Master's thesis

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The digitalisation of information sharing in new product development projects

A French multiple case study

Master's thesis in Global Manufacturing Management
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Abstract

Purpose - The purpose of the paper is to understand the impact of factors on the information sharing digitalisation (ISD) of new product development (NPD) project. To understand this impact, a focus was done on business level factors and project level factors that could impact ISD in NPD project. Business level factors consist of : the Industrial context, the company, the supplier companies. Project level factors consist of : project features, collaborators, supplier management.

Design - A qualitative analysis was conducted based on a multiple case study with three French companies from the automotive industry.

Findings - The impact of some business level factors and some project level factors on ISD in NPD projects is probable. The impact of a company and its collaborators are determined to be an important factor.

Research limitations - This research is only based on two interviewees from the same industry field. Thus the representativeness of the results can be questionable to some extend, such as project features.

Practical implications - This framework can help understanding an overall view of different factors impacting ISD in NPD from two level: the business level and the project level. It shows that a company culture, size and structure and collaborators have a major impact on ISD in NPD projects.

Originality/value - This framework has an overall view, as much as from the outside of a company that from the inside and both from a business level that from a project level. This helps to have an in-depth understanding of how ISD is impacted in NPD projects.

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Abbreviations

AI : Artificial intelligence

AR : Augmented reality

B2B : Business-to-business

B2C : Business-to-customer

C2C : Customer-to-customer

CAD : Computer-aided design

CEO : Chief Executive Officer

EDI : Electronic Data Interchange

ERP : Enterprise Resource Planning

ICT : Information and Communication Technologies

ISD : Information sharing digitalisation

IT : Information technologies

NPD : New product development

P2P : Peer-to-peer

PSM : Purchasing and Supply Management

R&D : Research & Development

RQ : Research question

SCM : Supply Chain Management

VR : Virtual reality

1 Introduction

1.1 Background and motivation

In the fall semester I conducted a project thesis that led me to develop a theoretical framework (Miguet, 2019). This framework topic was about the information sharing digitalisation (ISD) in New Product Development (NPD) projects. I was motivated to understand which factors could influence ISD in NPD projects. This is a topic of interest for companies because companies are involved in a global context where the competition used to be local and is now global (Li and Lin, 2006). This leads to very competitive environments, therefore companies need to be efficient and to adapt to change (Li and Lin, 2006). Companies are thus in an environment where it is needed that they focus on core competencies (Wynstra and Pierick, 2000). This naturally leads to a business environment where every company specializes in a field and works closely with suppliers. Companies do that to gain a competitive advantage over their competitors and deliver a higher product or service level to their customers (Baihaqi and Sohal, 2013; Fawcett et al., 2007; Wynstra and Pierick, 2000). Therefore, collaborating with suppliers is a key to adapt to the environment and this adaptation is supported by information sharing (Sriram and Stump, 2004; Shore and Venkatachalam, 2003). That is the reason why companies invest in information technologies (IT) systems to access, among other things, information sharing capabilities (Fawcett et al., 2007). Companies accessing high IT capabilities are more likely to outperform others according to Bharadwaj (2000). We can see here that companies spend resources on getting and using IT systems because they believe in their capabilities to enhance collaboration with suppliers. However, there are some issues raised by IT systems which complicate information sharing. One example is the integration of different IT systems (Fawcett et al., 2007). Indeed, this can be very complex to manage and quite costly (Bharadwaj, 2000).

In new product development (NPD) projects, companies have to work with suppliers to gain efficiency and effectiveness (Wynstra and Pierick, 2000). Every supplier is dealt at his own level, depending how much companies want to involve them in a project (Araujo et al., 1999).Shore and Venkatachalam (2003) mention that suppliers should be assessed based on their IT capabilities and IT integration, which is a feature to consider when managing suppliers. Here again, information sharing is a key factor in the success of a project (Peng et al., 2014). Information sharing based on IT leads to higher collaboration levels (Peng et al., 2014). Nevertheless,

when it comes to information sharing with suppliers or internal collaborators, there should be a balance in the information shared (Wynstra and Pierick, 2000). Jepsen (2013) mentions that a project manager spends a considerable amount of time on information sharing management tasks and ensures that every actors has every piece of information relevant for them. In his study, Jepsen (2013) focuses on e-mails as an information sharing medium. This makes me wonder what would be the impact of other technologies, new technologies. Besides, there is a need for managers to realize that IT used for collaboration are actually facilitators for higher levels of collaboration (Baihaqi and Sohal, 2013). This means that IT-based information sharing alone is not sufficient to reach significant levels of collaboration.

Lasi et al. (2014) mention today's industrial context of companies: the Industry 4.0. This is a new industrial revolution, the 4th one, that brings interconnection to technology. This means that very advanced technologies emerge and they might change the way business is done (Lu, 2017). Srai and Lorentz (2018) particularly had an interest for Purchasing and Supply Management (PSM) with regards to this new technological revolution. Researchers recently started to focus on the topic of Industry 4.0, and especially with a focus on purchasing. This means that many aspects of this phenomenon are not studied yet.

Therefore, I identified in my project thesis two different levels of factors that could influence ISD in NPD projects : business level factors and project level factors (Miguet, 2019). In this master thesis, my goal is to assess this framework with empirical data to understand how each factor and sub-factors might influence ISD in NPD projects. As I mentioned, I first studied this area because of the rising importance of IT systems for companies and the competitive advantage this could bring them in working in NPD projects. I want in this master thesis to gather empirical data that could reveal how companies actually use those IT systems in their daily operations and what could be their barriers in using them, but also the motivation of using them. Because of how important sharing information is for companies developing new products, I want to know how IT system can actually be a support, a vector of this shared information.

1.2 Problem statement, research scope and research questions

Because of all the points introduced above, I was really interested into the topic of ISD in NPD projects. Moreover, this topic was of interest to me because of this new industrial environment brought by the Industry 4.0 and all the new technologies that could bring change.

The research scope of this thesis was mainly about assessing a framework designed to evaluate the factors influencing the ISD in NPD project. I developed an initial framework during the Fall semester, where I identified business level factors and project level factors (Miguet, 2019). Therefore, the goal of this master thesis is to evaluate that framework and change some aspects of it after an empirical data analysis. This empirical data analysis is conducted through a comparative case study, where I focus on large French companies managing NPD projects.

Therefore, my main research questions (RQ) in this thesis are:

RQ1: How is ISD in NPD projects influenced by business level factors ?

RQ2: How is ISD in NPD projects influenced by project level factors ?

The goal is to analyze the ISD through two view points: one from the company level and one from projects level. Thus, this thesis aims at understanding the impact of those factors on ISD in NPD projects and their sub-factors.

1.3 Plan

First, the methodology used in this paper will be explained in chapter 2. Then the theory and the framework developed will be discussed in chapter 3. In the chapter 4, the empirical data collection will be introduced. The chapter 5 will be dealing with the data analysis. Then the discussion of this analysis will be carried out in the section 6. Finally, the conclusion will be drawn in the chapter 7.

2 Methodology

2.1 Introduction

In this section, we discuss different aspects of the methodology in this master's thesis. Those aspects are the entire research process, its quality and its limitations. The methodology section of this thesis is mainly based on two well-known researchers: Bryman (2016) and Yin (1984).

2.2 Research plan

2.2.1 Research strategy and design

As Bryman (2016) mentions there are mainly three approaches when conducting a study : the quantitative one, the qualitative one or even a mixed approach. My research question and my purpose were more to generate new theory, and understand complex relationships between entities being organisations and individuals. Therefore my epistemological and ontological orientation (respectively interpretivist and constructionist) were more oriented towards a qualitative research strategy (Bryman, 2016). My idea was to create theory, with an inductive use of the theory (Bryman, 2016). Indeed, I wanted to understand the progress of the digitalisation in companies, with a focus on the information sharing in NPD projects. I was afraid that with a quantitative approach it would be complicated to understand the point of views of each individual and organisation.

For my research design, I had different possibilities, the main ones for me being experimental, cross-sectional, longitudinal, case study or comparative (Bryman, 2016). Given a qualitative research strategy, Bryman (2016) notes that an experimental design is very rare. For practical reasons, a longitudinal design would have been complex to apply. Indeed, since business projects usually last many months, even years, and knowing that my master's thesis length is about five months, it would not have fit. Moreover, a cross-sectional design was not easily feasible either, because of the need of conducting all the data collection at a single point in time. Therefore, I was left with either a case study or a comparative study, which can also be named a multiple case study. The difference between those two designs is based on the number of

cases. Yin (1984) points that case studies are relevant when the researcher do not have control over events (unlike for experimental studies) and focuses on contemporary events. Those two points strengthened the idea of using a case study design. Indeed, having control over a company project in the context of a research seemed really complex and my research question on the digitalisation is about understanding the progress of this phenomenon. Moreover, in my intend to understand this phenomenon of digitalisation I thought it would be more relevant to get data from different companies, in an attempt to reach broader results through a replication logic (Yin, 1984). Yin (1984) mentions a typical example about multiple case design that supported my approach:

> "A common example is a study of school innovations (such as open classrooms, teacher aides, or new technology) in which independent innovations occur at different sites. Thus each site might be the subject of an individual case study, and the study as a whole would have used a multiple-case design." (Yin, 1984)

Hence I wanted to apply a comparative design, depending on how many companies I could gather empirical data, otherwise it could be a single case study.

Yin (1984) gives a methodology to follow when conducting multiple case studies, see figure 1. Each of those steps are explained in the following paragraphs.

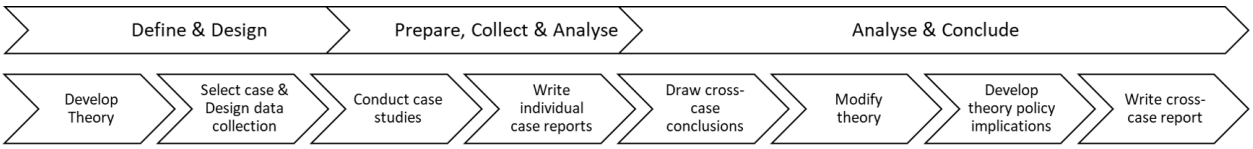

Figure 1: Case Study Methodology, Adapted from Yin (1984)

2.2.2 Data sampling

Bryman (2016) describes the purposive sampling approaches, as approaches with "a non-probability form of sampling" (Bryman, 2016). Some of those approaches, described by Bryman (2016) are: criterion sampling, theoretical sampling, snowball sampling, opportunistic sampling, etc. As Bryman (2016) notes it, usually more than one sampling is used, which is my case here. I wanted to used a criterion sampling, because I wanted the companies from which I was getting empirical data to meet some criteria that would be relevant for my topic. Those criteria were:

- Criterion 1: Rather large companies
- Criterion 2: Companies conducting quite complex projects, demanding a large number of suppliers
- Criterion 3: Companies among the leaders of its market

With those criteria, I could be able to find companies that would be relevant to my topic, because they would conduct quite competitive and innovative projects, where a efficient team organisation and communication certainly would be necessary. This sampling could be combined with a snowball sampling because I might not access all the companies I would like to. Another point being that managing my time would have been very complicated if I was to contact and get data from too many companies.

2.2.3 Data collection

When it comes to the data collection in qualitative research, Bryman (2016) mentions many possibilities, such as: participant observation, interviewing, focus group or gathering documents. I wanted to go with interviewing because it is what was the more relevant option given my time restriction and access restriction. Bryman (2016) notes that there are two main ways for qualitative interviewing: semi-structured interviews or unstructured interviews. The unstructured interview is about using almost no notes and having a conversation with the interviewee (Bryman, 2016). The semi-structured interview is more about using an interview guide and having questions that the interviewer wants to ask, but it is still quite flexible (Bryman, 2016). I wanted to chose a semi-structured interview for my data collection, because it could help me to replicate the same questions to different companies which helped in the generalisation of the results. Another reason was that I had almost no experience in interviewing, therefore unstructured interviews seemed really complicated to consider.

2.2.4 Data analysis

For the data analysis, I could use different options: an analytic induction, a grounded theory approach, a thematic analysis or even a narrative analysis Bryman (2016). The analytic induction involves analysing data and collecting data until a hypothetical explanation of a phenomenon matches the data (Bryman, 2016). The grounded theory aims at coding, then getting categories

until those categories are saturated (Bryman, 2016). Also this approach consider using a theoretical sampling. The thematic analysis consists of using themes to analyze data, which makes it simpler to discuss themes (Bryman, 2016). The narrative analysis is an analysis that includes taking into account of the time passing by, and the modifications it could bring (Bryman, 2016).

A important stage in any analysis is also the coding Bryman (2016). This coding needs to be systematic and done as soon as possible once the data collected according to Bryman (2016).

2.3 Research process

2.3.1 Research strategy and design

After some theoretical consideration raised by Bryman (2016), I applied a qualitative research strategy. For my research design, I applied a comparative design.

2.3.2 Develop Theory

In order to develop theory, as described by Yin (1984), I needed to do a literature review.

Therefore, I needed to gather literature relevant to my topic. My subject can be break down to three main parts: "digitalisation", "information sharing" and "NPD projects". Hence, I started looking for articles where the focus was on at least two of those points. In order to do so, I used research databases such as Oria (for NTNU members) and Google Scholar. Moreover, I added in my article list some literature that I had through my academic courses.

In the previous semester I already did a literature review for my project thesis (Miguet, 2019). In this project I developed a theoretical model based on my literature review. Therefore, in this master's thesis, I used this literature as a base, however I added more relevant literature.

This extended literature review enabled me to get more precise on some aspects of my initial theoretical model (Miguet, 2019), and to discuss and reflect more theories.

2.3.3 Data sampling

That purposive data sampling is the one that I used given the qualitative research strategy of my master's thesis. I used: a criterion sampling and a opportunistic sampling. I decided to anonymize the companies' names to avoid interviewees not sharing some information with me. Thus, a decided to call the companies the following : companies Alpha, Beta and Gamma. I was able to contact my first interviewee, from the company Alpha, thanks to the company Sia Partners, a French consulting company. The company Alpha matched the criteria I set for the data sampling. The second interviewee was someone I already knew, who accepted to participate to the interviews. His company, the company Beta, also matched the set criteria. It happened to be a coincidence that the company Alpha and Beta were in the same industry: the automotive one. Also, the company Beta is a subsidiary of another company, the company Gamma. The interviewee of the company has knowledge of the company Gamma and has worked on a project with this company.

2.3.4 Data collection

For the data collection I conducted semi-structured interviews mixed with unstructured interviews.

I prepared an interview guide to be used for my different interviews. As mentioned by Bryman (2016), I tried as much as possible not to ask leading questions in this interview guide.

During my interviews, I asked my interviewees if I could record the interview, in order for me to transcribe it for a better data analysis. This is a process suggested by Bryman (2016) and I really felt the need to do it given that I never conducted interviews before the master thesis. Also I conducted the interviews by Skype for practical reasons, given the Coronavirus crisis situation.

I had two interviewees from two different companies. For the first one I conducted a semi-structured interview that lasted for about 35 minutes. For the second interviewee I conducted two interviews, the first one was mainly an unstructured one and the second one was semi-structured, following the interview guide. The first interview with the second interviewee lasted about one hour and the second interview with the second interviewee lasted about one hour and a half. From those two interviewees and three interviews I was able to collect a sufficient

amount of data to conduct a comparative case study with three companies and not only two. This is the case due to the nature of the company of the second interviewee. Indeed, the latter works in a medium-size company that is part a much larger corporate group, led by a major company. Since he has been working in his company for over 16 years, he knew very well both companies and was able to give me information on those two companies. Another important point to consider when it comes to interviewing is that I conducted those interviews in French with French people (I am myself French). Thus it was easier for me to express and understand all the information shared by the interviewees. I also had to translate all the interviews, which is a step that came after the transcript.

In the figure 2, there is a summary of the information from the interviews and the interviewees.

