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MASTER THESIS
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for
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Complexity in Engineering R&D Projects

Klassifisering av komplekse situasjoner i R&D prosjekter

The master thesis will be based on the results obtained from specialization project conducted in the previous semester. The purpose of the research is to establish an understanding regarding the complex or complicated situations that arises during the course of the project because of elements that can be related to project complexities in engineering R&D projects. The research intends also to examine closely the role of the project manager and type of competencies needed to deal with these situations.

In this assignment the candidate should perform the following tasks:

Conduct a literature review in order to identify the characteristics of engineering R&D projects.

Conduct a comprehensive empirical investigation to identify the elements of project complexities along each stage of life cycle of the R&D projects.

Identify, classify and analyze the complex situations that arise because of these elements individually or combined.

Identify the role of the project managers in managing the resultant complex situations

Identify the type of competencies (skills, knowledge and attitudes) that are needed in order to deal with these situations in each stage of the project life cycle.

Within three weeks after the date of the task handout, a pre-study report shall be prepared. The report shall cover the following:

- An analysis of the work task's content with specific emphasis of the areas where new knowledge has to be gained.
- A description of the work packages that shall be performed. This description shall lead to a clear definition of the scope and extent of the total task to be performed.
- A time schedule for the project. The plan shall comprise a Gantt diagram with specification of the individual work packages, their scheduled start and end dates and a specification of project milestones.

The pre-study report is a part of the total task reporting. It shall be included in the final report. Progress reports made during the project period shall also be included in the final report.

The report should be edited as a research report with a summary, table of contents, conclusion, list of reference, list of literature etc. The text should be clear and concise, and include the necessary references to figures, tables, and diagrams. It is also important that exact references are given to any external source used in the text.

Equipment and software developed during the project is a part of the fulfilment of the task. Unless outside parties have exclusive property rights or the equipment is physically non-moveable, it should be handed in along with the final report. Suitable documentation for the correct use of such material is also required as part of the final report.

The student must cover travel expenses, telecommunication, and copying unless otherwise agreed.

If the candidate encounters unforeseen difficulties in the work, and if these difficulties warrant a reformation of the task, these problems should immediately be addressed to the Department.

The assignment text shall be enclosed and be placed immediately after the title page.

Deadline: June 10th 2013.

Two bound copies of the final report and one electronic (pdf-format) version are required.

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Preface

This thesis work was performed at the Department of Production and Quality Engineering. It constitutes the final thesis for the Master of Science in Project Management at the Norwegian University of Science and Technology during 2011-2013. This thesis work was a great experience for us. In an academic view, we specialized deeper in the field of complexity, which is important in the Project Management discipline.

We would like to thank our supervisor Bassam A. Hussein. He gave us the idea and inspiration to write the thesis, and the opportunity to learn from him. His support and guidance were imperative to reach the results which we are laying in this paper work.

As well, we are grateful to all the project managers who supported us with important and valuable information; and made our work have higher value.

We would also like to thank our parents and friends, who supported us during our stay in Norway.

Trondheim, June 2013

Pedro Pablo Silva and Giedre Pigagaite

Summary

The Literature is busying itself much with the subject of complexities in project work from the early 2000. There are many definitions proposed about complexity, but still no one suggested the unique one way to name it, and much less a proposed framework of how to reduce it. At the end, all the more complete solutions seem to make things more complicated. That's why our thesis's purpose was, firstly, to find *elements* and *situations* that cause complexity in engineering R&D projects; secondly, to identify and analyze them in order to come up with tangible solutions. Also, to see the role of the PM in the project, along with the impact he/she may have on the complexity issues.

A qualitative and reliable research of the literature within the field of project complexity and complexity in R&D projects was done. Then, an empirical research based on several interviews with PMs working in the field of R&D and dealing with constant complexity. The framework developed in the literature review was contrasted with the empirical analysis, to create our findings and solutions to possible complexity issues.

The thesis results show that the literature focus is somewhat narrow, and we could see that complexities in actual projects are nothing but broad. We have listed a few solutions —that we got from the empirical research— that are a shot at handling the two main *situations* we were involved with. The main finding is that *situations* of complexity that project managers have to face are more than simply caused by structural complexity or uncertainty alone, but of a compound effect of both.

The competencies needed from PMs differ depending on what kind of project and situation they have. In **Internal Improvement projects**: the PM had to have a good knowledge of what the capabilities of the project personnel are in order to achieve maximum flexibility, and come to the best possible final product. In **Client Engineering projects**: it was important to have good scope knowledge, and make sure that the project team did not "overdo" the scope, but only delivered what was necessary and asked for by the client. Two very important, universal competencies were singled out though: understanding of the whole project picture, and leadership.

