project-to-project learning in global NPD. Table 7.9 was developed to investigate primary knowledge sources discussed by the case study participants. Three categories of knowledge source were highlighted by the SLR in Chapter 2:

- **Knowledge internal to the project team:** knowledge sharing within the project team is identified as the second level of sophistication in Richtnér *et. al* (2013) project knowledge creation model reviewed in Chapter 2;
- **Knowledge from other projects of the organization:** project-to-project learning is identified as the third level of sophistication in Richtnér *et. al* (2013) project knowledge creation model reviewed in Chapter 2;
- **3rd party knowledge:** this is knowledge held by suppliers, partners or customers. The SLR clearly showed how 3rd party knowledge is key to radical NPD project success.

In addition to the three knowledge sources identified in literature, a review of the interview transcripts showed that interviewees gave particular attention to knowledge sharing and use with other departments. To clarify the interviews' understanding of *other departments*, the Author asked Interviewee 13 for a follow-up meeting to ask clarifying questions. Interviewee 13 is a product engineer and was selected as one of the two interviewees that commented the most on learning from other projects. Interviewee 13 defined what he intended as *other departments* as follows:

‘working in product engineering, when I talk about learning from other departments, I mean learning from people that are not part of the core project team, the people I talk with every single day, and are not

*part of my department. In my case, my department is the product engineering department [...]. A good example of learning from other departments is when I go to our manufacturing team and ask the details of how an assembly station works, or when I go to our finance team and learn about how weekly time reporting impacts the project's budget.*²⁵

Table 7.9 shows that more than 80% of the working-level teams and the middle management discuss about learning from external companies or 3rd parties; the percentage of interviewees that talk about learning from suppliers, customers or external partners drops to 50% amongst subject matter experts and middle managers. Learning within the project team was discussed more during the interviews, with the exception of SMEs, where only 1 out of 2 interviewees mentioned it as relevant for project learning. The vast majority of the interviewees discussed about project-to-project, with up to 90% of the working-level team talking about it during the interviews. It is interesting to observe how the trend of employees discussing about the importance of project-to-project learning reduces as seniority increases, with only 50% of the senior leaders interviewed discussing about project-to-project learning.

Learning from other departments is the single type of knowledge with the highest variation in the number of participants' references, going from 25% to 80%. Once again, the more employees with higher seniority are reportedly discussing less about learning from

²⁵ Follow-up interviews were scheduled with selected Project 1 and 2 NPD team members. Follow-up interviews were not recorded and full transcripts are not available for those interviews. Extensive note taking was used in alternative to interview recordings. Quotes based on researcher's notes are identified by a single inverted comma ' '.

other departments, while up to 80% of the working-level teams discuss about learning from other departments.

Table 7.9 – Interviewees’ responses – knowledge source

	3 rd party	Project team	Other projects	Other departments
Working-level team	80%	75%	90%	80%
SME	50%	50%	75%	25%
Middle management	86%	86%	71%	43%
Senior leaders	50%	75%	50%	50%

The next step in the analysis of the coding presence data is looking at the breakdown of knowledge type. The eight types of knowledge reported in the final coding Table 7.5 are used in Table 7.10 to capture interviewees responses. The eight types of knowledge, with a brief definition of the knowledge types are listed below. When the definition of type of knowledge was not clear from literature, Interviewee 13’s definition was included and is marked by citation marks “”:

- **Competitor knowledge:** knowledge about market trends and the performance of competing products. *“This can be both publicly available information, or anecdotes of how the competitor is doing better or worse than us”*;
- **Customer knowledge:** knowledge about customer needs, customer processes and contact persons;
- **Lessons learned:** product, process or socio-political knowledge captured by official company lessons learned databases;
- **NPD process knowledge:** knowledge about the company NPD stage-gate process;
- **Product technical knowledge:** knowledge about the technical performance of products, materials and their limits;

- **Product commercial knowledge:** knowledge about product strategy, product roadmap and performance targets;
- **Supplier knowledge:** knowledge about supplier capabilities and performance “[...] *but also historical memory of the organization: is this a good supplier to work with? Do they answer quickly to e-mails? Are they always late with prototypes? Do they always ask for exceptions?*”
- **FRACAS knowledge:** in *VehicleSystemsCo* FRACAS knowledge is a subset of lessons learned knowledge that are not captured in lessons learned databases. FRACAS are always related for a product failure during testing or in service. The learning associated with FRACAS is often not necessarily limited to product technical knowledge, but often includes learning related the engineering NPD process.

Table 7.10 details codes’ presence by interviewees’ seniority, focusing on knowledge type. Product commercial knowledge and supplier knowledge are the two categories of knowledge that show the highest variation in responses between seniority levels, with none of the senior leaders discussing either. The focus on customer and competitor’s knowledge is more balanced across the board and both show to peak with middle management. Product and technical knowledge are the type of knowledge discussed by the majority of interviews, with a consistently higher rate with senior leaders, where three out of four of the interviewed ones discussed about both. FRACAS knowledge also shows to be discussed by approximately one every two interviewees, with the sole exception of senior leaders that barely discuss FRACAS knowledge.

Literature clearly disuse the importance of tacit knowledge for NPD project success (Nonaka & Takeuchi, 1995; Kreiner, 2002). Goffin *et al.* (2010) argue that, while tacit

knowledge is difficult to be captured in written form, it is also difficult to measure and assess the presence of tacit knowledge in NPD teams and organization.

Table 7.10 – Interviewees’ responses – knowledge type

	Competitors knowledge	Customer knowledge	Lessons learned	NPD process knowledge	Product - commercial strategy	Product technical knowledge	Supplier knowledge	FRACAS knowledge
Working-level team	20%	55%	30%	65%	40%	45%	45%	45%
SME	25%	25%	50%	75%	0%	50%	50%	50%
Middle management	71%	71%	43%	71%	43%	57%	43%	43%
Senior leaders	25%	50%	75%	50%	0%	75%	0%	25%

Following the approach proposed by Koners and Goffin (2007), the use of metaphors is associated with the presence of tacit knowledge. The use of metaphors, together with the explicit discussion of tacit knowledge, is used to code mentions of tacit knowledge in interview transcripts.

As interview participants were directly asked to discuss tacit knowledge, the high presence of tacit knowledge in the transcripts is not surprising. While all interview participants discuss about explicit knowledge, approximately one third of the interviewees discuss about tacit knowledge. Subject matter experts are the NPD practitioners that discuss tacit knowledge the most, with three out of four interviewees engaging in discussions about tacit knowledge.

Table 7.11 – Interviewees’ responses – tacit and explicit knowledge

	Explicit	Tacit
Working-level team	95%	35%
SME	100%	75%
Middle management	100%	29%
Senior leaders	100%	25%

Looking at codes’ presence, no significant difference can be appreciated between the use of structured or social KMI. Table 7.12 summarizes the codes’ presence data for social and structured KMI. In the context of the interview coding, the following definition of structured or social KMI was used:

- **Structured KMI** rely extensively on written documents, data and drawings to store knowledge. A good example of structured KMI are lessons learned databases, design re-use, templates, guidelines, etc.
- **Social KMI** rely mostly on interpersonal interactions as a mean to transfer knowledge between individuals or groups of individuals. Examples of social KMI are experts re-use, communities of practice, brainstorming sessions, etc.

Table 7.12 – Interviewees’ responses – KMI type

	Structured KMI	Social KMI
Working-level team	100%	95%
SME	75%	100%
Middle management	100%	100%
Senior leaders	100%	100%

Finally, the last dimension of the 2x2 global project-to-project learning framework presented in Table 2.11 in Chapter 2 refers to the person who leads the KMI – i.e., KMI ownership. KMI ownership is defined as a key parameter in the 2x2 global project-to-project learning framework and is intended to assess if the effective KMI are led and organized by the company (i.e., *company-led*) or spontaneous and led by NPD practitioners, without explicit direction from the organization leadership (i.e., *informal*). Understanding the relative importance of company-led and informal KMI for project-to-project learning in global NPD is a key to providing recommendations to NPD practitioners on whether to directly implement one or more specific KMI or focus on creating an organizational culture that allows for spontaneous KMI to thrive.

The coding presence analysis shows that company-led KMI are discussed by all interviewee participants, while approximately 75% of the interviewees discuss about informal KMI. Interestingly, only half of the senior leaders discuss about informal KMI.

Table 7.13 – Interviewees’ responses – KMI ownership

	Company-led	Informal
Working-level team	100%	75%
SME	100%	75%
Middle management	100%	100%
Senior leaders	100%	50%

While understanding how many of the interviewees in each seniority bracket discuss KMI, knowledge types and knowledge source provides interesting information on the relative use of KMI or on the relative importance of a particular knowledge source, the analysis just reviewed shows that looking only at codes’ presence does not provide the full information about the perceived effectiveness and importance of KMI or knowledge source by different NPD practitioners and does not help to fully answer the RQ in terms of which KMI are considered most effective or most used. In order to further understand the relative

importance that NPD practitioners give to each KMI, the additional layer of code-count is reported in Table 7.14. While codes' presence is a Boolean "yes/no" tracking of whether interviewees have discussed about particular codes in their interviews, codes' frequency measures how many times a single code is repeated in a single interview. Codes' frequency for each interview and each code are reported in Table 7.14. The use of codes' frequency in conjunction with codes' presence helps to reduce the intrinsic bias connected to asking questions directly on each KMI, knowledge source or knowledge type: probing directly about the use of specific KMI might influence the interviewee to discuss about a particular KMI that s/he would have otherwise possibly ignored. Taking knowledge type as an example, tacit knowledge is a good example of intrinsic bias of directly asking about the importance of tacit knowledge. Approximately one third of the interviewees discuss about tacit knowledge but, looking at codes' presence only, it is hard to gauge the relative perceived importance of tacit knowledge compared to explicit knowledge. Looking at codes' frequency (i.e., looking at how many times tacit knowledge is discussed rather than just at *if* tacit knowledge is discussed) will help to better understand the relative importance of KMI, knowledge types and knowledge source.

7.3.2 Analysis of the codes' frequency in interview transcripts

The following data analysis assumes that codes' frequency is associated with the perceived importance and effectiveness of a KMI, a knowledge source or a type of knowledge by the interviewee participants. The coding frequency analysis was conducted in parallel with a qualitative assessment of the interview transcripts to ensure that instances where a high coding frequency is associated with a high degree of dissatisfaction with a KMI or a knowledge source were not included in the data analysis. As an example, Table 7.1 shows that while many interviewees discuss the use of lessons learned databases, several of them argue that lessons learned databases have limited or negative impact on project-to-project learning. Codes associated with negative or low impact of KMI, knowledge source or knowledge types are excluded from Table 7.14. The quote below on component re-use is an

example of a code associated with limited impact of a KMI that is excluded for the analysis:

“Because you know, component re-use, I think it's a requirement in the [REDACTED] matrix and [REDACTED] [VehicleSystemsCo proprietary stage-gate project management system] says you should do it, right? And, and yet, somehow, it's either glossed over or just not done with the same rigor or same consistency, because and I think many people, maybe there's a training gap, you know, I think about our program manager community has the opportunity to help to educate as well as drive expectations [...].”

(SL3)

Due to the significant difference in sample size between working-level teams and other groups (e.g., senior leaders) Table 7.15 to Table 7.21 also report codes' frequency data weighted by sample size, using the following calculation, where x is the seniority level under consideration:

$$\text{weighted code frequency } (x) = \frac{\text{code frequency } (x)}{\text{sample size } (x)}$$

Using line 1 in Table 7.15 as an example and focusing on “working-level team” (samples size 20) and “technical knowledge” (codes' frequency 46), the weighted codes' frequency of technical knowledge in working team is calculated as follows:

	Seniority				Geo distrib.		Degree of innovation		KMI																				Knowledge type														
	Working team	SME	Middle management	Senior leadership	Global	Regional / local	Incremental	Radical	Brainstorming	Camps	CoP	Design reuse	Documentation / guidelines	Expert reuse	F2F comms	Feedback loops	Formal comms - core team	Formal comms - other dep	Formal comms - other projects	FRACAS	Informal - core team	Informal - other dept	Informal - other projects	Informal - travelling	Job rotations	Mentoring / training (informal)	Mentoring / training (formal)	Middle management	Project reviews	Repositories / databases	Storytelling	Knowledge on competitors	Knowledge on customers	Lessons learned	NPD process knowledge	Product/commercial strategy	Product technical knowledge	Supplier knowledge	Tactic knowledge	Testing and prototyping			
Interviewee 1	✓											1	11			3			4	14	3	7	3	2		1									1						10		
Interviewee 3	✓				2			5					1				3	2				2	1		4	2			1			2		4			3			4			
Interviewee 4	✓				6	3		1				3	4			1				1	2	9	3			3										4			2		3		
Interviewee 6	✓				1	1						2				1		1	1			1	1				1	1					2	3			3		1		2		
Interviewee 9	✓				6	3	4					5		5				2	3		1	3	1		1			1						2					4				
Interviewee 10	✓				3	2					1	1				1	1	1			4		4		1						2					3	1	3		1	1		
Interviewee 11	✓				1	5	1					1					1		2			1							1				1		1	5			8	2			
Interviewee 13	✓				5	1			1				2	1			3	1	1	3	2		6		2						1					2			3		2		
Interviewee 14	✓				4													1		1	1						1									1	6	1	1	4			
Interviewee 15	✓				2	4		2	1			1								2	2	2	2	1										1		2		3		2			
Interviewee 16	✓				6	1		2			1	2		2			3		1		3									1					1	4	4	1	1	2		1	
Interviewee 17	✓				2	3	4	4				2						2	4	1	2	5						2		2				1	1		6		2		4	1	
Interviewee 18	✓				4		2	2			1			2			2			1		2	2		2			3		1						4			2				
Interviewee 19	✓				3	1							4		2		3		1	1	2	2	1								4										2		
Interviewee 20	✓							4				3	3		1			2	2				2								5			1		5		4	1		1		
Interviewee 21	✓				2							1	3	2						1		1	4						1		2			1		5					3		
Interviewee 27	✓					3		1				1	1	1								1			1									3		2	2						
Interviewee 28	✓				4	3							2	1			1				1	1	1						1									1	2				
Interviewee 34	✓				2	4		2	1			1								2	2	2			1										3		2	2					
Interviewee 35	✓				4	4									1		1		1						1	1	1		1						1	1	3	5	1	4		4	
Interviewee 2		✓			9	3		3				2	8	4					2	1			1			1	1								1	1				6	3		
Interviewee 22		✓			10	1	3					4	1		1				1		2				3	3	2				1	1		1	3	3	5		1	1	3	2	
Interviewee 25		✓			3	2	1	1																							1						1						
Interviewee 30		✓			3		1	2				2	1	3			4	1		3			1	2		1													2	2	1		
Interviewee 5			✓		16	7						3	1	2					1	3	2	3	6		1	2								2	4		4	1		1		3	
Interviewee 8			✓		5	2			4	1	1	1																		3				1	2	3	6						
Interviewee 12			✓		2	6	3			2		2		3	1		1		2	1		1	1	1	1	1	1	1		1				1	1	1	3	5	1	4		4	
Interviewee 24			✓		1	5	1	2					3	2						2	1		3			1			1							5		1			1	2	
Interviewee 26			✓		3	1							1				2				1					1								2	6	2	3	1					
Interviewee 29			✓		4	4									1		1		1	1			1	1					1						1	3			1	2		1	
Interviewee 33			✓		3	1							4		2		1				1	1	1						1									1	2				
Interviewee 7				✓	1			3	1		1			2				2			1		1	1						1						9	12						
Interviewee 23				✓	3	3	3	1					1	2																					1								
Interviewee 31				✓		4	2	8	3	1		3		1		2					3		2			3							2	1	3	1			3			2	
Interviewee 32				✓	4	3	2	2	1		2	2	5	2				1	1		3				1				1							3		3		2		1	

weighted technical knowledge code frequency (working team)

$$= \frac{\text{technical knowledge code frequency (working team)}}{\text{sample size (working team)}} = \frac{46}{20} = 2.3$$

The use of weighted codes' frequency allows to conduct an analysis of relative importance between groups of different sizes, reducing the impact that sample size has on the codes' frequency. Taking tacit knowledge as an example, and assuming that two groups perceive the same importance of tacit knowledge, when interviewing a group five times larger in size, it is expected to receive a total number of responses on tacit knowledge five times larger. If weighting by samples size was not considered, an observer could be led to believe that the larger group had five times as much interest in tacit knowledge than the smaller group.

Table 7.15 reports codes' frequency data (columns in green) and weighted codes' frequency data (columns in blue) for knowledge type by seniority level. Weighted codes' frequency data shows that technical knowledge is evenly discussed across the board, with all groups from working-level teams to senior leaders discussing approximately twice about technical knowledge in each interview. Process knowledge is the most widely discussed type of knowledge in interviews, with both the highest number of total occurrences (process knowledge was discussed a total of 98 times across all interviews) and with the highest codes' frequency per interview amongst all other types of knowledge, at 3.8 codes/interview.

It is interesting to observe how the process knowledge codes' frequency increases with the seniority levels, with the sole exception of SME that discuss process knowledge only 1.8 times per interview on average. Data on knowledge of suppliers also shows very interesting findings, with codes' frequency numbers steadily decreasing from just above one for working-level teams to zero in the case of senior leaders. Middle managers are they only seniority group that consistently discuss knowledge on competitors (on average once

per interview) while the other groups show very low codes' frequency levels for competitor knowledge. Interestingly, product commercial knowledge and product strategy knowledge are only discussed briefly by middle managers and working-level teams. Knowledge on customers is discussed more frequently by senior leaders and middle managers, with working-level teams and SME discussing knowledge on customers only one time per interview on average.

		Knowledge type							Knowledge type - weighted					
Working-level teams	20	46	53	26	5	14	21		2.3	2.7	1.3	0.3	0.7	1.1
SME	4	8	7	3	1	0	3		2.0	1.8	0.8	0.3	0.0	0.8
Middle Management	7	13	23	5	7	3	16		1.9	3.3	0.7	1.0	0.4	2.3
Senior Leadership	4	8	15	0	1	0	6		2.0	3.8	0.0	0.3	0.0	1.5
Total		75	98	34	14	17	46		-	-	-	-	-	-
		Technical knowledge	Process knowledge	Knowledge on suppliers	Competitors knowledge	Product / strategy knowledge	Customers knowledge		Technical knowledge	Process knowledge	Knowledge on suppliers	Competitors knowledge	Product / strategy knowledge	Customers knowledge

Table 7.15 – Codes' frequency in interviewees' responses – knowledge type

Two interesting trends can be highlighted looking at the knowledge type frequency codes: working-level team, middle managers and senior leaders show high interest in discussing process knowledge more than any other kind of knowledge; SME are the only seniority group where this trend is not observed, with SME not surprisingly focusing mostly on technical knowledge.

Table 7.16 reports the codes' frequency and weighted codes' frequency for global and local learning. Global learning, learning across regions and locations, is consistently more discussed in the interviews compared to local learning. However, this is not surprising as the project teams selected were NPD working in global NPD. While the interviews were conducted on global NPD teams, the interviews consistently also discussed local learning (with an average across all seniority groups of 2.4 times per interview). This shows that the interviews have a good understanding of learning happening both at local and global levels. Interestingly, the delta between local and global learning is more prominent in the case of SME.

Table 7.16 – Codes' frequency in interviewees' responses – project geographical distribution

		Local vs global			local vs global - weighted	
Working-level team	20	38	57		1.9	2.9
SME	4	6	25		1.5	6.3
Middle Management	7	26	34		3.7	4.9
Senior Leadership	4	10	8		2.5	2.0
Total		80	124		-	-
		Local	Global		Local	Global

Table 7.17 includes details of codes' frequency data for radical and incremental NPD. Working-level teams and senior leaders discuss almost double radical NPD than incremental NPD. SMEs and middle management show very similar interests in discussing both radical and incremental NPD; interestingly, middle managers overall engage very little in discussing the degree of innovation of NPD projects.

Table 7.17 – Codes' frequency in interviewees' responses – project geographical distribution

		Radical vs incremental			Radical vs incremental - weighted	
Working-level team	20	11	23		0.6	1.2
SME	4	5	6		1.3	1.5
Middle Management	7	4	2		0.6	0.3
Senior Leadership	4	7	14		1.8	3.5
Total		27	45		-	-
		Incremental	Radical		Incremental	Radical

Codes' frequency for tacit and explicit knowledge is reported in Table 7.18. Unsurprisingly, explicit knowledge is discussed ten times more often than tacit knowledge.

Table 7.18 – Codes' frequency in interviewees' responses – knowledge type

		tacit vs explicit			tacit vs explicit - weighted	
Working-level team	20	177	19		8.9	1.0
SME	4	26	10		6.5	2.5
Middle Management	7	75	5		10.7	0.7
Senior Leadership	4	41	1		10.3	0.3
Total		319	35		-	-
		Explicit knowledge	Tacit knowledge		Explicit knowledge	Tacit knowledge

A higher codes' frequency of explicit knowledge in the transcripts compared to explicit knowledge is expected, as not all interviewees were aware of the concept of tacit

knowledge before the interviews. Interestingly, working-level teams / SME show an opposite trend compared to middle management / senior leadership when looking at codes' frequency prevalence of one type of knowledge over the other:

- Explicit knowledge codes' frequency is higher in senior leaders and middle managers (more than 10 codes per interview) compared to SME and working-level team (approximately 7.5 code per interview found);
- In contrast, tacit knowledge codes' frequency is higher for SME and working-level teams (approximately 1.8 codes per interview) compared to senior leaders and middle managers (less than 0.5 code per interview found).

Table 7.19 looks at codes' frequency and weighted codes' frequency for type of KMI, comparing structured and social KMI (as defined in Section 7.3.1).

Table 7.19 – Codes' frequency in interviewees' responses – KMI type

		Structured vs social KMI			Structured vs social KMI	
Working-level team	20	220	93		11.0	4.7
SME	4	34	25		8.5	6.3
Middle Management	7	45	45		6.4	6.4
Senior Leadership	4	27	26		6.8	6.5
Total		326	189		-	-
		Structured	Social KMI		Structured	Social KMI

Weighted codes' frequency of structured and social KMI is evenly distributed in the interviews, showing an average codes' frequency higher than 6.5 for either structured or social KMI across SME, middle managers and senior leaders' interviews, with the important exception of working-level teams. While all other seniority groups do not show a distinct preference between structured and social KMI, working-level teams shows an almost double codes' frequency of structured KMI (11 code counted per interview average) compared to the codes' frequency of social KMI (4.7 code counted per interview on average).

KMI ownership is analysed in Table 7.20, comparing the codes' frequency of company-led versus informal KMI. Company-led KMI are consistently more discussed across the board compared to informal KMI.

Table 7.20 – Codes' frequency in interviewees' responses – KMI ownership

		Company-led vs informal			Company-led vs informal	
Working-level team	20	261	53		13.1	2.7
SME	4	47	12		11.8	3.0
Middle Management	7	63	27		9.0	3.9
Senior Leadership	4	44	9		11.0	2.3
Total		415	101		-	-
		Company-led	Informal		Company-led	Informal

Company-led KMI are discussed more than 11 times per interview, with working-level team and SME showing a slightly higher codes' frequency (up to 13 codes per interview in working-level teams) compared to middle managers and senior leaders (9 and 11 code per interview respectively). Informal KMI show significantly lower codes'

frequency across the board (approximately 3 codes per interview) with senior leaders discussing informal KMI only 2.3 times per interview.

Finally, Table 7.21 looks at weighted and unweighted codes' frequency of the different knowledge sources. Knowledge source is the category where the most significant differences are observed between seniority groups. Core project team learning is the knowledge source category that show the lowest spread of codes' frequency between seniority groups, with an average across the interviews of 1.5 codes found per interview; the working-level team is the seniority group with the highest codes' frequency for core team project learning at 2 codes found per interview.

Table 7.21 – Codes' frequency in interviewees' responses – knowledge source

		intra vs inter KSU					intra vs inter KSU			
Working-level team	20	52	40	54	49		2.6	2.0	2.7	2.5
SME	4	7	6	5	1		1.8	1.5	1.3	0.3
Middle Management	7	28	10	16	5		4.0	1.4	2.3	0.7
Senior Leadership	4	7	7	4	3		1.8	1.8	1.0	0.8
Total		94	63	79	58		-	-	-	-
		External	Core project team	Other projects	Other departments		External	Core project team	Other projects	Other departments

A similar trend to core project team learning can be observed in the case of learning from other projects with an average of almost 2 codes found per interview and the working-level teams discussing learning from other projects 2.7 times per interview, almost three times more than senior leaders. Learning from other departments is the single knowledge source category where significant difference can be observed between seniority groups with SME, middle managers and senior leaders discussing about learning from other

departments less than once per interview, while working-level teams discuss about it about three times as much.

Finally, learning from external companies and third parties (i.e., customer, suppliers and competitors) also shows a significant spread, with middle managers discussing third party knowledge up to four times per interview, working-level teams 2.6 and SME and senior leaders less than 2 times per interview.

Reviewing weighted codes' frequency by seniority group allows to identify important trends and findings. Good examples are the following:

- Process knowledge and technical knowledge are extensively discussed across all seniority groups; SME focus extensively on technical knowledge. Process knowledge codes' frequency increases as the seniority of the interviewees increases. Senior leaders do not discuss suppliers' knowledge in their interviews, while suppliers' knowledge is discussed by the lower seniority groups.
- Both local learning and global learning are discussed in the interviews, with global learning being more discussed compared to local learning.
- Explicit knowledge is discussed more than tacit knowledge across all groups, but the working-level teams and SME discuss more tacit knowledge than middle managers and senior leaders, while middle manager and senior leaders discuss more explicit knowledge than working-level teams and SME.
- Structured and social KMI are both extensively and equally discussed among the seniority levels, while the working-level teams discuss significantly more than the average about structured KMI and significantly less about social KMI.

- Company-led KMI are significantly more discussed than informal KMI.
- Core project team learning is discussed equally amongst the different seniority groups, while learning from other departments is mostly discussed by working-level teams. Project to project learning is more discussed by working-level teams and middle managers. Learning from third parties is extensively discussed by all groups, with particularly high codes' frequency found in middle managers interviews.

The analysis of the codes' frequency and the relevance of the findings to the research questions and global NPD project-to-project learning framework propositions are discussed in Chapter 7. However, a first review of the findings summarized above shows how the codes' frequency review can help answering the main research question (what KMI are most used and considered most effective for project-to-project learning in global NPD) but not sub-research questions 1 and 2, which refer to KMI use and effectiveness in relation to the type of knowledge (tacit or explicit) and the degree of innovation of the project (radical or incremental NPD). Further data refinement is needed to help to answer SRQ1 and SRQ2.

7.3.3 Coding analysis on knowledge type, degree of innovation and geographical dispersion data subsets

To answer SRQ1 and SRQ and focusing on the KMI best suited for tacit knowledge and radical NPD, the following section looks at subsets of the interview coding data. In particular, the first two data subset were created by isolating the data produced by the interviews that only discuss incremental NPD from the one produced by the interviews that only discuss radical NPD. The following data subset was obtained by isolating the interviews that only discuss explicit knowledge from the interviews that discuss both

explicit and tacit knowledge. Finally, two data sets were obtained by isolating interview data from interviews that only discussed local or global NPD.