Interviewee	Information gathered on the company	Company name, field and industry of the interviewee	Role and age of the interviewee	Interview type	Interview duration
1	Alpha	• Alpha • French automotive equipment manufacturer • Automotive industry	• Purchasing director of one category • 46 years old	Semi-structured interview	35 minutes
2	Beta and Gamma	• Beta (subsidiary of company Gamma) • French car assembler • Automotive industry	• Head ofthe architecture department • 51 years old, in the company for 16 years	Unstructured interview	1 hour 5 minutes
	Beta and Gamma			Semi-structured interview	1 hour 36 minutes

Figure 2: Information on the interviews

2.3.5 Data analysis

I decided to stick to a thematic analysis in my data analysis because it made a lot a sense given that the framework I developed was already following a theme logic. Therefore my data analysis consisted of coding the information from the interviews, and then putting this coded information in the different factors and sub-factors from my theoretical framework. My framework has three different levels, thus it enabled me to be quite precise in the analysis while also being able to see the overall trend. Those levels are : business or project level, then factors and sub-factors.

2.4 Quality and limitations

According to Bryman (2016) there are two main aspects to consider in judging the quality of a study: the reliability and the validity.

2.4.1 Reliability

According to Bryman (2016), the concept of reliability is really close to the concept of replicability. It consists of assessing the importance of the replicability of a study. Given the same context and the same settings, two studies should then have the same outcomes.

In the case of this thesis, the different steps of my methodology can be replicable to a certain extend. Indeed, the literature review was conducted using a keyword research method and then by assessing the interest of articles with the study. The extended framework was developed based on an initial framework and enhanced. Then the interviews were conducted based on an interview guide, but for the second interviewee there was a part of unstructured interviewing. Moreover, the data analysis was following a theme analysis approach.

The literature review has some subjective aspect in the assessment criteria to include or not an article in the basis for developing the framework. However, the sources of the articles was limited to some important purchasing and supply chain-oriented journals. The literature was not systemic, so its replicability is still quite limited.

The development of the extended framework was based on an initial framework that was developed by myself. The new features in the extended framework were also subjective, mainly depending on what I thought would be relevant. However my thoughts were based on a generality raised from different articles pointing at the same direction.

Then, the interview guide was developed by myself again and the wording of the questions is not replicable. The way I conducted and led the interviews is not replicable either. However, I transcripted all the interviews and analyzed them following a theme analysis approach, that can be replicable.

2.4.2 Validity

In terms of validity, Bryman (2016) mentions that this concept assesses the methods used for conducting a study. These methods need to be relevant given a certain study and methodology chosen. Bryman (2016) describe this concept through three axis : the construct validity, the internal validity and the external validity.

The construct validity is a validity that assesses if something is analyzed with the adequate measures Bryman (2016). In my case, I developed a framework based on several articles and through the methodological guidance of my supervisor, Tim Kristian Andreas Torvatn, professor in the Department of Industrial Economics and Technology Management at NTNU, who has a relevant experience and knowledge in supplier involvement in product development projects.

The internal validity assesses the causality of an argument Bryman (2016). In the case of my thesis, the analysis of my empirical data was theme-oriented, which helped understanding each aspect of the data. Moreover, the plurality of case companies helped generalizing some cause effects.

The external validity assesses the generalization of a conclusion Bryman (2016). In our case, the validity is complex to reach to a certain extend. Indeed, there were two interviewees, both from the automotive industry. Thus, it can help generalizing the conclusion to the automotive field. However, generalizing the conclusion to another field could be done but with extreme caution. Some aspects of the conclusions are generalizable because not depending on the automotive field, but other are not necessarily. The representativeness of the conclusions is an aspect mentioned in the discussion chapter, the chapter 6.

2.5 Conclusion

In this section, the intended methodology and the actual methodology conducted in this study were described. It shows the reader how the study was made and it also emphasises on the quality and limitation aspects of the study. This last aspect enables to warn on the generalization of some conclusions made in this study.

In the next section, the theory is introduced and the extended framework is developed.

3 Theoretical discussion

3.1 Introduction

In this chapter 3, we will discuss the different aspects of ISD in NPD projects. As mentioned earlier, I already conducted a project thesis that lead to a theoretical framework (Miguet, 2019). Based on that work and on the articles used to develop this model, I will explain the initial framework. I will also add other relevant articles to the initial model. The purpose of doing that is to extend the model and to add more discussion to the factors. In the chapter 3.2, I will briefly introduce the initial framework (Miguet, 2019). In the chapter 3.3 I will summarize the extended theoretical framework, resulting of additional articles and the initial framework. And in the chapters 3.4 and 3.5 I will introduce in depth the business level factors and the project level factors that composed the extended framework. I will finally conclude in the chapter 3.6

3.2 Initial theoretical framework

In this section, the initial framework is discussed. This model is introduced in the figure 3.

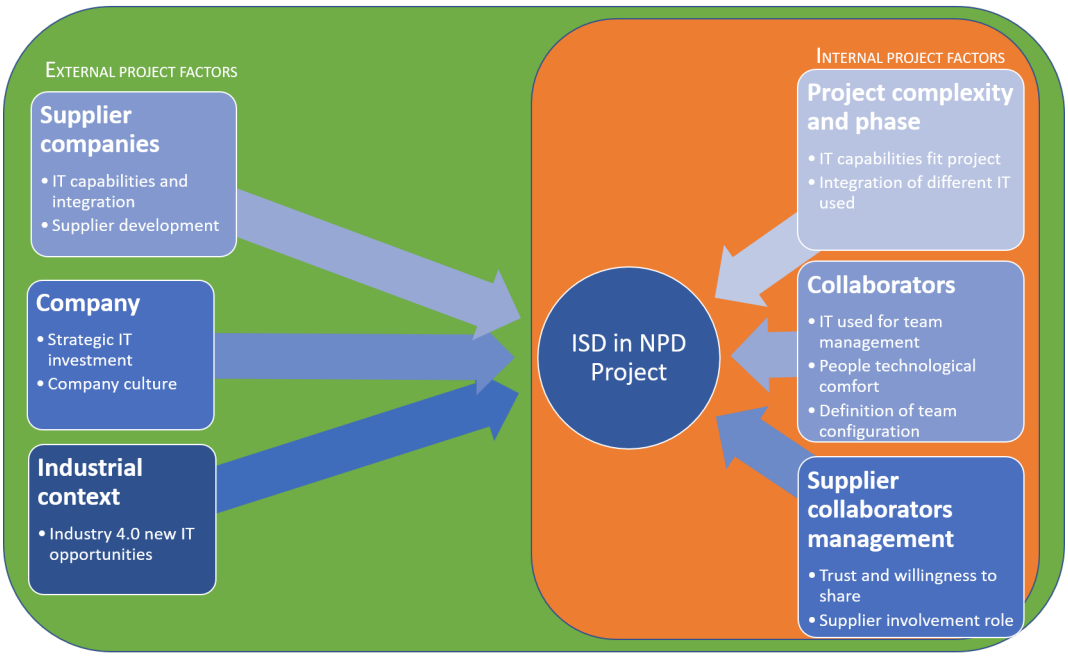

Figure 3: Initial framework: factors influencing ISD in NPD projects, source: Miguet (2019)

This framework describes factors that can influence ISD in NPD projects. We can notice that

there are two types of factors: external project factors and internal project factors. Indeed, in this framework, it was important to distinguish between factors that depend only on projects themselves and factors at a company level, which would therefore be external factors to the project. Therefore, those factors were renamed business level and project level factors in the extended framework.

The **external project factors** - or **business level factors** - are: the industrial context, the company and the supplier companies. The industrial context in this initial framework is mainly focused on the Industry 4.0 phenomenon and on the new IT opportunities this revolution brings (Miguet, 2019). The company factor underlines which aspect of a company could influence the digitalisation of information sharing. The aspects identified by Miguet (2019) are the strategic IT investment and the company culture. The last business level factor is the supplier companies. This factor focuses on the suppliers' IT capabilities, IT integration and the supplier development (Miguet, 2019).

The **internal project factors** - or **project level factors** - are: the project complexity and project phase, the collaborators and the supplier collaborator management. The project complexity and project phase deal with the project IT requirement, and if the IT capabilities of the company fit those requirements. It also deal with the integration of different IT used during a project (Miguet, 2019). The collaborators factor focuses on the human aspect of the project: which IT is used for team management, how people actually use IT and how the team is defined (Miguet, 2019). The last aspect is about the suppliers but at a project level, a human level. It focuses on the collaboration aspect, the supplier involvement role and the trust aspect for this collaboration (Miguet, 2019).

This section was just a short introduction to the initial framework developed by Miguet (2019). However, it will be further explained in the next sections and with more discussion with other relevant articles to reach an extended version of this initial framework.

3.3 Extended theoretical framework

In this section the outline of the extended theoretical framework is introduced. This framework is described in the figure 4.

In this framework, it can be noticed that the main factors have not changed. However, instead

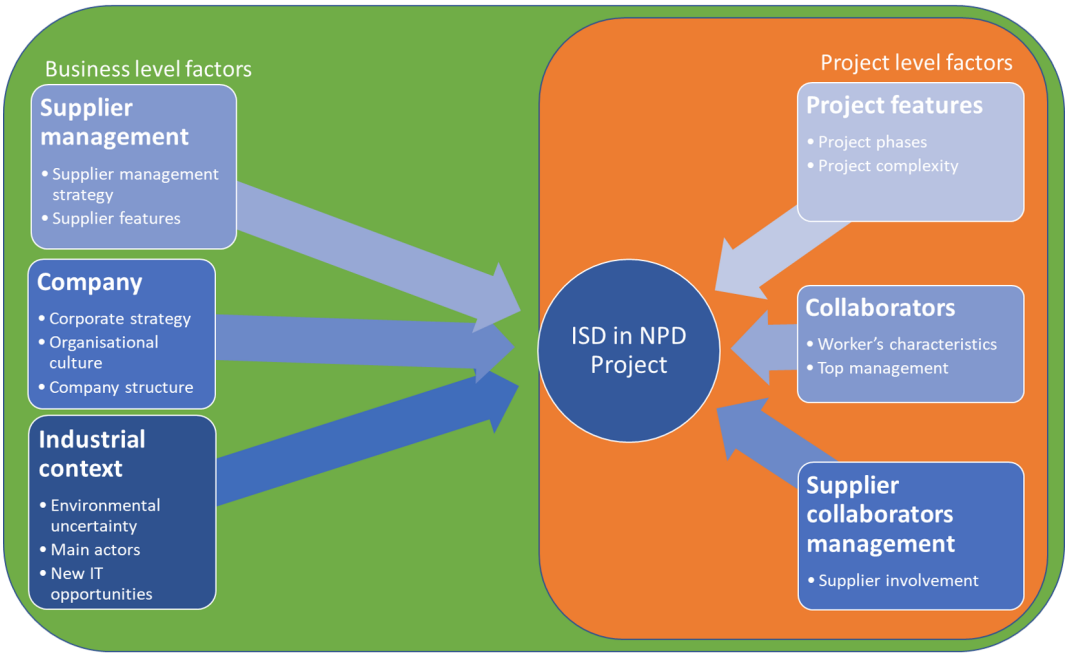

Figure 4: Extended framework: factors influencing ISD in NPD projects, source: Miguet (2019)

of external project factors and internal project factors are now referred as business level factors and project level factors respectively. Those two levels are addressed in the chapters 3.4 and 3.5.

3.3.1 New Business level factors

Business level factors are thus the same ones than in the initial framework, but business sub-factors have changed. This changed occurred after the master thesis literature review, where additional aspects to each factors were identified.

Industrial context: this factor was in the initial framework defined as the Industry 4.0 new IT opportunities. But this sub-factor is just summarized as New IT opportunities in the extended framework because Industry 4.0 is part of those new IT opportunities. Thus it makes more sense to describe the different new kind of IT opportunities in this sub-factor. Also, two other sub-factors were identified. The first new sub-factor is the Environment uncertainty, which is a important aspect that was not taken into account in the initial model. The second sub-factor is the Main actors. This factor describes the importance of the main actors of the industry and how they influence the industrial context in which a company evolves into.

Company: this factor was split into Strategic IT investment and company culture in the initial model. In the new model, the strategic IT investment is part of the sub-factor Corporate strat-

egy, because there is not only the IT strategy that can matter. The company culture becomes the organisational culture, which is not a major change. Finally, the company structure is added to the company factors, because a company structure is a major aspect of a company. A small-size company and a large-size company do not have the same structure and could therefore have different ways of leading their own businesses. This aspect was missing in the initial framework.

Supplier management: was originally supplier companies. But this factor's name was slightly misleading, because what actually matters in the model is how supplier companies that are managed by the company can influence ISD in NPD projects. Thus, it was renamed into Supplier management. The initial sub-factors were IT capabilities and integration and supplier development. The IT capabilities and integration were not the only aspects that could actually be of interest in a supplier companies, therefore they integrated the sub-factor Supplier features. As for the supplier development, it was integrated into the supplier management strategy, as well.

3.3.2 New Project level factors

Project level factors were Project complexity and phase, Collaborators and Supplier collaborators management in the initial framework. In the extended framework, the complexity and phase of a project were rename Project features.

Project features: in the initial framework IT capabilities fit project and integration of different IT used. In the extended version of the model, those aspects are integrated in the project phases and project complexity as features of the project.

Collaborators: was a factor described through IT used for team management, People technological comfort and Definition of team configuration. It now is worker's characteristics, which integrates people technological comfort and Top management, which integration team configuration and IT used for team management. Indeed, it is the top management who is in charge of those aspects.

Supplier collaborators management: the aspects of trust and willingness to share were integrated into the supplier involvement aspect.

3.4 Business level factors

Business level factors are the industrial context, the company and the supplier companies in this extended framework. Those factors are, by nature, at a business level, they do not depend directly on the projects themselves. Therefore, when it comes to those factors, projects are not the main focus. We hypothesize that those elements can influence the ISD of a company, which therefore means that they influence the ISD of NPD projects.

3.4.1 Industrial context

This chapter deals with the industrial context factor. It can be defined as the context in which a company operates. Therefore, this factor focuses on three main points: the **main actors** in the company industry, on the **environment uncertainty** and on the **new IT opportunities**. The elements of each point and the articles used for each point are summarized in the following table, see table 1. The Industry 4.0 and Internet-based technologies were already present in the initial framework (Miguet, 2019), however some additional literature about it was found to add more discussion.

Sub-factors	Elements	Main authors
Mains actors	- The actors influencing a company's strategy	Porter (2008)
	- A competitive environment	Li and Lin (2006) Shore and Venkatachalam (2003) Sriram and Stump (2004)
Environmental uncertainty	- Technology uncertainty and technology development	Li and Lin (2006) Patterson et al. (2003) Pavlou and El Sawy (2006)
	- Customer preferences change or flexibility	Crocitto and Youssef (2003)
New IT opportunities	- Monitoring market for new technologies	Wynstra et al. (2003) Song and Song (2010)
	- New ICT technologies	Montoya et al. (2009)
	- Industry 4.0: Applications and technologies	Lasi et al. (2014) Lu (2017)
	- Internet-based technologies: E-procurement, E-marketplace, B2B	Chang and Wong (2010) Albrecht et al. (2005)

Table 1: Literature on the industrial context factor

The **first point of the industrial context is about the main actors**. When discussing information sharing in supply chain management, Li and Lin (2006) consider that the supply chain partners have an influence on information sharing. Those supply chain partners are defined as the **suppliers** and the **customers**. Whereas, from a more strategic perspective Porter (2008) discuss the impact of **suppliers**, **customers**, **competitors**, subsidiaries and new entrants. Porter (2008) is focused on the industry level and how it can influence a company strategy. Therefore,

I decided to mainly focus on suppliers, customers and competitors as the main actors influencing company in information sharing. This choice was made because suppliers and customers are part of the supply chain of a given company and they are integrated in the information flow. Also, it seemed necessary to take into consideration competitors, because their choices could influence a given company. However, subsidiaries and new entrants were not considered in my framework mainly because: they are not part of the supply chain of the company; they do not play the same role as the competitors who are in a more direct confrontation. Suppliers and customers naturally play a role in the information flow and can influence information sharing, but a focus needed to be made on competitors. In a competitive environment, companies are pushed to be efficient and adapt to change (Li and Lin, 2006). Moreover, given the global context, the competitive environment has never been stronger: it used to be local but due to technology development it is now at a global scale (Li and Lin, 2006). And one way of quickly adapting to change because of a competitive environment is sharing information (Sriram and Stump, 2004; Shore and Venkatachalam, 2003). Shore and Venkatachalam (2003) precisely note that one factor influencing information sharing is a competitive market. This can be understood, because in a highly competitive market, to outperform competitors, companies have to be efficient and adapt to the market, in order to have a quick time to the market. And information sharing is one of the main way to accelerate the time to the market. Therefore, the main actors of such a competitive environment are defined as: the **competitors**, the **customers**, the **suppliers**. It is therefore hypothesized that each of those actors may have an influence on a company ISD.