Another interesting finding was that the leadership style adopted by the PM depends on the main success criteria.

Key words: *project complexity, uncertainty, leadership style, project manager.*

Table of contents

List of Figures

List of tables

List of Annexes

Abbreviations

PM - Project Manager

R&D - Research and Development

TOE - Technical, Organizational, Environmental complexities framework

WBS - Work Breakdown Structure

1 Introduction

This chapter gives a general introduction to the master thesis, describes the background of the work, and gives the main idea to what each chapter is speaking about. It also defines the preliminary research questions and sets the objectives of the research project.

1.1 Background

Project complexity has been shown to be an illusive subject throughout the years, with many authors like Baccarini (1996), Williams (1999), Geraldi and Adlbrecht (2007), etc. adding new concepts or even redefining the concept altogether. Our previous work tried to consolidate this knowledge and help project managers out there deal with complexity in their projects. The insight gained by dividing complexity into *elements* (project characteristics that make it complex) and *situations* (arising from the elements to add extra complexity to the project) seems to be very helpful for practitioners trying to deal with complexity. However, the findings still seem to be very general and it is hard, so far, to link them with a specific industry. Projects of R&D are an example of project type that is greatly influenced by complexity. For starters, they are usually very large projects, interconnected with several departments or even companies; which will certainly contribute to the structural type of complexity. Also, they deal with the development of new solutions and products —which is always a bit of a step into the unknown—, which makes these projects have a large amount of uncertainty. Both these *elements* give rise to *situations* that will make these projects even more complex and have a higher failure rate; however they also are what we have studied closely in our previous work. The knowledge of handling complex *situations* can be linked with this specific kind of industry. And, through this work, gain a better insight into how project managers in these type of projects can tackle complexity better, leading to better results from them.

1.2 Problem description

The engineering R&D industry is the target industry that was chosen for this master thesis, mainly because projects in this type of industry would tend to present high structural complexity and high uncertainty; making it a perfect candidate to apply our previous knowledge. Also, R&D is a complicated industry with a high failure rate for projects, which has definitely to do with the complexity present in the projects. Through this work we believe some solutions to this can be presented, and be a contribution to working project managers.

However, many things still need to be learned about this industry. This should first begin with a small literature review that will let us know what kind of problems and barriers are usually encountered in the industry, and how complexity is contributing to them. Also, there is much to find out about the PM's general role in these projects, and the specific role they would have throughout the life cycle of the project. This is the basic knowledge to be gotten before we can start applying our concepts into the engineering R&D projects.

1.3 Project objectives and scope

The assignment of this thesis can be divided into the following objectives:

- Conduct a literature review in order to identify the characteristics of R&D projects.
- Conduct a comprehensive empirical investigation to identify *elements* in engineering R&D projects.
- Identify, classify and analyze complex *situations* that arise from these *elements*, along with possible solutions.
- Identify the type of competencies needed to manage these complex *situations* in each step of the project life cycle, and what is the role of the project manager in this process.

1.4 Outline of the Thesis

The report is divided in six different segments.

The first chapter is the *Introduction* —where we are giving a brief introduction about the background of the project, stating the problem description and the scope of the work.

The second chapter is *Methodology* —here the research methods used in the project will be detailed, and what kind of effect they have for gathering data and writing the report.

The third chapter is the *Literature review* —this will look first at project complexity: from where it arises, what difficulties are met, and what is done already. In this part our theoretical framework will be formulated and explained. As a second part we will narrow down the topic and will look into R&D projects exclusively, and see the main complexities that are affecting these kind of projects.

The fourth chapter is *Findings* —where we will present the findings from the data collection, consisting of interviews with PMs who were or are involved in development projects.

The fifth chapter is *Discussion* —which contains an analysis of the findings compared with the literature, and other results of the data collection. Also the formulation of our work's main contributions will be here.

The sixth chapter is *Conclusions* —here the final conclusions of the work will be presented, along with recommendations for future research in this same area.

2 Methodology

This chapter begins with a description of the perspective on our research, it includes an explanation of why we chose this specific way to answer the research questions. The aim of this chapter is to show how we did our master thesis, and why we decided to do it like that. This will include the description of: what kind of research methods were used, how data was collected, and how it affected the result. During the master thesis writing we combined different research methods: literature review and case study.