Section 7.3.2 showed that both the degree of innovation and the knowledge type codes were frequently found in the interview transcripts. While a high presence of the degree of innovation and knowledge type codes is positive for research and shows that the case study and interview questions were appropriately matched, it also implies that isolating interviews that only talk about either global / radical NPD and only tacit / explicit knowledge will inevitably lead to a small sample size. The sample size obtained after the dataset refinement for degree of innovation and knowledge type is reported in Table 7.22.

Table 7.22 – Sample size for interview data refinement

Degree on innovation	Radical NPD only	Incremental NPD only
	9	4
Knowledge type	Explicit knowledge only	Tacit knowledge only
	22	0
Geographical distribution	Local NPD only	Global NPD only
	6	2

Unsurprisingly, the sample sized for “incremental NPD only” and “tacit knowledge only” are lower than those of “radical NPD only” and “explicit knowledge only”. A smaller sample size for “tacit knowledge only” interviews is expected, due to the limited awareness of the interviewees prior to the interviews of the concept of tacit knowledge. A smaller sample size for “radical NPD only” is expected, as two out of three case studies selected for the research are radical NPD projects, as reported in Chapter 4. The limited samples size is expected to reduce the representativeness of the findings, as the limited sample size do not allow to analyse important factors individually (e.g., seniority levels of the interview participants), that Section 7.3.2 shows are impacting codes’ frequency data. However, the

refined data, combined with the qualitative analysis of the full text of the interview transcripts, will help to answer SRQ1 and SRQ2.

The following paragraphs review the four data subsets. Six factors are considered in the analysis:

- NPD team dispersion (global vs local);
- KMI type (structured vs social);
- Knowledge source (internal vs external);
- KMI ownership (company-led vs informal);
- Knowledge type (tacit vs explicit) – this factor is not included in the analysis of the “knowledge types” subset;
- NPD type (radical vs incremental) – this factor is not included in the analysis of the “degree of innovation” subset.

Codes’ frequency is used as a measure for the KMI type, KMI ownership and knowledge source codes. In the case of codes’ frequency data, the total frequency number calculated on the total data set is reported. Codes’ presence is used as a measure for the NPD dispersion, knowledge type and NPD type codes. Codes’ presence is reported as percentage of how many data subsets show the presence of the code. Codes’ presence was preferred to codes’ frequency in the case of NPD dispersion, knowledge type and degree of innovation as the primary information needed was whether the interviews were discussing or not discussing those topics.

The first two dataset presented in Table 7.23 and Table 7.24 look at the interviews discussing only incremental NPD and interviews discussing only radical NPD, respectively. Table 7.23 shows that the interviews that focus only on incremental NPD discuss learning in both local and global NPD teams.

Table 7.23 – Interviewees’ responses - incremental NPD only

Interviewees discussing incremental NPD only – sample size 4		
Regional or global NPD	Global	Local
	100%	100%
KMI type	Structured	Social
	30	36
Knowledge source	Internal	External
	39	22
KMI ownership	Company-led	Informal
	45	21
Knowledge type (%)	Tacit	Explicit
	75%	100%

No significant difference was observed as far as the type of KMI most discussed in the case of incremental NPD only: structured and social KMI both show similar codes’ frequency levels. Knowledge internal to the organization is discussed almost twice as much as knowledge external to the organization. Company-led KMI were also discussed twice as much as informal KMI. Both tacit and explicit knowledge were extensively discussed.

Table 7.24 – Interviewees’ responses - radical NPD only

Interviewees discussing radical NPD only – sample size 9		
NPD team dispersion (%)	Global	Local
	78%	67%
KMI type	Structured	Social
	62	69
Knowledge source	Internal	External
	82	18
KMI type	Company-led	Informal
	82	49
Knowledge type (%)	Tacit	Explicit
	33%	100%

Table 7.24 shows that two major differences can be observed when looking at the interviews that only discuss radical NPD, compared to interviews that only discuss incremental NPD.

Knowledge internal to the organization is discussed four times more than knowledge external to the organization, a 4:1 ratio in favour of internal knowledge for radical NPD against a 2:1 ratio in the case of incremental NPD. Tacit knowledge is discussed by only one third of the interviewees that only discuss radical NPD, while three out of four interviewees discuss tacit knowledge in the case of incremental NPD. Social KMI and informal KMI are both discussed more often in the case of radical NPD compared to incremental NPD.

Table 7.25 – Interviewees’ responses – explicit knowledge only

Interviewees discussing explicit knowledge only – sample size 22		
Degree of innovation (%)	Radical	Incremental
	45%	23%
KMI type	Structured	Social
	153	79
Knowledge source	Internal led	External
	46	64
KMI type	Company	Informal
	96	54
NPD team dispersion (%)	Global	Local
	82%	73%

Table 7.25 reviews coded frequency and codes’ presences data in the case interviews only discussing explicit knowledge. As Table 7.22 showed, the interview data available do not allow for the creation of a dataset looking only at tacit knowledge. Two interesting observations can be noticed from Table 7.25. In contrast with the codes’ frequency data presented in Section 7.3.2 where internal knowledge was more discussed compared to external knowledge, when looking at interviews only discussing explicit knowledge, knowledge external to the organization is more discussed than knowledge internal to the organization. As expected, structured and company-led KMI are more discussed than informal and social KMI.

After the analysis of degree of innovation and knowledge type were completed, one additional data subset was created, focusing on NPD team dispersion and differentiating

between interviews that only discuss local NPD and interviews that only discuss global NPD. Table 7.26 includes details of the sample size for NPD team dispersion; unsurprisingly, the sample size for “local NPD only” is lower than the global NPD only sample size, as the projects selected as case study are global NPD projects. The two data sets created for NPD project dispersion and are intended to validation of the findings of the data analysis presented in Section 7.3.1 and 6.3.2.

Table 7.26 – Sample size for interview data refinement on NPD team dispersion

NPD team dispersion	Local NPD only	Global NPD only
	2	6

Table 7.27 reports the codes’ presence and codes’ frequency data for the interviews that only discuss local NPD. Not surprisingly, only one in two interviews discuss radical NPD: in *VehicleSystemsCo*, radical innovation projects are typically run by global NPD teams.

Table 7.27 – Interviewees’ responses – local NPD only

Interviewees discussing local NPD only – sample size 2		
Degree of innovation (%)	Radical	Incremental
	50%	100%
KMI type	Structured	Social
	7	18
Knowledge source	Internal	External
	10	7
KMI type	Company	Informal
	14	11
Knowledge type (%)	Tacit	Explicit
	0%	100%

Interestingly, interviews with a focus on local NPD only discuss significantly more social KMI compared to structured KMI. None of the interviews that discuss only local NPD discuss tacit knowledge.

Table 7.28 summarised codes' presence and codes' frequency data for the interviews that discuss global NPD only. In line with what was observed in the case of Table 7.27, the majority of the interviews only discussing global NPD focus on radical NPD. Knowledge internal to the organization is significantly more discussed than knowledge external to the organization; company-led KMI are significantly more discussed than informal KMI. An interesting finding is that, in the case of interviewees discussing only global NPD, social KMI are more discussed than structured KMI.

Table 7.28 – Interviewees' responses – global NPD only

Interviewees discussing global NPD only – sample size 6		
Degree of innovation (%)	Radical	Incremental
	67%	33%
KMI type	Structured	Social
	35	44
Knowledge source	Internal	External
	52	13
KMI type	Company	Informal
	53	16
Knowledge type (%)	Tacit	Explicit
	33%	100%

In addition to those provided by the codes' presence and codes' frequency findings summarized in Section 7.3.2, the data from the subsets discussed in Section 7.3.3 provide interesting insights. So:

- Interviewees focusing on radical NPD discuss internal knowledge four times more than external knowledge, significantly more than in the case of incremental NPD.
- Company-led KMI are discussed twice as much as informal KMI in both radical and incremental NPD; structured and social

KMI are both equally discussed in the case of both radical and incremental NPD.

- Tacit knowledge is discussed significantly more in the case of incremental NPD than in the case of radical NPD.
- Interviewees discussing explicit knowledge only discuss more knowledge external to the organization than knowledge internal to the organization. Structured and company-led KMI are more discussed than informal and social KMI by interviewees discussing explicit knowledge only.
- Interviewees focusing on local NPD discuss significantly more social KMI compared to structured KMI and do not discuss tacit knowledge.
- Interviewees only focusing on global NPD discuss significantly more knowledge internal to the organization than external knowledge. Company-led KMI are more discussed than informal KMI; Social KMI are more discussed than structured KMI in the case of interviewees discussing global NPD only.
- Company-led KMI are more discussed than informal KMI in both global and local NPD.

7.4 Findings from the company-level analysis

Chapter 7 introduced the three steps of the data analysis: (1) knowledge flow mapping, (2) KMI survey and (3) interview thematic coding. The knowledge flow mapping presented in Section 7.1 showed how extensive knowledge sharing exists between global NPD projects. The knowledge flow observed is higher than what could have been predicted looking only at key structured KMI deployed by *VehicleSystemsCo* on those projects (e.g., experts and design re-use) and suggest that informal, employee-led KMI play an important role in

project-to-project learning in NPD. Section 7.1 highlighted how the knowledge need experienced by the global NPD team members that develop a product to solve a customer need overcomes the additional boundaries create by the lack of propinquity and limited face-to-face interpersonal relationship available to global NPD team. Section 7.1 defined the phenomena of global NPD team managing to find access to many other global projects as *knowledge finds its way to the teams*.

While Section 7.1 showed that teams managed to access knowledge and secure key information from other projects globally, it provides no information on how global NPD team manage to access the knowledge they need. A survey on the use of KMI was presented in Section 7.2 to understand how global NPD teams access knowledge. The KMI survey showed that no single KMI is universally recognized as a key for project-to-project learning in global NPD. Interestingly, KMI survey data showed that informal communication is an effective way to access knowledge also in the case of global NPD. The KMI show that experts re-use, brainstorming sessions, feedback loops, design re-use and project reviews are effective tools for knowledge sharing and use in global NPD. The KMI survey also highlighted that no KMI is considered detrimental for KMI in global NPD, with the sole exception of lessons learned databases that are poorly ranked and that are described by many interviewees as a KMI providing very limited use for global NPD teams.

While the KMI survey helped to understand which KMI are used by global NPD team and to understand which KMI are considered most effective by NPD team, KMI survey provided limited information on the mechanisms behind the effectiveness – or lack of effectiveness – of KMI for global NPD projects. The KMI survey also showed that the

seniority of the interviewees impacted on the results of the KMI and that three levels of seniority exist in *VehicleSystemsCo*, with significantly different ideas on KM and KMI.²⁶

Section 7.3 introduced the thematic coding and the iterative process that leads to the definition of the final interview codes. Sections 7.3.1 to Section 7.3.3 analysed the coding data and identified key trends from the case study interviews. Section 7.3.1 defined *codes' presences* measured and provided initial insights from the interview data based on whether key topics and KMI were discussed or not in the interview transcripts. Section 7.3.1 showed that employees of different seniority levels show different sensitivity and that the geographical distribution and the degree of innovation matter. It also showed that middle managers and subject matter experts are more aware of the challenges of geographical dispersion and that senior employees are more aware of the challenges posed by radical innovation than less senior employees. Differences between the working-level teams and leadership persist when looking at knowledge source (i.e., knowledge internal to the team and to the organization or external to the organization). Finally, it showed that a vast majority of working-level teams and middle managers highlighted the importance of third parties and other departments knowledge, while the percentage decreases significantly looking at senior leaders and SME. Codes' presence data measures have not been able to highlight any measurable difference between structured or social KMI and informal or company-led KMI.

Codes' frequency measures were introduced in Section 7.3.2 to allow for a more granular review of the interview data, looking at "how much" interviewees discuss the selected themes, instead of looking at "if" the topics are discussed. Section 7.3.2 introduced

²⁶ The seniority categories and the impact of the categorization of the KMI survey data is further discussed in Chapter 8.

the definition of codes' frequency and the weighting of the sample data to account for different sample sizes. Interesting findings emerge from the codes' frequency data. Explicit knowledge is significantly more discussed than tacit knowledge in the interviews, up to ten times as much, but while senior leaders and middle managers discuss more explicit knowledge than working-level teams, working-level teams and SME discuss more tacit knowledge than senior leaders do. Focusing on the types of knowledge discussed, process and technical knowledge are the most discussed types of knowledge in the interviews; process knowledge codes' frequency increases with the seniority of the interviewees and, interestingly, suppliers' knowledge is barely discussed by senior leaders. When looking at the social or structured nature of KMI, the biggest finding from codes' frequency data is that working-level teams discuss much more frequently structured KMI compared to social KMI; structured and social KMI are both equally discussed by the other seniority groups. Company-led KMI are also significantly more discussed than informal KMI, across all seniority groups. As far as knowledge source is concerned, learning in the core team is extensively discussed by all the seniority groups, while learning from other departments is mostly discussed by the working-level teams; middle managers are the seniority group that mostly discussed learning from third parties.

In order to help answering SRQ1 and SRQ2 on KMI best suited for radical NPD and tacit knowledge, Section 7.3.3 looked at subsets of the interview coding data. Five data subsets were created focusing on clusters of interviewees discussing respectively (1) only incremental NPD, (2) only radical NPD, (3) only explicit knowledge, (4) only global NPD and (5) only local NPD. While the sample size of the subset was low, due to the high number of interviewees discussing most of the themes, some interesting findings emerge from the analysis. The internal knowledge to external knowledge ratio in radical NPD only subset is twice as high than that of incremental NPD only, showing that radical NPD teams discuss more internal knowledge compared to incremental NPD teams. Company-led KMI are discussed twice as much as informal KMI in both radical and incremental NPD. Tacit knowledge is discussed significantly more in the case of incremental NPD than it is in the case of radical NPD. Looking at KMI focus by type of knowledge, interviewees discussing

explicit knowledge only discuss more knowledge external to the organization than knowledge internal to the organization. Structured and company-led KMI are more discussed than informal and social KMI by interviewees discussing explicit knowledge only. Finally, interviewees only focusing on local NPD discuss significantly more social KMI compared to structured KMI. The findings of the data subset are interesting and the findings from the subsets are be compared to the findings on the full dataset and further discussed in Chapter 8. Table 7.29 summarizes the findings of the different phases of data analysis and empirical research. The table includes one line for each of the phases of data analysis; the thematic coding line is split into different lines, one for each of the sub-analysis (e.g., codes' presence, codes' frequency, data sub-sets).

Findings of each phase of the data analysis are broken down into (1) findings related the impact of the degree of innovation; (2) impact of geographical distribution of the NPD teams; (3-4) knowledge needs (focus and source of knowledge); (5-6) knowledge management initiatives, looking at both KMI leadership and KMI type.

7.5 Summary

Chapter 7 reviewed the company-level data analysis from the knowledge survey and coding of the interviews. It reviewed the three steps of data analysis, starting from knowledge flow maps. The findings were summarized and categorized as a function of the degree of innovation, geographical dispersion, knowledge source, knowledge focus and KMI type / ownership.

Chapter 8 will discuss the findings of the data analysis presented in Chapter 7, looking at the implications they have on the answer to the project-to-project learning framework propositions presented in Chapter 4 and, finally, to the research questions. Using the degree of innovation lens, Chapter 8 will look at the conflict between existing organizational knowledge and the new knowledge needed to solve NUDDs and will introduce the concept of the *radical innovation trap*.

Table 7.29 – Summary of findings from the company-level analysis

	Degree of innovation	Geographical dispersion	Knowledge focus	Knowledge source	KMI ownership	KMI type
Known ge flow maps	Strong knowledge links exist between global radical and incremental NPD projects, beyond formal and company-led KMI – <i>knowledge finds its way!</i>		Knowledge flow maps focused on explicit, technical knowledge flow between project-to-project		-	-
KMI survey	-	-	-	-	No strong preference for a single KMI type registered. Informal communication is effective for global NPD. Limited effectiveness of lessons learned databases is highlighted	
Codes’ presence analysis	Awareness of the challenges of radical innovation increases with employees’ seniority	Higher awareness found in SMEs and middle managers	Strong focus on technical and process knowledge. Suppliers’ knowledge and commercial knowledge show high variation across groups	Middle managers and working-level teams highlighted the importance of 3 rd party knowledge and other departments	Slightly lower preference for informal KMI observed	No appreciable difference was noticed between structured and social KMI
Codes’ frequency data	Radical NPD challenges are more frequency discussed by working-level teams and senior leaders	Global and local learning are discussed across all seniority levels	Strong focus on process and technical knowledge confirmed. Process knowledge importance grows together with seniority	Working-level teams focus more on project-to-project learning and other departments. Middle managers focus more on 3 rd party knowledge	Company-led KMI are significantly more discussed than informal KMI	Structured and social KMI are extensively discussed. Working-level teams discussed more about structured KMI
Radical NPD subset	-	Both global and local learning are discussed	Strong focus on explicit, technical and process knowledge	Internal knowledge is discussed four times more than external knowledge is	Company-led KMI are discussed twice as much than informal KMI	Structured and social KMI are both extensively discussed
Incremen tal NPD subset	-	Both global and local learning are discussed	Focus on both tacit and explicit knowledge	Internal knowledge is discussed twice as much than external knowledge is	Company-led KMI are discussed twice as much than informal KMI	Structured and social KMI are both extensively discussed

Explicit knowledge subset	Radical NPD is discussed twice as much incremental NPD	Global and local learning are both extensively discussed	-	External knowledge is more discussed than internal knowledge	Company-led KMI are more discussed than informal KMI	Structured KMI are more discussed than social KMI
Global NPD subset	Radical NPD is discussed twice as much incremental NPD	-	Explicit knowledge is discussed three times more than tacit knowledge	Internal knowledge is more discussed than external knowledge	Company-led KMI are significantly more discussed than informal KMI	Social KMI are more discussed than structured KMI
Local NPD subset	Incremental NPD is more discussed than radical NPD	-	Only explicit knowledge is discussed	Internal knowledge is more discussed than external knowledge	Company-led KMI are more discussed than informal KMI	Social KMI are more discussed than structured KMI

CHAPTER 8 – DISCUSSION

8.0 Introduction

This Chapter discusses how the findings of the case study research help to answer the research questions and the general understanding of project-to-project learning in global NPD. Section 8.1 summarizes the research propositions and the theoretical framework developed to guide the empirical research, while Section 8.2 discusses the project-level findings and Section 8.3 discusses the company-level findings. The combination of the findings of project-level and company-level findings, Section 8.4 discusses how the findings help to answer the research questions and Section 8.5 reviews the initial research propositions based on the findings of the research. The validation of the research proposition is used in Section 8.6 to revise the initial project-to-project learning in global NPD framework and Section 8.7 concludes the chapter with a summary of the discussion.

8.1 Background

The case study research that took place in *VehicleSystemsCo* was developed to help answer the research question and sub-research question presented in Chapter 2. The SLR Chapter 2 showed that major gaps exist in information and analysis on global NPD knowledge management and specifically on which KMI are most effective for global NPD and which KMI are used by global NPD practitioners. With the support of the SLR, a research question and two sub-research questions were developed to help to guide theoretical and empirical research to close these gaps:

RQ: In the context of global NPD, which knowledge management initiatives are most often utilised / considered by practitioners to be the most effective and why?

SRQ1: Which knowledge management initiatives are most used, and considered most effective, for **tacit knowledge** sharing and which for **explicit knowledge** sharing?

SRQ2: Which knowledge management initiatives are most used and considered most effective for **incremental NPD** and which for **radical NPD** project-to-project learning?

A simplified 2x2 framework of project-to-project learning in NPD was created that was detailed in two variations: the first one for local NPD and the second one for global NPD (see Figure 8.1).

Local NPD projects			Global NPD projects		
	Incremental NPD	Radical NPD		Incremental NPD	Radical NPD
	Key K. source Internal	Key K. source External		Key K. source Internal	Key K. source ?
Explicit knowledge	KMI focus Structured; company-led (discussed and in use)	KMI focus Structured/social; company-led (discussed and in use)	Explicit knowledge	KMI focus Formal; company-led. (briefly discussed)	KMI focus ?
	Key K. source Internal	Key K. source Internal		Key K. source ?	Key K. source ?
Tacit knowledge	KMI focus Social; company-led (discussed and in use)	KMI focus Social; company-led/informal (discussed and in use)	Tacit knowledge	KMI focus ?	KMI focus ?

Figure 8.1 – Project-to-project learning framework in local and global NPD

Based on the literature, a local NPD 2x2 project-to-project learning framework was fully defined. However, it clearly emerged that significant gaps exist in the project-to-project learning framework for global NPD which are highlighted by questions marks in

Figure 8.1. Based on the SLR, five propositions were created to fill the gaps and to guide the empirical research:

- P1:** In **radical** global NPD, the key **explicit** knowledge sources are external to the organization running the project;
- P2:** In **radical** global NPD, formal and company-led KMI are expected to be most used and effective for knowledge sharing;
- P3:** In **radical** global NPD, social KMI are expected to show limited effectiveness due to the geographical dispersion of the teams;
- P4:** In both **incremental** and **radical** global NPD, the key source for **tacit** knowledge is internal the organization running the project;
- P5:** However, social and employee-led KMI are expected to be less used and effective in the case of global NPD, compared to local NPD.

Chapter 4 described the research methodology and *VehicleSystemsCo*, introducing the three cases and the four data sources used: documentation, survey, interviews and project observations. Chapter 4 and Chapter 5 showed that *VehicleSystemsCo* is an innovative company with up-to-date knowledge management procedures, aligned with the best practices presented in literature. Chapter 6 detailed the narrative of main project events during the 12 months observation of the three case study projects. Interviews to the NPD project teams run alongside the project observations. Full interview transcripts are available and were the basis for the company-level data analysis presented in Chapter 7. Due to confidentiality reasons, neither recording of project meetings nor the use of *VehicleSystemsCo* procedures for coding analysis was allowed in the context of the research.

This Chapter uses the findings of the project-level and company-level analysis presented in Chapters 6 and 7 to compare them with the project-to-project learning in global NPD propositions presented in Chapter 2 and with the literature employed to

generate the propositions. While the qualitative data analysis presented in Chapter 7 provided interesting information on the relative interests that groups of employees show towards specific knowledge sources or KMI, direct quotes from the interviews are used in Chapter 8 to help to better understand the mechanisms behind the trends or, at times, refute the findings of Chapters 6 and 7.

8.2 Findings from the project-level analysis

The project-level analysis showed that, in responding to project events, the three project teams reacted in similar ways, relying extensively on hard documentation, procedures and guidelines to manage the unexpected events. Personal contacts between employees and informal communications were also used to overcome the shortcomings of formal documents and procedures. In particular, five types of events which necessitated or impacted on knowledge flows were observed on the three projects:

- Personnel changes;
- Technical failures;
- Supplier issues;
- Commercial issues;
- Events outside of the control of the team.

The project-level analysis showed that personnel changes were used as a KMI on the project (e.g., experts re-use) and also represented a knowledge event for the project team to manage (e.g., the resignations of the lead engineer in Project 1, the promotion of the sales manager and resignation of the project manager in Project 3). Storytelling was also observed within and across the three projects. Storytelling was used as a way to build the team (sharing stories of key project events within the team) and as a way to share knowledge outside of the project team. Mentoring and training were also used by the

project teams, which were mostly observed in reaction to personnel changes and not as an on-going process to develop the skills and competencies of the teams. The use of KMI to anticipate issues – rather than react to them – is generally considered one of the main goals of sharing knowledge and lessons learned. As far as the effectiveness of KMI is concerned, the observations that KMI are mostly used in the aftermath of an issue is very interesting.

During the observations of the three projects, the teams resorted multiple times to brainstorming sessions and consultation of experts (i.e., experts re-use) to respond to technical and unexpected project events (e.g., customer change requests). Interestingly, design re-use was observed as being both the solution and the root cause of technical issues. *VehicleSystemsCo*'s push to systematically re-use designs and components from previous projects showed that transferring an existing design to a new project, without ensuring that all underlying knowledge (explicit and tacit) were well understood by the new project team, could potentially lead to major project issues.

Finally, a limited and irregular use of lessons learned databases was observed: technical lessons learned databases (i.e., FRACAS logs) were systematically reviewed at the start of each new project, however, non-technical lessons learned databases were only consulted once a project event was encountered to understand what previous project teams did to solve the issue. While a reactive use of lessons learned databases was observed to still provide valuable information to the project teams, the objective of preventing project issues by consulting lessons learned databases at the start of the project was missed with the lessons learned approach observed in *VehicleSystemsCo*.

8.3 Findings from the company-level analysis

The first step in the company-level data analysis presented in Chapter 7 was the knowledge flow mapping. The knowledge flow mapping showed that knowledge extensively flowed between global NPD projects and that project team members managed to access knowledge created by the project in different areas of the business unit that were not directly linked to either by design re-use or expert re-use. This was particularly interesting as the limited

informal and face-to-face time was expected to reduce the ability of global NPD project teams to share knowledge amongst each other (Salomo *et al.*, 2010, Baxter *et al.*, 2013). The global NPD project teams managed to find and access knowledge across the globally distributed facilities, highlighting that NPD project teams are able to solve knowledge access issues and not just technical issues.

The second step of the company-level data analysis presented in Chapter 7 was the assessment of the KMI survey. The first assessment of the KMI survey showed that, with the exclusion of “boundary objects” and “relocation of offices”, most of the KMI identified in literature were used in *VehicleSystemsCo* and no single KMI was universally recognised as essential for project-to-project learning in global NPD, while many KMI identified in literature were used at the same time.