The **second point of the industrial context is the environment uncertainty**. It deals with **the technology uncertainty, the customer uncertainty and the supplier uncertainty** according to Li and Lin (2006). Pavlou and El Sawy (2006) define the uncertainty as the "changes in consumer preferences and technology development". It means that a company can face situations where a customer decides to change features of a product being developed while everything is already set for the development. Another example would be a customer that was expecting a product and gave the guidelines to develop it, but is finally unsatisfied with the product he gets. There, the customer could ask for a change, when the product is completely developed. Basically, at any stage of the development of the product, the company developing the product can not be entirely sure that the product will be what the customer really expects, even though the latter expressed his specifications. Crocitto and Youssef (2003) also discuss the customer uncer-

tainty, but mention his flexibility. This feature of the customer describe his uncertainty level. The less flexible a customer is, the more uncertainty the company will get from him. Because there are also other types of uncertainties, such as the technology uncertainty. The technology uncertainty is linked to its development, because companies need to keep pace of all the different developments (Li and Lin, 2006). This environment uncertainty factor could influence the information sharing and its digitalisation. According to Patterson et al. (2003) the environment uncertainty impact the supply chain technology adoption. Li and Lin (2006) on the other side, only consider the supplier uncertainty as a discriminating factor of high level of information sharing (and information quality). The supplier uncertainty deals with unreliable suppliers, that forces companies to reduce their supply base to only few suppliers and build a partnership with them (Li and Lin, 2006). Therefore, the environment uncertainty is hypothesized to influence information sharing and its digitalisation. In our model, technology, customer and supplier uncertainties are integrated in this environment uncertainty, to be able to assess them all in this context.

The **third point of the industrial context is about the new IT opportunities**. Those new opportunities can be **Internet-based procurement technologies, Information and Communication Technologies (ICT) and Industry 4.0 related technologies** (Miguet, 2019). Interned-based new technologies for **procurement** can have different e-commerce architectures. According to Albrecht et al. (2005) definition, those architectures are Electronic Data Interchange (EDI), company websites, e-procurement systems, Business-to-business (B2B) hubs, and web services, as shown in the figure 5.

Each of those architectures has its own advantages and drawbacks. The most traditional and ancient architectures are EDI and company websites (Albrecht et al., 2005). E-procurement is a more recent technology, which is led by the buyer (Chang and Wong, 2010). According to Hsin Chang et al. (2013), E-procurement consists of e-design, e-sourcing, e-negotiation and e--evaluation. Web services is, according to Albrecht et al. (2005) the latest technology of those architectures, with a potential to extend e-commerce. This technology includes Business-to-customer (B2C), B2B, Customer-to-customer (C2C) and Peer-to-peer (P2P) transactions (Albrecht et al., 2005). A type of Web Services is the B2B Hub, or marketplace, which facilitate exchange of data between buyers and sellers on the same platform (Albrecht et al., 2005). The difference between those technologies can be found in the information that is shared to all the stakeholders. When using EDI, the information is not shared in the same way than when using

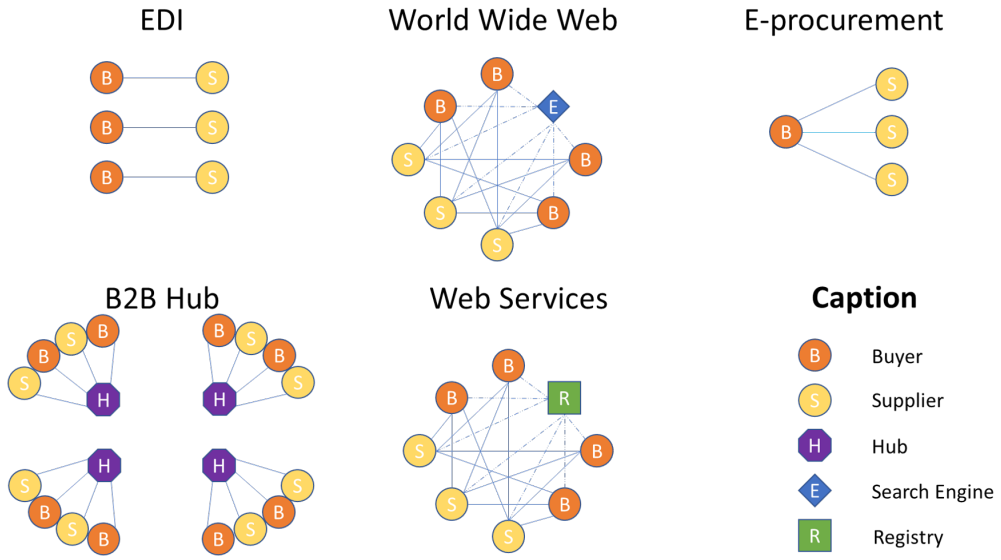

Figure 5: Different e-Business architectures, adapted from: Albrecht et al. (2005)

E-procurement software or B2B Hubs. Indeed, one of the strengths of those last two lies down in the ability to stock the information and let it be available at anytime to anyone who has access to it on the same platform.

Moreover, Interned-based technologies can also apply to the **ICT**. With the recent technology developed, virtual team are enabled to work together (Montoya et al., 2009). Those teams, work from different location, with different time zone. They are enable to communication and exchange data with each other with different media. This can have a major impact on travel costs and it is important for companies (Montoya et al., 2009).

In addition to that, the **Industry 4.0 technologies** also emerge (Lasi et al., 2014; Lu, 2017). Some of those technologies are: the Internet of Things (IoT), social media, the cloud, big data and analytics, artificial intelligence (AI), mobile technologies, virtual and augmented reality (VR/AR), blockchain and additive manufacturing (Srai and Lorentz, 2018; Lu, 2017). This Industry 4.0, or 4th industrial revolution, has two driving forces: an application pull and a technology push (Lasi et al., 2014). Those two forces enable companies to automate processes, reduce time-to-market, reach higher levels of flexibility, decentralize and get a higher level of ressource efficiency (Lasi et al., 2014). Also, companies start working in digital environment and components are more and more connected to the same network (Lasi et al., 2014). Miguet (2019) hypothesized that new technologies could influence information sharing digitalisation, because of the potential it brings to company. In this new framework, three types of technologies are hypothesized to influence information sharing digitalisation: **Internet-based technologies, ICT and**

Industry 4.0 technologies.

3.4.2 Company

This chapter deals with the company factor. This factor is by nature at the business level factor. This factor focuses on three main points: the company structure, the corporate strategy and the organisational culture. The elements of each point and the articles used for each point are summarized in the following table, see table 2. The organisational culture, the strategic IT investment and the IT infrastructure were already present in the initial framework (Miguet, 2019), however some additional literature for them too was found to add more discussion.

Sub-factors	Elements	Authors
Company structure	- Firm size	Shore and Venkatachalam (2003)
	- Centralisation degree	Mishra and Agarwal (2010) Patterson et al. (2003) Lasi et al. (2014)
Organisational culture	- Values	Mckinnon et al. (2003) Li and Lin (2006)
Corporate technology strategy	- Strategic IT investment	Bharadwaj (2000) Patterson et al. (2003) Montoya et al. (2009) Gordon and Tarafdar (2007)
	- IT infrastructure	Pavlou and El Sawy (2006) Gordon and Tarafdar (2007) Nambisan (2003)

Table 2: Literature on the company factor

The **first point of the company factor is about the company structure**. It has two main dimensions in this framework: a firm size dimension and a centralisation degree dimension. A firm size matters because it could influence a company's innovation (Mishra and Agarwal, 2010). Therefore, it could influence the digitalisation of information sharing. Moreover, the centralisation degree has to deal with control (Shore and Venkatachalam, 2003). In a centralised model, the company controls everything from one location and need all the relevant information shared. In a decentralised model, the control is made by all the different business units in different location. There is also a need for information sharing, but more at a local scale. Patterson et al. (2003) considers that decentralised organisational structure and organisational size are positively correlated with supply chain technology adoption. Which means that decentralisation leads to higher levels of technology in this configuration. In addition to that, Lasi et al. (2014) mention decentralisation as one of the application pull of the Industry 4.0, because

it leads to faster decision-making processes. Thus, we hypothesized that the size and the centralisation degree of a firm could influence the information sharing digitalisation.

The **second aspect of the company factor is the organisational culture**. Miguet (2019) already hypothesized that a company culture could influence the information sharing digitisation, because it would influence information sharing levels due to the management style, notably. Mckinnon et al. (2003) go deeper, and in a Taiwanese study, associated organisational culture values with employee responses, including their information sharing behavior. Those values were respect for people, innovation, stability and aggressiveness. Therefore, it can be imagined that at a general scope, organisational values can influence information sharing levels, which could therefore influence information sharing digitalisation. As mentioned by Miguet (2019), many researchers stressed the difference between the capability to share information and the will to do it, which are two distinct dimensions of information sharing. According to Li and Lin (2006), top management support could positively impact the information sharing, therefore the will to share information, however it would not influence the information quality. It can be understood that the environment given to employees through the organisational culture can push them to adopt a information-sharing behavior. In the framework, it is then hypothesized that organisational culture can influence information sharing digitalisation.

The **third aspect of the company factor is about the corporate technology strategy**. This technology strategy is about the information sharing strategy and the strategic IT investment.

First, this strategy is based on the **IT infrastructure** of the company. Gordon and Tarafdar (2007) and Pavlou and El Sawy (2006) mention three main IT systems that need to be mastered in a company, especially for NPD: Information and knowledge management systems, project management systems and finally collaboration and communication systems. Gordon and Tarafdar (2007) conclude that a company with IT competences in those areas and in business involvement could more easily innovate. Nambisan (2003) in their paper have one more system which is the process management system. Those systems are very costly but bring many capabilities that can add value or reduce time spent on non-adding value activities. Moreover, a company generally needs many systems and integrating the IT infrastructure is complex and requires time (Bharadwaj, 2000). Gordon and Tarafdar (2007) even mention that some IT competences are: IS and IT strategy - which consists of understanding the business strategy and use IS and IT to support it. Another IT competence is exploitation, which is the capacity to effectively use

IT investments. Pavlou and El Sawy (2006) and Gordon and Tarafdar (2007) both consider that IT, for NPD management, can be used but it needs to be effectively used.

This raises the matter of costly and time-consuming **IT investment** and the reasons of those investments which are then strategic (Miguet, 2019). Bharadwaj (2000) argue that companies with high IT capabilities tend to outperfom their peers. IT competences or capabilities are then seen as a valuable resource for companies, which is not easily imitated (Bharadwaj, 2000). The return on IT investment takes time and combined with a learning curve effect, Bharadwaj (2000) consider that the sooner IT investments are made, the more efficient a company's performance will be. It is also concluded that IT need to be efficiently and effectively used (Bharadwaj, 2000). Barratt (2004) consider technology as one of the strategic elements in the core of the supply chain collaboration. This means that IT investments are not only beneficial for the company investing in it, but also for his partners because it leads to higher level of collaboration. Miguet (2019) also mentioned it, high IT capabilities, between a company and his supplier for instance, can lead to higher collaboration levels. However, it was also mentioned that trust was also necessary in a relationship, not only the ability to collaborate effectively (Miguet, 2019). As mentioned in the industry context factor, technologies also develop quickly, which push companies to invest in technologies (Patterson et al., 2003). Indeed, if those companies do not meet the same technology levels than their competitors, suppliers or customers, they would be left behind. In order for them to protect their market share, they need to adopt technologies (Patterson et al., 2003). Those new technologies can give them more opportunities to maximize the use of their resources. With ICT for instance, companies can make virtual teams work (Montoya et al., 2009). Those teams are located in different countries with different time zone, which makes it really complex for workers to collaborate together. However, a company, that needs their competencies in one NPD project for instance, will use ICT. These technologies brings opportunities to work with people from all over the world and can cut travel costs and leverage global cost (Montoya et al., 2009). Gordon and Tarafdar (2007) also mention IT competences in their capacity to support innovation in NPD projects, through each phase of a project. In the new framework of ISD in NPD projects, it is then hypothesized that IT investment and the IT infrastructure of a company influence information sharing digitalisation.

3.4.3 Supplier companies

This chapter deals with the supplier companies factor. This factor focuses on two main points: the supplier features and the supplier management strategy. The elements of each point and the articles used for each point are summarized in the following table, see table 3. The supplier IT capabilities and the supplier development were already present in the initial framework (Miguet, 2019), however some additional literature for them too was found to add more discussion.

Sub-factors	Elements	Authors
Supplier features	- Supplier uncertainty	Li and Lin (2006) Patterson et al. (2003)
	- Power balance	Patterson et al. (2003) Porter (2008)
	- IT capabilities	Shore and Venkatachalam (2003) Handfield et al. (1999)
Supplier management strategy	- Innovation strategy	Wynstra et al. (2003)
	- Supplier interface	Liker and Choi (2004) Araujo et al. (1999)
	- Supplier development	Wynstra et al. (2003)

Table 3: Literature on the supplier companies factor

The **first point** of the supplier companies factor is about supplier features. It includes supplier uncertainty, power balance, IT capabilities and IT integration dimensions.

Supplier uncertainty can negatively impact information sharing and also information quality, according to Li and Lin (2006). Li and Lin (2006) also mention that information sharing is impacted by trust in the partners and their commitment. It is why it is recommended to build strategic partnership in order for the company to reduce the uncertainty of the suppliers (Li and Lin, 2006). Patterson et al. (2003) notice that inter-organisational factors such as trust and commitment and supplier pressure can influence technology adoption. Therefore, on the one side uncertainty, trust, commitment influence information sharing and on the other side trust, commitment and pressure influence technology adoption. It can be thus hypothesized that supplier uncertainty and power balance can influence information sharing digitalisation, because of its dual nature of technology and information sharing. Porter (2008) also mentioned the power balance of the suppliers, in their capacity to charge higher prices. Here again, there is a notion of trust, commitment and partnership which will define the type of relationship that a company has with its suppliers.

In addition to this relationship aspect, there is a more technical aspect of the supplier features which is based on their IT capabilities and IT integration. Shore and Venkatachalam (2003) consider that one of the criteria to assess a supplier's information sharing capabilities is its IT infrastructure, constituted of hardware and software capabilities, network infrastructure and data management capability. Therefore, in the same way that IT capabilities and IT integration matter for the company leading projects itself, they matter for the suppliers the company work with. A difference is that both the supplier and the company need to have an aligned technology roadmap (Handfield et al., 1999).

Therefore, it is hypothesized for this extended framework that supplier features (uncertainty, power balance, IT capabilities and IT integration) can influence ISD in NPD projects.

The **second aspect** of the supplier companies factor is about the supplier management strategy. This aspect focuses on innovation strategy, supplier interface and supplier development.

Araujo et al. (1999) consider four different interfaces with suppliers: a standardized one, a specified one, a translation one and an interactive one. From the standardized one to the interactive one, there is a rise in the amount of freedom given to the supplier. The latter can indeed be creative and discuss with the customer in the interactive interface while in the standardize interface there is no specific connection between the supplier and the customer (Araujo et al., 1999). Depending on the type of interface chosen, the client's productivity and innovation may have higher costs or benefits (Araujo et al., 1999). For instance, in an interactive interface, the customer needs to invest time in teaching and working with the supplier but in return the supplier can provide a wider set of solutions to the customer (Araujo et al., 1999). Liker and Choi (2004) define a hierarchy of different partnership stages that can exist with a supplier and the consequences of these stages, see table 4.