2.1 Defining scope

The idea to write the thesis about complexity in engineering R&D companies comes from our previous project, where we were looking at project complexity. During that project we didn't have a chance to go more into details on empirical practices and confirm our findings, we conducted just two interviews with project managers in the medicine sector in Norway. That's why in the master thesis we decided to do a lot more empirical investigation.

The first thing that we did before starting to work on our assignment was to divide our task into smaller sub-tasks, in that way we could understand the project scope more easy. This helped to structure the work process.

The thesis was divided into three parts (regarding empirical research):

- First of all, to identify *elements* in engineering R&D projects.
- Secondly, identify, classify and analyze complex *situations* that arise from these *elements*.
- Thirdly, identify the type of competencies needed to manage these complex *situations* in each step of the project life cycle, and what is the role of the project manager in this process.

Before identifying the *elements* of engineering R&D projects we needed to gather as much information as possible about them. That's why the literature review was the first part of the process.

The best tool to approve or dismiss findings is by comparing them with practices. For that reason the second step was to find companies who are working with product development projects. Our main goal was to get as many project managers as possible to speak with us by "face to face" interviews, or having video conferences or telephone calls. The result was that we interviewed 10 PMs.

2.2 Case selection

Choosing a specific field to analyze helped to narrow the topic. Moreover, the theoretical part helped us to see what is already done in the field and what needs to be improved. The case study helped us to see how things are being done in actual practice in our days, and what is necessary to run projects more easily, without making them complicated. Having live interviews with project managers makes it easier to draw the picture in our minds of how all the processes are being run. Furthermore, during the interview it is easier to steer questions in the direction you need more information from, or would like something explained in more detail. Also, you can add extra questions —which you did not plan to ask— if you see that it will help to find the right findings.

2.3 Data collection and process

To get the right data for our thesis we chose two main methods: literature review, and interviews with project managers from R&D companies.

- **Structured literature review:** the basic part of any academic work is to study already existing sources in the field of interest. In the literature review, we chose to read articles that are already published in different kind of journals and speak about R&D projects. As we had already data about project complexity, we needed to gather as much information as possible about complexities in engineering R&D companies. The collected data was examined, which helped to better comprehend the field and see what is lacking in those findings. It was easier to see where our focus had to go. Also, it established the research part before the empirical analysis began. (See chapter 3 - Literature review)
- **Case study:** to gather data from case companies we used the interview form. We contacted project managers who are working with development projects, because mostly it is them who are dealing with complexities and who are making the decisions. Our main purpose was to have a live interview to get the best possible data; for this we were taking active part in all of them to make sure that we wouldn't miss any important information. Besides, we were documenting each conversation by taking notes and recording the audio to validate the data if necessary. After each interview

the notes were evaluated by us and small conclusions were made, which are given in the chapter 4 - Findings.

- **Informants:** we interviewed project managers from different companies who are, or were, working with development projects in their career. Before the interview we contacted and gave them a little information (see annex 4) about our project work; the purpose of this was to introduce our informants to our project idea and goals. We decided to have a focused interview (Merton et al., 1990) in which a respondent is interviewed for a short period of time —about one hour.
- **Questionnaire:** the questionnaire was divided in two parts. The first one was delving into the more general things in the company and projects —type of organization, interaction with other departments, project manager opinion about uniqueness in R&D projects, and what skills PMs have to have to be able to finish a project successfully. The second part of the questionnaire was aimed to look at one particular project and analyze it. We were looking for specific elements that were making it complicated. It was interesting to see the actions from the PM's side and what kind of tools and methods they were using to reduce complexity.

  Combining personal opinion questions with company questions helped us to draw the full picture of how things are in reality; and how it differentiates itself from the literature. For example: the literature says that knowledge transfer has to be documented to be sure that information will stay in the company. However, in our interviewed companies, knowledge transfer is always being transferred orally. Some of them have official documentation, but afterwards no one knows where this information is going nor how it is going to be used again.

- **Analysis of the data:** looking for patterns in the answers of the informants was the first step towards our findings. What situations they might have had in common, and which ways they used to solve them.

  We were also looking at how their answers match our created framework, and how many different opinions appear each time.

- **Quality of research design:**

Table 1: Tactics which were taken to insure Reliability (Validity based on Yin (1994))

	Reliable	Valid
Literature review	- Data was collected from published journals, articles - The information was taken all the time from the first source	- The findings were based on the convergence of information from different sources, not quantitative or qualitative data alone - Matching patterns
Interviews	- All original evidence is kept (notes, voice records) - The information from informants is presented in the case study description - Developed case study data base	- Matching patterns

To conclude, we believe we have gathered all the important data we were looking for, and so our data collection tools have been functioning accordingly. For example: the literature review resulted in a clear picture of the theoretical background which was used to develop a research framework for project complexity. Then, the case studies were used to get involved in the practical relevance of the research.