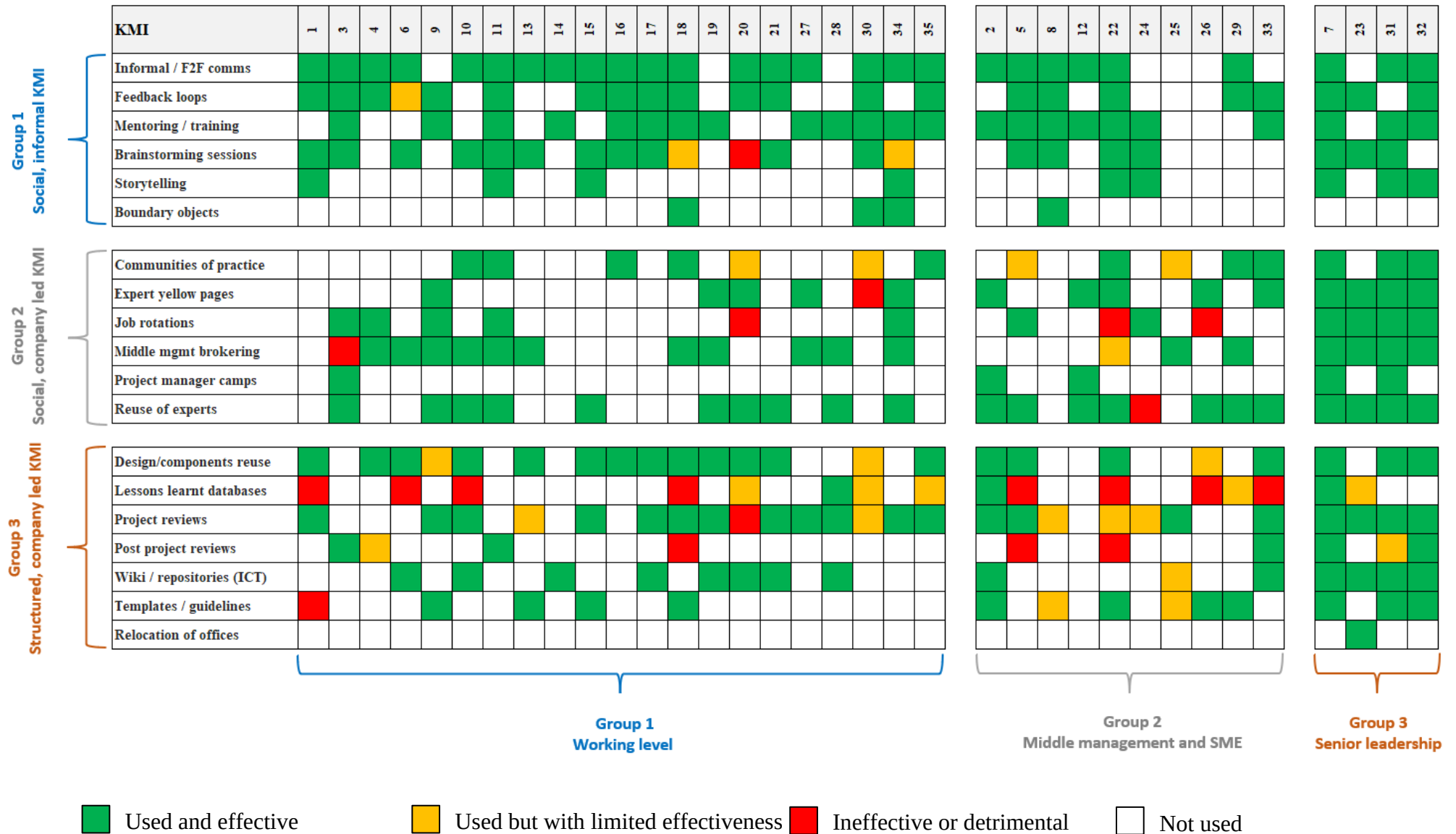
Informal and face-to-face communication and mentoring, and training were considered a key to project-to-project learning in global NPD by the majority of the interviewees and indicated that informal communications were effective for project-to-project learning in global NPD. No interview highlighted the potential detrimental effect on project-to-project learning. This finding was somehow in contrast with the limitation of global NPD projects highlighted in literature (e.g., lack of propinquity and contact) (Baxter *et al.*, 2013; Bernstein and Waber, 2019) and this finding had implications on the validation of the project-to-project learning proposition P3. Experts re-use, brainstorming sessions, feedback loops, design re-use and project reviews were also considered effective for project-to-project learning.

Chapter 7 also showed how the seniority level of interviewees impacted on their view on knowledge management, KMI and project-to-project learning. The KMI survey response data presented in the heatmap in Table 7.1 showed the interview responses listed by interview date (along the horizontal axis) and the KMI sorted by alphabetical order along the vertical axis. The content of Table 7.1 was rearranged in Table 8.1 using the structured and social KMI categories defined in Chapter 2 and the interviewees list order was rearranged using the *working-level*, *middle management* and *senior leaders* ‘seniority lens’ proposed in Chapter 7.

In particular, KMI on the vertical axis were divided between social (groups 1 and 2) and structured KMI initiatives (group 3). Social KMI were further split between informal KMI (group 1) and company-led KMI. All structured KMI were considered company-led in the context of this analysis. Interviews were divided between working-level employees (group 1), middle managers and SME (group 2) and senior leaders (group 3).

The revised KMI survey data presented in Table 8.1 confirms the findings of Chapter 7: the seniority level of NPD practitioners impacts their views on knowledge management initiatives. In particular, Table 8.1 shows that, overall, the three seniority groups have significantly different views on KMI effectiveness for knowledge sharing and use in global NPD.

Table 8.1 – Use and effectiveness of KMI in global NPD sorted by seniority of respondents



8.3.1 The working-level teams' view

Chapter 7 showed that the most discussed and important kind of knowledge for working-level teams were NPD process knowledge and technical knowledge. Compared to other seniority groups, working-level teams also highlighted that they needed access to product strategy and suppliers' knowledge, but technical and process knowledge were significantly more discussed than other kinds of knowledge.

The interviews and project observations showed that working-level teams acted in two ways to access the knowledge they needed, depending on their seniority in the organization. Working-level employees with high seniority in *VehicleSystemsCo* relied extensively on their professional network internal to the organization. Informal KMI, based on informal contacts and quick turn-around answers, were a key for senior working team members.

"[...] It's the reason why I like to go to the office [instead of working remotely], mainly because, OK, you can do that [chatting informally] also through teams, but it's a bit less efficient, but if you are in the same open space with your team and you have a question that is a not exactly in your field, then you know that the guy next to you is more skilled in this field. So, you directly go to him, ask him you have a 5-minute discussion. Then we have a discussion, and your problem is not necessarily already solved, but at least you have a good guidance. And that depends on the speed of the team and how well is the communication established, but it is, at least from my experience it's a very efficient way as well."

(P3-17)

Senior members of the working-level teams knew whom to ask and where to look for information. These employees used to have a tenure in the organization longer than five years and to know well the organization processes and products. Younger engineers extensively relied on documentation and preferred to refer back to pre-existing reports or hard documents to support and technical decisions: this data point emerged clearly from the FRACAS data and from the data on the high use of structured KMI presented in Chapter 7. Reportedly, younger engineers relied less on engineering judgment and looked for previous work to back-up their technical choices.

“The first time I created a drawing for a [REDACTED] I didn’t know what tolerance to put on the [REDACTED]. I asked [REDACTED] for the [REDACTED] part number, and I copied what they had on that print.”

(P3-12)

Chapter 7 also showed that working-level teams rely on company-led KMI significantly more than informal KMI, confirming the importance of explicit knowledge embedded in hard documents and procedures. The main knowledge source for working team members was internal; however, many working-level interviewees discussed about the key importance of external knowledge, for example suppliers’ or customers’ knowledge, as demonstrated by the following representative quote:

“[...] and, of course, supplier meetings, especially face-to-face ones. When you go visit suppliers you learn a bunch, those visits are essential.

I'll give you one example, I'm working with this new supplier, [REDACTED], this is basically the first time we work with them, they also gave us the name of another supplier, [REDACTED].

We went to visit [REDACTED] and we used them to gain a lot of knowledge on this new manufacturing process we are using. They are a very proactive supplier, extremely involved in the project. It's crazy how sometime our supplier knows more than our own experts [SME].”

(P2-7)

8.3.2 Senior leaders' view

The data analysis presented in Chapter 7 showed that senior leaders extensively focused on process knowledge and, to some extent, on technical knowledge. Many of the interviewed senior leaders provided details on the importance of formal processes, gates and procedures. While the data analysis in Chapter 7 showed that senior leaders discuss social KMI almost as much as structured KMI, commercial software and tools for capturing and sharing were also extensively highlighted as key to achieving project-to-project learning:

“We're trying to operate with a cadence and a standard approach that helps to make sure that the learnings can be shared because it's a consistent approach across the teams. So, those are some of the things I guess that come to mind outside of things like maybe engineering tools like is [REDACTED] and others.

What I've seen from a tool standpoint, on lessons learned is people take the time to document the learnings in tools. But people don't take the time to go out and read them or go out and understand them and really apply them. And so somewhere in the knowledge sharing

environment, we're falling short of connecting the learning with people that maybe that's a longer answer than you're looking for."

(SL3)

The overall feedback senior leaders provided on most KMI was positive, highlighting that they believed tools and procedures for KMI were in place and that *VehicleSystemsCo* was providing the right tools and focus to facilitate project-to-project learning. However, more focus was needed to ensure that the teams used the tools provided:

"I think it's what we believe or believed was design guides, standards, specifications, these kinds of paper documents that are written down and are known that are saved somewhere and one could argue [REDACTED], right, we smile, how easy it is to find, but I think historically would say, if you want to design [REDACTED], there's a design guide that says how to do it properly. It's been sanctioned and reviewed. So, if you're going to design [REDACTED], you follow the guide, I suppose. What do we hear about [REDACTED]? Right? You hear about subject matter experts think what's happening is our thinking is evolving. In that just having that stay with that [REDACTED] design guide. Even if it exists, maybe the team doesn't even know that it exists. Or, maybe we rely too heavily [on employees]. For example, right? 'Yep, yep. [REDACTED] [did you check] your [REDACTED] design?' 'Yep, I got it. I reviewed it with the guy just trust me. Trust me, I did it right.' And I think we're trying to go with [REDACTED] in the subject matter expert is that one that is supposed when we get there to end in the design review. It's supposed be pushing [knowledge to the teams], pushing to, not pull. It's supposed to be pushing to the person making an assessment, all of these standards that are applicable to what they're doing."

(SL1)

While senior leaders focused extensively on tools and procedures, they also understood the importance of social KMI:

“[VehicleSystemsCo] is really pushing kind of a digital mindset and digital platform. And so I think having things like teams, and even like these virtual stand ups, like we did this morning with a cross functional team, those people are on multiple projects. So I think my hope or my intent is by using teams, by having those cross functional calls, you know, kind of virtual, like we’re doing right now, you have an opportunity to share knowledge across team members that might contribute on those projects you mentioned, right.

So that's, that's one way I think our digital or digitalization efforts are helping to do those kinds of things. I think a second thing is in a lot of our program reviews, now it's become standard to have lessons learned reflection.”

(SL3)

8.3.3 Middle managers and subject matter experts’ view

While working-level teams and senior leaders focused mostly on informal networks and formal tools respectively, when discussing project-to-project learning, middle managers and subject matter experts (SMEs) mostly focused on their roles as knowledge holders and knowledge transfer facilitators. While it can be expected that middle managers and senior technical specialist had high regard of their role, what was less expected was their criticisms towards formal tools, often considered a “tick of the box exercise”, as one

interviewee reported. The criticism of SMEs and middle managers towards formal, company-led KMI clearly emerges from Table 8.1 and by reading the interview transcripts. Few quotes in this section substantiate the criticism:

“I think the key is capturing [knowledge in] FRACAS and ensuring that the teams starting a new project review the existing FRACAS and take the time to understand it. Based on the logic I discussed at the beginning, I don’t think there is any automated way to transfer knowledge. The only option you have is to give more responsibilities to managers and more responsibilities to the individuals running the projects. [...] The project teams don’t necessarily have a lot of experience [on the new product and technologies], so we have to ensure that the regional and global managers are involved.”

(MM1)

Chapter 7 showed that middle managers were the most aware group about of the complexity of running global NPD programs. A detailed review of the interview transcripts confirms the findings of Chapter 7. An example is provided below:

“[...] But for programs, which are region specific, I feel like each team does their own way. And, you know, right from, let's say, getting customer requirements and doing specifically for [REDACTED], or testing procedures, right, or things, I think there is no alignment or there is less alignment, I shouldn’t say it, but there is less alignment. But as I said, things are improving. But, you know, I think we have a long way to come. I’m surprised we have come so far with this [REDACTED], which is our core product. And we don’t have, you know, if I talk to you, let’s say,

■■■■ [regional SME], or if I talk to ■■■■ [regional MM], if I talk to, ■■■■ [regional MM], we are not aligned on what is the ■■■■ [technical requirements]. So, we start that initiative, but we don't take it to conclusion. It's just, you're so busy with projects and deliverable. We don't take it to conclusion.”

(SME1)

8.4 Discussion of project-to-project learning in *VehicleSystemsCo*

The findings reported in Sections 8.2 and 8.3 showed that knowledge flows exist between global NPD projects and that, with the use KMI surveys, *VehicleSystemsCo* employees did not highlight a single KMI or a set of KMI that were considered essential for global project-to-project learning. The case study data clearly showed that different seniority groups in *VehicleSystemsCo* had different views on project-to-project learning. Across the different seniority groups, data showed that *VehicleSystemsCo* employees were well aware of the different knowledge needs of radical and incremental NPD projects, especially amongst working-level and senior leadership. They were all very well versed with KMI and the importance of project-to-project learning, but also pointed out that day to day project activities prevented them from spending enough time learning from previous projects and studying previous failures and lessons learned. This finding is in agreement with previous studies on the use of lessons learned (Newell, 2004).

These findings are important to answer the main research question:

RQ: In the context of global NPD, which knowledge management initiatives are most often utilised / considered by practitioners to be the most effective and why?

The findings reported in Sections 8.2 and 8.3 highlight that the answer to the research question vary, depending on the seniority of the NPD practitioners.

Table 8.2 – Answering the research question: KMI effectiveness in global NPD

KMI	Used			Effective		
	Working level	Middle management	Senior leadership	Working level	Middle management	Senior leadership
Feedback loops	✓	✓	✓	✓	✓	✓
Boundary objects						
Brainstorming sessions	✓	✓	✓	✓		✓
Communities of practice			✓			✓
Design/components re-use	✓	✓	✓	✓		✓
Expert yellow pages		✓	✓			✓
Informal / F2F comms	✓	✓	✓	✓	✓	✓
Job rotations			✓		X	✓
Lessons learnt databases				X	X	
Mentoring / training	✓	✓	✓	✓	✓	✓
Middle mgmt brokering		✓	✓		✓	✓
Post project reviews			✓	X		✓
Project manager camps			✓			✓
Project reviews	✓	✓	✓	X	X	✓
Relocation of offices						
Re-use of experts	✓	✓	✓	✓	✓	✓
Storytelling			✓			✓
Templates / guidelines		✓	✓	✓	✓	✓
Wiki / repositories (ICT)			✓		X	✓

Table 8.2 summarise the KMI which are most often utilised and considered most effective by seniority. A ‘tick’ sign (✓) in the second column of Table 8.2 indicates that the KMI is used. The third, fourth and fifth column of Table 8.2 track the considered effectiveness of the KMI by seniority: a ‘tick’ sign (✓) indicates that the KMI is considered effective and an X that it is considered not effective.

It is interesting to observe how some KMI are considered useful (e.g., templates and guidelines for working teams) but not used, due to the way in which they are currently implemented in *VehicleSystemsCo*.

Section 8.3 also highlighted some of the key reasons why working teams, middle managers and senior leaders consider KMI effective. In particular, depending on their seniority in the organization, working-level teams either rely extensively on their professional network internal to the organization to access the knowledge they need or, in the case of more junior employees, make an extensive use of existing project documentation. Middle managers mostly focused on their roles as knowledge holders and knowledge transfer facilitators: they believe they possess the technical and know-how knowledge the teams need, and they can mentor and train the teams to success. Finally, senior leaders trust in the process implemented and believe that *VehicleSystemsCo* provided the teams with the tools they need to be successful.

The combination of the project-level and company-level analysis is needed to answer the sub-research questions 1 and 2:

SRQ1: Which knowledge management initiatives are most used, and considered most effective, for **tacit knowledge** sharing and which for **explicit knowledge** sharing?

SRQ2: Which knowledge management initiatives are most used and considered most effective for **incremental NPD** and which for **radical NPD** project-to-project learning?

Table 8.3 – Answering sub-research questions 1 and 2

KMI	Incremental NPD		Radical NPD	
	Explicit knowledge	Tacit knowledge	Explicit knowledge	Tacit knowledge
Feedback loops	✓	✓	✓	✓
Boundary objects		✓		✓
Brainstorming sessions			✓	✓
Communities of practice	✓	✓	✓	✓
Design/components re-use	✓		✓	
Expert yellow pages	✓		✓	
Informal / F2F comms	✓	✓	✓	✓
Job rotations		✓		✓
Lessons learnt databases				
Mentoring / training	✓		✓	
Middle mgmt brokering	✓	✓	✓	✓
Post project reviews	✓	✓	✓	✓
Project manager camps				
Project reviews	✓		✓	
Relocation of offices				
Re-use of experts	✓	✓	✓	✓
Storytelling		✓		✓
Templates / guidelines	✓		✓	
Wiki / repositories (ICT)				

Table 8.3 summarizes which KMI are considered most effective for either tacit or explicit knowledge sharing and use in global NPD, for radical and incremental NPD

projects, based on research findings. It is important to point out that, with few exceptions, the same KMI used for radical project should be used for incremental NPD. Social KMI are recommended for sharing tacit knowledge and are expected to be effective in both radical and incremental global NPD. Generally, the recommendation is for NPD practitioners and managers not to focus exclusively on ICT-based KMI initiatives, but to focus on company-led KMI that can help to create employee networks and awareness between geographically distant employees.

Combining project-level and company-level analysis also highlights two additional key findings emerged for the case study research in *VehicleSystemsCo*. The first finding is related to incremental NPD projects and the second one to radical NPD projects. As far as incremental NPD projects were concerned, the key finding was that the stage-gate and risk assessment methodologies in *VehicleSystemsCo* mandated the use of KMI on radical NPD project, but not on incremental NPD projects. The use of separate teams and lower frequency of internal review were observed in the case of incremental NPD projects, as these projects were considered lower risks for the organization. As a result, the rate of technical and project issues observed on incremental NPD projects was higher than expected and planned for.

When directly asked if KMI were most needed for incremental or radical NPD projects, a senior leader in *VehicleSystemsCo* commented:

“[...] and to which my honest answer is the lower risk projects. And, and here's why I say that. What I've noticed is a bias where the perceived higher risk, bigger bet projects usually get the chief engineers and the top focus and all the resources and all the dedication. And then it's the smaller projects that are almost deprioritized, and don't get the same resources and don't get the same rigor and don't get the same cadence or the same knowledge sharing. Because it's just assumed that we know how to do this. And we're just going to figure it out, right? And

what I've noticed is those lower risk projects really test the organization's process, and cadence and rigor. And if you don't have the experts to infuse experience in that or to infuse their perspective into that, you tend to see a lot of little programs have issues, at least it's funny, because I would have given a completely different answer a couple of years ago, I was 'Oh, of course, the higher risk projects have all the issues'. But I've noticed this pattern where, you know, we made a decision a couple of years ago to give higher risk projects to the product line, lower risk projects to the regions. And the thought process was, okay, well, lower risk projects can be managed within the region, pretty pretty simply. And I'll be honest, I think of all the projects I think about other than maybe one or two, most of our issues have been on those smaller projects, ones that we really underestimated the risk."

(SL3)

In *VehicleSystemsCo*, the NPD teams that managed radical NPD projects and incremental NPD projects of the same business unit were led by different managers and reported into different product lines and organization. This was in line with what reported in literature: Jugend *et. al* (2018) reported that different management practices were used in radical and incremental NPD, with radical NPD projects led by technical and engineering departments and incremental NPD projects led by non-technical managers. While this organizational design allowed for the teams to specialize and learn very different NPD project methodologies, it impacted on the ability of the teams to share knowledge between incremental and radical NPD projects.

A very similar finding was observed in the case of radical NPD and the knowledge needs of radical NPD projects. According to *VehicleSystemsCo* definition, radical NPD projects were those projects where the manufacturing process or the technology behind the

product being developed were significantly different to those previously developed by the organization²⁷.

Projects that were categorized as radical NPD, to be successful, were assumed to be needing significant amounts of knowledge not available in the organization. This knowledge was either knowledge that existed outside of the organization (in academia, at suppliers or at customers) or that needed to be newly developed with the help of R&D. The clear focus of radical NPD teams was on creating or securing this new knowledge. The project and team reviews often focused on this new knowledge. The NUDDs, introduced in Section 7.4 were often used to guide the review and focus the teams on new knowledge. The case study interviews, however, highlighted that existing organizational knowledge was where radical NPD projects struggled the most. This observation is analogue to the fact that incremental NPD projects were often the projects that faced the higher number of issues. This was discussed by one of the senior leaders interviewed:

“But if the [redacted] program [radical NPD] if the first time we ever used [redacted], we don't know anything about it. And what I probably would say is I think we find or we're suspicious of that. It is like when you hear [redacted] when he's talking about NUDDs. What I think we realize is when we, when we're doing something that's totally new, it does scare us, we do pay a lot more attention to it. And almost by oversight and for fear of the unknown, we really focus on that. And we get it taken

²⁷ VehicleSystemsCo stage-gate project management process mandates a risk assessment before the project is officially approved. A multifunctional team is required to rank different project characteristics and a semi-automated tool calculated and categorizes the project as radical or incremental NPD.

care of, because we have a lot of attention. A lot of eyes. It's the things like a [REDACTED]. Oh, it's just a [REDACTED], we've been doing [REDACTED] for hundreds of years. How freaking hard can it be? And then you realize, dammit, you know, we replaced that we had that failure. So that's so that's my, that's my assessment."

(SL1)

The two categories of key findings from the case study research have profound impact on the research proposition and the project-to-project learning, as well as for practitioners designing and using KMI for project-to-project learning and academics studying the topics.

8.5 Validation of the research propositions

Section 8.2 and 8.3 discussed the findings from the case study projects first at a project-level, subsequently at a company-level and finally combining the two views. The findings of the research could be divided in two categories. The first category of findings is related to KMI in global NPD; the second category is related to the knowledge needs of global NPD.

As far as KMI are concerned, Section 8.2 showed that the seniority level of the interviewed NPD practitioners impacted on their views about KMI. The research also showed that, while company-led and structured KMI were most used in global NPD, social and informal KMI were also considered effective and used by global NPD projects.

Section 8.3 also showed that two key findings were identified on the knowledge needs on global NPD project that were very important for project-to-project learning: the first one for radical NPD projects, while the second one for incremental NPD projects. The first observation is related to the importance of existing internal company knowledge and lessons learned for radical NPD projects. This is a key finding, as both literature and

practitioners highlighted that the key knowledge source for radical innovation projects is external knowledge (Ahuja and Katila, 2001; Laursen and Salter, 2006; Zhou and Li, 2012). Many interviews pointed out that in several cases project failures (e.g., FRACAS) were related to lack of internal knowledge transfer from other projects and might have been avoided if more attention were paid to existing company knowledge instead of focusing on new and external knowledge.

Table 8.4 – Validation of the research propositions

	Propositions from the SLR	Empirical research findings	Validated?
P1	In radical global NPD, the key explicit knowledge sources are external to the organization running the project	Global and radical NPD teams discuss significantly more about knowledge internal to the organization	✗
P2	In radical global NPD, formal and company-led KMI are expected to be most used and effective for knowledge sharing	Formal and company-led KMI are more used than informal KMI in both global and radical NPD. However, limited participation to structured KMI was observed	✓
P3	In radical global NPD, social KMI are expected to show limited effectiveness due to the geographical dispersion of the teams	Social KMI are less discussed than structured KMI but considered effective in global NPD	✗
P4	In both incremental and radical global NPD, the key source for tacit knowledge to is internal the organization running the project	Limited data is directly available for tacit knowledge, but internal knowledge is consistently considered	✓
P5	However, social and employee-led KMI are expected to be less used and effective in the case of global NPD, compared to local NPD	Formal KMI serve as catalysts for social KMI, which are used in global NPD. Interpersonal and informal communication are extensively used and effective for project-to-project learning in global NPD	✗

The second finding is that organizations running both radical and incremental global NPD and using separate teams to run the two kinds of projects had a tendency to scrutinize

and deploy stricter policies in the case of radical NPD projects. They often underestimated the risk of incremental global NPD projects.

The idea that organizations over-focus on radical NPD and on new / external knowledge was referred to in Section 8 as the *radical innovation trap* and was a key concept considered when validating the initial research propositions against the research data.

Both categories of findings are used in Table 8.4 to validate the initial research propositions P1-P5 against the finding of the research. A 'tick' sign (✓) in the fourth column of Table 8.4 summarizes if the research findings confirm the initial propositions for each of the five propositions.

The first initial research proposition P1 stated that the key knowledge source for radical, global NPD projects was new and external knowledge to organization. Table 8.4 shows that the evidence from the case study refutes this proposition. The knowledge flow maps, surveys and interviews clearly showed that radical, global NPD teams needed extensive access to organizational knowledge to be successful and that, despite the geographical dispersion of NPD projects, global, radical NPD managed to access the knowledge they needed, even though sometimes with significant delays. The second research proposition P2 stated that structured and company-led KMI were the most used and effective KMI for global, radical NPD projects. The KMI surveys and the interview coding data confirmed that company-led and structured KMI were most used and effective. While the proposition P2 was validated by the case study, the mechanisms behind the effectiveness of formal and company-led KMI were very different from those that were assumed when P2 was formulated. P2 assumed that structured and company-led KMI were the most effective KMI largely because the lack of propinquity and the geographical dispersion of NPD teams would make informal KMI ineffective. However, the research showed that social KMI and informal communications were very used and effective in the case of global NPD. The research showed that the key driver for the use of structured and

company-led KMI was the need for technical and process knowledge highlighted by the teams, not the non-effectiveness of social KMI.

Assumptions about the mechanisms behind project-to-project learning that were just discussed for P2 were also the basis of P3. The third and fifth research propositions, P3 and P5, stated that social KMI and social-informal KMI were expected to have limited effectiveness for global NPD. The case study data refuted these propositions. While social KMI were less used in global NPD, interview coding data showed that social KMI were effective and used in global NPD. The analysis of the interview transcripts showed that, while developing close interpersonal relationships is harder for global NPD than for local NPD team, interpersonal networks and informal communications were extensively used and created by social KMI. Finally, the fourth proposition (P4), focusing on tacit knowledge in global NPD, stated that the source of tacit knowledge in global NPD was internal to the organization and that social and employee-led KMI were most used and effective for tacit knowledge sharing and use. While the case study data provided limited insights on tacit knowledge sharing and used, the interview coding data confirmed the proposition.

Chapter 2 showed how the five propositions were developed to fill the gaps in the project-to-project learning framework in global NPD and how they were used to populate the draft framework. This Section showed that three propositions out of five were invalidated and that, therefore, the framework for project-to-project learning in global NPD needed to be modified accordingly.

8.6 A revised framework for project-to-project learning in global NPD

Five research propositions were introduced in Chapter 2 to populate the framework for project-to-project learning in global NPD. Section 8.2 showed that the case study data refuted P1, P3 and P4, showing that (1) internal knowledge is a key for radical, global NPD projects, (2) social KMI are effective in global NPD even though less used than structured KMI and (3) structured KMI serve as catalysts for social KMI, which are used in global

NPD. Interpersonal and informal communication are extensively used and effective for project-to-project learning in global NPD. Table 8.5 includes the details of the updated project-to-project learning in global NPD framework. The changes to the initial framework are highlighted with the help of colour coding: invalidated assumptions are highlighted in red and crossed-out, the updated and revised findings are highlighted in green.

Table 8.5 – Revised project-to-project learning in global NPD framework

Global NPD projects		
	Incremental NPD	Radical NPD
Explicit knowledge	Key K. source Internal	Key K. source External Internal
	KMI focus Structured; company-led	KMI focus Structured and social ; company-led
Tacit knowledge	Key K. source Internal	Key K. source Internal
	KMI focus Structured and social ; Company-led and informal	KMI focus Structured and social ; Company-led and informal

Red text indicates invalidated assumptions. Green text indicates revised assumptions.

8.7 Summary

Chapter 8 reviewed and discussed research findings. The project-level and company-level analysis identified a number of different findings that can be grouped in two categories. The first category includes findings related to the use of knowledge management initiatives

in global NPD. The second category includes findings related to the knowledge needs of radical and incremental NPD. The following lists are provided as a summary of the key findings discussed in the Chapter.

- **Findings on KMI in global NPD:**

1. Many KMI are used in global NPD projects and significant knowledge flows exist between global NPD projects;
2. KMI can be both a cause of project events (e.g., job rotations or components re-use) and a tool for project teams to manage project events;
3. Employees and managers preference towards specific KMI is impacted by the seniority of the employees and managers involved;
4. Social and employee-led KMI are less used in global NPD compared to structured and company-led KMI but are effective for knowledge sharing and use. Structured and company-led KMI act as catalysts form social KMI;
5. KMI are often used to access knowledge after a project event impacting knowledge flows, rather than help the teams to anticipate and prevent project events.