In those stages, it can be noted that contrary to Araujo et al. (1999) there is no standardized interface. Indeed, in the paper by (Liker and Choi, 2004) the focus is on building deep supplier relationships. And in this framework, intense and selective information sharing is the second last stage of this deep relationship (Liker and Choi, 2004). However, some aspects of information sharing are conducted in each phase, e.g. in "Send monthly report cards to core suppliers" (Liker and Choi, 2004). Therefore, it can be noticed that it is mainly for core suppliers, suppliers that are meant to be part of a joint venture or a strong relationship with the customer, that information sharing matters. Baihaqi and Sohal (2013) noticed that it is when companies invest

Stage	Consequences
Understand how your suppliers work	- Learn about suppliers' businesses - Go see how suppliers work - Respect suppliers' capabilities - Commit to co-prosperity
Turn supplier rivalry into opportunity	- Source each component from two or three vendors - Create compatible production philosophies and systems - Set up joint ventures with existing suppliers to transfer knowledge and maintain control
Supervise your suppliers	- Send monthly report cards to core suppliers - Provide immediate and constant feedback - Get senior managers involved in solving problems
Develop suppliers' technical capabilities	- Build suppliers' problem-solving skills - Develop a common lexicon - Hone core suppliers' innovation capabilities
Share information intensively but selectively	- Set specific times, places, and agendas for meetings - Use rigid formats for sharing information - Insist on accurate data collection - Share information in a structured fashion
Conduct joint improvement activites	- Exchange best practices with suppliers - Initiate kaizen projects at suppliers' facilities -Set up supplier study group

Table 4: The Supplier-Partnering Hierarchy, source : Liker and Choi (2004)

in suppliers and develop them that they realize the interest of sharing information. The idea behind the supplier interface is also to have the most efficient use of the supplier capabilities (Wynstra et al., 2003). Through different interfaces, the customer has access to an entire supply base and can monitor all his suppliers, evaluate them, make them develop some knowledge for his products (Wynstra et al., 2003). There is therefore an innovation strategy behind the interface concept. Wynstra et al. (2003) consider that supplier interface management serves the idea of maximizing the supplier technical capabilities. Moreover, developing suppliers is also a key to pointing them towards the technological capabilities the customer need (Wynstra et al., 2003).

Thus, it is hypothesized in the extended framework that ISD is influenced by the supplier management strategy and supplier features.

3.5 Project level factors

In this framework, three factors of ISD in NPD project were identified: the project complexity and phase, collaborators and suppliers (Miguet, 2019). Project level factors are, contrary to business level factors, at the level of projects. Therefore, it is hypothesized that those factors may directly influence ISD in NPD projects.

3.5.1 Project features

This chapter deals with the project features. This factor focuses on two main points: project complexity and project phase. The elements of each point and the articles used for each point are summarized in the following table, see table 5. All the elements were already present in the initial framework (Miguet, 2019), however some additional literature for them too was found to add more discussion.

Sub-factors	Elements	Authors
Project phases	- Amount of information through each phase	Wynstra et al. (2003) Hoegl et al. (2004) Handfield et al. (1999) Gordon and Tarafdar (2007) Olson et al. (2001) Krishnan and Loch (2005)
	- IT capabilities fit project	Pavlou and El Sawy (2006) Montoya et al. (2009) Nambisan (2003)
Project complexity	- Product size, novelty and task interdependency	Jungbae Roh et al. (2008) Olson et al. (2001) Goodhue and Thompson (1995) Hoegl et al. (2004) Nambisan (2003) Montoya et al. (2009) Banker et al. (2006)

Table 5: Literature on the project phase and complexity factor

The **first point** is the project phase. It focuses on the amount of information shared through each phase and the IT capabilities required for the project.

Before diving into the specificity of project phase on ISD in NPD projects, it seems necessary to define what are the phases of a project. In all papers dealing with project, the definition of the stages of a project is always slightly different; Krishnan and Loch (2005) took the following approach: 1) opportunity (or idea) generation, 2) idea selection, 3) requirement assessment, 4) detailed development, 5) market and manufacturing launch, 6) product life cycle changes. Handfield et al. (1999) also used a long version of project phases: 1) idea generation, 2) business or technical assessment, 3) concept development, 4) engineering and design, 5) prototype and ramp-up for operations. Gordon and Tarafdar (2007) only used 3 phases: 1) initiation, 2) development, 3) implementation. Hoegl et al. (2004) also opted for a short split of project phases: 1) early phase stage : idea generation, 2) later design stage : problem-solving stage. In our extend framework, the focus is not so precise that every phase of a project need to be defined. The focus

is more on a general trend, that could be clarified in further research. Therefore, a short version of project phase will be adopted in our extended framework, such as the one mentioned by Gordon and Tarafdar (2007), in **3 phases : initiation, development and implementation.** Those 3 phases includes the other detailed phases discussed above.

If project phases are discussed in this extended framework, it is because some researchers noticed that information flows and and information type differ in the project phases (Wynstra et al., 2003; Hoegl et al., 2004; Olson et al., 2001). For instance, in the initiation phase, Wynstra et al. (2003) consider relevant that product management members provide information on technologies development and new technologies in the market or already developed ones. Hoegl et al. (2004) consider that more information sharing is necessary in the early phase of a project, which is the initiation stage. Indeed, in the initiation stage, teams have to meet frequently and gather to brainstorm ideas (Hoegl et al., 2004). Meanwhile, in the development and implementation stages, the need for cooperation is less imperative, on the contrary team members need to focus on crucial information and only share those pieces of information to avoid overloading other team members with information (Hoegl et al., 2004). Olson et al. (2001) understress the importance of information sharing in different project phases between different teams. Research & Development (R&D) and marketing should cooperate the most in the initiation stage, therefore share information the most in that phase (Olson et al., 2001). While, operations and marketing and operations and R&D information sharing should be the most important in later stages, such as development and implementation (Olson et al., 2001).

This being said, it shows that information sharing flows and types are different in the project phases. This underlines the importance of IT in all those different phases. For instance, given the major significance of the initiation phase, NPD teams need to be connected to each other and collaborate together. However, it was already mentioned earlier that virtual teams have emerged (Montoya et al., 2009). This raises the matter of the relevance of IT and especially ICT in the initiation phase for virtual teams, because teams cannot travel to another country every time they need to collaborate (Montoya et al., 2009). The need for IT in NPD projects brings back the different IT systems used mentioned in the company factor : project and resource management system, knowledge management system and cooperative work system (Pavlou and El Sawy, 2006) and process management systems (Nambisan, 2003). Each of those systems help companies to deal with different aspects of information flows and information type. It seems then necessary that those systems fit project requirements.

Therefore, it is hypothesized in this extended framework that ISD in NPD project is influenced by project phases and the IT used.

The **second point** is about the project complexity. It deals with product size, product novelty and task interdependency Miguet (2019). (Jungbae Roh et al., 2008) consider that the product type, which would be whether functional or innovative, influences the supply chain strategy, and therefore the information sharing strategy. Olson et al. (2001) consider that innovative products need high levels of cooperation, especially in late stages of NPD projects, between operations and R&D and marketing. Moreover, as mentioned above, cooperation is now embedded with IT. Therefore, the innovative level of product could influence ISD. (Banker et al., 2006) understress the influence of product size on collaboration, which influences information sharing. Goodhue and Thompson (1995) noticed that task interdependency can influence a task technology fit which influence the IT used. Therefore the more interdependent the tasks, the more IT can be used to deal with it. It is actually a matter for collaboration and team performance to manage task interdependency (Hoegl et al., 2004). This specific aspect of project complexity is one of the core of project management software according to (Nambisan, 2003). This kind of software can help coordinate tasks, especially for teams from different workplaces (Nambisan, 2003). Montoya et al. (2009) also pointed out the importance of ICT for managing tasks at distance.

Therefore, it is hypothesized that the project complexity can influence ISD in NPD projects.

3.5.2 Collaborators

This chapter deals with the collaborator factor. This factor focuses on two main points: worker's characteristics and team management. The elements of each point and the articles used for each point are summarized in the following table, see table 6. The worker's technological comfort and the team configuration and communication were already present in the initial framework (Miguet, 2019), however some additional literature for them too was found to add more discussion.

The **first point** is about worker's characteristics. With regards to ISD in NPD projects, it deals with workers' technological comfort. As mentioned by Bharadwaj (2000) IT infrastructure and human IT resources matter to translate IT as an organisational capability. Bharadwaj (2000)

Sub-factors	Elements	Authors
Workers' characteristics	- Technological comfort	Bharadwaj (2000) Montoya et al. (2009) Pavlou and El Sawy (2006) Fred D. et al. (1989)
Team management	- Top management	Li and Lin (2006) Fred D. et al. (1989) Sarin and O' Connor (2009)
	- Team configuration & Communication	Barczak et al. (2008) Montoya et al. (2009) Pavlou and El Sawy (2006)
	- Cross functional integration	Olson et al. (2001) Durmusoglu et al. (2006) Song and Song (2010)

Table 6: Literature on the collaborator factor

defines human IT resources as technical IT skills and managerial IT skills, the latter will be discussed in the team management aspect of the collaborators factor. Those human IT resources enable an easier integration of IT and a more efficient collaboration in the different business units (Bharadwaj, 2000). Also, given the globalisation context, Montoya et al. (2009) noted the importance of virtual teams and the significant improvements made in collaboration thanks to ICT. This means that team members need to master those ICT but also other IT to work in NPD projects. Those other IT are the ones mentioned above: project and resource management systems, knowledge management systems, cooperative work systems (Pavlou and El Sawy, 2006). Therefore, it is understressed that the ability of collaborators to master different types of IT systems is important for companies' projects. Fred D. et al. (1989) investigated the factors influencing the user acceptance of computer technology. Indeed, in order for collaborators to use IT, they must first accept it and want to use it. Fred D. et al. (1989) found that two mains factors influence people acceptance of computer technology : the perceived usefulness and the perceived ease, the first one having the strongest influence on the acceptance. It can be noted that it is not the usefulness or the ease of the IT that is at stake, it is the perception of it. It shows that people would need to be shown the advantages and the ease of using a type of IT, otherwise they might not use it. Therefore, it is hypothesized that people technological comfort influence ISD in NPD projects, because if collaborators themselves do not support ISD by using IT, then there is no digitalisation possible.

The **second point** is the team management. It focuses on top management, cross-functional integration, team configuration and communication. Li and Lin (2006) investigated the factors impacting information sharing in the supply chain management and top management had

an influence on it, but not on information quality. This means that top management support can push collaborators to share information, but it does not mean that the information will be qualitative. But it shows that it is important that top management encourages people to share information and lead them on how to do it and why they should do it, as part of the perceived usefulness and ease discussed by Fred D. et al. (1989). Sarin and O' Connor (2009) studied the influence of team leader characteristics on a cross-functional NPD team. It was found out that team leader, therefore top management, influenced collaboration, communication formality and quality. Therefore, the communication quality aspect is to opposite to what Li and Lin (2006) concluded on information quality. Indeed, it can be understood that communication is made of information, thus communication quality and information quality are connected. The difference between the two point of view might lie in the fact that Li and Lin (2006) was at a Supply Chain Management (SCM) level focusing on top management in general and Sarin and O' Connor (2009) was at a project level, focusing on team leader specifically. When it comes to team configuration and communication, this aspect was already mentioned above, it deals with virtual team or teams located at different location, as discussed by several papers. It seems that IT usage depends on team configuration and communication, because communication is of great importance for team throughout a project and given the fact that there are more and more teams not located in the same place, this communication is made through IT, and ICT especially (Barczak et al., 2008; Montoya et al., 2009; Pavlou and El Sawy, 2006; Boutellier et al., 1998). Therefore, ISD in NPD projects could be influence by team configuration and communication. Cross-functional integration is also a topic when NPD projects are discussed, because of the nature of the work where marketing, R&D and operations have to work together (Olson et al., 2001). Durmusoglu et al. (2006) investigated the relevance of adding more IT in NPD projects and showed that the IT department was also important in NPD projects. Indeed, IT can enable NPD projects to be more agile, and reach higher levels of cooperation (Durmusoglu et al., 2006). Therefore, not only the marketing, R&D and operations departments might be important in the cross-functionality but also the IT department. As mentioned by Song and Song (2010) IT helps integrating different departments, such as R&D and marketing, and get a higher performance of NPD projects. Therefore, cross functional integration is hypothesized to influence ISD in NPD projects.

3.5.3 Supplier collaborators management

This chapter deals with the supplier collaborators management factor. This factor focuses on supplier involvement in the project. The elements of supplier involvement and the articles used for it are summarized in the following table, see table 7. The communication and trust were already present in the initial framework (Miguet, 2019), however some additional literature for them too was found to add more discussion.

Sub-factors	Elements	Authors
Supplier involvement	- Moment	Wynstra et al. (2003) Handfield et al. (1999) Ragatz et al. (1997)
	- Communication and trust	Barczak et al. (2008) Wynstra et al. (2003) Fawcett et al. (2007) Humphreys et al. (2004)

Table 7: Literature on the supplier collaborators management factor

The point of this factor is the supplier involvement. It deals with the supplier involvement moment and the communication and trust.

Wynstra et al. (2003) define that some aspects of project management are to define the workload and the moment of involvement of suppliers as well as the integration between different suppliers and actors. Handfield et al. (1999) notes that the integration of a supplier depends on his role and the NPD project phase. Ragatz et al. (1997) conclude in their paper that practitioners said that suppliers should be involved earlier and more in NPD projects. Therefore, the moment of involvement of a supplier is significant in a project. However, Barczak et al. (2008) mentioned that outsourcing leads to more digitalisation through the use of IT, because it simplifies communication and cooperation. Wynstra et al. (2003) mentioned the importance of supplier workload and the integration of development activities, which are enabled through IT use, because IT is a key to collaboration (Nambisan, 2003). Also, Humphreys et al. (2004) noted that a customer could see his performance be higher when developing suppliers, and this could be done through an effective communication and trust (along other elements). It shows the importance of communication and trust when involving suppliers in a NPD projects. Therefore it is hypothesized that supplier involvement might influence ISD in NPD projects.

3.6 Conclusion

In this theoretical discussion section, the extended framework was thus discussed. It was explained that this framework was based on the initial framework developed by Miguet (2019). This framework and the additional articles red raised more hypothesis and led to the extended framework.

This extended framework consists of two categories of factors : business level ones and project level ones. Business levels factors are composed of the industrial context, the company and the supplier companies. Project level factors are composed by project features, collaborators and supplier involvement. Each of those factors is hypothesized to influence the ISD in NPD projects, in its own manner. Each of those factors has sub-factors that help understanding aspects of influence of theses factors.

In the next chapters, the empirical data is introduced and is then analysed.

4 Empirical data

4.1 Introduction

In this chapter, the empirical data is introduced. Given the anonymous nature of the data, the company in the case study is called company Alpha.

4.2 Company Alpha description

4.2.1 Presentation of the interviewee

The interviewee of this company is a purchasing director of one of the company Alpha's purchasing categories. He is 46 years old and has worked in different industries.

4.2.2 The company Alpha and its industry

The company Alpha is a French automotive equipment manufacturer within the **automotive industry**. The company is in a changing environment with major transformations, where innovation is the key. Historically, the environment has been extremely competitive and the competition has been mainly about price levels because it is a low-margin industry. Today, it tends to be more innovation-driven and product-driven.

Company Alpha's **customers** are car manufacturers which deliver vehicles to final customers. Those manufacturers evolve very quickly and are very demanding. They want more evolutionary products, more experience and information. Those car manufacturers have to take risks with their products which future is uncertain between electric cars or thermic cars. For instance, given the health crisis due to the coronavirus, the price of oil is falling which could be beneficial for thermic cars. Moreover, electric cars need major investments from both from manufacturers and the country. In addition to that, the future of other technologies used within a car are not set either.