3 Literature review

3.1 Project Complexity

The term Project Complexity is one to have arisen more and more in the project management literature. What's more: it's a term that has also been evolving through time. From Baccarini (1996) (arguably the first academic paper to deal with project complexity) to Geraldi et al. (2011) several authors have been dealing with the subject. However, even though there seems to be an evolution in the usage of the term, it is quite clear that the academic community in project management has yet to arrive at a consensus of what project complexity truly is. After all these years, there are many articles still trying to define the term, and as everybody has their own definition —or adds something to a previous one— the terms surrounding project complexity become more and more complex. What most authors seem to agree upon is that complexity is not merely complicatedness (Richardson, 2008). The concept that is given by Richardson (2008) about what really makes complexity is non-linearity. This can be described better as the idea that small changes can have large consequences, which, for the most part, cannot be anticipated. When we talk about complexity, we are talking about something which cannot really be modeled nor very well understood how it works; as Richardson (2008) says, the more we look into complexity, the more we see how little we understand about it.

3.1.1 Elements

Nevertheless, authors have tried to frame this concept and bring it into the project management context. The emergence of this practice has been rather recent, with authors claiming that projects are becoming more complex themselves with time (Williams, 1999). What they have been focusing on is on listing the dimensions affecting projects that contribute to complexity (in a way: what makes projects complex). Most models of complexity are based on this, and these traits have been called *elements* by us. These *elements* are inherent characteristics of projects that contribute to make the project complex. With time, and further investigation, the researchers have been seeing more and more *elements* having an influence on project complexity, and so we present a table (see Table 2) that shows the most relevant models of complexity in their chronological evolution.

Table 2: Project Complexity Frameworks

Author	Based on	Complexity definition
Baccarini (1996)	New model	Consisting of many varied interrelated parts and can be operationalized in terms of *differentiation* and *interdependency.* Baccarini provides two basic definitions: -Organizational complexity: *By differentiation*- the greater differentiation the more complex the organization; *By interdependency*- degree of operational interdependencies between organizational units. -Technological complexity: *By differentiation*- refers to the variety or diversity of some aspects of a task; *By interdependency*- between tasks, within a network of tasks, between teams, and different technologies.
Williams (1999)	Baccarini (1996); Turner and Cochrane (1993)	-Structural complexity: number of elements; interdependence of elements (reciprocal interdependence adding the most to complexity). -Uncertainty: uncertainty in goals; uncertainty in methods.
Geraldi and Adlbrecht (2007)	Baccarini (1996); Williams (1999)	The pattern of complexity is formed from 10 characteristics, which belong to three main types of complexity: faith, fact, and interaction. Complexity of faith: Refers to uncertain situations (uncertainty). Complexity of fact: Is related to the structural complexity. Complexity of interaction: Concerns the complexity of the relationship (from intercultural communication to technical interfaces).
Maylor et al. (2008)	Baccarini (1996); Williams (1999)	MODeST model with five different complexity structural parameters: mission, organization, delivery, stakeholders, and team. Two different dimensions have impact in these factors: Structural complexity (based on project characteristics), and Dynamic Complexity (based on project interaction).
Remington et al. (2009)	Extensive literature review and Interviews with	Divides complexity into two factors: *dimensions* (where the complexity comes from), and *severity* (to what extent will it be a problem). A mixture of both gives the degree of complexity. Dimensions: Goals; Means to achieve goals; Number of

	practitioners	interdependent elements; Timescale of Project; Environment. Severity factors: Non-linearity; Uncertainty; Uniqueness; Communication; Context dependence; Clarity; Trust; Capability.
Vidal, Marle, Bocquet (2010)	Baccarini (1996)	Used the two classical divisions of Baccarini (1996) Technology and Organizational complexity, divided into four families of factors: Project size, Project variety, Project interdependencies, and Project context-dependence. Based on the framework 70 factors adding to complexity were found, but later narrowed down to 17 only (fitting into each category).
Bosch-Rekveldt et al (2010)	Extensive literature review and interviews with practitioners	TOE framework divided into three main groups of complexity: -Technical complexity: Focused on content of the project. -Organizational complexity: Softer aspects of the project. -Environmental complexity: Influence from the environment on the project. Identifies over 40 factors affecting complexity, grouped into each of these categories.
Gul and Khan (2011)	Baccarini (1996); Williams (1999)	-Structural complexity: Differentiation (number of elements), Interdependencies (between elements). -Uncertainty: Goal uncertainty, Methods uncertainty, Environmental uncertainty. -People uncertainty: Social interactions, Rules of interaction (process of relating)
Geraldi et al. (2011)	Geraldi and Adlbrecht (2007); Maylor et al. (2008)	-Structural complexity: Classical concept; entails size (number of elements), variety, and interdependence -Uncertainty: Also much discussed before, how prone would the project be to vary. -Dynamics: Change inside the other dimensions of complexity, closely linked with uncertainty, but more to do with consequences than likelihood of happening. -Pace: Rate (or speed) at which the project should be delivered. -Socio-political complexity: People relationship in the project, both between themselves and how the environment (political context) affects the project.