- **Findings on knowledge needs of global NPD projects:**

1. Five types of project events impacting knowledge flows were observed;

2. Compared to radical NPD, the knowledge needs of incremental global NPD projects tend to be underestimated and a reduced number of KMI are deployed;
3. Radical NPD project need extensive access to internal and pre-existing knowledge. KMI and NPD processes deployed for global radical NPD projects focus on new and external knowledge, reducing the focusing the project team have on internal knowledge.

The findings above were used to validate or refute the five research propositions and update the project-to-project learning framework form global NPD. The findings from the research and the updated framework for project-to-project learning have potential implications for both NPD managers and NPD knowledge management researchers. The contributions of the research to knowledge and implications for practitioners are discussed in Chapter 9, together with the limitations and possible next steps.

CHAPTER 9 – CONTRIBUTIONS AND RECOMMENDATIONS

9.0 Introduction

This Chapter highlights the implications of research findings, discussing both the contribution to knowledge and the recommendations for global NPD practitioners. Section 9.1 introduces the problem under investigation and summarizes the findings discussed in Chapter 8. Section 9.2 focuses on the contribution of the research to knowledge. Section 9.3 highlights the implications of research findings for global NPD practitioners and includes a list of recommendations for supporting knowledge sharing and use in global NPD. Section 9.4 explores the limitations of the research and recommendations for further developments. Section 9.5 summarises the conclusions of the research. Finally, Section 9.6 includes few personal considerations.

9.1 Review of the research findings

An increasing use of global NPD in the product development community (Gemünden, 2015; Sivakumar and Roy, 2021; le Duc and Gammeltoft, 2023), coupled with the well-known issues of communication and trust between team members geographically and culturally distant from each other (Grant, 1996; Baxter *et al.* 2013), generated questions in NPD practitioners and knowledge management scholars on what the best knowledge management practices for global NPD were. Following the SLR, the research presented in this Thesis was developed out to answer questions on project-to-project learning in global NPD. The research was designed to answer the research question:

RQ: In the context of global NPD, which knowledge management initiatives are most often utilised / considered by practitioners to be the most effective and why?

Global NPD is a growing trend in the NPD industry (Gemünden, 2015; Sivakumar and Roy, 2021; le Duc and Gammeltoft, 2023) and SLR questions were created to help to understand what was known in literature about knowledge management in global NPD. The literature introduced in Chapter 1 and reviewed in Chapter 2 showed that very little empirical research existed investigating project-to-project learning in global NPD. Chapter 2 also explained the importance and relevance of project-to-project learning in global NPD: while global NPD projects are expected to perform worse than local projects due a reduced knowledge sharing among team members (Paulin and Winroth, 2013; Pavanelli Stefanovitz and Jabbour, 2022; le Duc and Gammeltoft, 2023), global projects were found to be as successful as local NPD projects (Baxter *et al.*, 2010). While the increasing number of global NPD projects shows the increasing interest and relevance of the topics, practitioners explicitly reported this trend during the interviews. Furthermore, the importance of the topics amongst practitioners was expected to grow, as teams resorted to distributed and remote NPD teams as a consequence of Covid-19 (Cecchi *et al.*, 2022; Revoredo-Giha and Russo, 2022; Caccamo, Pittino, and Tell, 2022). While some authors (Salomo *et al.*, 2010) theorized that a higher access to diversified knowledge and local markets knowledge offsets the limitations caused by geographical distance, interesting findings emerged from the research presented in this Thesis.

Chapter 2 introduced a project-to-project learning framework together with five research propositions (P1-P5) to close the gaps in the project-to-project learning in global NPD framework to draft an initial project-to-project learning in global NPD framework.

An in-depth case study design was developed to investigate three global NPD projects in a global multinational cooperation active in the field of automotive components: *VehicleSystemsCo*. With the help of *VehicleSystemsCo*'s leadership team, three global NPD

projects with different degrees of innovation and at different stages of the NPD progress were selected. The project cases were analysed using data from four different sources, including documentation reviews, surveys, project observations and interviews. Chapter 5 provided an overview of *VehicleSystemsCo* knowledge management processes. Chapter 6 narrated the key project events during the 12 months of observation of the three projects, focusing also on project-level analysis of the project events. A three-step approach was used to analyse case data, including thematic coding of interview transcripts. The results of the thematic coding were presented in Chapter 7. Chapter 8 discussed the findings of the case study research and used the findings to answer the research questions, providing a list of used and effective KMI for knowledge sharing and employed in global NPD. The discussion in Chapter 8 included details of the mechanisms underlining the considered effectiveness of KMI. Chapter 8 also pointed out that eight key findings were identified from the case study data and grouped in two categories, (1) five findings on KMI in global NPD and (2) three findings on knowledge needs of radical and incremental global NPD projects.

Starting with KMI, the first finding from the case study research was that extensive and unexpected knowledge links existed among global NPD projects. NPD projects teams managed to create knowledge networks and to access the knowledge they needed to run their global projects.

The second finding is that KMI were observed as both a cause of project events (e.g., job rotations) and a tool to be employed by project teams to react to project events. This finding highlights that NPD managers and practitioners are very much careful when implementing KMI and assess benefits and risks connected with the use of KMI. This is connected with the sixth finding of the research: a total of five types of project events were observed.

Answering the first part of the RQ, the third finding is that the evaluation of KMI usefulness for project-to-project learning in global NPD depends directly on the interviewee. Company senior leaders tended to think that formal processes and commercial tools, and the implementation of guidelines and procedures were the best way to ensure

project-to-projects learning. Middle managers and technical specialist tended to rely extensively on their mentoring and training of the project teams and considered their direct intervention the best way to ensure project-to-project learning in global NPD. Working-level teams tended to rely extensively on hard documentation (e.g., templates, previous project reports) and their professional network to identify formally and informally what was done on previous projects and existing organizational knowledge. This third finding has vast implications particularly for practitioners deciding which KMI to implement, extend or sponsor in global NPD.

The fourth finding focused on the types of KMI that are considered effective in global NPD. The research conducted in *VehicleSystemsCo* showed that, while structured and company-led KMI are more used than social KMI in global NPD project-to-project learning, social KMI were still considered effective and were used in global NPD. This finding is particularly interesting for both knowledge management scholars and NPD practitioners.

While the evidence clearly showed that teams managed to have access to the needed knowledge (the first finding of the research), NPD practitioners commented that this knowledge is often discovered after a failure, or a problem occurred. This is the fifth finding of the research.

As far as the knowledge needs of global NPD are concerned (the second category of findings), the sixth finding was already discussed in the first category. The seventh finding is related to the knowledge needs of incremental global NPD projects. The research showed that the knowledge needs of incremental, global NPD projects tended to be underestimated and a reduced number of KMI were deployed, compared to radical NPD. This reduced effort on the implementation of KMI and frequent reviews in radical NPD projects impacted on the ability of the incremental NPD projects to deliver their projects successfully, often experiencing instead unexpected issues.

The eight, and final, finding is related to the knowledge needs of radical, global NPD. The results of the data analysis from the interview transcripts presented in Chapter 7

and Chapter 8 showed that global radical NPD projects had high need for internal knowledge. This is also a particularly interesting finding as many scholars observed that explicit knowledge was a key enabler for radical NPD, while the research in *VehicleSystemsCo* showed the opposite.

Chapter 8 compared the case study findings with the initial propositions introduced in Chapter 2 and used the case study data to validate or invalidate the research propositions. The five research propositions were used to feed the project-to-project learning in global NPD framework presented in Chapter 2. Chapter 8 updated the project-to-project learning in global NPD framework with the findings of the case study. While the case study reported in this Thesis only focused on global NPD, dynamics similar to the ones observed for global NPD are likely to apply in the case of local, radical NPD, outside the scope of this project (see Figure 9.1). Further research to investigate the knowledge behaviours of global NPD teams based on the degrees of innovation of the projects is recommended. Limitations of the research presented and further recommendations for future research are included in Section 9.4.

Local NPD projects – out of scope				Global NPD projects			
		Incremental NPD	Radical NPD			Incremental NPD	Radical NPD
Explicit knowledge	Key K. source	Internal	Internal?	Explicit knowledge	Key K. source	Internal	External Internal
	KMI focus	Formal; company-led (discussed and in use)	Formal/social; company-led (discussed and in use)		KMI focus	Formal/social; company-led	Structured and social; company led
Tacit knowledge	Key K. source	Internal	Internal	Tacit knowledge	Key K. source	Internal	Internal
	KMI focus	Social; company-led (discussed and in use)	Social; company/employee-led (discussed and in use)		KMI focus	Structured and social; company-led and informal	Structured and social; company-led and informal

Figure 9.1 – The radical innovation trap potential impact on local NPD programs

9.2 Review of the contribution to knowledge

The eight main findings of the research presented in this Thesis also contribute to knowledge on NPD projects and to the KM body of knowledge. The six contributions to knowledge are identified and discussed in this Section.

The first contribution of the research, confirming the findings by Cecchi *et al.* (2022, p.49), is that “engineers like to solve problems”, including knowledge flow problems, and “will find a way to make it work”. This finding is interesting for knowledge management researchers as it shows that, while global dispersion is indeed one of the rising complexities of NPD (Pavanelli Stefanovitz and Jabbour, 2022), global NPD teams still manage to access the knowledge they need. This Thesis showed that – surprisingly and despite the challenges posed by remote working and remote cooperation with distant colleagues – global NPD teams manage to find and access the knowledge they need from projects run by remote and local project teams. This observation was referred to as *knowledge finds its way!*

The second contribution of the research is related to the effectiveness of social KMI in the case of global NPD projects. The reviewed literature showed that social and informal KMI initiatives are expected to have limited effectiveness for global NPD projects, due to the limited face-to-face interaction, propinquity and the implication that this has on interpersonal trust (Baxter *et al.*, 2013; Bernstein and Waber, 2019). The findings of the case study research showed that social and employee-led KMI are effective in the case of global NPD project, even though less used than structured and company-led KMI. Interestingly, the research showed that company-led KMI, both formal and social, serve as catalyst for informal knowledge sharing and use between global NPD project team members. The research showed that high value added is shared via informal and social KMI, highlighting that implementing structured and company-led KMI is necessary but not sufficient for knowledge sharing and use in global NPD. This contribution to knowledge is

also a key finding for NPD practitioners and managers wanting to improve knowledge sharing and use in global NPD.

The third contribution of the research, closely connected to the second one, is also relevant to the general effectiveness of global NPD team to execute innovation projects. The literature showed that global NPD projects face additional challenges compared to local NPD projects but are, surprisingly, as successful as local NPD. This success is explained in the literature by the fact that the limited knowledge sharing is offset by the increased access to local experts, situated knowledge and a better understanding of local customer needs (Sole and Edmondson, 2001 and 2002; Salomo *et al.*, 2010; Mathrani and Edwards, 2020). The findings of this Thesis showed instead that KMI are effective in the context of global NPD and that global NPD teams have access to existing knowledge, including tacit knowledge. In order to be successful and produce new products that answer the individual local market needs (highlighted by knowledge on the local customer needs from local experts), global NPD need first to be completed and this requires knowledge sharing and the use of existing knowledge within the organization.

The fourth contribution of the research is related to the knowledge needs of global NPD projects. The reviewed literature showed that external knowledge is a key for radical NPD projects to be successful (Chesbrough, 2003; Katz and Du Preez, 2008; Rosell, Lakemond and Melander, 2017). This was also reinforced by the high focus that radical NPD practitioners have on NUDD product characteristics. However, the findings of the research highlighted the importance of internal knowledge for the success of global NPD projects. This observation was referred to as the *radical innovation trap* and the findings of the research offer evidence supporting the observations of Zhou and Li (2012) about the limits of mainstream literature on knowledge needs of NPD projects.

Closely connected to the fourth contribution, the fifth one is related to the focus of senior leaders on radical NPD. The findings of the research show that senior leaders are more invested on radical NPD projects than on incremental NPD projects. Radical NPD projects carry the most risks and complexity, but also the highest opportunity for innovation and growth of the business. Radical NPD projects naturally attract higher focus

from senior leaders and company procedures mandate more frequent reviews and more KMI. However, the research showed that incremental NPD also suffer from limited KMI implementation and have high knowledge needs that, if not addressed, can endanger the successful execution of incremental NPD projects.

The sixth and final contribution of the research is related to the seniority bias that NPD practitioners show towards KMI. In particular, the research showed that senior leaders are biased towards structure and company-led KMI and consider these KMI and processes effective for knowledge sharing and use: once the tools are implemented and in place, the global NPD teams have all what they need to be successful. Middle managers are biased towards their roles as knowledge holders and knowledge coaches of the global NPD teams. Middle managers are very sceptical about structured KMI, ICT based KMI especially, and believe that the most effective way for global NPD teams to access knowledge is through their guidance. Finally, working-level teams act in two ways to access knowledge: the most senior working-level employees rely extensively on their personal professional network and are able to quickly find the right expert or knowledge holder; the more junior employees rely extensively on hard data and procedures. This contribution to knowledge has also implications for practitioners, that are discussed below.

9.3 Recommendations for practitioners

NPD managers and practitioners wanting to increase the knowledge flow between global NPD projects are faced with very limited practical recommendations on what KMI are most effective in the case of global NPD projects. The findings of this research can help providing recommendations to NPD managers on the knowledge needs and effectiveness of KMI for global NPD project-to-project learning. These findings have implications that have been translated in eight recommendations for global NPD practitioners and managers. The recommendations presented in this section are mostly directly derived from the findings of the research. Yet, the findings are also complemented by the observations and practical considerations of the Author during more than six years of research on the topic.

The first recommendation is derived from the knowledge flow maps presented in Section 7.1 and shows that, thanks to working-level teams informal networks and knowledge brokering of middle managers, global NPD project teams manage to access the knowledge they need. While the findings of the case study research showed that NPD teams manage to get access to the knowledge they need, questions still exist on the timeliness of the access to knowledge, which some interviewees reported being sometimes too late in the life of the project. NPD managers should not only focus on ICT based KMI and encourage social activities between global team; they should also facilitate the creation of informal networks between the global NPD projects teams with the aid of company-led social KMI. A good example of this is the global team meetings hosted by the global engineering managers in *VehicleSystemsCo*. Global NPD managers are recommended to host monthly meetings with the global functional team where different project teams present their work and are introduced to colleagues in other facilities and teams working on similar projects and technologies. NPD managers should also encourage the formation of Communities of Practice (CoP), based on product technologies or market segments, by formally appointing CoP leaders and joining at times the CoP meetings.

The second recommendation relates to the intrinsic bias that different groups of employees have on KMI. In particular, middle managers reportedly consider their role as a key in knowledge brokering for project-to-project learning and tend to minimize the importance of structured KMI (e.g., lessons learned databases). Similarly, senior leaders tend to rely almost exclusively on structured and company-led KMI. When implementing KMI for global NPD project-to-project learning, NPD managers should be aware of the intrinsic bias and take it into account when designing a balanced KMI system, including both structured and social KMI.

The third recommendation concerns the way in which working teams find the knowledge they need. The recommendation for global NPD managers is to ensure that project documentation (e.g., drawing prints, product specifications, test procedures, etc.) are well categorized and archived and that they ensure that junior employees have access to the archives.

As hard documentations are expected to be only allowing sharing of explicit knowledge, the fourth recommendation for NPD managers is to schedule regular informal and social events to introduce the more junior team members to more senior team members in the multiple locations where the company is active (see the example of the cooking competitions in Cecchi *et al.*, 2022). When budget allows, it is recommended for the global NPD managers to approve the travel expenses for junior employees to other company facilities and engage in face-to-face interactions with global team members.

The fifth recommendation for NPD managers and senior leaders is to deploy the same KMI for radical and incremental NPD global NPD projects, to ensure that incremental NPD project have access to the knowledge they need to be successful. Similarly, the same cadence of senior leadership reviews used for radical NPD projects is recommended in the case of incremental NPD projects, to offset the natural higher involvement that senior leaders have in radical NPD project.

The sixth recommendation is for NPD line managers to create clear yearly goals for middle managers and subject matter experts to coach specific individuals. These goals should be communicated to both the middle managers and subject matter experts, to create a “learning mandate” (Sense, 2003). This recommendation is expected to have higher effectiveness in those organizations that have a yearly goal setting and review schedule.

The seventh recommendation is for NPD line managers to create long-term development plans that include jobs rotations. These development plan should be planned in advanced and well known to the portfolio managers responsible for planning the projects. By doing so, NPD managers should never be surprised by team members unexpectedly leaving a project and creating a project event for the global NPD team working on the projects.

The eighth, and final, recommendation for NPD managers and practitioners relates to the knowledge needs of global NPD projects. The findings of the case study research showed that global NPD projects teams need access to both internal and external knowledge. NPD practitioners and managers running global, radical innovation NPD

projects incur the risk of prioritizing external knowledge needed to close risks related to NUDDs projects characteristics, reducing the efforts to integrate existing organizational knowledge. NPD practitioners and managers working on global NPD should carefully assess and track the knowledge needs of their projects, considering both the external knowledge needed to solve the new technical challenges and the knowledge existing in the organization which is needed to solve the incremental NPD contents of the radical NPD projects. NPD manager and practitioners should not fall in the *radical innovation trap*!

9.4 Limitations of the research and recommendations for further research

The methodology defined in Chapter 3 and the findings are very interesting for NPD practitioners and researchers and offer many insights into the knowledge behaviour of *VehicleSystemsCo*. Yet, in reading these findings, practitioners and scholars are encouraged to exert caution when working in contexts that differ from *VehicleSystemsCo*. Chapter 5 showed that *VehicleSystemsCo* is a very modern organization and active, as far as knowledge management is concerned. *VehicleSystemsCo* employees are well versed in KMI and their leadership team is well aware of the importance of knowledge and knowledge management – in Sense’s (2003) terminology *VehicleSystemsCo* employees have a strong “learning mandate”. Interviews with *VehicleSystemsCo* employees showed that trust exists between employees working in different locations and even if they never met face to face. Further research should investigate if trust develops between remote employees also in the case of organizations less explicitly focused on knowledge management. A multi-organization in-depth case study on radical, global NPD projects would be helpful to better understand how organizational culture impacts on the ability of NPD teams to access the organizational knowledge they need, answering the question does *knowledge (eventually) find its way* despite organizational and cultural barriers?

Chapter 3 explained the need for the research to have access to in-depth cases to be able to answer the research questions. To secure sufficient in-depth access to the cases, the decision was taken to limit the research to a single organization, well known to the Author.

Chapter 3 also highlighted the risks and opportunities offered by the pre-existing ties between the Author and the host organization: the risk of incurring in the so-called involvement paradox (Langley and Klag, 2019); the emergence of further risks related to conducting the research in a host organization known to the Author; and finally additional limitations which arise from selecting a small number of cases.

The decision to limit the cases to three was driven by timing constraints on both the Author's and the host organization's side: increasing the number of projects, while maintaining the depth required by the research question, would have implied extending the duration of the empirical research well beyond the availability offered by *VehicleSystemsCo* and by the time frame available to the Author as part of the PhD program. The selection process was carefully designed to identify three cases as diverse as possible, considering geographical dispersion, degree of innovation and product families involved. However, conducting the research on three cases from the same organization reduced the possibility of generalizing the findings. This is due to the fact that, the findings are influenced by other factors which were not accounted for in the case selection. Factors as the overall success of the project, the overall seniority of the project team, the communication styles and requirements of the customers and changes to the organization direction and leadership style (the overall project direction) are expected to impact on the findings

So, to increase the generalization of the findings, it would be necessary to carry out further in-depth research on more projects, in different organizations and different sectors (i.e., outside of the automotive environment). Repeating the research on other *VehicleSystemsCo* automotive projects is expected to produce similar findings, due to the common processes and organizations structure. While this Thesis showed the importance that organizational culture for knowledge sharing and use, similar findings are expected to be observed in other organizations, with a similar focus on knowledge management, and also operating in the automotive sector. As far as the generalisation of the findings in other industries is concerned, the Author's professional experience in other business units of *VehicleSystemsCo* (e.g. in the aerospace sector) showed that similar findings can be

expected in companies with a comparable organizational culture and a focus on knowledge management. Further research across other organizations and sectors is needed to study and confirm the generalization of the findings in other organizations and industries.

Chapters 6 and 7 showed that the research methodology used in this Thesis was more effective to investigate explicit knowledge than to investigate tacit knowledge. Interviewing NPD practitioners and asking directly about tacit knowledge showed limited effectiveness for understanding tacit knowledge sharing and use. Due to the important role that literature pays to tacit knowledge for NPD projects (Kreiner, 2002), investigating the dynamics of tacit knowledge in global NPD could prove very useful. Initially, the research in the Thesis targeted the investigation of both tacit and explicit knowledge sharing. However, the data analysis showed that the complexity of knowledge sharing in global NPD, coupled with little pre-existing knowledge on global NPD knowledge sharing, made the research design not particularly effective to investigate tacit knowledge sharing. The results of this Thesis now offer a framework for project-to-project learning in global NPD that can be used to continue the research into tacit knowledge sharing in global NPD. Further research should focus on tacit knowledge in global NPD following the ethnographic approach proposed by Koners and Goffin for the investigation of tacit knowledge (2007).

Finally, Chapter 7 showed that three of the five research propositions were refuted and have highlighted the risk that global NPD team have of falling in the *radical innovation trap*, prioritizing external and new knowledge over existing internal and organizational knowledge. It can be expected that local NPD might face the same risks as global NPD. Further research should investigate the relative importance of internal and external knowledge in local, radical NPD projects.

9.5 Conclusions

This Thesis reviewed a selected knowledge management and NPD management body of literature to conclude that limited empirical research existed to explain factors limiting or facilitating project-to-project learning in global NPD. NPD practitioners wanting to

implement knowledge management initiatives to facilitate project-to-project learning in global NPD were provided with limited guidance on which KMI to focus on. Three research questions and five research propositions were created to guide empirical research on project-to-project learning in this context.

An in-depth case study of three global NPD project teams in *VehicleSystemsCo* was developed to answer the call of Baxter *et al.* (2013) and Idrees *et al.* (2023) that further research was needed to investigate project-to-project learning and global NDP projects. Case study methodology using data from observations, survey, interviews and reviews of documents was used to uncover the project-to-project learning behaviour of global NDP teams. A three-step approach to data analysis was used to review the case study data with the help of knowledge flow mapping, thematic coding and survey data analysis.

The findings of the research showed that radical, global NPD project teams need high volumes of both internal and external knowledge to be successful and showed that intrinsic bias exists at different seniority levels, impacting on their approach to knowledge management. The findings also show that both social and structured knowledge management initiatives are effective and used for project-to-project learning in global NPD. They contributed to the knowledge management and new product development body of knowledge in six ways and provided practitioners with eight practical recommendations to improve knowledge sharing and use in global NPD.

Finally, the research provided scholars and practitioners with a simplified 2x2 model of project-to-project learning in global NPD that can be used by practitioners to develop tailored knowledge management initiatives for specific organizations and by scholars intending to continue the research on project-to-project learning by testing the applicability of the framework in other organizations or local NPD.

9.6 Personal considerations

As an NPD professional and after spending many years away from academia, going back to university was a refreshing experience. Working in NPD is an extremely rewarding profession and I find it both fascinating and extremely interesting. Engaging with demanding customers, complex technical challenges and cooperating with third parties to develop new solutions stimulates creativity. Yet often times it also requires to stop activities ahead of time to achieve strict timelines and ensure product delivery. Immerging myself once again into academia after many years in the industry reminded me, the hard way of the rigor that academic research demands. As one of my supervisors perfectly summarized during one of our frequent PhD progress reviews (for which I will be always very thankful to both my supervisors!) “There is no such thing as a Minimum Viable Product, when it comes to a PhD”.

During my almost seven years as a part-time PhD student, I matured as a person and as an NPD professional. I learned to challenge everything I hear and read and check the sources. This has not always made me the most popular in meetings or with my family and friends, but I believe overall it made me more confident of my work and my ideas. Also, thanks to the tools and ideas I developed as a PhD student, I developed also as an NPD professional and moved in many different roles, from the role of senior project engineer I had when I joined the PhD program at Cranfield to my current role of global NPD manager. I am confident that in my current and future roles I will always be able to bring a bit of the rigor and scepticisms I learned during my PhD years and share it with my teams.

Last, but in no way least, all the learnings on knowledge sharing in global teams have already proved very useful in my professional career. Just by having the interviews and the discussions with NPD teams about project-to-project learning made us all more aware of how we cooperate and learn from each other. I am confident that project-to-project learning in *VehicleSystemsCo* will further benefit from the findings of my Thesis.