On the other side, **suppliers** are close to the company Alpha, which makes it more convenient to adapt to change. For the given category of the interviewee, those suppliers companies are

rather large or medium-size companies, with a global presence. They use different IT systems than the one used by company Alpha. They do not need the same amount of systems, they can use lighter IT systems. The distribution of those suppliers follows a Pareto rule with around 80% of strategic suppliers. There are few non strategic suppliers, used for single sourcing sometimes. As mentioned above, the market was very price sensitive, but the company Alpha builds up partnerships with strategic suppliers. This is enabled by supplier quality development teams in charge of developing suppliers. The company Alpha also provides tools to improve suppliers capabilities. This strategy is made with the lens that suppliers will be grateful of those investments and will propose more competitive prices or innovative products earlier. Also, there is a supplier monitoring, enabled by IT systems, to prevent from any delay. In the case of specific events, such as the health crisis of the coronavirus, task forces are constituted and action plans as well.

As mentioned above, the company Alpha is a **French automotive equipment manufacturer**.

The company Alpha heavily invests in **new technologies**. This leads to products that used to be only part of a mechanical set to products that are part of a mechanical set and a digitalised set. This new set enables different products within a car to predict, collect data and interface with each other. The company uses different new technologies. Some technologies are used for innovative products, such as : AI or Big Data. Some other technologies are collaboration tools, such as : Business Intelligent Reports, knowledge sharing hubs. The Chief Executive Officer (CEO) of the company Alpha is technology and innovation driven, which pushes products and processes to be more embedded in new technologies (e.g. predictive maintenance or the Cloud for emails).

The company Alpha is in a **decentralised configuration**. It used to be centralised, but then when a project needed to be done or an innovation was identified it was slowed down because of the hierarchical configuration of the company. Whereas, with this new centralised configuration, the company is more innovation-driven and it is enabled by collaborative IT systems. Workers can share their work and ideas with workers from different locations. The corporate culture is for people to develop their potential. This happens while collaborators keep in mind the communicated corporate strategy.

4.2.3 The company Alpha and its projects

The company Alpha conducts many projects at the same time. Those projects are very complex because of their size, their product novelty and their tasks interdependency. Those products developed are thus complex and embedded into an even more complex product : the car. There are many other inputs related to that, such as the customer marketing needs, the technology required, the level of quality. Those projects are supported by about 15 to 20 IT systems, with the Entreprise Resource Planning (ERP) counted as one system. Those numerous systems are all integrated. Generally, the amount of information and the type of information are quite similar throughout a project phases. They are up to seven phases in a project, with interdependent tasks and many different teams working together.

In a project, every function has a representative in the project team. All the teams of the project frequently meet, use the same IT systems, share information. The project team is cross-functional with a project manager coordinating the team. The cross-functional aspect of the project team is crucial for the product success. Also, those projects teams are worldwide dispersed, which is enabled by coordination IT systems that help teams to share information, such as files, audios, screens, etc... The top management has a significant aspect in the digital transformation, by using all those digital tools and making the the maximum use of it. As a result, collaborators have a fairly high level of mastery of IT systems. This is enabled by distance learning tools and platforms. Also, every time a new system is introduced or changed, there are training sessions conducted to help collaborators using those systems.

When it comes to supplier involvement in projects, information sharing is also a key. Suppliers are invited to take part at meetings and files are shared with them thanks to a file-sharing IT system. In addition to that, suppliers have confidentiality agreements with the company Alpha. Suppliers and the company Alpha brainstorm together and introduce to each other their technologies. The information shared with the suppliers is not as flowing as the one shared within the project team due to different IT systems. However, the level of shared information is rather high. Not all the information is shared, but as mentioned above, all suppliers are under a confidentiality agreement. Nevertheless, the automotive industry is an industry where time-to-market is the main challenge. Therefore, the level of information shared needs to be rather high. Thus, suppliers know what the company Alpha's needs are and they can answer them more efficiently. The flow of information is then quite significant, but it is managed by IT

systems. This flow of information used to be shared mainly by emails which made it complex to structure the information. Today, the use of IT systems help the company Alpha to share information more effectively, using the Cloud for instance and focusing all the information in one location.

4.3 Company Beta description

4.3.1 Presentation of the interviewee

The interviewee of this company has been the head of architecture department since 2008. He was been in the company for 16 years. His department is in charge of developing cars.

4.3.2 The company Beta and its industry

The company Beta is a subsidiary of a major French car assembler corporate group within the **automotive industry**. The company Beta is a medium-size company specialised in manufacturing sport cars. Beta's parent company, which is the leader of the corporate group, is a traditional car assembler company. The parent company will be named the company Gamma and has its own description in section 4.4. The automotive industry is innovation-driven by connected cars. Assembling those cars require having strong capabilities in both hardware and software assembling.

The company Beta sells to both individual clients and for racing competitions, because they manufacture sport cars. The environment is very competitive.

The company Beta mainly uses components already used in other cars from the company Gamma. Therefore they have the same suppliers. However for some components that need to be adapted for sport cars, they can have different suppliers.

The company Beta uses different IT systems, such as collaborative ones, where collaborators can communicate and exchange files on the Cloud and access databases, a computer-aided design one (CAD). As mentioned above, the company Beta invest in partnership with suppliers so that those suppliers develop for them IT systems and new technologies.

The company Beta is an engineering center, that leads the guidelines of the company Gamma,

but the company Beta has autonomy when developing cars. The company Beta is a medium-size company and most of collaborators are located in one location.

The culture of the company Beta is customer-oriented a philosophy of reusing already developed components as much as possible (to cut cost). Also collaborators are all passionate about sport cars and they respond to a culture of challenge. Directors of the company Beta uses this aspect of the culture by challenging their teams to develop the best cars. There is also a notion of innovation and measured risk-taking. Also, teams manage problems by communicating and directors only take decision on cost issues. The interviewee manages around 15 people, without including suppliers, which counts as 30% of his time spent.

4.3.3 The company Beta and its projects

The department of the interview develops cars. Developing a car takes about 500 up to 700 collaborators. The development is highly segmented. There is the product team, which is in charge of imagining of what the product will be. This team conducts surveys, studies the market and tries to forecast this market in 4 years. 4 years is the developing cycle time of a car : 1 year of explanatory phase, 2 years of development and 1 year of industrialization. Depending on the top management strategic inputs, this product team will orient the product they would like to develop. There are going to define potential customers and they are going to start putting a number of great values into the project. For example, they want it to be an easy to drive vehicle, a safe vehicle, a connected vehicle. So they're going to produce a macro definition of the car, of the product. Then an engineers team will translate those guidelines into the first technical data, around 450 items that are distributed in more than 30 fields (e.g. longitudinal vehicle dynamics, acoustics, passive safety, etc.). In each field there are experts who will set the target performance level, from 0 to 10. Then the architecture department is in charge of distributing the space of the car between each field. The architecture department will define given volumes for each components and each component will be developed by a specific team (e.g. the brake team, the wheels team, the seat team or the piping team, etc.). A bit more than 30 technical perimeters of the car (e.g. seat, upholstery, train, wiping, etc.) are thus developed by those teams. They will build a set of specifications, they will send it to the purchasing department. The purchasing department will send this to a number of potential suppliers.

Project plannings change all the time, and a planning is only valid when created. There is no

project management IT systems, if not an exchange of emails and a databases with archived emails. The interviewee for example receives 120 emails a day, which is time-consuming. Every meeting has a report, that should be archived in a database. Once a meeting report is written, the link to access it in the database should be sent in the email to the participants. In reality, both the link and the report are sent in the email or just the report. This happens because it takes time to archive the report and because not everybody can access the report. Therefore, the report is directly sent in the email. This process makes it very complex to find old reports. When looking for an email, one needs to remember who was the sender or what was the topic. Moreover, reports are not standardized which leads to quality differences in the reports.

Collaborators tend to email and add many people to the mailing list. This leads to a situation where some collaborators do not read their emails anymore because of the amount of emails sent. There is also a tendency to have many meetings, which has been amplified with the remote working (due to the coronavirus health crisis in France). Some meetings can last for more than 2 hours, without an specific agenda. This leads to collaborators that are not always listening to meetings and multitasking with their computers. A tendency that has increased with remote working. Meetings can gather up to 20 different collaborators. There are many recurrent meetings to have an update on the project, every week or month. Meetings are always available with a computer, where collaborators can participate and hear the other workers. Another complex aspect of meetings is setting up a schedule, because some collaborators (or suppliers) can work in different time zones. That is the reason why the company Beta tries as much as possible to gather people working on the same project in one location. Another point is that collaborators can work on 6 to 10 projects simultaneously to maximize their knowledge. Therefore there are meeting schedule conflicts that collaborators need to manage every week.

When collaborators want to share large files, such as CAD files, the company Beta needs the IT department of the corporate group to take care of the file exchange. To do so, they have to indicate them which files need to be shared via an application and then the IT department take care of it. This type of exchange exist because of the need of optimizing cost : sharing files with partners is a necessity. That type of sharing can occur every 4 months during a project.

When it comes to sharing information with suppliers, the company Beta share files with them through hubs or online databases, for light files. Some suppliers even have access to the company Beta internal databases to directly access files. For small suppliers most of the sharing is

done by email. Otherwise for larger files, the IT department also take care of the file exchange.

When the company Beta has never had any business with a suppliers and that they work on innovative aspects, they only share the shell of the CAD components files. They do not share all the files before an agreement is signed.

4.4 Company Gamma description

4.4.1 Presentation of the interviewee

The interviewee is the one from the company Beta, but he has knowledge of how the company Gamma works, since he has been part of the corporate group since 2008. He experienced working with the company Gamma on a project, thus he also about their culture and ways of working.

4.4.2 The company Gamma and its industry

The company Gamma is the leader of the corporate group. This company is a traditional car assembler company.

The company Gamma sells to both individual and corporate clients. In France, the majority of sells go to corporate clients, to whom they sell car fleets. The car catalog is the same for small-size car fleet than for individual customers. For larger car fleets, customers can ask for a specific car colour. For the largest fleets, customers have different technical needs that the Beta's parent company adapt to each cars. Most of the fleets are however basic car fleets with low margins. Nevertheless, a major part of marketing is conducted towards individual customers with different media. It is because the environment is very competitive.

The company Gamma has a specific supplier relationship management mainly based on price. There are different suppliers, with different functions. Automotive equipment manufacturers are usually medium to large size innovation-driven company. They innovate to sell new features to car constructors, based on the market needs or future market needs. The company Gamma signs major partnership with them. Secondly, there are part small size automotive equipment manufacturers that are sources of components, but not innovation. Those suppliers compete

based on price. Thirdly, there are IT suppliers, either major IT companies or start-up businesses. The company Gamma signs partnership with them because those suppliers have the know-how to develop adaptive IT systems for their cars, or to develop the AI technologies in the cars. Indeed, the corporate group specialisation is in assembling cars, not taking care of their IT systems or innovative technologies such as AI. Also corporate needs them because IT systems development cycle time are much shorter (6 months) than car development cycle time (4 years).

The company Gamma uses the same IT systems as the company Beta, such as collaborative ones or a CAD. As mentioned above, the company Gamma invests in partnership with suppliers so that those suppliers develop for them IT systems and new technologies.

When it comes to the configuration, the company Gamma has engaged a "centralized decentralisation" process. For instance in the components sourcing they try to source most of the components directly to the closest suppliers to the car factory. It is especially the case for low value-added components. However for the most innovative components, they are more likely shipped to the factory. Most of their major suppliers have therefore their own factories close to the car assembling factories. So there is a local integration, which is cheaper than sourcing all components from a single location and then shipping them. This means that the same car model assembled in South America or in Europe will not have the exact same components. Thus, there is a continuous exchange between the factories about the quality of the suppliers. Another type of centralized-decentralisation is with the delocalised engineering centers. The corporate group developed them in different parts of world, where engineering is cheaper than in France. They first started with simple engineering studies, but they are now in charge of whole part of projects. However when there is an emergency is the project, engineers from the parent company are sent over to support them. Those centers however do not have all the autonomy is the development of projects, they need to stick to the corporate group requirements. Those centers are mainly used for development of additional versions of cars. The innovation is still kept in the parent company. The company Beta is in its own way a delocalised engineering center but the company has autonomy when developing cars. Another local integration is conducted when it comes to defining the needs of the local population for the car to be developed or even when marketing is made.

The company Gamma, which is a large-size company, has an extremely segmented organisa-

tion, with many managers and collaborators. This configuration tends to lower the communication between different teams. This leads to directors taking decisions for minor problems because of this lack of communication. Also, because of this extreme segmented organisation, teams are not well integrated and do not know which team is in charge of specific tasks. The last CEO was someone with a strong personality who has cut back on innovation due to his management style. This has led to collaborators no longer taking any sort of risks and a very hierarchical organisation, which slows down initiatives. People are mainly managed based on key performance indicators, which could hide some problems. For example if some files are needed at some point in a project, an indicator could indicate if they exist or not. It happened that some collaborators created empty files, so that the indicator is green but there is nothing in the file. Also, the organisation tend to have many managers, some of them that could manage very few people (e.g. down to 3), which represent 100% of their time.

4.4.3 The company Gamma and its projects

The company Gamma is a car assembler, therefore 95% of car components are manufactured by suppliers. For some components of the car, suppliers will get all the specifications and will be expected to provide the exact components. For more complex systems (e.g. the heating system), a volume and a set of specifications will be given to the supplier and the latter will have return a study and then develop the system, with discussions with the company Gamma. There is a third type of suppliers, automotive equipment manufacturers. They develop components by themselves and then sell them to car assemblers, they do not make custom parts. Those suppliers look for components that fit the volume given by the architecture department and the required specifications among their components set. Those suppliers will be in charge of setting up a part of the system program. In any system program, there is the basic program part that the supplier does and then there is the system settings part. Sometimes there are suppliers with which the company Gamma is used to working with, the company knows their systems, thus suppliers will intervene very late. Their system is almost the same. So when it is not the first car that has the system, the company Gamma will just ask suppliers to make a software adaptation in the project, so very late. On the other hand, if it is an innovation, the supplier will be involved very early in the process. And there are even new technologies where, before applying it to a project, there will have been some initial steps. Those steps will be exchanges with suppliers, a start of development made without it being applied to a particular

project. It is developed in the absolute. So the company Gamma is going to discuss this with certain suppliers, major groups, where there are technical exchanges on what the suppliers are developing, innovating and what the company Gamma needs, hoping that it can match. So there is this development, and at a given moment, the company Gamma judges that this development is sufficiently mature to be passed on to a project that is under development. So probably the company Gamma is going to go into an industrial application of that object. When the company Gamma is working on innovative pieces, it sometimes can take longer than expected and the company Gamma cannot get the object it wants to do right. Thus it would be very risky to try to integrate it into a project that is already in development if there is an uncertainty related to the new technology. That is why the company Gamma decorrelates the development of the new technology with the project development. If the new technology is ready, it then will be switched to the project, if it's not ready with a certain maturity, it will wait for the next project. In a new technology today there is a dialogue between different parts. So there are different systems that will have to dialogue with each other. Software dialogue exchange systems are complex, therefore there are a lot of things to settle before taking the risk of putting this application on a vehicle.

4.5 Companies Beta and Gamma

4.5.1 Presentation of the interviewee

The interviewee is still the one from the company Beta, but he experienced working with the company Gamma on a project, thus there is also empirical data on that collaboration

4.5.2 A common NPD project

The culture of the companies Beta and Gamma are quite different, so is the team management or the team configuration. Indeed, as mentioned above, the culture of the company Beta is more risk-taking than the one of the company Gamma. The company Gamma has a much more segmented organisation than the company Beta. The latter is more agile and tend to solve problems quickly. This led to situations were the collaboration was not entirely fruitful. For instance, delaying the project for some weeks because of missing information on whom to contact about a specific topic in the company Gamma.

Also in the company Beta there was only one project manager while in the company Gamma there were more than five. Thus, the exchange of information in the project was not simplified. Each project managers having his own targets, which were not necessarily compatible.

For these reasons, the common project was complex to handle and got delayed for several months.

5 Data analysis

5.1 Introduction

In this section, the data is analyzed and discussed with regards to the developed framework and based on the research questions. First, the business level factors will be analyzed, then it will be the project level factors. Cases analysis will be done for each factor and sub factor. The analysis will be summarized in the section 5.4.

5.2 Business level factors for each case

In the developed framework, one of the analysis axis is about business level factors : the industrial context, the company and the supplier companies. We will assess this factors based on the collected data.