From this table we can see some of the most predominant frameworks for project complexity. As we have said before, most of them are concerned with what we call *elements*. Structural complexity was the first to arrive with Baccarini (1996) and this *element* is clearly linked with our point, it relates to the size of the project (number of tasks or elements) and their relation with each other (interdependence). This is definitely a characteristic inherent to the project and little or nothing can be done about it by managing the project (the project will have the size it has no matter what management approach is taken). The second most quoted concept is that of uncertainty, first introduced by Williams (1999), and this one is less clear in its scope than structural complexity. In this case the uncertainty in a project makes the project more unpredictable in its nature: goals change, methods change, scope changes, and people move around the project. The uncertainty of the project cannot be managed very well (it is just given in relation to the nature of the project), but the consequences of this uncertainty can certainly be felt along the life cycle of the project.

3.1.2 Situations

There is, however, to our understanding, another dimension to project complexity besides the *elements* that contribute to it. This second dimension arises from the *elements* in the way that they— by themselves, or added together— create *situations*, which contribute to complexity. They are not something that is really a second part of project complexity, completely separated from the *elements* which we have already discussed; both are indeed very closely related. *Elements*, as a way of putting it, set the initial conditions for project complexity, with them we can see how a project may be complex in its own right, however *elements* by themselves do not increase any complexity, they are just there. When things are put into practice, and the underlying *elements* are there, *situations* appear which will have an impact on the complexity of the project. As a way of seeing it, *situations* are the more dynamic side of project complexity. They arise during the course of the project, thanks to the complexity *elements* of the project, and they have the potential of making things truly more complex, however —unlike *elements*— they also have the potential to be managed; since they are not underlying conditions, but have more to do with how the project is carried out.

These two concepts make the whole of project complexity. One part is inherent to the project, and holds the factors that can make a project complex. The other is changeable, and derives from the initial *elements*, however the *situations*, while adding to complexity, can be managed, and their impact diminished.

3.1.3 Managing project complexity

As we have seen in the previous section, there is a large array of literature that has busied itself with trying to identify *elements* and develop frameworks of complexity. However, there is virtually no literature that deals directly with the *situations* we are talking about now. Even so, we have found articles that brush upon the concept of *situations*, and have some tips about how to manage them. In Geraldi (2008), the author looks at how multi-project companies should function. The findings are very interesting to us, as it takes into account two very well known complexity dimensions: structural complexity, and uncertainty. Depending on what kind of dimension predominates in projects, the company should have more or less flexibility in their procedures. If structural complexity is high then it is better for the company to have lower flexibility and a more structured approach while managing projects. On the other hand, when uncertainty is high in projects, the approach to managing them should be more flexible and less structured; as changes are certain to appear along the way. This type of framework is indeed very general (and only focused on the fit dimension), but it can give us the first approach to what is needed to handle complexity *situations* (based on structural complexity and uncertainty at least).

Focusing only on structural complexity we can look at the findings of Duimering et al. (2006) in which was stated that communication, coordination, and availability were helpful behaviors to manage projects that require high integration. Also, Chronéer and Bergquist (2012) in their study of Swedish manufacturing companies doing R&D projects, came to the conclusion that the most important tool in such projects (being made up of many interrelated departments, technologies, and products) is integration. Everybody needs to be on the loop of what is going on in the project, the part they should play, and the overall goal of it; that way all sort of interface inconveniences were minimized. As such, we can be fairly certain that the way to handle a large amount of structural complexity, and the *situations* that come with it, is to try to integrate all the parts that come into the project as much as possible. And that can be achieved by having a solid communication mechanism, good structure on the project team, and a functional project organization. This can be achieved, as Geraldi (2008) states, by being more based on mechanical processes and structures than on actual flexibility.