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APPENDIX A – SLR SEARCH RESULTS

Title	Year	Authors	Included based on title review?	Included based on abstract review?
Boundary Objects as Facilitators of Knowledge Transfer in Project Based Organisations	2019	Butters, Rosanna; Duryan, Meri	YES	YES
Employing the Internal Marketing Theory to Explain How Knowledge Dissemination Can Be Enhanced in Organizations	2019	Lawson, Sheron	YES	YES
EXPLOITING FIRM CAPABILITIES BY SENSING, SEIZING AND RECONFIGURING CAPABILITIES: AN EMPIRICAL INVESTIGATION	2019	Breznik, Lidija; Lahovnik, Matej; Dimovski, Vlado	YES	NO
Impact of knowledge sharing and absorptive capacity on project performance: the moderating role of social processes	2018	Ali, Imran Musawir, Ata Ul	YES	YES
Case Study: Re-Visiting the Roles of Project Management Maturity and Organisational Culture for Perceived Performance – A Replication based on German Data	2018	Ronald, Busse; Tamara, Henze		NO
Evaluating Continuous Improvement Efforts in New Product Development	2018	Dybvik, Henrikke; Erichsen, Jørgen Andreas Bogen; Steinert, Martin; Welo, Torgeir	YES	NO
Gestão do conhecimento e inovação	2018	César Ricardo Maia de Vasconcelos; Ahiram Brunni Cartaxo de Castro; Pinto Brito, Lydia Maria	NO	
Initiating Factors Affecting Information Systems Project Success	2018	Afolabi, Jonathan Olubunmi	NO	
Innovative by Design: How Organizations Can Sustain Continual Innovation in Highly Competitive Markets	2018	Hoffbauer, Andreas	NO	
Lean leadership in major projects: from “predict and provide” to “predict and prevent”	2018	Holweg Matthias; Maylor Harvey		NO
Managing Knowledge and Co-creation in Service Innovation: The Case of the Advertising Industry	2018	Pan, Fengjie	NO	

Title	Year	Authors	Included based on title review?	Included based on abstract review?
Managing technological distance in internal and external collaborations: absorptive capacity routines and social integration for innovation	2018	Enkel, Ellen; Groemminger, Annika; Heil, Sebastian		NO
Old theories, new contexts: extending operations management theories to projects	2018	Maylor Harvey; Meredith, Jack R; Söderlund, Jonas; Browning, Tyson	NO	
Strategies Certified Project Management Professionals Use to Prevent Counterproductive Behavior	2018	Hansson-Vazquez, Lisa Annika Christin	NO	
The Experiences of Project Leaders with Project Retrospective and Planning Processes: A Case Study	2018	Majeed, Ibrahim	NO	
A Paradox of Progressive Saturation: The Changing Nature of Improvisation over Time in a Systems Development Project	2017	Molnar, Wolfgang Alfred; Nandhakumar, Joe; Stacey, Patrick	NO	
Clarifying the feedback loop concept for innovation capability: A literature review	2017	Chirumalla, Koteswar		YES
Examining project learning, project management competencies, and project efficiency in project-based firms (PBFs)	2017	Wise Mainga	YES	YES
Managing Knowledge in High Technology Firms	2017	Mohannak, Kavooos	YES	YES
Between a rock and a hard place: Management and implementation teams' expectations of project managers in an agile information systems delivery environment	2017	Nkukwana, Songezo; Terblanche, Nicky HD	NO	
Business process management – a construction case study	2017	Bhargav Dave	NO	
Integrating supplier knowledge in new product development projects: decoupled and coupled approaches	2017	Rosell, David T; Lakemond, Nicolette; Melander, Lisa	YES	NO
Intellectual Management: An Integrative Theory	2017	Yu, Dengke; Zhou, Rong		NO
Management Of Sustainable And Innovative Projects: A Bibliometric Study	2017	Graziela Darla Araujo Galvão; Leandro Alves Patah		NO

Title	Year	Authors	Included based on title review?	Included based on abstract review?
Performance in new product development: a comprehensive framework, current trends, and research directions	2017	Müller-Stewens, Benedikt; Möller, Klaus	NO	
Proceedings of the 59th Annual Meeting of the Academy of International Business "The Contribution of MNEs to Building Sustainable Societies" Dubai, United Arab Emirates July 2-5, 2017	2017		NO	
The Influence of Individual Trust on Knowledge Sharing in Distributed Work Environments: A Systematic Review Using Realist Synthesis	2017	Metzger, Mark A.	NO	
The motivations, institutions and organization of university-industry collaborations in the Netherlands	2017	Bodas Freitas, Isabel Maria; Verspagen, Bart	NO	
THE USE OF KNOWLEDGE MANAGEMENT PRACTICES BY BRAZILIAN STARTUP COMPANIES: REVISTA DE ADMINISTRAÇÃO E INOVAÇÃO REVISTA DE ADMINISTRAÇÃO E INOVAÇÃO	2017	Dalmarco, Gustavo; Maehler, Alisson Eduardo; Trevisan, Marcelo; Janaina Mortari Schiavini	NO	
Titan Cement Co. S.A. – Annual Report, 2017	2017		NO	
Uncovering the structures and maturity of the new service development research field through a bibliometric study (1984-2014)	2017	Mendes, Glauco HS; Maicon Gouvea Oliveira; Gomide, Eduardo H; José Flávio Diniz Nantes	NO	
Why Leader-Member Exchange Is Important to Business Thinking	2017	Coto, Linda L. Zorn	NO	
A study of the relationship between the project management office (PMO) leader sources of power and the quality of the PMO leader member exchange influence on project success	2016	Gadison, Paulette D.	NO	
An Empirical Study on the Effect of Knowledge Management on Ramp-up Performance in the SME Sector	2016	Bu[beta]wolder, Peter; Basse, Felix	NO	
Antecedents to Team Performance on Student IT Projects	2016	Havelka, Douglas	NO	
Emergent approach to knowledge management by small companies: multiple case-study research	2016	Zieba, Malgorzata; Bolisani, Ettore; Scarso, Enrico	YES	NO

Title	Year	Authors	Included based on title review?	Included based on abstract review?
Frugal Innovation and Knowledge Transferability: Innovation for Emerging Markets Using Home-Based R&D	2016	Altmann, Peter; Engberg, Robert	YES	YES
Benefits of Conducting Post project Review to Capture Lessons Learned	2016	Fadairo, Olayemi	YES	NO
Strategic intent, organizational environment, and organizational learning mechanisms: A multiple-case study in the construction industry in Taiwan	2016	Fang, Shih-Chieh; Chen, Hung Ku	YES	YES
THE EFFECT OF DIMENSIONS OF KNOWLEDGE SHARING ON A VARIETY OF STRATEGIC MIND MAP OF MANAGERS AND EMPLOYEES	2016	Azema, Pegah; Jafari, Mostafa	YES	NO
EFFECTIVENESS OF KNOWLEDGE TRANSFER MECHANISMS FOR IMPLEMENTING PROCESS IMPROVEMENT FRAMEWORKS IN SERVICES OFFSHORING	2016	Balint, Bryon; Forman, Chris; Slaughter, Sandra	YES	NO
Examining the Project Management Professional Certification as a Predictor of Project Performance Outcomes	2016	Dunams, Bruce	NO	
Exploring Knowledge Management Models on Information Technology (IT) Projects	2016	Foote, Alan Richard	TBC	NO
FROM THE EDITORS: EMJ EMJ	2016	Doolen, Toni, PhD; Van Aken, Eileen, PhD	NO	
Information Technology Project Management Office: Exploring the Reasons Influencing the Adoption of IT PMOs for Organizational Success	2016	Lopez, Filadelfo Bertrand	NO	
Knowledge Barriers in Univesity-Industry Knowledge Networks	2016	Vouri, Vilma; Helander, Nina	NO	
Knowledge integration with customers in collaborative product development projects	2016	Eslami, Mohammad H.; Lakemond, Nicolette	YES	NO
Knowledge Sharing Intentions in Wholesale Distribution Organizations	2016	Roth, Andrew E.	NO	
LA CULTURA ORGANIZACIONAL Y SU INFLUENCIA EN LAS BUENAS PRÁCTICAS PARA LA GESTIÓN DEL CONOCIMIENTO EN LAS PYMES DE COLOMBIA/ORGANIZATIONAL CULTURE AND ITS INFLUENCE ON BEST PRACTICES FOR KNOWLEDGE MANAGEMENT IN SMES IN COLOMBIA	2016	Echeverry, Carlos Eduardo Marulanda; Trujillo, Marcelo López; Galeano, José Fernando Castellanos	NO	

Title	Year	Authors	Included based on title review?	Included based on abstract review?
Proceedings of the 58th Annual Meeting of the Academy of International Business "The Locus of Global Innovation" New Orleans, Louisiana, USA June 27-30, 2016	2016		NO	
Project Management: Bibliometric Comparative From Annals Of The Brazilian Congress In The Area Of Administration And Production Engineering	2016	Ronielton Rezende Oliveira; Patricia Souza Amaral Tardivo Boldorini; Henrique Cordeiro Martins; Alexandre Teixeira Dias		NO
Scheduled project stakeholder management techniques and their effectiveness in reducing project failure: A qualitative study	2016	Price, Gwendolyn	NO	
SUCCESS EVALUATION MODEL FOR PROJECT MANAGEMENT	2016	Doskocil, Radek; Skapa, Stanislav; Olsová, Petra	YES	NO
The Alchemy of Creativity: An Operating System for Innovation, Collaboration and Enhanced Creativity	2016	Zaboski, David; Dierberger, George F; Douglas, Ryan		NO
The Association of Knowledge Management and Project Management: An Enterprise-wide Approach Based on Stankosky's Four Pillar of Knowledge Management and PMI's Project Management Knowledge Areas	2016	Oun, Tariq Ahmed		NO
The co-ordinative practices of temporary organisations	2016	Peters, Linda D; Pressey, Andrew D		NO
The Level of Use of Project Management Methods, Techniques and Tools and Their Impact on Project Success - Selected Region of Czech Republic	2016	Doskocil, Radek	NO	
The relationship between project managers' age, gender, and professional experience on career success: A correlation study	2016	Sava, Danny C., Jr.	NO	
Transformational Leadership Behavior's Effect on Knowledge Application: A Systematic Review	2016	Lo, Felicia F.	NO	
Análise da transferência de conhecimento em projetos na indústria petroquímica/Analysis of knowledge transfer in projects in the petrochemical industry	2015	Marcelo Müller Beuren; Alejandro Germán Frank; Duarte Ribeiro, José Luis	NO	NO
Complex factors related to capital construction project success: A case study	2015	Lambert, Esther L.	NO	NO

Title	Year	Authors	Included based on title review?	Included based on abstract review?
At what level is your organization managing knowledge?	2015	Galati, Francesco	YES	YES
Developing complex-project capability through dynamic organizational learning	2015	Ahern, Terence; Byrne, P J; Leavy, Brian	YES	YES
Issues in the management of embedded knowledge in project-based organizations: the project actor's role	2015	D'armagnac, Sophie	YES	YES
Knowledge creation and utilization in project teams	2015	Oluikpe, Paul Ihuoma	YES	YES
Managing knowledge and managing knowledge work: what we know and what the future holds	2015	Newell, Sue	YES	YES
Current State of Virtual Project Management and Global Project Implementations	2015	Ekpo, Felix J.	YES	NO
The influence of informal governance mechanisms on knowledge integration within cross-functional project teams: a social capital perspective	2015	Zhang, Lianying; Cheng, Jiajia; Wang, Danfeng	YES	YES
THE PROTECTION OF VALUABLE TACIT KNOWLEDGE IN A LEARNING ALLIANCE: A CASE STUDY IN INTERORGANIZATIONAL LEARNING	2015	Edwards, Thomas V, Jr	YES	YES
Unpacking 'lessons learned': investigating failures and considering alternative solutions	2015	Wiewiora, Anna; Murphy, Glen	YES	YES
Exploring Critical Success Factors for Managing Complex Information Technology Projects in Federal Agencies	2015	Boyles, Kyle	NO	
Information Systems Strategy and the Role of Chief Information Officers: Strategizing and Aligning Practices	2015	Karpovsky, Anna	NO	
Learning cycles and focus groups: A complementary approach to the A3 thinking methodology	2015	Tortorella, Guilherme Luz; Viana, Samanta; Fettermann, Diego		NO
Organizational learning from information technology projects: A case study exploring lessons learned	2015	Johnson, Kirk L.		NO

Title	Year	Authors	Included based on title review?	Included based on abstract review?
Proceedings of the 57th Annual Meeting of the Academy of International Business: "Global Networks: Organizations and People"	2015	Mudambi, Ram; Kiyak, Tunga	NO	
Strategies for managing exploration, global value chains, and knowledge flows in high-technology firms	2015	Craig, Thomas Dominic		NO
Virtual R&D Project Teams: From E-Leadership To Performance	2015	Bonet Fernandez, Dominique Bonet; Jawadi, Nabila		NO
A maturation model for project-based organisations - with uncertainty management as an always remaining multi-project management focus	2014	Jerbrant, Anna	NO	
An investigation of the role of communication in IT projects	2014	Marly Monteiro de Carvalho		NO
Antecedents and consequences of using information from customers involved in new service development	2014	Carbonell, Pilar; Rodriguez-Escudero, Ana-Isabel		NO
Aspects of project learning in construction: a socio-technical model	2014	Ali Mohammed Alashwal; Abdul-Rahman, Hamzah	NO	
Asset Re-use of Images From a Repository	2014	Herman, Deirdre	NO	
Beyond projection: using collaborative visualization to conduct qualitative interviews	2014	Comi, Alice; Bischof, Nicole; Eppler, Martin J	NO	
Diagnostic framework and health check tool for engineering and technology projects	2014	Philbin, Simon P; Kennedy, Donald A	NO	
Does investment in project management pay off?	2014	Spalek, Seweryn		NO
Domtar Corp - Annual/10K Report, 2014	2014		NO	
An integrative model for knowledge transfer between new product development project teams	2014	Frank, Alejandro Germán; Ribeiro, José Luis Duarte	YES	YES

Title	Year	Authors	Included based on title review?	Included based on abstract review?
Analyzing Lessons Learned Practice in Complex Product Development: Identification of Barriers and Recommendations	2014	Chirumalla, Koteswar	YES	YES
Examining the effect of individualism and collectivism on knowledge sharing intention	2014	Yu, Mi	YES	YES
Influence factors and process stages of knowledge transfer between NPD teams: A model for guiding practical improvements	2014	Alejandro Germán Frank; Duarte Ribeiro, José Luis	YES	YES
Inter-organizational Relationship and Innovation: A Review of Literature	2014	Najafian, Mina; Colabi, Amir Mohammad		YES
Knowledge Sharing in Project Teams: A Research Model Underpinned by Action Learning	2014	Ahmed, Ghosia; Ragsdell, Gillian; Olphert, Wendy	YES	YES
Towards a Methodology for Lessons Learned Practice in Complex Product Development	2014	Chirumalla, Koteswar	YES	YES
Knowledge Management in the Project Life Cycle - Initial Research on Polish Smes	2014	Lapunka, Iwona; Pisz, Iwona		NO
Linking project-based production and project management temporary systems in multiple contexts: An introduction to the special edition	2014	Oerlemans, Leon Ag; Pretorius, Tinus		NO
The Formation of Cross-Sector Development Partnerships: How Bridging Agents Shape Project Agendas and Longer-Term Alliances: JBE	2014	Manning, Stephan; Roessler, Daniel	NO	
The History Of Project Management	2014	Seymour, Tom; Hussein, Sara	NO	
The impact of collaborative engagement on knowledge and performance gains in episodic collaborations	2014	Nix, Nancy W; Zacharia, Zach G		NO
The Innovation Imperative: Not Without Design	2014	Hardin, Dianne		NO
Trajectory of innovation in emerging industries: Evidence from the global wind power industry	2014	Awate, Snehal S.	NO	

Title	Year	Authors	Included based on title review?	Included based on abstract review?
A Percepção Da Inovação No Contexto De Serviços E Sua Influência Na Satisfação E Lealdade Do Cliente: Revista Brasileira de Marketing Revista Brasileira de Marketing	2013	Wanderley Amaral, Nicoli; De Oliveira Mota, Marcio; Augusta Ferreira De Freitas, Ana; Botelho Junior, Sergio	NO	
Assessing the role of pre-project planning sessions in developing a successful project strategy	2013	Hoeger, James A.	NO	
Aveng Ltd. - Annual Report, 2013	2013		NO	
Bridging situated learning theory to the resource-based view of project management	2013	Jugdev, Kam; Mathur, Gita	YES	NO
Characteristics and Leadership Strategies of Effective Virtual Team Leaders	2013	Desper, Deane Antonio		NO
Classifying virtual collaboration skills: A case study of social network site users' skills and transference to virtual teamwork	2013	Buckholtz, Dale R.	NO	
Client Knowledge Opportunities for a Small Software Firm*	2013	Migliaccio, Mirella; Rivetti, Francesca	NO	
Complexities in innovation management in companies from the European industry: A path model of innovation project performance determinants	2013	Tepic, Mersiha; Kemp, Ron; Omta, Onno; Fortuin, Frances		NO
Endless Development is the Best Quality Assurance: The Case of "Hidemaru Mail"	2013	Ikuine, Fumihiko; Fujita, Hideki	NO	
Enhancing graduate employability through work-based learning in social entrepreneurship: A case study	2013	Huq, Afreen; Gilbert, David H	NO	
Abandoned Projects: Organizational Knowledge and Learning in New Product Development	2013	O'Toole, Jay	YES	YES
Exploring the Alignment of Organisational Goals with KM: Cases in Four Irish Software SMEs	2013	Heavin, Ciara; Adam, Frederic	YES	YES
Facilitators, Inhibitors, and Obstacles - a Refined Categorization Regarding Barriers for Knowledge Transfer, Sharing, and Flow	2013	Paulin, Dan; Winroth, Mats	YES	YES

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Knowledge objects as shared system representation	2013	Di Maio, Paola	YES	YES
Managing knowledge in large-scale virtual projects: a community-based approach	2013	Marabelli, Marco; Rajola, Federico; Frigerio, Chiara; Newell, Sue	YES	YES
Systematization of Recurrent New Product Development Management Problems: EMJ EMJ	2013	Costa, Janaina M H; Rozenfeld, Henrique; Amaral, Creusa Sayuri Tahara; Marcacinit, Ricardo M; Rezende, Solange Oliveira	YES	YES
The Effects of Organizational Leadership and Culture on Tacit Knowledge Utilization	2013	Evans, Carl	YES	YES
Understanding communication channel choices in team knowledge sharing	2013	Snyder, Jason; Joo Eng Lee-Partridge	YES	YES
Identifying some internal S/F factors of NSD project performance	2013	Boukis, Achilleas	NO	
Knowledge Agent Theory (KAT) for Knowledge Activation in the Leagile Manufacturing Environment of the Soft Goods Industry	2013	Chan, Yan Yu	NO	
Knowledge Sharing and Mobilization Barriers Within a Matrix Organization	2013	Juneau, Harry L., Jr.		
Methodological issues in dynamic capabilities research - a critical review	2013	Eriksson, Taina	NO	
Modeling the improvement-user satisfaction relationship in mobile applications: a user review-based decision tree approach	2013	Song, Bomi; Jo, Haejin; Park, Yongtae	NO	
Organising project-based companies	2013	Jerbrant, Anna		NO
Practicing Technology Implementation: The Case of An Enterprise System	2013	Awazu, Yukika	NO	

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REDE SOCIAL PARA TRANSFERÊNCIA DE CONHECIMENTO E INOVAÇÃO SOCIAL/NETWORK FOR KNOWLEDGE TRANSFER AND INNOVATION	2013	Mussi, Clarissa Carneiro; Faraco, Rafael Ávila; Angeloni, Maria Terezinha; Peres, Felipe Marcon	NO	
Reflections on knowledge-based approaches to the organization of production	2013	Grant, Robert M		NO
The Impact of Knowledge Inflows on the Performance of National Laboratories in Technological Latecomer Countries	2013	Ploykitikoon, Pattravadee		NO
The role of project management offices (PMOs) in IS project success and management satisfaction	2013	Ward, John; Daniel, Elizabeth M	NO	
The Use of System Dynamics to Understand the Consequences of Project Controls with Dynamic Performance Measures in DoD Project Management	2013	Cantwell, Patrick R.	NO	
Toward a new understanding of the project manager as a mixing valve of organizational knowledge: A case study approach	2013	Bibbes, Theodore Nicholas		
Web-based project portfolio management portal success: A quantitative investigation	2013	Excellent, Frendy		NO
An Analysis of Bilateral Project Consortia in the Case of Greece and Bulgaria	2012	Katsikis, Ioannis N; Garyfalos Frangidis	NO	
Design of a knowledge management and organizational learning system for IT project portfolio management	2012	Erhard, Itay Moshe Valter		
Evaluating the Influence of Internal Project Management Communities of Practice on Project Management Performance	2012	Papa, Ronald P., Jr.		NO
Examining an Effective Project Management Office Model for Global Software Development Environments	2012	Lim, Jonathan	NO	
Examining the relationship between project risk management and information technology (IT) project success	2012	D'souza, Christopher	NO	
Exploring Stakeholder Alignment Within the Requirements Planning Phase of Business Integration Projects	2012	Coffey, Andrew Paul	NO	

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Gender-based comparison of project manager leadership behaviors: A quantitative study	2012	Karch, Donna M.	NO	
Do interactions among elements of knowledge management lead to acquiring core competencies?	2012	Shaabani, Esmaei; Ahmadi, Heidar; Yazdani, HamidReza	YES	YES
Dynamics of Knowledge Integration in a Project Network	2012	Tiwari, Shalini R; Gupta, Rajen	YES	YES
KNOWLEDGE IS POWER? AN INQUIRY INTO KNOWLEDGE MANAGEMENT, ITS EFFECTS ON INDIVIDUAL CREATIVITY, AND THE MODERATING ROLE OF AN ENTREPRENEURIAL MINDSET	2012	Phipps, Simone T A; Prieto, Leon C	YES	YES
Improvement in Product Development: Use of back-end data to support upstream efforts of Robust Design Methodology	2012	Vanajah Siva	NO	
Knowledge transfer between NPD project teams	2012	Frank, Alejandro; Echeveste, Márcia	YES	YES
Storytelling as a Factor in Increasing Intellectual Capital of Project-Based Companies	2012	Aramo-Immonen, Heli; Jussila, Jari	YES	YES
The Effects of a Multilevel web Based Daily Reporting System on Knowledge Management of a Multi Project Organization	2012	Fotoohi, Hadi	YES	YES
The Interactions Among Information Technology Organizational Learning, Project Learning, and Project Success	2012	McKay, Donald S., II		YES
Intégration des connaissances client dans un projet en systèmes d'information : influence de l'environnement de connaissance du projet	2012	Carton, Sabine; Farastier, Armelle	NO	
Leadership in projects: what we know from the literature and new insights	2012	Clarke, Nicholas		NO
Managing project problem-solving patterns	2012	Cavaleri, Steven; Firestone, Joseph; Reed, Fred	NO	
Marketing and technology strategies for innovative performance	2012	Sicotte, Hélène; Drouin, Nathalie; Delerue, Hélène	NO	

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NPD innovation with creativity templates utilizing innovation reflection in units of practice	2012	Johnson, Erik Albert Johan	NO	
Organizational adoption of new service development tools	2012	Jin, Dayu; Chai, Kah-Hin; Kay-Chuan Tan	NO	
Organizational Memory and Project Development: A Case Study Examining How a Small Business Uses Its Organizational Memory When Making Project Development Decisions	2012	Berridge, Mary Stephanie	NO	
Sociomateriality and boundary objects in information systems development	2012	Doolin, Bill; Mcleod, Laurie		NO
TAKING STOCK: CAPABILITY DEVELOPMENT IN INTERORGANIZATIONAL PROJECTS**	2012	Schüßler, Elke; Wessel, Lauri; Gersch, Martin		NO
The dynamics of client-consultant relationships: exploring the interplay of power and knowledge	2012	Pozzebon, Marlei; Pinsonneault, Alain		NO
The relationship between organizational culture and quality of communication in project management	2012	Iroanya, Clifford Chukwuemeka		NO
Web 2.0 technologies for effective knowledge management in organizations: A qualitative analysis	2012	Nath, Anupam Kumar	NO	
A Framework for Organizing Lean Product Development: EMJ EMJ	2011	Hoppmann, Joern; Rebentisch, Eric; Dombrowski, Uwe; Zahn, Thimo		NO
A Modified Delphi Study of Leadership Profiles of the New Product Development Process Stages	2011	Moore, Darryl Allan		NO
A qualitative exploration of entrepreneurial knowledge transfers	2011	Burns, Alan T; Acar, William; Datta, Pratim		NO
Awaking the Public Sector with Strategic Corporate Philanthropy: Revitalizing the Public Servant's Organizational Knowledge, Innovative Capability, and Commitment	2011	Jackson, Janese Marie	NO	
Communication, goals and collaboration in buyer-supplier joint product design	2011	Yan, Tingting	NO	

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Enterprise system implementation projects: A study of the impact of contextual factors on critical success factors	2011	Van Scoter, Diane J.	NO	
Improving Product Development through Front-Loading and Enhanced Iteration Management	2011	Martínez, Cecilia; Farris, Jennifer A; Letens, Geert		NO
Identifying knowledge boundaries: the case of networked projects	2011	Swart, Juani; Harvey, Philippa	YES	YES
Improving project learning: a new approach to lessons learnt	2011	Fuller, Paul A; Dainty, Andrew R J; Thorpe, Tony	YES	YES
Knowledge-mapping model for construction project organizations	2011	Gangcheol Yun; Shin, Dohyoung; Kim, Hansoo; Lee, Sangyoub		NO
Learning through shared objects in outsourced software development	2011	Vakkayil, Jacob D	NO	
Linking internal market orientation and new service performance	2011	Sanchez-Hernandez, M Isabel; Miranda, Francisco J	NO	
Resolving the creativity-conflict tension in functionally diverse innovation teams	2011	Todorova, Gergana	NO	
Study on Quality control of CoPS Innovation Based on Quality Chain and Quality House	2011	Wang, Xiuhong		NO
The drivers of ERP implementation and its impact on organizational capabilities and performance and customer value	2011	Hwang, Woosang	NO	
The human resource's influence in shaping IT competence	2011	Crawford, Jeff; Leonard, Lori N K; Jones, Kiku	NO	
The relationship between PMI PMBOK guide's nine project knowledge areas and project success: An investigation of manufacturing information technology projects	2011	Maryman, Valerie	NO	
When sugar turns to sh%&: Immediate action decision making and resilience in high reliability teams	2011	Wesner, Bradley Scott	NO	

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A framework for integrating Knowledge Management with Risk Management for Information Technology Projects (RiskManiT)	2010	Karadsheh, Louay A.	NO	
Boundary spanning in offshored information systems development projects	2010	Krishnan, Poornima	NO	
Critical factors for knowledge management in project business	2010	Mian Ajmal; Helo, Petri; Kekäle, Tauno	YES	YES
MANAGING LESSONS LEARNED AND TACIT KNOWLEDGE IN NEW PRODUCT DEVELOPMENT	2010	Goffin, Keith; Koners, Ursula; Baxter, David; van der Hoven, Chris	YES	YES
Leadership: The Project Management Essential	2010	Patterson, James H	NO	
Projects and Processes for Sustainable Organizational Growth: Quarterly Journal	2010	Chinta, Ravi; Kloppenborg, Timothy J		NO
The effect of market orientation on innovation speed and new product performance	2010	Carbonell, Pilar; Rodríguez Escudero, Ana I	NO	
The role of the Project Management Office on Information Technology project success	2010	Stewart, Jacob S.	NO	
Three Essays on New Product Development in Supply Chain	2010	Wang, Zhiqiang	NO	
Towards a better understanding of capital investment decisions	2010	Emmanuel, Clive; Harris, Elaine; Komakech, Samuel	NO	
A multidimensional and visual exploration approach to project portfolio management	2009	Zheng, Guangzhi		NO
DISRUPTION FROM THE VIRTUAL WORLD	2009	Noor, Ahmed K	NO	
Examining the dynamics of managing information systems development projects: A control loss perspective	2009	Narayanaswamy, Ravi	NO	

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Exploring IT-based knowledge sharing practices: Representing knowledge within and across projects	2009	Dulipovici, Alina M.	YES	NO
Information systems offshore outsourcing in China: A case study of inter-organizational collaboration in offshore software development for a large-scale Taiwanese bank	2009	Huang, Shyh-Lu	NO	
Integrated test and evaluation (T&E) management: The Information Mission Assessment Tool (IMAT) prototype	2009	Guernsey, Gregory Gene	NO	
Cultural impacts on knowledge management and learning in project-based firms: Very Informal Newsletter on Library Automation Very Informal Newsletter on Library Automation	2009	Ajmal, Mian M; Kekäle, Tauno; Takala, Josu	YES	YES
Proactive knowledge accessibility and causal clarity: Key factors in improving project management and cross -project learning	2009	Wasiyo, Khaitisa	YES	YES
Project leader's dual socialization and its impact on team learning and performance: A diagnostic study	2009	Gautam, Tanvi		YES
Leveraging diversity and technology for team performance: The role of variety, disparity, virtuality and knowledge sharing	2009	Gajendran, Ravi Shanker	NO	
Models and strategies for managing knowledge in networked environments: The viewpoint of small business*	2009	Bolisani, Ettore; Scarso, Enrico	YES	NO
Team learning, top management support and new product development success	2009	Islam, Md Zahidul; Doshi, Jason A; Hanif Mahtab; Zainal Ariffin Ahmad	YES	NO
The alignment of knowledge strategies	2009	Denford, James Stephen	NO	
An Integrated Knowledge Management Framework for knowledge enablement of Information Systems Development projects	2008	Konda, Damodar	NO	
Collaborative academic/practitioner research in project management: Examples and applications	2008	Derek H.T. Walker; Anbari, Frank T; Bredillet, Christophe; Söderlund, Jonas; Cicmil, Svetlana; Thomas, Janice	NO	