5.2.1 Industrial context

As mentioned in the framework, it is hypothesized that the main actors, the environment uncertainty and new IT opportunities could influence ISD, and therefore ISD in NPD projects.

It was stressed that **the main actors** are the competitors, the suppliers and the customers of a given company. They are part of the competitive environment of the company. Therefore, given their important role in the supply chain of a company, including being part of the information flows, is was hypothesized that they could influence ISD.

Company Alpha

For this company, the different actors and the competitive market play a different role in the influence of ISD. Indeed, customers are really demanding because the market has changed from a price-sensitive market to an innovation-sensitive market as well. This innovation is required because products themselves feature more digital technologies. Those technologies are used to share data and to feed other technologies (e.g. forecasting technologies based on AI). Therefore, **the market influences ISD of data products**. The customer of company Alpha are very

demanding because of this market. This put company Alpha in a situation where innovation is the key, and especially time-to-market. This pushes company Alpha to adapt the ways of working and share information more quickly. In that way, **customers influences the ISD** of the company Alpha, at the level of **collaborative IT**. On the other hand, suppliers are quite tied to the company Alpha, through framework agreements, which already enable them to have high level of information shared. **Suppliers do not directly influence the ISD**. I make this analysis because company Alpha ISD on collaborative IT is mainly made because of the competitive market and the pressure of the customer. Suppliers are therefore included in the collaborative network, but they are not the reason of the use of this network.

Company Beta

The company Beta has individual clients and racing clients, thus they are very different clients. Moreover, the company as the same suppliers as the company Gamma, for most of them. Furthermore, the market is a very competitive innovation-driven market. This strongly influences ISD for technologies within the cars, because cars need to be innovative products. Thus customers and suppliers might not influence ISD directly, but the innovative market pushes the company to develop innovative products with recent technologies and concepts such as the Internet of Things through connected cars. Also managing many suppliers definitely influences ISD because the company Beta assembles cars with mainly supplied components.

Company Gamma

The company Gamma has mainly business customers, buying car fleets, but also private customers. The company Gamma is mainly price-oriented when it comes to discussions with its suppliers. Those discussions can last for months even years. For innovative products or technologies, the price is still important as well. Given that the innovation is an important aspect of cars, the company has developed partnerships with major actors of the software development and has invested in start-up companies to access new technologies. The reasons of this is that the automotive market is a very competitive market, in a declining phase. There is an important budget spent in advertising for private customers (which are not the main customers) which stresses how competitive the market can be. Also the company Gamma faces complexity because the company is not present in the US or in China, which are important marketplaces. Thus the company Gamma develops car, but cannot take important risks in its development because of its absence from those important marketplaces. Then, the main actors and the com-

petitive market in which the company Gamma operates push the company to have very intense communication with its suppliers, which can influence ISD.

The **environment uncertainty** was constituted of a technology uncertainty, a customer uncertainty and a supplier uncertainty. The latter is also mentioned in the supplier companies factor.

Company Alpha

The environmental uncertainty of the company Alpha is quite related to its market. As mentioned above, customers are really demanding because they need innovative products. But this is related to the uncertainty. The technology uncertainty in the automotive industry is quite high, no one can predict if electrical cars are going to perform better than thermic cars, or if autonomous car are going to be a success. This uncertainty pushes customers to be very demanding because they are the ones directly facing this uncertainty. Therefore they need their suppliers, such as company Alpha, to adapt and be reactive to their needs. This puts the company Alpha in an environment where there is an uncertainty of product technologies and where agility is needed. Therefore, the analysis would be that **technology uncertainty impacts ISD of products** and it also impacts **customer uncertainty**. This latter **influences ISD of the company Alpha**, in terms of collaboration management IT or even project management IT. Again, the **supplier uncertainty is not really influencing ISD** here, because suppliers are quite close and tied to the company Alpha.

Company Beta

There is uncertainty in the environment of the company Beta when it comes to technology and customers. The technology uncertainty is based on its development cycle which is much shorter than the car development cycle. This pushes the company to have decorrelated development of technologies and cars because of the uncertainty of developing the technologies, given than it is not the core competency of the company Beta. This impacts the technologies of ISD of the cars. Moreover, there is a major uncertainty when it comes to the customers because of the car cycle development which is 4-year long. Thus, the company has to define the needs of the customer 4 years prior, which leads to uncertainty. As for the suppliers, there is a low uncertainty when they deliver components, which does not affect ISD. On the other hand, there is uncertainty with suppliers that develop technologies for the company Beta. Thus more intense communication is needed. Overall, the company Beta is in a rather uncertain environment,

which influences the ISD technologies in the developed cars.

Company Gamma

The technology development being shorter than the car development but still rather uncertain, it does influence the integration of technologies in the car, especially for software developments. Thus the software environment need to be adaptive and able to integrate a new software when the latter is finally developed. There is a real technology and software development risk to handle. Especially because of the smaller market of the company Gamma, where NPD projects need to have n significant enough return on investment because of the small market the company has access to. The risk is even higher given that the car cycle time is 4 years long and the customers needs are not known. Especially given that those needs can differ from area to area of the world. This impacts the company technology development and investment to lower the risk. The supplier uncertainty is rather low for hardware components, but as mentioned above when suppliers develop software systems there is a higher uncertainty. Thus the environment uncertainty influences ISD because of the need to react quickly to changes and the development of software and technologies.

New IT opportunities were based on Internet-based procurement technologies, ICT and Industry 4.0 technologies.

Company Alpha

In this company, ICT and Industry 4.0 technologies are already a reality, given the innovation level of the industry. Especially **Industry 4.0 technologies have an direct impact on the product data aspects**. Industry 4.0 basis was about digitalizing product. Company Alpha Industry 4.0 technologies directly impact the ISD of products themselves, through AI or Big Data for example. **ICT definitely influence ISD in the company Alpha**, because of the need of shared information within projects, and the collaboration level it enables. Indeed, company Alpha has to manage virtual teams as well.

Company Beta

The new IT opportunities influences the company Beta, through ICT such as collaborative IT systems. Also, Industry 4.0 influences the company towards Internet of Things technologies for the cars. Thus, the new IT technologies influences ISD of the company Beta.

Company Gamma

For the company Gamma, the new IT opportunities are a reality but mainly for Industry 4.0 technologies. Indeed, the company is mainly concerned about innovation for cars, based on the IoT technologies and on AI. ICT are also a reality but less important, since emails are still the number one medium of communication in the company. However the company recently acquired a new collaborative IT system. Thus, new IT opportunities influences ISD for cars and to a lesser extend ICT.

5.2.2 Company

As mentioned in the framework, it is hypothesized that the company structure, the organisational culture and the corporate technology strategy could influence ISD, and therefore ISD in NPD projects.

The **company structure** was based on the centralization degree of a company and the firm size.

Company Alpha

The company Alpha is a large company, with subsidiaries in different countries. In addition to that the company has a decentralized organisation, which leads to more innovation. This decentralisation influences technology adoption and decision-making processes speed. Indeed, due to this decentralisation, the company had to be equipped with collaboration IT, to enable the teams to correctly work. Therefore, the **large** size of this company and its **decentralisation** organisation **influences ISD in terms of collaboration IT**.

Company Beta

The company Beta has a rather decentralised structure and it is a medium-size company, with most of the collaborators at one location. This impacts the ISD in NPD projects because collaborators mainly use emails and the collaborative IT system to communicate.

Company Gamma

The company Gamma is a large-size company with factories in different countries and continents. The company started a few years ago a decentralisation process. This means that engineering centers in other countries that France can develop some part of even whole cars. How-

ever, those engineering centers must follow the regulations of the company Gamma. Moreover whenever there is a major incident, specialist from France are sent to those engineering centers abroad. Another decentralisation exist for factories, where some factories are located in countries where the company Gamma sells cars. This decentralisation enables to reduce cost, but also to share information about difficulties some factories could have manufacturing cars. Indeed, given that those factories do not use the same supplier base for most of the car components, they can have some quality issues. Thus, this decentralisation enables communication between different sites. The size and the decentralisation of the company Gamma is a strong factor influencing the ISD. Given that some operations of the car development do not occur at the same locations or that one factory can be working with others or even that suppliers bases are different for different factories, there is inevitably ISD in NPD projects.

The **organisational culture** of a company was composed of company values and its management style.

Company Alpha

The company supports the value of enabling people to develop their potential and to innovate. A way of doing it, is by allowing collaborators to share ideas and information on their internal network. This can lead to new projects and to innovative products. However, this way of working needs to be supported by collaborative IT. Therefore, the **company values influence** information sharing in the company, and especially **ISD** thanks to the internal networks of **collaborative IT**. When it comes to the management style and top management, a main point has to be made on the CEO of the company. Indeed, the CEO is a major supporter of all new technologies. Moreover, the interviewee himself was rather a supporter of new technologies and he mainly use technologies when it is possible. The fact that the CEO, and the interviewee, are into new technologies influences ISD because their teams are supported to use collaborative IT for instance. Therefore, **management style also influences ISD**.

Company Beta

The culture of the company Beta is customer-oriented, challenge-oriented, innovative-oriented and it is about taking measured risks. Also the collaborators are passionate about sports cars. Moreover, managers use this culture of the challenge to push people at their best and do not have to intervene in solving problems because different teams usually solve problems together.

Thus the company values and the management style support collaborators in sharing information, which is mainly done through emails.

Company Gamma

Due to the organisational culture of the company Gamma, collaborators avoid taking risks or even initiatives. One reason of that, explained by the interviewee, is based on the CEO who played a role in reducing the risk taking to a point where the employees even avoid initiatives. Also the management style has evolved into using performance indicators. This management method has led in some situations to hiding problems behind numbers and colors. Moreover, because of the high number of people involved in projects and the extremely segmented organisation, teams tend not to communicate with each other when problem occurs. This leads to situations where managers or even directors have to deal with minor problems. The culture of the company Gamma definitely influences the ISD in NPD projects, because of how teams and collaborators tend not to communicate.

The **corporate strategy** was dealing with the IT infrastructure and the IT investment of a company.

Company Alpha

The IT infrastructure of the company Alpha relies on all types of IT systems mentioned in the theory chapter, e.g. information and knowledge management ones, project management ones, collaboration and communication ones. The company have more than 20 different IT systems, including the ERP which counts many internal modules as well. Those systems are all integrated together. Therefore, the **IT infrastructure of the company Alpha influence the ISD** thanks to all those IT systems provided and of their mutual integration. When it comes to the IT investments, even with the time-consuming and cost aspects of it, the company invests in it. This investment is supported by the CEO. Everything is therefore digitalised, whether it be the product features or the way of working. Thus, **IT investment** clearly **influences ISD** in this company.

Company Beta

The company Beta has different IT systems : a collaborative one, a project management one and databases. The project management system is however not really used by the collaborators. Also the company mainly invest in innovative technologies for the cars. Thus the IT systems are

influencing the ISD, because they are not fully used, given that collaborators tend to use emails to deal with project management aspects. Also the IT investment are product-oriented, which does not push collaborators in using IT systems for collaborative aspects.

Company Gamma

The company Gamma has mainly the same IT systems that the company Beta. However in terms of investment it is done at a larger scale. For instance the company Gamma invest in start-up companies to develop AI or IoT technologies for their cars. The company Gamma also invest in partnership with major companies developing software environments for the cars. This means that the company invest in suppliers for innovations but that the investments in IT systems for collaboration or project management systems are less common. Thus the IT infrastructure and the IT investment influence ISD.

5.2.3 Supplier companies

As mentioned in the framework, it is hypothesized that the supplier features and the supplier management strategy could influence ISD, and therefore ISD in NPD projects.

In the framework, **supplier features** were the supplier uncertainty, the power balance and the supplier IT capabilities.

Company Alpha

The supplier uncertainty is quite low for the company Alpha, because of two points : most of their suppliers are partners, so there is trust between them, and secondly the company Alpha has monitoring systems. Those systems alert the company Alpha of any issue in the delivery of an item for instance. Therefore, the supplier uncertainty, even if it is low because of the nature of the relationship, influence the ISD of the company Alpha. This influence is made through the use of monitoring IT that shares the information of a supply risk. This can also be used because of the amount of suppliers the company Alpha has to monitor. As for the power balance between the company Alpha and its suppliers, the company Alpha has the upper hand. In this context, the company Alpha tries to build partnership and push suppliers to innovate through it. The fact that the company Alpha has the upper hand influences the supplier interface, but not directly the ISD. The IT capabilities of the suppliers of the company Alpha are lower. Indeed,

the suppliers do not need the same amount of IT systems because of their size. It does impact the ISD, but it is completely manageable and is not a major barrier at all.

Company Beta

The supplier uncertainty of the company Beta is low for components, but when it involves complex systems or technology development it is higher. For components providers, the company Beta has the upper hand, but for innovative aspects it is more even. Also the innovative suppliers have usually higher IT capabilities. Thus, the supplier features do not really influence the ISD for the company Beta.

Company Gamma

The supplier uncertainty of components providers is rather low, but when it comes to innovative systems or technologies it is higher. The power balance between the company Gamma and suppliers differ depending on the suppliers. For components providers, the company Gamma has the upper hand and can spend months or even years negotiating prices. For supplier developing complex systems or software it is more balanced, and partnership occurs. In general, innovative suppliers will have higher IT capacities than the the company Gamma. Thus, the supplier features do not directly influence ISD.

Supplier management strategy was focused on the innovation strategy of the company, the supplier interface and the supplier development.

Company Alpha

The supplier management strategy of the company Alpha is to develop their suppliers, through partnership, to help them innovate and therefore provide more advanced products. Thus, the innovation strategy impacts directly the supplier interface and the supplier development, but not directly the ISD. The supplier interface, which tends to be partnerships (so an interactive interface) for 80% of the suppliers and a more standardized one for the rest of them, can influence the ISD. Indeed, the company Alpha adopts partnerships with most of its suppliers, therefore the information sharing is impacted because they are in an interactive interface. For the other suppliers, the standardized interface leads to the use of e-procurement to simply purchase from them when necessary. Moreover, for partners information shared can be done through ICT when needed, such as a health crisis or when they are not located at the same place. Thus, the supplier interface can influence ISD, in different level of information based on different IT

systems. The company Alpha develops its suppliers, and supplier quality development teams work with them to help them improve. These teams coach and challenge suppliers, but also share with them IT tools to enhance their capabilities. Therefore, the supplier development has a real influence on ISD.

Company Beta

The supplier management strategy of the company Beta is price-oriented for components and innovation-oriented for complex systems or technologies but only the ones that could make direct difference to the customer (the company has a customer-oriented culture). The company mainly uses suppliers to bring innovation to the developed cars. Thus the suppliers interfaces are interactive ones. The supplier management strategy thus influences ISD, because interactive interfaces bring communication and ISD is a necessity to work with those suppliers.

Company Gamma

The company Gamma is a car manufacturer, where around 95% of the car components are manufactured by suppliers. The supplier management strategy is based on price for car components. The supplier interface is standardized and there is no room for innovation from the suppliers. However, when it comes to complex systems or software development, the interface is an interactive one. As for the company Beta, the company Gamma develops technologies separately from cars, because of the difference of cycle time development and their uncertainty. Moreover the company invest in partnership with major software developing companies and in start-up companies for innovative technologies. The supplier development is based on innovation. Thus there are intense collaborations between some suppliers and the company Gamma. However there is a major amount of suppliers to manage for all the different components of the car and this management is made based on emails and meetings. The supplier management strategy thus impacts the ISD in NPD projects.

5.3 Project level factors for each case

In the developed framework, the other analysis axis is about project level factors : project features, collaborators and supplier collaborators management. We will assess this factors based on the collected data.

5.3.1 Project complexity and phase

As mentioned in the framework, it is hypothesized that project phases and the project complexity could influence ISD in NPD projects.

In the framework, **projects** were composed of three given **phases** and the amount of information and the IT capabilities of a project were hypothesized to influence ISD in NPD projects.

Company Alpha

In the company Alpha, the quantity and type of information shared in the different phases of projects is generally the same. In the company Alpha, there are up to 20 IT systems, including the ERP, and they are all integrated to one another. Therefore the IT capabilities needed in projects influence the ISD because they fully support it, without any barrier.