On the other hand, uncertainty generates *situations* that have more to do with the unexpected; rather than lack of coordination like structural complexity. When this element is present things may change quickly in projects, and there might not be a real appreciation of what needs to be done. This is clearly something that would put a high strain on people. Azim et al. (2010) state in their article that the most important skills a manager can have while dealing with people are soft skills. One would have to master dealing with the human issues in a project in order to be able to better tackle uncertainty. Following also what Geraldi (2008) proposes, it would be logical that to handle uncertainty in projects a higher degree of flexibility is required. Formalization would only stand in the way when one has to adapt to situations quickly, and a high degree of uncertainty will certainly bring about many unexpected occurrences in a project. From this we gather that in order to manage uncertainty generated *situations* one would require less mechanization of the work, and take decisions more based on feeling and empathy, as clear information might not always be apparent.

As a complement to the theoretical findings a short empirical investigation was done, interviewing two project managers in charge of large projects in the medical sector in Norway. In both cases we found that project teams were very horizontal, encouraging discussion among members regarding most project decisions. This is certainly a way to handle structural complexity, as all team members are always communicated and integration in the project team is high. However, this dimension adds also the flexibility needed to deal with uncertainty, as through the cohesiveness of the team they were able to reach decisions quickly, and adapt to new situations with few problems. The key to this aspect was the loyalty presented by the team to the project. The managers put great emphasis in keeping the team aware of the project goals, and ensuring the team is always aligned with them. This is something akin to what Söderlund (2002) found, that managers tried to make team members feel important to the project. The bond people will feel with the goals of the project is going to be strengthened by this, and the integration of the project team will be higher. In the empirical research we saw clear examples of this, as the teams had the goals very clear, and among them (through discussion with all members) they could solve quickly and effectively almost any unexpected situation, while keeping the overall goals of the project as a priority. This new findings give us the first clue that the solutions for managing structural complexity and uncertainty need not be exclusive of each other, and one highly integrated team can handle both given the right setting.

The tools we have listed here, however, seem to be either very general in its scope (as most theoretical management findings were), or very particular about a certain type of project (the empirical research focused on projects in the medical sector, with a relatively low amount of team members and very high education). So now we will focus our efforts solely on understanding complexity in engineering R&D projects, and —combined with our previous findings— find ways to better manage complexity on these type of projects. On the next section we will discuss engineering R&D projects, and what *elements* of complexity are unique to them.

3.2 Engineering R&D Projects

Now we will take a deeper look into the chosen area for our study: R&D Projects. There are many different definitions of what an R&D project is, for Lager (2002) these projects are mainly internal in a company, and include the development of new process technology in order to achieve better production capabilities, or deliver new products. Balachandra and Friar (1997) state that these projects involve the development of new products for the market. Whatever the case, most authors agree that these projects have to do with innovation and newness, it is not the usual development of something that the market has seen many times before. That being said, there are still degrees that an R&D project can have: some of them are merely updates to products already in the market, while others can be brand new innovations, for which there is no market yet. As De Meyer (1985) states, this distinction can have to do with the type of company we are talking about: some of them pride themselves on always being on the edge –developing the new technologies that will change the world–, while others are merely satisfied with following the curve and optimizing their products as the times dictate. Their aims, and most importantly: their uncertainty, may not be the same, but both type of companies develop something new —even if it is a very small change—, and both will be on the focus of our study.

While newness and innovation are the main factors that distinguish R&D projects from other kind of projects, this difference adds for much more depth in the complexity of these projects. For most projects it is enough to meet the classic project success criteria (time, cost, and quality) to be deemed a success in the eyes of most stakeholders. However, for R&D projects this can be different, as a successful project execution can be still be met with market failure. First of all, the market a new product will hit is not usually an established market — although it is true that sometimes innovations are so small that they fall into an existing market—, and this means that the reception the product will have is hard to predict. Moenaert et al. (1995) rightly state that communication between the development department and marketing department at the front-end phase can be highly valuable to make the project more marketable. The closer the project idea is to a client want, the better it will do in the market once it is developed. And in the case that the product is so innovative it will create a market of its own, it helps to understand what this new market will be like. On the other side, considering the findings of Carbone (2005), a project may know the market demands very well, be a success in execution, and still fail because the company does not have the capacity to manufacture the new product. This is also something to be taken in mind by companies developing R&D projects, because when working with something new you may end up with a product that is impossible to manufacture with the current company equipment. This will end up costing the company so much more money on new equipment that the project may not be profitable anymore, and it may very well never hit the market. So project managers also have to bear in mind the connection this new development will have to the company's existing manufacturing capabilities, and there will always be pressure on the manager to try and keep it as simple for manufacturing as possible.