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Creating new technologies in the semiconductor industry: An investigation of the search and diffusion of knowledge	2008	Ota, Kazuhiko		NO
Dynamics in team-based knowledge work: Understanding processes and media use	2008	Erhardt, Niclas L.	NO	
Étude des phases en amont des projets d'adoption des technologies RFID pour l'amélioration des chaînes d'approvisionnement	2008	Bendavid, Ygal	NO	
Examining publicly-funded value chain projects: Five case studies involving the Ontario agrifood industry	2008	Snoek, Glen	NO	
Heedful interrelating, knowledge sharing, and new drug development	2008	Styhre, Alexander; Ollila, Sanne; Roth, Jonas; Williamson, David; Berg, Lena	NO	
Hybrid Offshoring: Composite Personae and Evolving Collaboration Technologies	2008	Denny, Nathan; Mani, Shivram; Nadella, Ravi Sheshu; Swaminathan, Manish; Samdal, Jamie		NO
Enhancing organisational learning in teams: has the middle manager got a role?	2008	Costanzo, Laura A; Tzoumpa, Vicky	YES	YES
Evaluating Benefits and Challenges of Knowledge Transfer Across Projects: EMJ EMJ	2008	Landaeta, Rafael E	YES	YES
Impact of the internal business environment on knowledge management within construction organisations	2008	Chen, Le; Mohamed, Sherif	YES	YES
Lean Principles for the Lean Project-Based Enterprise	2008	Letens, Geert; Farris, Jennifer; Van Aken, Eileen	NO	
Permanent and temporary work practices: knowledge integration and the meaning of boundary activities	2008	Maaninen-olsson, Eva; Wismén, May; Carlsson, Sven A	YES	YES
The management of consultancy knowledge: an internationally comparative analysis	2008	Donnelly, Rory	YES	YES
Leveraging knowledge assets to improve new product development performances	2008	Linzalone, Roberto	YES	NO

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Project business as a research field	2008	Arto, Karlos; Kujala, Jaakko		NO
Success factors in telecom service development: A grounded theory. Case studies research in the Latin American telecommunication sector	2008	Munoz, Jairo	NO	
The impact of social capital and dynamic capabilities on new product development: An investigation of the entertainment software industry	2008	Voelker, Troy A.	NO	
An Exploratory Study on the Roles of Network Structure and Knowledge Processing Orientation in Work Unit Knowledge Management	2007	Song, Seokwoo; Nerur, Sridhar; Teng, James T C		NO
Graduate Student Project: Operations Management Product Plan	2007	Fish, Lynn	NO	
Knowledge management approach in build-to-order supply chains	2007	Harry K.H. Chow; Choy, K L; Lee, W B	NO	
Knowledge management repositories: Supporting knowledge work and activity in organizations	2007	Voon, William	YES	NO
Learning and knowledge management in corporate entrepreneurship: Portfolio-level and product-level determinants of launch in continuous new product development	2007	Green, Kimberly M.		NO
Harmonising codification and socialisation in knowledge management	2007	Apostolou, Dimitris; Abecker, Andreas; Mentzas, Gregoris	YES	YES
Innovation and the dynamics of capability accumulation in project-based firms	2007	Bayer, Steffen; Gann, David	YES	YES
Managers' perceptions of learning in new product development	2007	Koners, Ursula; Goffin, Keith	YES	YES
Multidisciplinary knowledge transfer in training multimedia projects	2007	Freyens, Benoît; Martin, Marguerite	YES	YES
Tacit knowledge and organisational performance: construction industry perspective	2007	Pathirage, Chaminda P; Amaratunga, Dilanthi G; Haigh, Richard P	YES	YES

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Unwrapping front -loading: Explaining problem-solving performance in complex product development	2007	Gouel, Philippe E.	NO	
A success paradigm for project managers in the aerospace industry	2006	Bauer, Barry Jon	NO	
Constructing, enacting and packaging innovations	2006	Mørk, Bjørn Erik; Hoholm, Thomas; Aanestad, Margunn		NO
Implementing knowledge management to support executive decision -making in a joint military environment: Key enablers and obstacles	2006	Ward, Thomas E., II	NO	
Incorporating environmental concern in product development: A study of project characteristics	2006	Johansson, Glenn	NO	
Innovating for supply chain integration within construction	2006	Malik M.A. Khalfan; McDermott, Peter	NO	
IT personnel sourcing decisions in IT projects	2006	Wu, Wilfred W.	NO	
Knowledge integration in software teams: An analysis of team, project, and IT -related issues	2006	Mehta, Nikhil	NO	
Knowledge management for technological innovation in organizations: The fusion process for creating intellectual capital	2006	Heffner, Michael Clifford	NO	
Learning how to learn from each other: The educational possibilities of a company work improvement team	2006	Severson, David Irving	YES	NO
Exploring the Dynamics of Knowledge Integration: Acting and Interacting in Project Teams	2006	Enberg, Cecilia; Lindkvist, Lars; Tell, Fredrik	YES	YES
Managing Trade-offs and Tensions between Knowledge Management Initiatives and Expertise Development Practices	2006	Oshri, Ilan; Pan, Shan L; Newell, Sue	YES	YES
Sharing Knowledge Across Projects: Limits to ICT-led Project Review Practices	2006	Newell, Sue; Bresnen, Mike; Edelman, Linda; Scarbrough, Harry; Swan, Jacky	YES	YES

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Strategies for Preventing a Knowledge-Loss Crisis	2006	Salvatore Parise, Rob Cross, Thomas H. Davenport	YES	YES
Program and project managers becoming part- time marketers in Gummeson's relationship marketing networks model: Framework, implications, and operational strategies	2006	Lu, Paul J.	NO	
Project Performance: How to Assess the Early Stages: EMJ EMJ	2006	Parsons, Vickie S	NO	
Project strategy: The path to achieving competitive advantage/value	2006	Poli, Michael		NO
The drama of knowledge transfer in a merger environment: A case study	2006	Perri, Mary	NO	
Three perspectives on innovation in interorganizational networks: Systemic innovation, boundary object change, and the alignment of innovations and networks	2006	Taylor, John Eric		NO
A Hierarchical Product Development Planning Framework	2005	Anderson, Edward G, Jr; Joglekar, Nitin R	NO	
A study of transformational and transactional leadership and the effect on project manager turnover intentions	2005	Epstein, William G.	NO	
An exploratory study on interorganizational knowledge sharing in an information system implementation environment	2005	Lertpittayapoom, Nongkran	NO	
Anatomy of knowledge: A grounded theory investigation towards a knowledge emergence model for high -tech organizations	2005	Jasinski, Debra A.	NO	
Assessing NASA strategic project leadership in an era of 'better, faster, cheaper'	2005	Sauser, Brian J.		NO
Identification in Face-to-Face, Hybrid, and Pure Virtual Teams: Untangling the Contradictions	2005	Fiol, C Marlene; O'Connor, Edward J	YES	NO
Information systems development as emergent socio-technical change: a practice approach	2005	Luna-Reyes, Luis F; Zhang, Jing; Gil-García, J Ramón; Cresswell, Anthony M	NO	

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Learning during developing and implementing new bank offerings	2005	Stevens, Eric; Dimitriadis, Sergios	NO	
Linking project management with business strategy	2005	Srivannaboon, Sabin	NO	
Management of Knowledge in Project Environments	2005	Davenport, Elisabeth		NO
Managing the new service development process: towards a systemic model	2005	Stevens, Eric; Dimitriadis, Sergios	NO	
Methods for modeling and supporting innovation processes in SMEs	2005	Scozzi, Barbara; Garavelli, Claudio; Crowston, Kevin	NO	
Barriers and levers towards knowledge management configurations: A case study-based approach: IMS	2005	Martini, Antonella; Pellegrini, Luisa	YES	YES
Operations & Production Management	2005	Anonymous	NO	
Continuous improvement in product development: Improvement programs and quality principles	2005	Nilsson-Witell, Lars; Antoni, Marc; Dahlgaard, Jens J		YES
Inter-project improvement in product development	2005	Antoni, Marc; Nilsson-Witell, Lars; Dahlgaard, Jens J	YES	YES
KNOWLEDGE TRANSFER AND LEARNING: PROBLEMS OF KNOWLEDGE TRANSFER ASSOCIATED WITH TRYING TO SHORT-CIRCUIT THE LEARNING CYCLE	2005	Newell, Sue	YES	YES
Learning from collaborative new product development projects	2005	Kleinsmann, Maaike; Valkenburg, Rianne	YES	YES
Learning-Based Project Reviews: Observations and Lessons Learned from the Kennedy Space Center: EMJ EMJ	2005	Kotnour, Timothy; Vergopia, Catherine	YES	YES
Trade-offs between knowledge exploitation and exploration activities	2005	Oshri, Ilan; Pan, Shan L; Newell, Sue	YES	YES

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A multi-dimensional view of entrepreneurship: Towards a research agenda on organisation emergence	2004	Jin-ichiro Yamada	NO	
Achieving Organizational Learning Through Team Competition: EMJ EMJ	2004	Szarka, Frank E; Grant, Kevin P; Flannery, William T		NO
Ethnography/Observational Research	2004	Anonymous	NO	
Hispanic	2004	Anonymous	NO	
Increase of organizational performance in complex knowledge -intensive industries through the employment of IT applications	2004	Bach, Christian	NO	
Information Management & Technology	2004	Anonymous	NO	
Innovation by hybridization: Managing the introduction of lean production into Volvo do Brazil	2004	Wallace, Terry	NO	
Innovation management and organizational learning: a discursive approach	2004	Chanal, Valerie		NO
Knowledge acquisition and transfer in product development: A comparative case study	2004	Burns, Alan T.	YES	NO
Managing NPD: Cost and Schedule Performance in Design and Manufacturing	2004	Bajaj, Akhilesh; Kekre, Sunder; Srinivasan, Kannan	NO	
Organizational learning, knowledge and technology transfer: a case study	2004	Daghfous, Abdelkader	YES	NO
Paths to deutero-learning through successive process simulations: a case study	2004	Haho, Päivi		NO
Project Manager Skill Development: A Survey of Programs and Practitioners: EMJ EMJ	2004	Carbone, Thomas A; Sampson Gholston	NO	

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Cultural Mix and Success Factors in New Product Development: An Example from the Thai Food Processing Industry	2004	Speece, Mark; Prisana Suwannaporn		YES
Enhancing Cross-Project Learning: EMJ EMJ	2004	Newell, Sue	YES	YES
What Do Organizations Know? Dynamics of Justification Contexts in R&D Activities: The Interdisciplinary Journal of Organization, Theory and Society The Interdisciplinary Journal of Organization, Theory and Society	2004	Tell, Fredrik		YES
Technological learning of new technology -based ventures in the context of university -linked technology incubators	2004	Scillitoe, Joanne Lee	NO	
Antecedents of project learning and time-to-market during new mobile service development	2003	Blazevic, Vera; Lievens, Annouk; Klein, Evelien		NO
Control enactment in global virtual teams	2003	Crisp, Charles Bradley	NO	
Critical project competences - a case study	2003	Ruuska, Inkeri; Vartainen, Matti		NO
Developing and sustaining project management as a strategic asset: A multiple case study using the resource-based view	2003	Jugdev, Kam	NO	
Exploring the customer feedback process	2003	Fundin, Anders P; Bergman, Bo L S		NO
Information systems as a reference discipline for new product development	2003	Nambisan, Satish		NO
Innovation and network: The impact of initial conditions on interfirm network formation of entrepreneurial firms	2003	Ding, Hung-bin	NO	
Knowledge management across projects	2003	Landaeta Feo, Rafael Ernesto	YES	YES
Knowledge management and the occasional links with performance	2003	Kalling, Thomas	YES	NO

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Linking team competences to organisational capacities in health care	2003	Hyland, Paul; Davison, Graydon; Sloan, Terry	NO	
Linking team competences to organisational capacity	2003	Hyland, Paul; Davison, Graydon; Sloan, Terry	NO	
Managing action and research for rigor and relevance: The case of Fokker aircraft	2003	Ayas, Karen	NO	
MANAGING PRODUCT VARIETY: AN INTEGRATIVE REVIEW AND RESEARCH DIRECTIONS*	2003	Ramdas, Kamalini	NO	
Marketing Research and New Product Development Success in Thai Food Processing	2003	Prisana Suwannaporn; Speece, Mark	NO	
Organizational learning in multidisciplinary teams: Knowledge brokering across communities of practice	2003	Beers, Robin L.	YES	NO
Palliative care teams and individual behaviors	2003	Davison, Graydon; Sloan, Terry	NO	
INNOVATION OR MULTIPLE COPIES OF THE SAME LOTTERY TICKET: THE EFFECT OF WIDELY SHARED KNOWLEDGE ON ORGANIZATIONAL ADAPTABILITY	2003	Stewart, Anne M; Mullarkey, Guy W; Craig, John L	YES	YES
Learning generators: Project teams re-conceptualized	2003	Sense, Andrew J	YES	YES
Technological and organizational tools for knowledge management: In search of configurations	2003	Corso, Mariano; Martini, Antonella; Pellegrini, Luisa; Paolucci, Emilio		NO
The effect of an integrated knowledge management architecture on organizational performance and impact. The case of the World Bank	2003	Fonseca, Ana Flavia	NO	
Memory of the Organisation and Memories within the Organisation	2003	Paoli, Massimo; Prencipe, Andrea	YES	YES
The knowledge advantage: Tracing and testing the impact of knowledge characteristics and relationship ties on project performance	2003	Kang, Jina	NO	

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The praxis of knowledge sharing in organizations: A case study	2003	Ipe, Minu	NO	
The role of reputation building in international R&D project collaboration	2003	Christiansen, John K; Vendelo, Morten T		NO
Achieving Visions through Strategic Project Management (Presentation Supporting Paper)	2002	Kotnour, Tim, PhD	NO	
Organizational models for collaboration in the new economy	2002	DeFillippi, Robert J		NO
Strategic ambitions as drivers of improvement at DaimlerChrysler	2002	Bossink, Bart A G; Jan-Nico Blauw		NO
Anatomy of a failed knowledge management initiative: lessons from PharmaCorp's experiences	2002	Braganza, Ashley; Mollenkramer, Gerald J	YES	YES
Developing a Theory of Knowledge Management Across Projects	2002	Kotnour, Timothy, PhD; Landaeta, Rafael	YES	YES
Dynamic learning capability and actionable knowledge creation: Clinical R&D in a pharmaceutical company	2002	Ingelgard, Anders; Roth, Jonas; Shani, A B; Styhre, Alexander	YES	YES
The role of the project management office in achieving project success	2002	Dai, Xiaoyi Christine	NO	
The transfer and transformation of tacit knowledge in new product development: A case study	2002	Fulton, Julia		
Women's experiences...Women's ways of leadership	2002	Ng, Diana Pik-Yi	NO	
An analysis of information technology investment justification for Minnesota state government	2001	Johnson, Nancy Jo	NO	
Artemis Introduces New Enterprise Collaboration Offering Through Intraspect Alliance	2001	Business Editors & Technology Writers	NO	

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Continuous product innovation: A comparison of key elements across different contingency sets	2001	Hapman, Ross L; O'Mara, Charles Edward; Ronchi, Stefano; Corso, Mariano	NO	
E -business as a radical innovation: The effect of organizational capabilities on its adoption in brick and mortar companies	2001	Rauseo, Nancy Ann	NO	
Grafting innovation: The acquisition of entrepreneurial firms by established firms	2001	Puranam, Phanish	NO	
Integrating operations and marketing perspectives of product innovation: The influence of organizational process factors and capabilities on development performance	2001	Tatikonda, Mohan V; Montoya-Weiss, Mitzi M	NO	
Learning typology for new product development teams: A socio -cognitive perspective	2001	Akgun, Ali E.		
Occupational clusters as determinants of organisational learning in the product innovation process	2001	Hyland, Paul W; Gieskes, Jose F B; Sloan, Terrence R	YES	NO
Organizational improvisation and learning: A Field study	2001	Miner, Anne S; Bassofo, Paula; Moorman, Christine		NO
Performance effects of corporate diversification: Roles of knowledge resources, knowledge management capability and information technology	2001	Tanriverdi, Huseyin		NO
Product development decisions: A review of the literature	2001	Krishnan, V; Ulrich, Karl T	NO	
Success and communication in virtual project teams	2001	Delisle, Connie Louise Gail	NO	
The dynamics of knowledge in international strategic alliances: A longitudinal study of service firms	2001	Martin de Holan, Pablo	NO	
The impact of contingent workers on knowledge flow within the firm	2001	Castaneda, Laura Werber		NO

Title	Year	Authors	Included based on title review?	Included based on abstract review?
Knowledge and continuous innovation The CIMA methodology	2001	Boer, Harry; Caffyn, Sarah; Corso, Mariano; Coughlan, Paul; Gieskes, José; Magnusson, Mats; Pavesi, Sara; Ronchi, Stefano		YES
The Project Manager and Project Team Involvement: Implications for Project Leadership	2001	Grant, Kevin P; Graham, T Scott; Heberling, Michael E		NO
Use of a strategic planning process to reinvent corporate training: A case study in developing governance and organizational influence	2001	Kalman, Howard Keith	NO	
Vasa syndrome: Insights from a 17th-century new-product disaster	2001	Kessler, Eric H; Bierly, Paul E, III; Gopalakrishnan, Shanthi		NO
A comparison of corporate and non-corporate adult education as a vehicle for organizational capability migration	2000	Treichler, David Howard		NO
A process model of multiple -concurrent new product development (NPD) process: Analysis of best practices	2000	Verma, Devesh		NO
A theory of product introduction under competition	2000	Souza, Gilvan C.	NO	
Assessing the critical behavioral competencies of information technology (IT) project managers at Southern California Edison	2000	Dutta, Sanjay Kumar	NO	
Assessing the excellence and maturity of new product development processes	2000	Subra, Anand K.	NO	
Building collaborating team trust	2000	Herzog, Valerie Lynne		NO
Continuous learning process in new product development in the Thai food-processing industry	2000	Suwannaporn, Prisana; Speece, Mark	NO	
Facilitating total quality through effective project management	2000	Hides, M T; Irani, Z; Polychronakis, I; Sharp, J M	NO	

Title	Year	Authors	Included based on title review?	Included based on abstract review?
How management can foster continuous product innovation: IMS IMS	2000	Corso, Mariano; Pavesi, Sara	NO	
Information systems development project success and failure: An agency theory interpretation	2000	Mahaney, Robert C.	NO	
Infrastructure under construction: continuous improvement and learning in projects: IMS IMS	2000	Jose F.B. Gieskes; ten Broeke, Andre M	?	NO
Supporting business by facilitating organizational learning and knowledge creation in the MOT community of practice (CoP)	2000	Yi, Jessi Qing		NO
Technological innovation and knowledge creation: A study of the enabling conditions and processes of knowledge creation in collaborative R&D projects	2000	Johnson, William Harold Alexander	YES	NO
A contingency perspective of R&D cross-functional communication in new product development	2000	Chen, Shiuann-Shuoh	YES	YES
Organizational learning practices in the project management environment	2000	Kotnour, Tim		YES
Planning Knowledge for Phased Rollout Projects	2000	Douglas C Bower , Walker, Derek H T	YES	YES
Artificial intelligence and expert systems applications in new product development--a survey	1999	S. Subba Rao; Nahm, Abraham; Shi, Zhengzhong; Deng, Xiaodong; Syamil, Ahmad	NO	
Knowledge management for new product development meetings: The roles of information technology in shared knowledge creation	1999	Raven, Arjan	YES	NO
Management today innovation awards	1999	Myerson, Jeremy	NO	
A learning framework for project management	1999	Kotnour, Tim	YES	YES
United States Fortune 500 companies human resource directors' perceptions regarding competencies required in the 21st century of entry-level business employees with four-year business degrees	1999	Porterfield, Sheila Yvette Crowther	NO	

Title	Year	Authors	Included based on title review?	Included based on abstract review?
Hybrid new product development strategies: EMJ EMJ	1998	Scarcia, Frank; Herrera, Gregory; Sparadoski, Robert; Lichnowski, Andrew; Ehrgott, Jane	?	NO
U.S. Army: New product development: A case study: EMJ EMJ	1998	Corea, Patricia; Gedge, George; Lemmons, Sandi; Pinsky, Judy; et al	NO	
Firms as knowledge brokers: Lessons in pursuing continuous innovation	1998	Hargadon, Andrew B	YES	YES
An anatomy of a decision-support system for developing and launching line extensions	1997	Cohen, Morris A; Eliashberg, Jehoshua; Ho, Teck H	NO	
Behind the learning curve: An investigation of managing learning activities for quality and productivity improvement	1997	Lapre, Michael Armand	?	NO
Continuous improvement and inter-project learning in new product development	1997	Bartezzaghi, Emilio; Corso, Mariano; Verganti, Roberto	YES	YES
MULTIPROJECT STRATEGY AND SALES GROWTH: THE BENEFITS OF RAPID DESIGN TRANSFER IN NEW PRODUCT DEVELOPMENT	1997	NOBEOKA, KENTARO; Cusumano, Michael A		YES
Innovation speed: An empirical analysis of context, antecedents, and outcomes	1996	Kessler, Eric H.	?	NO
Towards the fifth-generation innovation process	1994	Rothwell, Roy	?	NO

APPENDIX B – SLR INCLUSION AND EXCLUSION CRITERIA

Inclusion criteria – general criteria	Rationale
Peer reviewed journals and conference papers were included. No journal “star-rating” selection was considered.	Due to the nature of the topic considered including a “star-rating” selection might have excluded practitioner literature that relevant to the research.

Exclusion criteria – general criteria	Rationale
Works not in the English language were excluded from the SLR.	Works not available in the English language were excluded from the review to avoid misinterpretation of the content due to translation errors.

Inclusion criteria – title review	Rationale
Works including NPD in the title were selected for abstract review.	Works found with the SLR search string containing NPD in the title had a high probability of being of interest for the research.
Works including knowledge management in the title were selected for abstract review.	Works found with the SLR search string containing knowledge in the title had a high probability of being of interest for the research.
Works including knowledge management initiatives in the title were selected for abstract review.	Works found with the SLR search string containing a knowledge management initiative in the title had a high probability of being of interest for the research.
Works that could not be directly included or excluded with the inclusions and exclusions criteria mentioned were included for abstract review.	Papers with a title that did not clearly help understanding the research domain were include for abstract review.

Exclusion criteria – title review	Rationale
Works explicitly not connected to NPD or knowledge management were excluded by title selection.	The challenges NPD project face are very different to those of operations and service projects. NPD projects require a high amount of diversified knowledge and methodologies effective in operations or service environments might have different effect in the NPD context.
Works explicitly belonging to not-NPD or knowledge management domains were excluded by title selection (e.g., operations, marketing, HR, supply chain, strategy, customer satisfaction, artificial intelligence, public sector, studies on gender, etc.)	The SLR search string was running using the “full text” option and therefore a number or articles clearly belonging to different research areas were included in the results and were excluded.
Works explicitly only discussing construction projects were excluded by title selection.	The challenges faced by the construction projects are very different and more similar to those of operations projects and were excluded from the systematic SLR.
Works only discussing performance management only were excluded by title selection.	Performance management is outside of the scope of this research as stated in the problem definition and works only related to performance management were excluded by title review.

Works explicitly only discussing the service sector were excluded by title selection.	The challenges faced by the service sector projects are very different to the NPD challenges and were excluded from the SLR.
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Inclusion criteria – abstract review	Rationale
Works explicitly discussing knowledge management in NPD were included for full paper review.	Knowledge management in NPD is one of the key knowledge domains pertinent to the research.
Works discussing knowledge management initiatives were included for full paper review.	Knowledge management initiatives are the key methodologies for knowledge sharing and use in NPD and works discussing the can be relevant to the research.
Works discussing barriers to knowledge sharing and use were included for full paper review.	Understanding barrier to knowledge sharing and use is important to understand the effectiveness of knowledge sharing and use and were included for full paper review.
Works discussing facilitator to knowledge sharing and use were included for full paper review.	Understanding facilitators to knowledge sharing and use is important to understand the effectiveness of knowledge sharing and use and were included for full paper review.
SLR papers on knowledge management and NPD were included.	SLR papers can provide insights to new theories and empirical works and were included for full paper review.

Exclusion criteria – abstract review	Rationale
Works explicitly only related to performance management were excluded by abstract review.	Performance management is outside of the scope of this research as stated in the problem definition and works only related to performance management were excluded by abstract review.
Works explicitly related to construction projects were excluded by abstract selection	The challenges faced by the construction projects are very different and more similar to those of operations projects and were excluded from the SLR.
Works discussing boundaries and facilitators to knowledge sharing and use as included by title selection.	In order to understand which knowledge management initiatives are effective in NPD and why, it is important to understand what barriers and facilitators exist to knowledge sharing and use.