Company Beta

In the company Beta, there are three phases : 1 year of explanatory phase, 2 years of development and 1 year of industrialization. Thus projects last for 4 years. The amount of information needed in each phase is very different. Moreover, the IT capabilities of the company Beta are at a middle level because the company has a project management IT system, a collaborative IT systems and databases with archives but they are not fully used. Emails are the number one support for sharing information. Thus, when collaborators need to find information 3 or 4 years old, it becomes challenging. Then, the project phases being long, the information between those phases being different and the IT capabilities of the company Beta clearly influence the ISD in NPD projects.

Company Gamma

The project phases of the car development of the company Gamma are very similar to the project phases of the company Beta. Indeed, projects last for 4 years, the amount of information varies a lot between each phase and the IT capabilities are rather low because not fully utilized. For the same reasons that the company Beta, the project phases influences ISD in NPD project of the company Gamma.

The **project complexity** was defined by the product size, the product novelty and the task interdependency.

Company Alpha

The project complexity of the company Alpha has a product size dimension, because they product different components of cars, a product novelty dimension, because of their market need of innovative product and a task interdependency dimension. The product novelty levels needed influence the use of collaborative IT for more reactivity. The task interdependency is extremely high in their projects, with inputs from the customer and suppliers, so there is a need for project management IT. Therefore, the project complexity influence ISD in NPD projects of the company Alpha.

Company Beta

The project complexity of sports car is high : the product requires many components, with a hardware and a software duality. This influences the number of suppliers needed and naturally the exchange of information is more important given the amount of suppliers. Also, the product novelty which mainly is about the technology development and the software development makes the projects very complex. The need of developing technologies separately from the cars pushes the company Beta to have suppliers developing flexible software environment that could integrate those new technologies if they are developed in time. Another point of complexity is based on the tasks being completely interdependent. This forces teams to communicate to not getting the project delayed. Overall, the product size, its novelty and the tasks interdependency clearly influences ISD in NPD projects here.

Company Gamma

Again, the project complexity of the car developed by the company Gamma are very similar to the project complexity of the car developed by the company Beta. Indeed, the amount of components and systems needed in the car and the fact that 95% of those are supplied increases a lot the complexity of the manufacturing. This leads to dealing with many different suppliers. Also, there is the same technology uncertainty surrounding the moment of the integration of a technology in a car. Moreover, the task interdependency is also very high, but in this company the lack of communication between teams increases a lot the complexity of projects. Thus, the project complexity influences ISD in NPD projects of the company Gamma.

5.3.2 Collaborators

As mentioned in the framework, it is hypothesized that workers' characteristics and team management could influence ISD in NPD projects.

Workers' characteristics were mainly based on the workers' technological comfort.

Company Alpha

The technical IT skills of the workers of the company Alpha is rather good, which enable them to master most of the IT systems needed to work. Knowing that there are up to 20 IT systems in total, mastering all those systems is not easy. However, the company Alpha has a training team based abroad, which is in charge of the training of the collaborators. For example, recently a new IT system was used to replace an old one, and this training team had to train collaborators on a large scale. Therefore, workers' technical comfort influences ISD in NPD projects, because collaborators might not master all the IT systems, however they can be trained. Thus, the influence is rather moderate.

Company Beta

The technical skills of the collaborators of the company Beta is rather good when it comes to their technological tools such as the CAD system. But when it comes to the IT systems, it is rather low. For instance there is a project management IT system that takes care of the planning, but it is not used by the collaborators. Another point is the use of emails, which is extreme (the interviewee receives more than 100 emails a day). This leads to collaborators not reading emails anymore or waiting to get called for anything important. This intense use of emails also leads to complex situations when collaborators try to retrieve information from a report meeting. There is no standardization of report meeting and finding the location of the file can be extremely complex. This occurs because the database IT system is not properly used by collaborators. Indeed, archiving the information is time-consuming and they do not see the added value of doing it. Also this systems it not necessarily well set up and all collaborators do not have access to files they would like to access. The technological comfort and the motivation of the collaborators thus clearly impact the ISD in projects.

Company Gamma

The technical skills of the collaborators of the company Gamma are again similar to the ones of

the company Beta. This leads to the same situation where emails are overused and floods their mailboxes. Thus workers' characteristics influences ISD in NPD projects.

Team management was hypothesized to influence ISD in NPD projects through top management, team configuration, team communication and cross functional integration.

Company Alpha

Top management at the company Alpha is a supporting force that shows the use of IT systems to the collaborators. The interviewee for example uses all sort of IT systems whenever they can be used (especially the collaborative ones). Thus, top management here influences ISD of the collaborators by showing the example. In addition to that, project teams are often dispersed through space and quite large. They have function representatives and project manager that ensure a correct course of project phases. This management is completely supported by project management IT systems and collaborative IT systems. Therefore, the team management and the communication influence the ISD in NPD project. Another factor, being the cross-functional integration, pushes all the stakeholder to share digitalised information in their collaborative IT systems. The project manager can also handle this cross-functional integration more effectively with project management IT systems. Moreover, this integration is critical to the success of projects. Therefore, the cross functional integration influences ISD in NPD projects.

Company Beta

Team management in the company Beta is supported by a top management that only needs to intervene for main issues in project development. Indeed, thanks to a proper team configuration and team communication, when problems occur teams solve them by an effective communication. As mentioned before, this communication is mainly made by email which can really be time-consuming. Another consuming activity is meetings, which can last for a few hours and where agendas are not necessarily clear. Also collaborators can be integrated from 6 to 10 projects at the same time, to maximize their knowledge sharing, but this lead to extreme complexity for them to manage their time and share relevant information at the appropriate time or just join meetings. Indeed, as mentioned by the interviewee, there is a need to select which meetings to attend to, because of their important amount and the fact that they overlap. Also teams are cross-functionally integrated and can communication with each other to solve

problems. All those points stress how the team management can definitely influence ISD in NPD projects.

Company Gamma

The team management in the company Gamma is particular. Teams are extremely segmented, the amount of teams in one project are very consequent and collaborators can be part of several projects. This organisation is thus very complex. Given the amount of collaborators and the culture of the company, teams tend not to communicate with one another, which leads to postponing problem solving. Top management has to intervene for both major and minor problem solving, which can take place in the form of many time-consuming meetings. There is by this lack of communication and segmented organisation a lack of cross-functional integration. Thus, the team management influences ISD in NPD projects.

5.3.3 Supplier collaborators management

As mentioned in the framework, it is hypothesized that supplier involvement could influence ISD in NPD projects.

Supplier involvement was based on the moment of the supplier involvement and the communication and trust between suppliers and collaborators.

Company Alpha

The company Alpha involves suppliers rather early in projects when those suppliers are partners. They can interact and brainstorm together. Suppliers can introduce technologies to the company Alpha during early phases. This early supply involvement influences ISD in NPD projects, because the company Alpha uses collaborative IT systems to interact in a more effective way with those early involved suppliers. In addition to that, communication with suppliers is supported by meetings, sharing files with collaborative IT systems.

Company Beta

The company Beta involves suppliers early when those suppliers are developing new technologies. They brainstorm together but without agreement they will not openly share files or information to each other. This influences ISD. Also, some suppliers help developing some sub-

systems of the car, and they are involved as if they were part of the company, with a complete access to the internal network of the company. All suppliers signed agreements with the company Beta. However information sharing is not always as fluid as it can be between collaborators of the company Beta, because of the difference of IT systems. For instance when CAD files (which are heavy) need to be shared, it requires a team from the company Gamma to share those files. Otherwise, the main communication system is emails. Thus the amount of emails shared in even more important. Overall, the supplier involvement impact the ISD in NPD projects.

Company Gamma

The supplier involvement in the company Gamma is similar to the company Beta on several points. For components suppliers, the involvement is minimum, but when it comes to technology development or software development supplier are involved early in the project development. Given that technology are separately developed from cars, it could even be said that suppliers are involved before some car development are even started. There is also an important involvement of suppliers who develops the software environment of the car because this environment needs to be adaptive to new systems that could be added at any point of the development. The communication and the trust with those suppliers is mainly based on agreements but also on the history between the company Gamma and the suppliers.

5.4 Summary of the data analysis

In this section, all the data analysed and introduced in the different factors and sub-factors is summarized following the two research questions around Business level factors and Project level factors.

5.4.1 Business level factors

The summary of the data analysis for Business level factors of each company influencing ISD in NPD projects is in the figure 6.

	Business level factors influencing ISD in NPD projects							
	Industrial context			Company			Supplier companies	
	Main actors	**Environment uncertainty**	**New IT opp**	**Company structure**	**Organisational culture**	**Corporate strategy**	**Supplier features**	**Supplier management strategy**
Alpha	• Customers are demanding. The company Alpha must innovate with a short time-to-market development cycle	• Customer uncertainty is high. The company Alpha needs to be flexible, agile and quick	• Industry 4.0 technologies is integrated in products • The company uses ICT	• The company has a decentralized organisation and is a large-size company	• Innovation is a strong value, supported by top management and enabled by ICT	• The company massively invest in IT for product innovation and ICT	• Supplier features do not clearly impact ISD	• The innovation strategy is based on developing suppliers
Beta	• The environment is very competitive and suppliers are close to the company Beta. The company has to manage many suppliers	• The environment is quite uncertain, due to the 4 year of car development. The company Beta has to be close to their suppliers to avoid uncertainty	• The IoT is part of innovation in car development. • The company uses ICT and emails	• The company has a rather decentralized organisation and it is a medium-size company	• The culture of the company Beta pushes collaborators to communication and solve problems together	• The company Beta invest in partnership with suppliers to bring innovation.	• Overall, supplier features not clearly influence ISD, because the company Beta has rather low IT capabilities and use of IT	• The strategy is based on developing partnerships and investing in suppliers that are sources of innovation. For other suppliers there is not many discussions
Gamma	• The environment is very competitive and the company has not access to the entire market. • Many suppliers to manage	• The environment is quite uncertain and very complex. • The company lowers supplier uncertainty of innovative suppliers	• The IoT is part of innovation in car development • The company uses ICT and emails	• The company is a large-size company with factories and engineering centers all around the world. • The company has a decentralized organisation for business units but not within business units	• The culture of the company Gamma and top management do not support open communication	• The company Gamma invest in partnership with suppliers to bring innovation • Those suppliers are start-up companies or major software developers	• The supplier features do not clearly influence ISD, given that the company Gamma had rather low IT capabilities or IT use.	• The company Gamma can negotiate for months or years prices with suppliers • The company has partnerships with innovative suppliers and has standardized relationships with components suppliers

Figure 6: Summary of business level factors influencing ISD in NPD project for each case

It can be noticed that the company Beta and Gamma can sometimes share the same elements. This is explained because the company Beta is a subsidiary company of the company Gamma, thus some elements will be very close if not the same.

5.4.2 Project level factors

The summary of the data analysis for Project level factors of each company influencing ISD in NPD projects is in the figure 7.

	Project level factors influencing ISD in NPD projects				
	Project features		Collaborators		Supplier management
	Project phases	**Project complexity**	**Workers' characteristics**	**Team management**	**Supplier involvement**
Alpha	• There are 6 to 7 phases in projects • Up to 20 IT systems and ERP system, all integrated, efficiently used	• Different car products development • Innovative products • Task interdependency • Customer inputs highly important	• Collaborators usually master different IT systems • Team abroad in charge of e-training	• Top management uses all IT systems and push collaborators to do so • Dispersed teams, regular meetings, use collaborative IT systems • Project manager handles cross-functional integration	• Innovative technologies and partnerships are discussed early in projects • Exchange of information done with meeting and sharing files hubs • Information sharing not as fluid as internally • Innovation is key, thus sharing information is essential
Beta	• 3 phases : 1 year of explanatory phase, 2 years of development phase and 1 year of industrialisation • Amount and type of information different during a project • Low use of IT for project management of collaboration	• Important amount of components in a car : important amount of suppliers • Technology development uncertainty, which leads to separate development from car development • Task interdependency : need for intensive information sharing	• Medium level of technological comfort, depending on the technologies • Do not fully use IT for project management or for email storage	• Top management support teams to handle problem themselves • Top management allow space for measured risk taking and innovation • Team communication mainly done by emails : up to more than 100 emails a day • From 6 to 10 projects for each collaborator • Cross-functional integration and effective communication between different teams	• When suppliers develop innovative products : involve early in projects, or even before projects started : separate development • Agreement policy before sharing detail information to suppliers • Suppliers can have access to the internal network and work as if they were internal collaborators
Gamma	• 3 phases : 1 year of explanatory phase, 2 years of development phase and 1 year of industrialisation • Amount and type of information different during a project • Low use of IT for project management of collaboration	• Important amount of components in a car : important amount of suppliers • Technology development uncertainty, which leads to separate development from car development • Task interdependency : need for intensive information sharing	• Medium level of technological comfort, depending on the technologies • Do not fully use IT for project management or for email storage	• Top management do not allow much space for risk taking • Teams extremely segmented and lack of communication : not full cross-functional integration • Top management has to intervene in minor to major problem solving processes • High number of managers, managing few collaborators	• When suppliers develop innovative products : involve early in projects, or even before projects started : separate development • Agreement policy before sharing detail information to suppliers • Suppliers can have access to the internal network and work as if they were internal collaborators

Figure 7: Summary of project level factors influencing ISD in NPD project for each case

Again, it can be noticed that the company Beta and Gamma can sometimes share the same elements. This is explained because the company Beta is a subsidiary company of the company Gamma, thus some elements will be very close if not the same.

5.5 Conclusion

In this section, each factor and sub-factor of the business and project level factors were analysed for each case. In the next section, a discussion between the differences for each case company will be raised.

6 Discussion

In this section, there is a discussion between the cases. The point is to be able to draw general conclusions from those different cases. The research questions addressed were aiming at understanding the impact of **RQ1** : business level factors ; **RQ2** : projet level factors on ISD in NPD projects.

6.1 Business level factors

In the extended framework it has hypothesized that three business level factors - the industrial context, the company, the supplier companies - could influence ISD in NPD projects. Those factors have sub-factors and the impact of each of those sub-factor on the company cases was summarized in the figure 6. Let us now discuss the overall impact of each of those sub-factor and factor on ISD in NPD project.

6.1.1 Industrial context

In the extended model, is was hypothesized that the industrial context could influence ISD in NPD project, through three sub-factors : the main actors, the environment uncertainty and the new IT opportunities.

It can be noted that the companies Alpha, Beta and Gamma are in a competitive environment. The company Alpha's customers are companies such as the company Beta and Gamma. Therefore, the company Alpha must be innovative and the customers are demanding. The customers of the companies Beta and Gamma can be individual customers or private ones needing specific cars. However developing cars takes about 4 years. Thus those companies need to define their future client needs 4 year prior. Therefore, the companies Beta and Gamma need companies such as the company Alpha to support them and supplying them innovative products. Indeed, as the market is very competitive, innovation is key.

However, there is a real technology uncertainty for the companies Beta and Gamma, due to the 4 years of car development. This uncertainty impacts companies such as the company Alpha, that needs to face it by being agile. The companies Beta and Gamma are thus using

their innovative suppliers to reduce the technology uncertainty. This technology uncertainty for those companies is partially due to the customer uncertainty being based on specifications defined 4 years prior.

Some of those technology developments are related to the Industry 4.0. The companies Beta and Gamma have their suppliers developing those technologies for them for cars. Thus, the company Alpha develops technologies based on the IoT or the Big Data for instance for companies such as the companies Beta and Gamma. Other new IT opportunities are based one the ICT. The company Alpha is leading in this field, because of the intensive use of it. The companies Beta and Gamma are less innovative when it comes to communicating: most of their exchanges are supported by emails. It can be noted that the company Alpha needs to be agile because of its location in the supply chain, thus innovation from ICT is one of the way of reaching high levels of agility. One the other hand, the companies Beta and Gamma are not in the same need for agility, thus ICT is not at the same level of needs.

In terms of representativeness, the three companies are all in the automotive industry, thus this is complex to generalize this discussion to all sectors. However, the innovation and agile aspects could be of importance for other sectors.