It is also difficult for companies to judge performance on their R&D projects. Elmquist and Le Masson (2009) wrote a very enlightening article about a project that was at first deemed a complete failure by the company, however, with time, the technologies and learning, developed in the project, served as the cornerstone of several highly successful projects. Many a company will find itself in a similar case regarding R&D projects from time to time, when a complete market failure can contain the very idea of a more successful project idea. The learning inside the company can prove to be as important as a commercial success, however it is much harder to measure. As such, most companies have a hard time judging the combined effect that all of its R&D projects have on the company. It is somewhat easy for them to judge a singular project independent of the others, however as McGrath and Romeri (1994) state, it is much harder to measure the performance of all projects put together. As they are not really independent and one can influence the other. So, even if companies would rather have only successful projects in their portfolio, it can be argued that some failures can be as important for commercial success than successful projects. Particularly when it comes to the development of new technologies and intra-company learning.

Technology is another factor that cannot be ignored in these type of projects. By definition R&D projects are about achieving something new, and, as such, new technology will always be involved ―be it in a small or large amount. Kim and Wilemon (2003) discussed two different ways in which technology can add to the complexity of R&D projects. Firstly, component integration in which several different technologies have to be assembled in a single product and work together, which makes a much more challenging integration process. Secondly, technological newness, which refers to how radical the new technology is, and this affects the development of the project as there is a lot of uncertainty related to the technology.

Both cases affect different *elements* of complexity. The first has more to do with structural complexity, and the second more with uncertainty. Depending on the project you can suffer from either, or even both —creating a compound effect that heightens the complexity—, however it is extremely rare that an R&D project has none. Kim and Wilemon (2009) have stated in their empirical findings, which they extracted from experienced project managers, that most managers in R&D projects always list technological challenges as a major source of complexity. As it is, R&D projects and new technology go hand in hand, and managers must always keep this in mind as it will definitely contribute to the overall complexity of the project.

3.2.1 Structural Complexity in R&D Projects

We have seen some of the factors that make R&D projects special, and now it is time to be more specific about the *elements* of complexity we have already discussed. We will start by discussing structural complexity management. We have already named some of the *elements*, which are unique to R&D projects, and how they can affect structural complexity. The interconnectedness of departments inside the company is definitely a factor. Most projects would deal with this factor too, but what is special about R&D projects is that it has to connect departments in the upstream and downstream process. We have said that it is important to communicate with the marketing department to ensure the product is one that will sell, and the manufacturing department to make sure the product is possible to produce by the company. It is no use for a manager to have ties with these departments at just one point in the project development phase —this is more complicated and has to be closely linked throughout the whole life cycle. There is an interesting approach to handle this *situation* proposed by Iansiti (1995). This author proposes the use of a “flexible approach” for companies doing development in turbulent environments. Basically, this is applied by overlapping the planning and development phases of the project. This is not a real measure to win time —as it can be inferred from the previous description—, but one to maintain flexibility throughout the whole project. By doing development while still planning the basic product features the manager has a lot more flexibility in his product, and can implement changes recommended by the manufacturing department, or marketing with ease; and reach the freezing of the final product concept as late as possible. The flexibility of this system would give the manager the chance to maintain a close and meaningful relationship to both marketing and manufacturing throughout most of the life cycle. The author, however, is the first to state that this system is not easy to perform, and a good set of personal skills (on the part of the manager), and organizational managerial processes (on the part of the company) are required.

Another point that comes to mind in this subject is the component integration technology *element*. As previously discussed, this is about integrating a lot of different technologies into a single product —whether they will be inside the product, or to make it able to interact with different technologies. Not only will this mean working together with a lot of different experts in the project, but this might also mean interacting with different companies, which may very well be placed in other parts of the world and subject to a different working culture. The article written by Chiesa (2000) is one that advices companies dealing with global projects, in which several centers for development are scattered around the world. The focus of this article is global, but the theory, we think, can be brought also to fit intercompany exchanges. The author says that there are two types of organizational structures one can have when dealing with scattered contributors to the project. One is the "specialized structure" in which there is one main center (or department, or technology) that has the most weight in the project, and all the others have a more minor role. In this case it is better to let the main center carry the reins of the project and all the others provide support in their own area of expertise. The second option is called "integration structure" in which there is no clear main center that provides the basic technology, and there are several that can be equally important. In this case it is better to create a network between all centers and have them work together towards integration of all their areas of expertise. As it was said before, this framework was originally meant to be applied to projects dealing with centers all around the world, however it can be brought down to fit projects dealing with different technologies, just by replacing the center with the technology —and the expert that provides it— that is being used in the project.