APPENDIX C – ADDITIONAL SLR RESULTS (2019 - 2023)

Title	Year	Authors	Included based on title review?	Included based on abstract review?
A Study on the Impact of Digital Management on Willingness to Transfer Knowledge in Whole-Process Engineering Consulting Projects	2023	Qing'e Wang;Ding, Mengmeng	NO	
Enhancing Sustainability in Project Management: The Role of Stakeholder Engagement and Knowledge Management in Virtual Team Environments	2023	Bernat, Gisele Blak;Eduardo Linhares Qualharini;Marcela Souto Castro	YES	YES
Influence of motivational factors on knowledge sharing methods and knowledge creation process in an emerging economic context	2023	Azizi, Neda;Akhavan, Peyman;Ahsan, Ali;Khatami, Rahele;Haass, Omid;Saremi, Shahrzad	NO	
Knowledge integration in interdisciplinary research teams: Role of social networks	2023	Xueyan Zhang	YES	YES
Knowledge Management Integrating Organizational Knowledge	2023	Xiaoying Dong, Mengling Yan & Yanni Hu	YES	YES
Project knowledge sharing mechanisms - an exploratory analysis	2023	Sylva Žáková Talpová, Petr Smutný and Jakub Procházka	YES	YES
The effectiveness of relationship quality on knowledge transfer in project teams: the roles of project organizational structure	2023	Xu Ren, Jing Xu, Yali Hao, Song Wang	YES	YES
The mediating role of social dynamics in the influence of absorptive capacity and tacit knowledge sharing on project performance	2023	Fredrick Ahenkora Boamah, Jianhua Zhang, Muhammad Usman Shehzad, Mubashir Ahmad	YES	YES
The R&D Canvas: A Design Thinking Tool for the Management of R&D Projects	2023	Santos, José; Brandão, Ana Sofia	NO	
Agile or Traditional Project Organization: A Quantitative Assessment of Decision Criteria among Firms in the DACH Region	2022	Maier, Nuria Magdalena;Emmerich, Philip	NO	
Bridging the knowledge gap between technology and business: An innovation strategy perspective	2022	Peykani, Pejman;Namazi, Mehdi;Mohammadi, Emran	YES	NO

Title	Year	Authors	Included based on title review?	Included based on abstract review?
Do the Project Manager's Soft Skills Matter? Impacts of the Project Manager's Emotional Intelligence, Trustworthiness, and Job Satisfaction on Project Success	2022	Castro, Marcela;Barcaui, André;Bahli, Bouchaib;Figueiredo, Ronnie	NO	
Dynamic Capabilities in Information Systems Research: A Critical Review, Synthesis of Current Knowledge, and Recommendations for Future Research	2022	Steininger, Dennis M;Mikalef, Patrick;Pateli, Adamantia;Ortiz-de-Guinea, Ana	NO	
Exploring Innovation Ecosystem of Incumbents in the Face of Technological Discontinuities: Automobile Firms	2022	Kim, Joohyun;Paek, Byungjoo;Lee, Heesang	NO	
From the wall of the industry to the soul of society: a review and multi-level analysis on projectification.	2022	Mariana Voros Fregolente;Achilles Camilo Soares Neto;Pereira Ribeiro, Daniel Ricardo;Salerno, Mario Sergio;Davi Noboru Nakano;Marly Monteiro de Carvalho	NO	
Generating Customer Insights in Mid-sized B2B Companies: Integrative Review and Future Research Directions	2022	Seiler, Matthias;Prof. Dr. Andreas Engelen;Prof. Dr. Keith Goffin	NO	
Improving the Effectiveness of Organisational Collaborative Innovation in Megaprojects: An Agent-Based Modelling Approach	2022	Zhao, Na;Congcong Lei;Liu, Hui;Wu, Chunlin	NO	
Knowledge sharing in an interorganizational setting: empirical evidence from the Orange Line metro train project	2022	Rehab Iftikhar and Tuomas Ahola Abstract	YES	YES
Mechanisms for capturing and transferring tacit knowledge between projects	2022	Ricardo Duarte Correa, Luciano Ferreira da Silva and Isabel Cristina Scafuto	YES	YES
Prioritizing Multi-Interwoven Factors in the Project Management Office Using Delphi and Fuzzy DEMATEL	2022	Abozar Zare Khafri;Abbas Sheikh Aboumasoudi;Shakiba Khademolqorani	NO	
Product development management complexity: emerging challenges and the role of senior leadership	2022	Juliano Pavanelli Stefanovitz and Ana Beatriz Lopes de Sousa Jabbour	YES	YES

Title	Year	Authors	Included based on title review?	Included based on abstract review?
The changing context of innovation management: A critique of the relevance of the stage-gate approach to current organizations	2022	Trott, Paul;Baxter, David;Ellwood, Paul;Van der duin, Patrick	NO	
The effect of project management dynamic capabilities on firm performance	2022	Hermano, Víctor;Martin-Cruz, Natalia;Pajares, Javier	NO	
What Skills for Multi-Partner Open Innovation Projects? Open Innovation Competence Profile in a Cluster Ecosystem Context	2022	McPhillips, Marita;Nikitina, Tatjana;Tegtmeier, Silke;Wójcik, Michał	NO	
Exploring coordination practices in digital–physical product development: IMS	2021	Hendler, Stine	NO	
Globalized Adoption of Knowledge Management in New Product Development: A Conceptual Framework	2021	Bak Aun Teoh1, Wei Hong Ling, Amlus Ibrahim	YES	YES
Impact of Communication on Capital Project Performance: A Mediated Moderation Model	2021	Hong-Long, Chen	NO	
Knowledge transfer in institutionalised supplier development and operational performance: the mediating role of absorptive capacity	2021	Sikombe, Shem;Phiri, Maxwell	YES	YES
Ten commandments for successful implementation of Design for Six Sigma	2021	Gijo, E V;Bhat, Shreeranga;Jiju Antony;Park, Sung H	NO	
THE ROLE OF THE PROJECT MANAGEMENT OFFICE IN KNOWLEDGE TRANSFER IN A MATRIXSTRUCTURED ORGANISATION: A CASE STUDY	2021	N. Gomo, H. Steyn1 & C.C. van Waveren1	YES	YES
The Value of Big Data Analytics Pillars in Telecommunication Industry	2021	Keshavarz, Hassan;Akbariah Mohd Mahdzir;Talebian, Hosna;Jalaliyoon, Neda;Ohshima, Naoki	NO	
A structured literature review and suggestions for future effectuation research	2020	Grégoire, Denis A;Cherchem Naïma	NO	
Characterization of Best Practices for Customer/Supplier Collaboration in Co-innovation Projects	2020	Carlos Abraham Moya;Boly, Vincent;Morel, Laure;Gálvez, Daniel;Camargo, Mauricio	NO	

Title	Year	Authors	Included based on title review?	Included based on abstract review?
How open innovation strategy and effectuation within platform ecosystem can foster innovation performance: Evidence from digital multi-sided platform startups	2020	Santoso, Adhi S;Prijadi, Ruslan;Balqiah, Tengku E	NO	
In the field of tension between creativity and efficiency: a SLR of management control systems for innovation activities	2020	Philipp Lill, Andreas Wald and Jan Christoph Munk	YES	NO
Knowledge forms in the project lifecycle: A blueprint for knowledge management in small creative agencies in Johannesburg	2020	Labuscagne, Cobi W	NO	
Knowledge-Sharing Strategies in Distributed Collaborative Product Development	2020	Sanjay Mathrani and Benjamin Edwards	YES	YES
Repository KMS Use and Work Group Performance: The Contingent Role of Group Composition	2020	Kishen Iyengar, Jeffrey Sweeney and Ramiro Montealegre	YES	YES
The intervening role of ambidexterity in the knowledge management project success connection	2020	Alshawabkeh, Rawan;Amani Abu Rumman;Al-Abbadi, Lina;Abu-Rumman, Ayman	YES	YES
The Project-Based Firm: A Theoretical Framework for Building Dynamic Capabilities	2020	Hermano, Víctor;Martin-Cruz, Natalia	NO	
The relationship between knowledge management and leadership: mapping the field and providing future research avenues	2020	Massimiliano Matteo Pellegrini;Ciampi, Francesco;Marzi, Giacomo;Orlando, Beatrice	YES	YES
Communication Management And Knowledge Management In Complex Projects: A Literature Review	2019	de Nadae, Jeniffer;Marly Monteiro Carvalho	YES	YES
Employing the Internal Marketing Theory to Explain How Knowledge dissemination Can Be Enhanced in Organizations	2019	Sheron Lawson	YES	NO
EXPLOITING FIRM CAPABILITIES BY SENSING, SEIZING AND RECONFIGURING CAPABILITIES: AN EMPIRICAL INVESTIGATION	2019	Breznik, Lidiya;Lahovnik, Matej;Dimovski, Vlado	NO	
Global new product development: moderating role of national culture on the link between buyer–seller interactions and innovation outcomes	2019	K. Sivakumar and Subroto Roy	YES	YES

Title	Year	Authors	Included based on title review?	Included based on abstract review?
HIGH-TECH ENTREPRENEURSHIP IN DEVELOPING COUNTRIES: WAY TO SUCCESS	2019	Mukhtarova, K S;Kozhakhmetova, A K;Belgozhakzy, M;Dosmbek, A;Barzhaksyyeva, A	NO	
Impact of critical chain project management and product portfolio management on new product development performance	2019	Octaviano Rojas Luiz;Bernardi de Souza, Fernando;Rojas Luiz, João Victor;Jugend, Daniel;Salgado, Manoel Henrique;da Silva, Sergio Luis	NO	
Projectification The forgotten variable in the internationalization of firms' innovation processes?	2019	Christophe Midler	YES	NO
Root Cause Analysis in Post Project Phases as Application of Knowledge Management	2019	Radek Doskočil and Branislav Lacko	YES	YES
Subsidiary survival: a case study from the Portuguese electronics industry	2019	Silva, Pedro;António Carrizo Moreira	NO	
The Effects of Maturity of Project Portfolio Management and Business Alignment on PMO Efficiency	2019	Ko, Joong Hoon;Kim, Daecheol	NO	
Using scaffold innovation-thinking frameworks to integrate food science and technology into the transdisciplinary engineering design classroom: Revista de Universidad y Sociedad del Conocimiento	2019	Bosman, Lisa;Eom, Sangjun	NO	

APPENDIX D – CASET SELF ASSESSMENT

CASET - Evaluation Template for Case Study Articles			
<div style="border: 1px solid black; padding: 2px; display: inline-block;">ecchi, MA</div>	<div style="border: 1px solid black; padding: 2px; display: inline-block;">Article title</div>	<div style="border: 1px solid black; padding: 2px; display: inline-block;">Project-to-project learning in Global NPD</div>	<div style="border: 1px solid black; padding: 2px; display: inline-block;">Journal</div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">NA</div>
<div style="border: 1px solid black; padding: 2px; display: inline-block; width: 100px; text-align: center;">3</div> <div style="float: right; text-align: right; font-size: small;"> Note how many sources of data were collected, based on the following: </div>			
<div style="font-size: x-small;"> i. interviews (face to face, including unstructured/semi-structured/structured interviews and informal conversations) is ii. surveys iii. observations (including site visits, workshops, ethnography, data feedback sessions) is </div>			
Explanation of measure	Anchoring Statements		
Was a clear explanation given of why the case method was the most appropriate method to adopt?	0 = "No": no explicit argument was given for why the case method was adopted in the research. 1 = "Yes": there was an explicit argument for why the case method was adopted in the research.		
Was there a pilot study proceeding the main study?	0 = "No": there was no pilot study. 1 = "Yes": a pilot study was conducted before the main study.		
Was an explanation provided of which case(s) were chosen and why?	0 = "No": no explicit argument was given about how the case(s) was / were selected. 1 = "Yes": case(s) were selected for theoretical purposes, example ranges from a discussion on why case(s) were chosen to a discussion of polar extremes where cases exhibited extremely high or extremely low value on the constructs of interest.		
Was the research based on multiple sources of data?	0 = "No": the research was based on only one source of data 1 = "Yes": the research was based on more than one source of data		
Was the evidence reviewed and validated by external parties?	0 = "No": the evidence was not reviewed and validated. The article did not explicitly state if the evidence is reviewed and validated by researchers not part of the primary data collection. 1 = "Yes": the evidence was reviewed and validated by the interviewee and/or the company (e.g. through data feedback-sessions); 0 researchers not part of the primary data collection.		
Was it made clear how the data collection process was conducted?	0 = "No": the data collection process was not clear and transparent because there was not sufficient information about the origin and data collected (in terms of areas, topics, themes or constructs), which would allow replication. 1 = "Yes": the data collection process was clear and transparent because interview themes, questions and/or research instruments and protocols specifying data collection circumstances were reported, which would allow replication.		
Were the data coded by multiple investigators?	0 = "No": the data were not coded by multiple investigators working independently, or there was no information about how inter-coder agreement was achieved. 1 = "Yes": the data were coded by multiple investigators working independently, and there was an explanation about how an acceptable agreement was achieved.		
Were findings and empirical evidence presented in a way that made it clear how the author(s) reach their conclusions?	0 = "No": The way in which the author(s) reached their conclusions based on the case data was neither clear nor documented. They "telling the story" and not "showing the evidence", and any quotes used were selected to support the authors' conclusions. 1 = "Yes": The article was explicit and clear in demonstrating how the empirical data were used to arrive at the conclusions, providing evidence" (through the use of approaches such as tables, data displays, coding schemes and other visual aids).		
Did the case analysis move beyond description and conceptual ordering?	0 = "No": The results from the case analysis were mostly descriptive and/or simply consisted of condensing data into patterns and case facts. This was achieved by, for example, developing a conceptual framework or model from the case(s), formulating propositions by future research, and/or systematically discussing results in relation to existing literature.		
Was there a discussion about the quality of the research?	0 = "No": there was no explicit discussion about the quality of the research. 1 = "Yes": there was an explicit discussion reflecting on the quality of the research (either in the section on research design stage or of limitations), which covered one or more dimensions of validity and reliability, showing that authors were aware of the need to enhance the quality of the research.		
Overall quality			

APPENDIX E – PROJECT 1 EXAMPLE FROM THE OBSERVATION NOTEBOOK

██████████ – ██████████ [supplier] visit ██████████, 19 Oct 2019

VehicleSystemsCo participants: Michele Cecchi (MC), ██████████ (TB), ██████████ (KL), ██████████ (TL), ██████████ (EG); ██████████ (CJ), ██████████ (LZ).

██████████ [supplier] participants: ██████████ (LW) Sales Director, ██████████ (BZ) Project Engineer, ██████████ (RL) Project Manager, ██████████ (MW) CEO.

Timing: ██████████ [supplier] says the ██████████ [component] tooling is 8 weeks late due to sub-supplier mistake: they produced the tooling to 603152 Rev A instead of the 603152 Rev B. The tooling will need to be completely remade. TB: ‘We need to deliver parts to ██████████ [customer name] by 11/3, we have 3 weeks of assembly and 4 weeks on internal testing. What can you do to go faster? Can we offer more money to the tooling supplier to fast-track?’ LW will try and escalate with the leadership team of the ██████████ [sub-supplier].

Technical: BZ reported status of internal testing. Part-to-part variation and inconsistent final flow measurements reported. TB commented that he doesn’t expect the components to cause the issue and that’s its more likely a problem with the end of line measurement station. Joint DoE needed.

Assembly line review: visited the new automatic assembly line. Good progress of automated assembly line readiness. Impressive static discharge preventions installed. Risk

on O-ring installation poke-yoke for the [REDACTED] [customer 1] and [REDACTED] [customer 2] parts. End of line tester is not ready and needs fixing.

APPENDIX F – INTERVIEW INVITATION NOTICE

From: Cecchi, Michele Angelo

Sent: Sunday 11 July 2021 18:52

To: Cecchi, Michele Angelo; [REDACTED]

Subject: Project-to-project learning in NPD - PhD interview

When: Wednesday 21 July 2021 18:30-19:00 (UTC+01:00) Amsterdam, Berlino, Berna, Roma, Stoccolma, Vienna.

Where: Microsoft Teams Meeting

Hello [REDACTED],

Thanks again for the research. Please let me know if this slot works for you?

As anticipated, my research investigated “project to project learning in global NPD”, so how we share knowledge across projects in global new product development. Please see below the 3 questions I would like us to discuss.

1. Tell me about how you joined the [REDACTED] and your role on the program
2. What actions did you or the team take to access the knowledge you need on the [REDACTED] program?
3. How did Covid-19 impact your ability to access / share knowledge on the program?

Please let me know if at any time during the chat you feel our discussion is making you uncomfortable and we will change topic / close the call.

Ideally, I would like to record the interview via Teams: this would allow me to be fully focused during the interview, without being distracted by note-taking. The recording will be used to complete my notes/transcript from the call and then deleted. All notes and transcripts will be fully anonymized. Please let me know if you are OK with the recording – I will also ask for confirmation in the call.

Looking forward to chatting with you!

Many thanks,

Michele

APPENDIX G – INTERVIEW KMI PROMPT SHEET

From: Cecchi, Michele Angelo

Sent: 20 July 2021 07:56

To: [REDACTED]

Subject: RE: Project-to-project learning in NPD - PhD interview

Hello [REDACTED],

Thanks again for accepting the meeting invitation. In preparation for tomorrow's review, please find below a list from my literature review of activities NPD teams introduce to increase knowledge sharing. If time allows, please scroll through the list, we will briefly touch on some of these tomorrow.

- Feedback loops
- Brainstorming sessions
- Communities of practice
- Design / components re-use
- Expert yellow pages
- Informal / face-to-face communications
- Job rotations
- Lessons learnt databases
- Mentoring / training
- Middle management knowledge sharing
- Post project reviews
- Project manager camps
- Project reviews
- Re-use of experts
- Storytelling
- Templates / guidelines
- Wiki / repositories

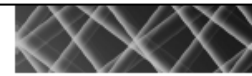
Many thanks,

Michele

APPENDIX H – LIST OF *VehicleSystemsCo* PROJECTS DISCUSSED

Project reference	Degree of innovation	Regional or global	Planned start of production year	Case study
Project A	Incremental NPD	Regional	2023	
Project B	Incremental NPD	Regional	2019	
Project C	Radical NPD	Global	2023	
Project D	Radical NPD	Regional	2025	
Project E	Incremental NPD	Regional	2022	
Project F	Radical NPD	Global	2020	Project 1
Project G	Incremental NPD	Global	2021	Project 2
Project H	Radical NPD	Global	2024	
Project I	Incremental NPD	Global	2025	
Project J	Radical NPD	Global	2023	Project 3
Project K	Radical NPD	Global	2016	
Project L	Radical NPD	Regional	2007	
Project M	Radical NPD	Regional	2018	
Project N	Incremental NPD	Regional	2016	
Project O	Radical NPD	Global	2016	
Project P	Radical NPD	Regional	2017	
Project Q	Incremental NPD	Regional	2011	
Project R	Incremental NPD	Regional	2027	
Project S	Incremental NPD	Regional	2019	

APPENDIX I – RTM PAPER – CECCHI ET AL., 2022



FEATURE ARTICLE

How COVID-19 Impacted The Tacit Knowledge and Social Interaction of Global NPD Project Teams

The complexity framework offers managers an effective way to analyze problems and to generate solutions to manage tacit knowledge and social interaction in dispersed global NPD project teams.

Michele Angelo Cecchi, Stuart Grant, Matthias Seiler, Neil Turner, Richard Adams and Keith Goffin

OVERVIEW: Multinational, technology-intensive companies routinely use globally distributed R&D teams, but COVID-19 represented an additional challenge. Lockdowns and home-office working severely limit human interaction and can impact the communication, social interaction, and knowledge sharing critical to successful R&D. Our study investigated how COVID-19 affected R&D processes at three global companies, using a project complexity perspective. Although R&D managers responsible for global projects are accustomed to the challenges of managing communications, the fact that teams were forced into home-office working made new product development more difficult in several ways. Ensuring that technical details are understood by all members of dispersed teams is crucial. Of particular note, and central to our findings, is the emphasis that R&D managers placed on maintaining a high level of social interaction in their teams, and special efforts were needed to keep interactions at a sufficient level to foster the generation and transfer of tacit knowledge. The findings have strong implications for the way that R&D project management is likely to be conducted in a post-COVID-19 world, and we demonstrate how the complexity framework we used can benefit managers in navigating this and other challenges.

KEYWORDS: COVID-19, NPD team, Social interaction, Tacit knowledge, Complexity

Michele Angelo Cecchi is a leadership and management PhD researcher at Cranfield University's School of Management. His current research focuses on knowledge management in new product development (NPD) in global projects. He has an aerospace engineering background; holds an MSc in aeronautical engineering from Sapienza, University of Rome, and an MSc in thermal power from Cranfield University; and is a chartered engineer with the UK Institution of Mechanical Engineers. As a global engineering manager, he has NPD experience in the automotive, aerospace, and electrical sectors, where he held roles in product engineering and program management. michele-angelo.cecchi@cranfield.ac.uk

Stuart Grant is an R&D leader in a medical devices company, where he has worked for 23 years designing and developing orthopedic devices. He has led product development teams at the UK, US, and China. He has a BSc in product design, an MSc in project management, and is currently a leadership and management PhD researcher at Cranfield University's School of Management. His current research focuses on the discovery of customer insights in product innovation. stuart.grant@cranfield.ac.uk

Matthias Seiler is CEO of BFI GmbH and managing partner of Innovation Management & Business Development GmbH. Prior to his current positions he worked for almost two decades as executive director of innovation management for an international group of companies and as director of new business development and innovation in the chemical industry. He also teaches innovation management and marketing at Heinrich-Heine-University Düsseldorf, Germany. He received his PhD in process/plastics engineering

and thermodynamics from the University of Erlangen-Nuremberg, and an Executive MBA from Mannheim & ESSEC Business School. matthias.seiler@uni-duesseldorf.de

Neil Turner is a professor of project management at Cranfield University's School of Management, having joined from a previous career as an engineering manager in a major telecommunications firm. His current research activities involve organizational knowledge and learning in the context of complex projects, and how managerial practices and organizational strategic choices can improve both delivery performance and resilience. His interests lie primarily in how managers deal with the organizational realities they face and focus on ambidexterity and complexity as ways of understanding this. He has published extensively on the subjects of project management, organizational learning, and ambidexterity. neil.turner@cranfield.ac.uk

Richard Adams is Reader in Entrepreneurship at the Bettany Centre for Entrepreneurship, Cranfield University, where he is also deputy director of doctoral programmes. Previously he held positions at the Universities of Surrey and Exeter, Imperial College London, and with the UK Cochrane Centre. His research is practically focused and lies at the intersection of (responsible) innovation, sustainability, and technology entrepreneurship. He also has a research interest in the methodology and practice of systematic literature reviewing. He has published more than 90 journal and conference papers and is a consulting editor for the *International Journal of Management Reviews*. rj.adams@cranfield.ac.uk

Keith Goffin is a research professor at the Department of Entrepreneurship, Innovation and Technology, Stockholm School of Economics. He is also an Emeritus Professor at Cranfield University's School of Management, UK. Before joining academia, he worked for 14 years in the medical electronics industry. His research has been widely published in journals such as *Journal of Product Innovation Management*, *Journal of Operations Management*, and *R&D Management*. His textbook *Innovation Management: Effective Strategy and Implementation* (Palgrave, 2017, with Rick Mitchell) is now in its 3rd edition. k.goffin@cranfield.ac.uk

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Innovation is essential not only in stable business environments but also in times of crisis (Głodziński and Marcinia 2016; McCausland 2020) to ensure that companies can take advantage of improved conditions once the difficulties pass (Prabhu 2010). Volatile business environments can lead to a focus on damage limitation, operations, and cost control, and thus overwhelm a firm's ability to innovate. The evidence from research is mixed, showing firms reducing (Archibugi and Filippetti 2011; Brenčić, Pfajfar, and Rašković 2012; Archibugi, Filippetti, and Frenz 2013), maintaining, or even increasing, their innovation efforts (Cincera et al. 2012) during a crisis. With respect to the COVID-19 pandemic, the evidence is similarly mixed, reflecting either a slowdown in innovation investments (Bar Am et al. 2020) or concrete plans to continue innovating (Rainmaker 2020).

Although more innovative firms are more likely to survive a crisis (Cefis, Bartoloni, and Bonati 2020), crises impose significant constraints on a firm's innovation processes and activities; existing procedures become destabilized. Companies need to find new ways of working (Dynes and Aguirre 1979; Pearson and Clair 1998), but there is insufficient research on how individual organizations continue to innovate during a crisis.

Similarly, there is only sparse research on R&D management at the project level during crisis situations, and COVID-19 has created new challenges and difficulties. The very nature of R&D presents a series of socio-technical, cultural, and coordination challenges. For co-located teams, these challenges are somewhat easier because their physical proximity facilitates familiarity among team members (Wilson and Doz 2012) and direct communications. For distributed teams, the challenges are greater (Chiesa 1996) because R&D projects are complex and rely on the generation of new knowledge (Goffin and Koners 2011). The rapid rise of globally distributed R&D teams (Gerybadze and Reger 1999; Von Zedtwitz and Gassmann 2002; Jaruzelski, Schwartz, and Staack 2015; Farrington 2020; Papanastassiou, Pearce, and Zanflet 2020) has meant approximately one-third of new product development (NPD) teams use distributed working (Markham and Lee 2013). Global distributed teams are "a single, coordinated product development operation that includes distributed teams in more than one country" (Eppinger and Chittkara 2006, p. 23), enabling the use of both the parent company assets and the advantages of the host countries (Moncada-Paternò-Castello, Voigt, and Vivarelli 2011).

COVID-19 brought additional disruptions: lockdowns, home-office working, social-distancing, and self-isolation severely limiting interaction and negatively impacting the communication and knowledge sharing so critical to successful R&D. The global R&D management challenge has intensified as local units of international teams themselves became physically dispersed by home-office working.

In 2020, we interviewed R&D managers to investigate how COVID-19 had affected global R&D processes and teams. Our respondents came from three global companies in the automotive components, medical devices, and metal

component industries, purposively selected. Maylor and Turner's (2017) complexity framework facilitated our analysis, and respondents validated the findings derived via this framework in a follow-up study in 2021. Our findings show that managers not only implemented technical solutions to keep communication flowing, but they took steps to generate a high intensity of social interaction within teams, which proved vital to keep connections at a sufficient level to foster the generation and transfer of tacit knowledge. We suggest the idea of "tacit knowledge half-life" to indicate the requirement to maintain this potentially fragile aspect of global teamwork, which is so critical to product development, and highlight that continuing to nurture social capital is vital in making this kind of dislocated, distributed work effective. These ideas have strong implications for the way that R&D project management is likely to be conducted in a post-COVID-19 world. We further demonstrate the utility of the Maylor and Turner (2017) framework as a validated, practical tool for ongoing managerial problem-solving in the NPD context, and as a method to reflect and learn from completed work.

Literature Review

Our literature review covers the following topics: knowledge management in global R&D teams; ICT usage in global R&D; social and cultural factors in global R&D; and COVID-19's impact on global R&D.

Knowledge Management in Global R&D Teams

Global R&D teams are not a new phenomenon (Boutellier et al. 1998), and many companies use them successfully (de Brentani, Kleinschmidt, and Salomo 2010; Papanastassiou, Pearce, and Zanflet 2020). Effective communication within and between teams is critical to the NPD process because NPD is a knowledge-intensive activity (Johannessen, Olaisen, and Olsen 1997; Mehra and Dhawan 2003), and project managers must specify "which information different teams will need from each other at particular stages of the project" (Sosa, Eppinger, and Rowles 2007, p. 134).

In R&D projects, teams must share both explicit, codified knowledge and, *tacit knowledge*—that is, knowledge that is extremely difficult to articulate, share, and document (Nonaka and Takeuchi 1995; Hull, Coombs, and Peltu 2000; Soderlund 2002; Goffin and Koners 2011). Projects conducted at a single location benefit from the constant interaction between team members, as this interaction facilitates the exchange of tacit knowledge (Wilson and Doz 2012). By contrast, the challenge in global teams is to transfer embedded knowledge from the main R&D facility (Moncada-Paternò-Castello, Voigt, and Vivarelli 2011) to other R&D locations and vice-versa, particularly in cases where other locations have teams with stronger technological capabilities than the main R&D facility (Song and Shin 2008). Furthermore, the success of global teams stems from the availability of a range of specialists with specific technical knowledge in host countries, unavailable in the home

location (Sole and Edmondson 2002). Global teams can leverage “a diverse but unique combination of talents and knowledge-based resources, thereby enhancing the firm’s ability ... in international markets” (Salomo, Keinschmidt, and de Brentani 2010, p. 955). Another advantage is that global teams can be close to markets, allowing them to have specific local market knowledge, which allows more appropriate products to be developed (Salomo, Keinschmidt, and de Brentani 2010) and more customer-oriented (Comstock 2013).

Sharing knowledge is fundamental to global R&D (Papanastassiou, Pearce, and Zanel 2020), but it presents many challenges (Von Zedtwitz 2020), including the geographic and time zone separation of teams, and differences in culture, work ethics, and communications (Boutellier et al. 1998). Global teams’ ability to access knowledge from different locations brings with it “a curse (a source of communication difficulty) for dispersed teams” (Sole and Edmondson 2002, p. 17). Lewis (1998) identified the problem of achieving a common, consistent understanding of complex projects. The more dispersed a team is, the more challenging the constraint becomes, and so “companies need to identify the optimal level of R&D dispersion that allows them to minimize the cognitive, transaction, and organizational costs of technology acquisition” (Ardito et al. 2018, p. 174).

ICT Usage in Global R&D

Global teams working at multiple locations need optimal communications, which has led to the intensive use of information and communication technology (ICT) to support the creation, capture, and sharing of knowledge (Forman and Zeebroeck 2012). Hauptman and Hirji (1999, p. 179) found “information technology [can help] overcome the negative effect of geographic distance and time-difference in cross-national teams.” Similarly, Zhao et al. (2019) demonstrated how information technology can be leveraged to build organizational agility within global teams. Many studies of ICT have focused on the transfer of information (explicit knowledge), but researchers have found that when ICT focuses heavily on explicit knowledge, knowledge management is not effective (Braganza and Möllenkrater 2002).