6.1.2 Company

All three companies differ in structure, culture and strategy. The company Alpha and Gamma are large-size companies with factories and facilities all over the world. The company Beta is a medium-size company mainly located in one area. The company Alpha is more decentralized than the company Gamma. The culture of the company Alpha is innovation-driven, the one of the company Beta is customer- and communication-oriented. On the other hand, the company Gamma do not clearly support open communication. Those differences of culture and structure are also emphasized by ICT. Indeed, since the company Alpha is innovation-oriented and has a decentralized structure, ICT plays an important role in the innovation. This enable collaborators from different location to share ideas and communication with each other and start projects without needing approvals from top management. Top management supports innovation and welcomes those initiatives. On the other hand, the company Gamma that is close to the company Alpha in size does not have the same approach. Indeed, top management does not support initiatives and this leads to difficulty to communication among collaborators.

The company Beta that is smaller in size than the two other companies was a culture of sharing which support ISD through ICT (mainly emails).

In terms of representativeness, the three companies are different in size, structure and culture. Thus, there is a rather good representativeness of cases that could occur in other companies. This aspect of the discussion could thus apply to other companies.

6.1.3 Supplier companies

In the framework, the two sub-factors of the supplier companies factor are the supplier features and the supplier management strategy. It can be noticed that supplier features might not clearly impact ISD in NPD projects, in any of the companies. In the case of the company Alpha, the suppliers have lower IT capabilities which can be slightly more time-consuming when exchanging information, but it is not so demanding. As for the companies Beta and Gamma, their suppliers can have higher IT capabilities, but not often lower ones. Thus, those supplier features do not influence ISD.

The supplier management strategy is also similar among the case companies. The company Alpha bases its innovation on developing suppliers. It is the same case for companies Beta and Gamma. Especially the company Gamma that develops partnerships with major IT companies and also invests in start-up companies.

In terms of representativeness, the three companies are similar with there innovation strategy based on suppliers. However they differ in terms of IT capabilities ratio between the company and the suppliers. Thus this aspect can probably be more generalizable.

6.2 Project level factors

In the extended framework it has hypothesized that three project level factors - the project features, the collaborators, the supplier collaborators management - could influence ISD in NPD projects. Those factors have sub-factors and the impact of each of those sub-factor on the company cases was summarized in the figure 7. Let us now discuss the overall impact of each of those sub-factor and factor on ISD in NPD project.

6.2.1 Project features

The project features are divided into project phases and project complexity in the framework. The company Alpha has projects with 6 to 7 different phases and uses up to 20 different IT systems additionally to the ERP system. All those systems are efficiently integrated with one another. On the other hand, companies Beta and Gamma have 3-phase projects and they use fewer IT systems. For instance, there is a project management IT system in the company Beta that schedules planning: this IT system is not used by the collaborators. In fact, in the companies Beta and Gamma, most of the project-related information is shared by email.

Projects are complex in all three companies. In the company Alpha, they develop innovative products, tasks are interdependent and customers inputs are highly important. In companies Beta and Gamma, because of the complexity of developing innovative softwares or technologies, there are two development streams: on for car development and one for innovative features development. This enables those companies to deal with the uncertainty of the technology development. However, this also increases the difficulty to develop car software environment able to integrate those other developed technologies. Thus, task are also interdependent and highly complex. All three companies have high need of sharing information. Moreover the way of sharing information can definitely have an impact on the project complexity. In the case of Beta and Gamma, for example, it is very complex to manage a project using almost only emails. Thus, the length and complexity of projects can influence ISD in NPD projects.

In terms of representativeness, the three companies are engaged in rather long development projects which are also complex. It is then complicated to generalize this discussion to simpler products or with short cycle development projects.

6.2.2 Collaborators

The workers' characteristics differ from one company to another. In the company Alpha, collaborators usually master all the different IT systems. They even have a dedicated team in charge of e-training. In the companies Beta and Gamma, workers have a rather medium level of technological comfort. Collaborators mainly use emails to share information, which is very time-consuming when retrieving information. They have a storage IT system for emails and meeting reports, but not all workers use it correctly. Therefore, the IT system is not fully used. Moreover,

this system in not correctly set up either, because it does not give anyone access to files. Thus when a collaborator wants to share a file with someone that has no access it is impossible. That is the reason why some workers do not try to store those files. There is also a complexity in dealing with the amount of emails. Indeed, workers in the companies Beta and Gamma tend to sent emails to all the stakeholder, even if the topic does not concern them. Thus, the level of technological comfort and training clearly can influence ISD in NPD projects.

Moreover, there are three levels of top management support with those three companies. The company Alpha has a top management that supports collaborators to use IT system and shows the example. The company Beta has a top management that supports teams into communication with one another and solving problems together. The company Gamma has a top management that does not allow risk taking or initiative. Yet, those companies work in dispersed teams. Thus they work in the same way but top management completely differs from one company to another. This clearly impacts ISD in NPD projects.

In terms of representativeness, the three companies have different collaborators and top management characteristics. Thus the discussion could apply to other companies as well.

6.2.3 Supplier collaborator management

The involvement of innovative suppliers is early done for all three companies. In the case of the companies Beta and Gamma, it can even occur before a car development project is even started, given that some car technology development projects are not conducted at the same time as car development. Thus early involvement influences ISD in NPD project.

Overall, all the companies involve and share information in the same way. Companies Beta and Gamma require agreement to fully share information, to a point where suppliers can even access their internal network and work as one of the internal collaborator. All three companies also experience some difficulties from time to time in sharing information. For instance companies Beta and Gamma, when sharing large files, need a dedicated team to handle the file exchange. The interviewee of the company Alpha also noted that information sharing with suppliers was not as fluid as with internal collaborators. However, this do not significantly impact ISD in NPD projects.

In terms of representativeness, the three companies have similar approach of supplier collabo-

rators management. It is then complex to generalize this discussion to other companies.

6.3 Summary

The figure 6 summarizes all the different discussion raised in this discussion section:

	Business level factors			Project level factors		
	Industrial context	Company	Supplier companies	Project features	Collaborators	Supplier management
Discussions	• Competition and innovation required in an industrial context can influence ISD in NPD projects • This can be emphasized by the need of new technologies to support agile working methods • On the other hand, for more traditional companies, there is no urgent need to use new ICT	• The culture of a company, its structure and size can influence ISD in NPD projects • A collaboration-oriented culture, supported by top management, will tend to push collaborators to share information with one another • It can be easier for smaller companies to support information sharing, but the size of the company is only one of the aspect of the collaboration factor	• Supplier IT capabilities do not clearly impact ISD in NPD projects • Indeed, companies with higher IT capabilities than their suppliers can manage this difference by spending a little more time on some tasks • Similarly, if a supplier has higher IT capabilities than a company, then the latter is not impacted • Supplier management can be based on an innovation-driven strategy. Thus companies tend to be closer to innovative suppliers, with higher levels of information sharing needed	• Project phases and length can impact ISD in NPD project as well as project complexity • Project management without effective IT systems can be time-consuming, especially for long projects. • Especially for complex projects (interdependent tasks, innovative and large products) without IT systems, the ISD is extremely time-consuming for collaborators	• The level of technological comfort and training of collaborators can impact ISD in NPD projects • Top management support can have an influence on collaborators sharing information • Dispersed teams requires higher level of shared information than teams located at one location, thus the structure of a team can impact ISD in NPD projects	• Supplier involvement can influence ISD in NPD projects • An history of trust between a company and his suppliers and agreements can be necessary to share information more openly • Especially for innovative suppliers, early supplier involvement is necessary which influence ISD because of the innovative aspect of the information
Representativeness	**Medium** • Same industry • But innovation and agile aspect could be generalized	**High** • Different types of company size, centralization and culture	**Medium** • Same innovation strategy based on suppliers • But with different ratio of IT capabilities between the companies and suppliers	**Low** • Rather long and complex projects	**High** • Differences in collaborators and top management characteristics	**Low** • Same types of supplier collaborators management

Figure 8: Summary of discussion of factors influencing ISD in NPD project

7 Conclusion

7.1 Problem statement and research plan

In the introduction chapter, the problem statement and the research plan were introduced. The research questions raised were RQ1: How is ISD in NPD projects influenced by business level factors? ; RQ2: How is ISD in NPD projects influenced by project level factors? The research plan consisted of a French multiple case study based on a qualitative analysis.

This qualitative analysis conducted with semi-structured and unstructured interviews enabled to efficiently answer those research questions. Indeed, the interviews conducted were long enough and complete enough to answer every part of the extended framework. It could have been more appropriate as well to conduct more interviews with different collaborators from a same company to see the maturity level in terms of IT systems. Moreover, the representativeness of the interviewees and the company cases do not enable to have a very generalizable conclusion for some of the factors. For instance, all the company cases are in the automotive industry. However, for the company and collaborator factors, the representativeness is quite high, thus general conclusions can be drawn from this thesis on those factors especially.

7.2 Theory framework and further research

The theory developed with the extended framework enabled a general and complete approach. This was necessary because the topic of ISD in NPD projects could involve many different factors. The initial framework developed was a proper first version, but the extended framework enable to go deeper in each business level factor and project level factor.

Some part of the theory were more relevant when dealing with this topic. Indeed, the ICT aspect was for example very relevant. However the Internet-based procurement technologies were not systematically relevant in this study. One of the reasons why is also because the interviews did not necessarily focused only on the type on Interned-based procurement technologies.

The extended framework was then sufficient to conduct this study, but it could be enhanced. As an example, a more in-depth literature review could be conducted on the collaborator factor

and the worker's characteristics. Indeed, this topic could almost be psychology-related and understanding the dynamics of workers or of teams can be very complex. There is a topic of change management in using IT.

Another interesting point for future research would be opening this study to companies from other countries than France to look for a country-related factor. As a matter of fact, it would not be surprising to see differences between companies from different countries given that cultures differ knowing how important a company culture is in the process of ISD. Also, because of the low representativeness of companies, it could be relevant to conduct a similar study to other sectors than the automotive industry. It would be relevant as well to focus on companies with shorter and more agile projects, to be able to compare those project management methods with more traditional ones and study the impact of ISD in those projects.

7.3 Managerial implications

There are some aspects that could be interesting to take into account in a ISD process in the context of NPD projects for managers and project leaders. It is important for managers to adapt ISD in NPD projects depending on the company structure, size and culture but also on the team configuration and project aspects.

For instance it could be necessary to work on a collaborative culture and emphasizing on an opened information sharing culture before even digitalizing all shared information. This point also echoes with team structures. Indeed, if a team structure is too complex and information sharing is not supported or part of the culture, then ISD is not likely to be more effective.

Also, there is not the same need of advanced ISD in a small or a large company depending as well on the number of collaborators involved in projects. The more collaborators involved, the more digitalised information sharing should be. It is however important to note that ISD needs to be properly done by all collaborators.

It could be easier to support best practices of ISD thanks to training courses for collaborators when setting up new IT, but also thanks to continuous training courses for all IT. Indeed, collaborators could use such training courses and thus learn to efficiently use IT. An important point of training could be focusing on the importance of using IT, not just on how using it. Such training courses could also focus on best practices for emailing for instance, because it is one

of the most common way of sharing information in most companies.

Moreover, with best practices of ISD, it would become easier to retrieve past information shared. It can be extremely relevant in two cases: for long-term projects and for knowledge sharing. Indeed, for long-term projects, if information is not digitally shared properly it can become very challenging to retrieve pieces of information shared months ago. The same applies when trying to find information on previous projects to could be helpful for current projects. Thus, an effective and efficient ISD in complex and long NPD projects could avoid many time-consuming tasks.

Furthermore, when involving suppliers in projects, depending on the levels of trust and involvement, suppliers could have a more complete access to internal IT of the company. Some suppliers are involved in projects such as regular collaborators, thus they should have an almost complete access to internal IT, to maximize their involvement. Also, the more strategic and close a suppliers are, the more exchanges there should be with them. Those exchanges could mainly be based on ISD.

An interesting point for managers is also to learn from the practices used during the Covid-19 crisis and the general use of remote working in France. It has shown to some extend that ISD is sufficient to collaborate, in some fields. It has also shown some limits of ISD and the efficiency of group work dynamics in the same location. It echoes with the virtual team configuration and can have shown to some managers that a total virtual team collaboration can be really challenging.

Thus a main take-away would be for managers to support their collaborators by showing them the best practices with IT when sharing information. Managers could not only develop training courses to develop those competencies for their collaborators but they could also be the pioneers and examples in the use of those IT and their best practices.

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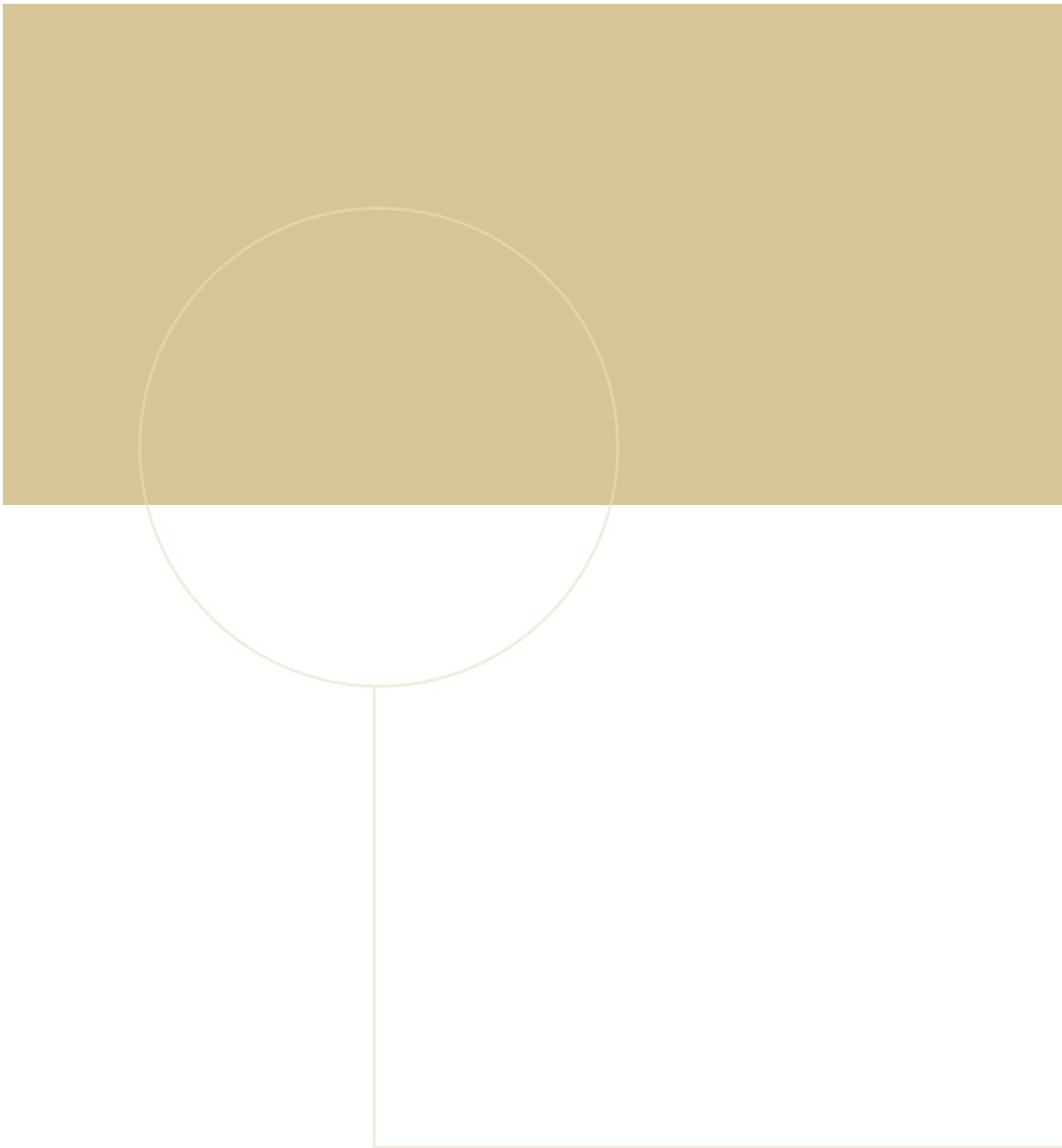

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