ICT tools include videoconferencing, social media, shared CAD systems, and the like. For example, to support the creation and transfer of tacit knowledge, so-called *boundary objects* such as virtual white boards and chat functions can be useful. These boundary objects in virtual communities “impact the relationship between people and technology ... [and] facilitate knowledge sharing among differing social domains” (Marheineke, Habicht, and Mösele 2016, p. 1086). Managers need to consider carefully how and in what ways ICT supports collective or individual processes (Montoya et al. 2009) and remain alert to the human dimension.

ICT can support knowledge management (Howells 1995; Marlon, Barczak, and Hultink 2014), but it cannot mimic the richness of face-to-face social interaction so beneficial to

global R&D. Communications using ICT can also lead to misunderstandings (Wilson and Doz 2012), so, to be effective, the technology needs to be complemented by suitable organizational and human resource practices (Boutellier et al. 1998).

Social and Cultural Factors in Global R&D

Beyond ICT use, social interactions influence a team’s ability to be successful in NPD (Muethel, Siebrat, and Hoegl 2012). Grant (1996) argued that stable and good social relationships positively impact the work of global teams and, similarly, Baxter, Goffin, and Szwedczewski (2013) observed that, for globally distributed projects, these factors are essential if knowledge sharing is to take place. Based on a single case study, “management can encourage the formation of V-CoP [virtual communities of practice] if, along with the creation of virtual project teams they promote informal interaction between the team members, encourage commitment, and put together ‘the right mix of people’” (Marabelli et al. 2013, p. 310), an observation supported by Lee-Kelley and Turner (2017). Athreye, Batsakis, and Singh (2016) declared social interaction as the only way for the tacit and context-dependent nature of the technological knowledge required for new product development to be channeled between sites.

Researchers have studied how the global distributions of teams impact NPD. Stark and Bierly III (2009) found that the more distributed teams become, the more deleterious is the effect of conflict as relationships become harder to rebuild and resolve. This finding has important implications for management. Stark and Bierly III (2009) suggest conflict resolution strategies are needed when teams are highly dispersed along with a suitable mix of virtual and face-to-face interactions.

Cultural factors can impact social factors (Slade 2020). Both national and local cultures play a role in NPD communications, and the possibility of integrating different skills, experiences, and knowledge bases (Salomo, Keinschmidt, and de Brentani 2010) is one opportunity that makes global R&D attractive for innovative firms. A positive organizational culture that stimulates engagement, allows people to take risks in a safe environment, encourages learning, and stimulates independent thinking is essential for innovation (Rao and Weintraub 2013; Hill et al. 2014).

COVID-19’s Impact on Global R&D

With its emphasis on generating new knowledge, face-to-face interactions to support tacit knowledge transfer, internal and external collaborations, cultural tolerance and conducive climates, contemporary R&D proves to be a very human, social, activity (Anderson and West 1998; Leonard-Barton 1998; Markham and Lee 2013; Dutton, Turner, and Lee-Kelley 2014; Marlon, Barczak, and Hultink 2014; Nambisan et al. 2017). COVID-19 has compounded the challenge, as home-office working became necessary for previously collocated teams, working as part of global networks. The pandemic has made the face-to-face interaction, communication,

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and knowledge sharing critical for the transfer of knowledge tangibly more difficult. Knowledge sharing and learning can be successful in globally dispersed NPD projects (Sole and Edmondson 2002), but the topic requires further research.

Methodology

To investigate the Impact of COVID-19, we asked three questions: 1) What effect has COVID-19 had on global R&D processes?; 2) How are managers and teams responding?; and 3) What activities are global R&D teams carrying out to manage knowledge sharing? Previous studies of global R&D have used surveys (Bierly, Stark, and Kessler 2009) or case studies (Braganza and Möllenkrater 2002; Gassmann and Von

Zedtwitz 2003). Due to the transient nature of the response to COVID-19 and the need for unintrusive data gathering from time-pressed R&D managers, we opted for online semi-structured interviews. We designed the interviews to be 30 minutes long and focused on five topics, with two questions for each topic.

The main focus was on the project level. Most of the interviewees are experienced project leaders and R&D or business managers able to give perspectives across multiple projects. Purposive sampling from the research team's existing relationships allowed fast access to three global companies in the automotive components, medical devices, and precision-formed components industries. The companies are referred to as AutoComponentsCo (AC), MedDeviceCo (MD), and PrecisionCo (PC), to preserve anonymity and confidentiality.

At each company we interviewed 10 experienced NPD professionals (Table 1). We completed over 20 hours of interviews during four weeks (June–July 2020). Interviews were recorded and transcribed, although some respondents opted for no recording and, in those cases, interviewers made extensive notes. We had follow-up conversations in the spring of 2021 to understand how the organizations were faring and to determine the suitability of the complexity assessment approach. The typical projects run by the firms

TABLE 1. Data sample

#	Company	Company Characteristics (somewhat disguised)	Managers Interviewed	Interviewees' Locations
1	AutoComponentsCo [Respondents AC _i]	Automotive supplier designing and manufacturing complex components and systems Approximate turnover: \$10B to \$20B 50,000–100,000 employees	R&D Manager (AC1) R&D Manager (AC2) Project Leader (AC3) Project Leader (AC4) Project Leader (AC5) Project Leader (AC6) Project Leader (AC7) PM Manager (AC8) PM Director (AC9) BU Manager (AC10)	China, Czech Republic, India, Italy, and US
2	MedDeviceCo [MD _i]	Medical Device supplier designing and manufacturing implants and instruments Approximate turnover: \$10B to \$20B 10,000–20,000 employees	R&D Manager (MD1) R&D Manager (MD2) Project Leader (MD3) R&D Manager (MD4) Director R&D (MD5) Project Leader (MD6) Project Leader (MD7) R&D Manager (MD8) Project Leader (MD9) Project Manager (MD10)	Switzerland, UK, and US
3	PrecisionCo [PC _i]	Producer of precision formed components Approximate turnover: \$500M to \$1B 1,000–5,000 employees	New Business Development Director (PC1) Project Manager (PC2) R&D Manager (PC3) Project Manager (PC4) Project Manager (PC5) R&D Manager (PC6) Innovation Manager (PC7) Technical Director (PC8) Innovation Manager (PC9) Innovation Director (PC10)	UK, Spain, and Germany

studied are NPD/NPI (new product introduction), with a 24 to 60 months' timescale, each involving 5 to 25 full-time employees, from 2 to 6 national cultures and based in 2 to 5 different geographical locations.

We sought to understand the multiple factors in managing R&D projects by applying the *project complexity* perspective (Baccarini 1996; Dvir et al. 1998; Pich, Loch, and De Meyer 2002; Jaafari 2003; Xia and Lee 2005; Gerald, Maylor, and Williams 2011). We drew on work that emphasizes the managers' "lived experience" (Williams 2005; Cicmil et al. 2009), allowing us to investigate the realities they faced during the pandemic.

We applied the Maylor and Turner (2017) complexity framework (based on Maylor, Turner, and Murray-Webster 2013) for three reasons: It is an established and validated framework; it has been used to investigate complexity in various scenarios; and it focuses on three different characteristics of complexity, which appeared useful in investigating global teams. *Structural Complexity* increases with the number of people involved, financial scale, scope, number of interdependencies, and the pace of the work. *Socio-political Complexity* represents the challenge from people, politics, and the range of stakeholders that have influence. *Emergent Complexity* is a function of novelty, and a lack of clarity about a project's vision and how the future will unfold. These dimensions highlight that R&D complexity involves more than technical (structural) challenges; it encompasses subtler social factors that are so vital (perhaps even the most important) in ensuring a successful outcome. Maylor and Turner (2017) proposed that typical responses fit into three categories: a *planning and control* approach (for example, established project management tools and techniques), *relationship development* with key stakeholders, and *flexibility* (that is, deviations from normal processes). Combining the complexities and responses gives a 3x3 analysis framework (Turner, Altken, and Bozarth 2018). Although the complexity framework has not, to our knowledge, been used in such an R&D context before, it enabled coding and classification of typically "messy" project data (Ackoff 1979) and enabled us to identify complexities and responses. Our approach is also in line with current work that uses this framework in analyzing COVID disruption (Boehme et al. 2021).

Results

Managers of R&D teams during lockdown encountered a range of complexity challenges requiring a variety of responses (Table 2). Just over half of the complexities coded in the data were structural, including issues such as planning effective communication and ensuring tasks were completed effectively. One-third were socio-political complexities associated with the interpersonal aspects of managing NPD teams. Project leaders tried hard to make sure that their personnel had the necessary support, but they were also aware that the lack of face-to-face contact inhibited the previously accepted ways of operating and knowledge sharing. Interestingly, all respondents highlighted structural challenges, and 26 of the 30 respondents brought up socio-political complexities. Finally, emergent complexity represented one tenth of the

The respondents acknowledged the lack of "fortuitous" knowledge sharing, so managers implemented meetings and social events in the hope of "planned serendipity."

complexities, and these focused on recognizing future uncertainties and attempting to mitigate them. The respondents acknowledged the lack of "fortuitous" knowledge sharing, so managers implemented meetings and social events in the hope of "planned serendipity" (a term used by one of the respondents). The interviewees could not fully quantify the benefits that they anticipated would come from these interactions, but they viewed such events as valuable in cementing interpersonal relationships and stimulating practical discussions that aid complex product development. The respondents also acknowledged the importance of relationship building, especially with new customers and staff, and the idea of supporting staff in their search for novel solutions.

Over half of the complexity challenge responses coded in the data related to "planning and control" solutions, and all 30 respondents mentioned these challenges. One-third of the coded responses were "relationship development," emphasizing again the vital social aspect inherent in R&D: 27 of the 30 respondents gave responses related to relationship development. Respondents viewed teambuilding and reinforcing existing relationships as essential to enable the complex knowledge to be shared and judgments made in the fluid R&D environment. Flexibility responses accounted for the rest of the responses, with staff adapting rapidly and, seemingly, effectively. Although some of the results were as the researchers expected—that is, structural complexities addressed by planning and control solutions—the analysis of the data showed that all three complexities (structural, socio-political, emergent) could be tackled with each of the response types (planning and control, relationship development, flexibility)—that is, offering nine permutations. The

TABLE 2. Summary of coding data

	Respondents (#)	Total References (%)
Complexity challenge		
Structural	30 (100%)	103 (55%)
Socio-Political	26 (87%)	63 (34%)
Emergent	10 (33%)	20 (11%)
Challenge response		
Planning and Control	30 (100%)	93 (51%)
Relationship-building	27 (90%)	63 (35%)
Flexibility	14 (47%)	26 (14%)

prevalence of the “non-obvious” solution types highlights the usefulness of the framework in uncovering ways forward when faced with these challenges.

Structural Complexities and Responses

Respondents from the three organizations voiced similar issues and experiences. From a structural perspective, the rapid lockdown transition meant that the initial effort entailed ensuring that staff could function from home effectively. Videoconferencing tools (some preexisting, some new) caused a major shift in how staff interacted. Immediate concerns included straightforward practical issues such as the availability of laptops, Internet bandwidth, and familiarity with the tools. Once NPD project managers had overcome the practical difficulties, more subtle and challenging issues arose, such as ways of communicating effectively in this new situation.

Managers tended to have more meetings, whereas many engineering staff had fewer meetings and more uninterrupted work (for which some were thankful). Teams became aware of colleagues’ personal issues such as childcare, but these domestic realities did not appear to cause disruption. The predominant perception amongst respondents was that younger staff adopted this new way of working more favorably than senior staff, though they were less likely to have a home office. Respondents also noted that since almost everybody was now working remotely, the distinction between each manager’s co-located “home” team and team members in other locations diminished, thereby seemingly reducing the effect of “distance.”

A common theme was the increased number of shorter-duration meetings. Online meetings enabled information transfer, but most respondents highlighted their limitations. For example, the multiple communication options (video calls, phone calls, instant messaging, email) necessitated an understanding of the hierarchy of urgency. As one MD manager noted, “If it’s urgent, call me. If it’s not urgent, instant message me, and if it’s super-not-urgent, email me.” (MD3).

Respondents expressed concern that project teams did not fully understand project-related technical issues (and not the ICT tools mentioned). This uncertainty made discussions longer and required more rigor in email follow-ups (meeting minutes) to ensure that all points were clear. Ensuring the necessary clarity was harder across national cultures, and respondents expressed doubts about whether each side understood the details, thereby leading to increased time spent establishing a consistent and agreed upon understanding. Some managers thought that their written communication had improved as a result. Some respondents indicated that the lack of boundary objects in discussions (whiteboard, laptop, coffee machine) made knowledge sharing harder. One manager said, “You can get away with that not being quite as clear when you’re all together” (MD5).

A major challenge for most interviewees was that lack of social interaction meant serendipitous knowledge sharing no longer took place. One manager said, “In the office you are accidentally exposed to information that may be useful”

(AC2). To overcome this, managers deliberately scheduled meetings both for project teams and also for project-to-project knowledge sharing, to implement a mechanism for communication that would no longer occur naturally. Meeting behavior, though, varied between organizations. AC staff generally did not use the cameras on calls, relying only on voice. Others emphasized how important visual communication was. In some instances, there was a significant improvement in meetings, as previously the offsite/offshore members who would dial in voice-only could get neglected or overlooked in meetings. An increased equality was noted if everyone was on the video call, regardless of location, and respondents indicated that they perceived it increased tacit knowledge sharing in particular.

We determined that structural complexities can be addressed through the three response types: planning and control (use of tools), relationship building (setting up regular virtual meetings), and flexibility (changing working patterns to accommodate others’ needs).

Socio-Political Complexities and Responses

Social aspects were a major theme. According to one manager, “the spontaneous conversations in the kitchen at work are not taking place anymore” (PC2). Managers scheduled extra one-to-one meetings with their direct reports to offer support and “check in” with no particular agenda. In addition, cohesion could be bolstered by informal social events such as coffee meetings, Zoom quizzes, virtual treasure hunts, book clubs, Friday drinks, cooking events, fancy-dress themes, and “people are posting three pictures from their home and then the rest of the colleagues guess whose house that is” (MD1).

A point that came up regularly was that preexisting relationships with colleagues could continue with few problems, but new relationships were hard to forge online. One respondent said, “With some colleagues that sit next to me in the office, when I speak they already know what I mean. With new hires, it’s more difficult. I have to make everything very clear, explain the main objectives, the action items and put everything in writing” (AC9).

For team management, trust developed pre-lockdown extended to working from home. One interviewee said, “We encourage our colleagues to produce good quality work rather than quantity. I trust my team completely even if everybody is working from home” (PC7). The importance of delivering the work, rather than putting in the hours, means, one manager said, “[the] stigma around not being in the office at eight o’clock and leaving before five o’clock, or whatever, is completely gone” (MD5).

Responses to socio-political complexities could also be mapped to the three forms. Planning solutions included the regular one-to-ones to ensure communication and support; relationship-building was strongly evident, encompassing the focus from respondents on stimulating regular social interaction; and flexibility included supporting colleagues’ unavailability (for example, due to childcare issues) and working around that.

Emergent Complexities and Responses

Customer input in NPD was now harder to obtain. Similarly, developing new business relationships without in-person meetings was a significant challenge. One manager stated, “Many aspects of communication cannot be captured properly especially ‘non-said information’ like fear, pressure, concerns, and emotional aspects. This is dramatic ... when it comes to establishing new business relationships” (PC1). Given the wholesale change, virtually overnight, in how people worked, the overwhelming perception was that the disruption was not affecting project delivery significantly, and everyone was stepping up.

The three companies took some major steps that might never have occurred pre-COVID-19. MD’s NPD required prototype testing together with surgical teams. Usually this major milestone entails NPD teams flying around the world to directly observe simulated surgery. Instead, since the start of the pandemic, the company has sent prototypes to their customers so that the simulated surgery sessions could be conducted in the customer’s home country with the NPD team observing them online, which has saved time and costs.

Overall, respondents indicated that the experience of remote working was successful. Despite the rapid transition, respondents found that knowledge sharing did continue, albeit differently, with projects generally progressing according to the original plans. Uncertainty remained as to how “normality” would resume, and what it would look like. Respondents acknowledged that returning fully to pre-COVID-19 conditions was unlikely and many aspects of remote working had been validated. At the time of initial interviews (summer 2020), the plans for returning to “normal working” were unclear, but the need to address the social aspect of NPD teamworking was front of mind.

Responses to emergent complexities came in three forms. Planning and control included actively seeking meetings with other groups to keep “in the loop” and ensure sharing of current issues and knowledge. Relationship development

Given the wholesale change in how people worked, the overwhelming perception was that the disruption was not affecting project delivery significantly, and everyone was stepping up.

included supporting staff by updating them regularly on the current and evolving situation (for example, on the “return to work” expectations). Finally, respondents reported on the flexibility involved in finding practical, context-dependent solutions for sharing detailed technical information with others.

We identified a wide range of practical managerial responses to the pandemic (Table 3). Mapping these to the Maylor and Turner (2017) framework highlighted the variety of solutions implemented, as all nine of the options were populated. This variety of practical options reinforces the challenge of R&D, in that “template” answers are unlikely to be sufficient. It also underlines the importance of the critical “social” aspects despite the inherently technical nature of the contexts.

Discussion

We sought to investigate how global R&D teams responded to the COVID-19 pandemic and its impact on knowledge sharing. Certain aspects, such as the rapid shift to a reliance on electronic communication was unsurprising, especially as it was evident in other sectors worldwide. Similarly, our

TABLE 3. Examples of managerial complexities and responses during the pandemic

		Complexity		
		Structural	Socio-political	Emergent
		Increases with the number of people involved, financial scale, scope, number of interdependencies, and the pace of the work	Represents the challenge from people, politics, and the range of stakeholders that have influence	A function of novelty, and a lack of clarity about project’s vision and how the future will unfold
Response	Planning and Control	Use of tools (for example, technology); coordination	Regular one-to-ones to ensure communication and support	Actively seeking meetings with other groups to keep “in the loop” and ensure sharing of current issues and knowledge
	Relationship Development	Setting up regular virtual meetings	Focus on stimulating regular social interaction	Support staff by updating them regularly on the current and evolving situation (for example, on the “return to work” expectations)
	Flexibility	Changing working patterns to accommodate others’ needs	Support colleagues’ unavailability (for example, due to childcare issues) and working around that	Finding practical, context-dependent, solutions for sharing detailed technical information with others

Technology can help maintain preexisting work relationships that support the sharing of tacit knowledge, yet these social bonds are unlikely to remain effective indefinitely.

finding that ICT plays a key role in supporting R&D activities confirms previous research (Boutellier et al. 1998). R&D teams rapidly overcame initial practical problems with equipment availability and connectivity and respondents reported that projects continued relatively smoothly. The relatively seamless transition from pre-pandemic working to pandemic working is testament to the utility of the ICT tools used in support of existing relationships.

Our novel findings are connected to knowledge management challenges, which all three companies clearly identified as important. Managers discussed how the explicit and tacit knowledge-sharing mechanisms (Nonaka and Takeuchi 1995; Goffin and Koners 2011) changed in the pandemic working environment. Explicit knowledge, which is generally understood as easy to share, now proved to be a challenge. Ensuring that technical details were correctly shared and understood required additional, clearer documentation of meetings. One observable benefit was that the companies achieved a “level playing field” between the main R&D facility and other locations, since everyone was in the same situation on video calls. Attempting to share tacit knowledge proved even more challenging than before COVID-19—it required different thinking to account for the lack of informal, serendipitous interaction and knowledge sharing that occurs in a direct, shared physical environment. Managers tried to stimulate informal social interaction in the virtual space and highlighted consistently how important pre-COVID relationships and culture were in supporting working remotely. While it proved relatively straightforward for staff who had already established relationships that built trust to continue to work together, it was difficult to build new internal and external relationships without face-to-face contact.

The lens of complexity (Maylor and Turner 2017) was instructive and revealed a different perspective on the response to the pandemic. Structural complexities, representing primarily technical and coordination challenges, accounted for just over half the challenges coded. Given the nature of the work and the new situation, we initially expected that this figure would be higher. Socio-political (people) issues accounted for over one-third of the challenges, representing mainly the difficulty of maintaining relationships under these new conditions. Interestingly, emergent complexities, representing uncertainty about the

future, was only one tenth. Our results indicate that the managers were, understandably, focused primarily on the immediate project requirements, and the evidence suggests that despite upheaval of the ways of working, the managers’ focus on safeguarding key project activities from delays was successful in the case organizations. A planning approach (half) and relational mechanisms (one-third) dominated the responses, showing that the more mechanistic “engineering” and “project management” functions need the significant support of the social and interpersonal factors that help to make the projects work in practice and enable practical and effective knowledge transfer.

What does this mean for practitioners and researchers? Managing global R&D involves structure, ICT, and good project management practices; however, these elements could be considered as “necessary but not sufficient.” In addition, the social capital of the global project team, with other teams, and a range of stakeholders, is crucial. The evidence from this study shows that the social relationships can survive the major disruption of lockdown, allowing projects to continue despite the dramatic change. Working from home can be effective, but it is more difficult. Specific efforts need to be taken to maintain relationships, and ICT can enable working with limited disruption and even offer new, efficient ways of collaborating. Some issues, such as mechanical engineers being prevented from accessing important hardware in the offices, were harder to overcome.

Management skills are needed to keep relationships going. Managers need to ensure that explicit knowledge continues to be shared and understood, and to reinforce informal interactions. Through the COVID-19 crisis, some of these previously less-visible social factors became more evident and overt. Viewing the issues through the complexity lens makes “people” aspects more distinguishable, which brings to the fore the idea that social factors are inherent to R&D, even if they appear less prominent than more formal processes (Dutton, Turner, and Lee-Kelley 2014). Managing social complexity (Maylor and Turner 2017) is a skill that managers need to hone for working with dispersed teams.

The data suggest organizations can work remotely, at least in the short-term, because of already established relationships and knowledge sharing. Technology can help maintain preexisting work relationships that support the sharing of tacit knowledge, yet these social bonds are unlikely to remain effective indefinitely. We posit the idea of “tacit knowledge half-life”—that is, the ability of teams to share tacit knowledge will decay over time if participants remain predominantly dispersed. Building new relationships with staff, suppliers, or customers without face-to-face interaction is difficult. As the underlying intangible assets begin to decay, there could be a decline in the momentum of existing and new projects. Managers must use their judgment as to how best to support their staff and projects. In this uncharted territory, the maps used previously (for example, processes, standards, and best practices) do not accurately reflect the new terrain of managing social interaction to stimulate serendipitous exchange of tacit knowledge.

COVID-19 has had major impacts on R&D management. For managers, many of these problems are related not to structural (traditional) project management issues but to social interaction. Many of the complications of dispersed working will remain in the future but, as one respondent said, “Engineers like to solve problems ... [so we will] make this work.” (MD8).

Managerial Implications

Most technical organizations and staff are comfortable with structural challenges, but many of the most demanding project issues have their roots in social and “people” issues. In conducting our research, we asked managers in the case companies explicitly about the structural, socio-political, and emergent risks and issues that team members were worried about. A manager from MD said they scheduled “short and frequent” one-to-one meetings and used new technologies for better communication and cooperation. A manager from AC noted that, to cope with the difficulties of planning under uncertainty, they gave more attention to understanding employees’ personal/family needs and worries, as well as supporting the use of flexible working solutions. The complexity framework enables structured (often informal) discussion about the kind of practical steps that would be most valuable. In uncertain times, this open discussion can be more beneficial than “standard” risk processes, which often miss socio-political and less-quantifiable concerns. We share additional examples of the problems and responses implemented by the spring of 2021 by the case organizations in support of their NPD (Table 4). It is not necessary (nor likely) that all nine boxes will be populated.

Our framework offers a valuable approach to practical problem-solving in managers’ R&D functions. Managers

can use it with their teams to identify solutions to the ongoing challenges they face in their R&D projects. For NPD managers, the framework can be beneficial in two distinct ways. First, in ongoing projects with difficulties, it facilitates a structured conversation, which can identify the particular problem. NPD managers can use the framework to identify the type of problem (structural, socio-political, or emergent) and potential solutions (planning and control, relationship development, or flexibility). Second, it can be valuable as a tool for reflection and learning, either during the project (such as at a gate review) or at its conclusion. Reviews often focus primarily on structural issues such as “How did we perform versus our targets?” and “What technical issues did we encounter?” By also explicitly considering the socio-political (“How well did we deal with the stakeholders and their concerns?”) and emergent (“How effectively did we deal with change and the unexpected?”), managers and teams can gain a more rounded appreciation of a project’s performance and how it may be improved in the future.

Within an R&D context it is important to capture the (often intangible) “social” aspects and tacit knowledge use that underlie performance, especially in distributed teams. Our experience indicates that this framework effectively brings these more “hidden” challenges to the surface, along with the more readily identifiable technical issues. By acknowledging the complex reality of the project, managers can gain insights that might otherwise not be identified, enabling practical solutions to be implemented in a timely fashion.

Study Limitations

The main limitation of our study is the restricted dataset, based on three companies. However, the data represent an

TABLE 4. 2021 review of complexity/responses with managers from case organizations

		Complexity		
		Structural	Socio-political	Emergent
Response	<i>Planning and Control</i>	Need for more frequent NPD team meetings to build and share knowledge. → Schedule meetings that can be attended in person or remotely.	Existing pre-COVID-19 personal relationships are insufficient. → Ensure short frequent one-to-ones and group meetings with staff to refresh social capital.	Traditional NPD knowledge channels are lost or limited. → Ensure tacit and explicit knowledge and learnings are shared with group, both formally and informally.
	<i>Relationship Development</i>	Enable direct reports to communicate in the group network to support the continuity of product development.	Challenge of “on-boarding” new starters. → Make time for all team members to meet the new staff and ensure regular conversations to make them part of the development team.	Difficulty of planning under uncertainty. → Managers should support discussions about concerns both in meetings and informally to allay members’ worries.
	<i>Flexibility</i>	Ongoing challenge of coordination and sharing NPD information given uncertain availability of individual team members. → Managers should support and institutionalize flexible working according to personal circumstances.	Empathize with colleagues’ personal situations, including family commitments, childcare, and working hours.	Scan new technology opportunities to aid communication and teamwork. This involves both the (relatively straightforward) IT aspects and the more difficult challenge of effective knowledge sharing.

Important snapshot of R&D during the COVID-19 crisis. Future work may look at what happens over an extended period with teams working from home—does it remain effective? How much face-to-face meeting time is required to sustain effective relationships? From this we may gain insight into the implications for the home/office balance in R&D projects. Many of the findings are applicable to co-located but not dispersed teams.

Conclusion

We looked at how three global organizations responded to the impact of the COVID-19 pandemic on the management of R&D projects. When faced with this sudden and wholly unanticipated operational challenge, all three organizations managed to transition rapidly to new ways of working, with surprisingly little impact on their ongoing projects. R&D managers can take three main lessons from our study. ICT and project management are essential tools to enable global R&D teams to function in dispersed, homeworking situations. When used in isolation, these tools are not sufficient for the task of creating and sharing the amount of knowledge, which is central to R&D project work. Explicit and tacit knowledge created in typical projects needs to be communicated between team members. Informal social interaction within global R&D teams is pivotal. R&D managers took steps to stimulate social interaction: maintain relationships built on trust; focus on tacit knowledge; and ensure regular informal interactions. Respondents made significant efforts to support such activities, despite the challenge of the disruption. Our results demonstrate the advantage of considering the complexity of managing global teams in terms of structural, socio-political, and emergent issues. Managers can use the Maylor and Turner (2017) complexity framework to systematically analyze problems and to generate different solutions spanning planning and control, relationship development, and flexibility. Managers now have a new perspective on how to manage tacit knowledge and social interaction in global NPD project teams.

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