3.2.2 Uncertainty in R&D Projects

Uncertainty is an *element* that can be very easily related to R&D projects, as they, by definition, are about doing something new. There will always be a step into the unknown in these kind of projects, so it is virtually impossible to completely eliminate uncertainty from them. The concept of new technology from Kim and Wilemon (2003) is something that greatly illustrates this point. Some projects will have breakthrough technology that has not been worked with before; others will simply optimize something that is already operational. The degree of uncertainty is certainly much higher in the former, but both have to deal with it anyways. There is also the question of the market the desired project outcome will hit. A project with very high technology newness will most likely hit a market that is quite new or doesn't even exist, in that case the uncertainty is raised even higher. Not only will it be a problem during the project execution (as working with the new technology will not be easy), but it will still be present once the project is finished and the output enters its market phase.

When talking about managing uncertainty the point is always raised of increasing flexibility in the processes, and allow for more freedom so the people in the project can react to the changes uncertainty will certainly bring along. This is usually seen as something that will eventually decrease the more formal structure of the project. Both Tatikonda and Rosenthal (2000), and Naveh (2007) have made an empirical investigation in R&D projects regarding this issue. Their findings are not only that flexibility and formality can coexist in the same project, but that it is actually beneficial to project performance. Projects increase their performance with formality in their processes and also increase with flexibility. Having a mechanistic approach to the project seems not to hurt while dealing with uncertainty, and according to Tatikonda and Rosenthal (2000) flexibility comes more from the resources and autonomy from the firm than from the systems and processes. This is an interesting finding as it points to having the project isolated from the main company to give the PM freedom in his approach and control over his resources. Then you would need resources that are flexible: easily traded to new tasks, or capable of doing several tasks in different ways. Lastly, the whole project can be managed in a structured way.

In support of these findings there is also the work of Larson and Gobeli (1989). The authors in this article made a large empirical research in order to find out which project organizational structure was the best for development projects. Their answers were quite clear, always having pure project structure and strong matrix structure the best results in project performance; while weak matrix structure and department structure had usually bad results in these kind of projects. This is clearly in line with what was discussed before: that the project manager should have complete control of his project, and a certain amount of autonomy from the main company to get better results, so he can deal with the uncertainty better.

4 Findings

This chapter will present the results of 10 interviews done with Project and Product Managers, who are dealing with different degrees of complexity in development projects in their work life every day. All of these managers have more than ten years of experience in their field, and have participated in many different projects. All the project managers are indicated as informants 1 to 10 in order to respect their —and their company's— privacy. The findings are presented in three main sections and these are divided according to our main project scope. The first part presents the main complexity *situations* these managers have mostly encountered in their work experience, and explains how they came to arise. The second part is about the competencies project managers have to have in order to handle the complex *situations*, and be able to finish the project successfully. The third, and last, part presents the leadership style project managers use depending on the success criteria they have.

The main findings, lessons learned, and valuable information are going to be highlighted in the text.

4.1 Complexity situations

Independent of the type of professionals we have interviewed, the findings point that the *situations* of complexity that project managers have to face are more than simply caused by structural complexity or uncertainty alone, but of a compound effect of both. The manifestation of these *situations* also varies from project to project, as no project faces the exact same *situation* of another. However, we were still able to see greater patterns, and were able to differentiate between the *situations* faced by Internal Improvement projects, and those faced by Client Engineering projects (both projects about developing something new).

4.1.1 Situations in Internal improvement projects

Starting with Internal Improvement projects, we have interviewed 5 project managers who have dealt with these type of projects. These projects are about changing the internal working processes of the company, so the main source of complexity for the project managers are the stakeholders, which are the different departments of the company and the end users of the project deliverable. As the Informant 7 stated:

"*The main challenge is the people, because we change the way they are going to work.*"

The main structural complexity of this type of *situation* is the sheer number of stakeholders involved, and their diversity of opinion. In a project that involves a main application of the company, every single unit will be affected and will have a say in what they want the final deliverable to do. The informant 2 said to illustrate this point:

"The complexity lay in finding a common ground that accommodated everybody, each department had a way of doing things and they were not keen to part with it."

Indeed, project managers are certain to get a lot of resistance from the stakeholders they are trying to accommodate, because it is troublesome for them to change their way of working; even if the new solution will be better than the current. The informant 1 said:

"Sometimes he [the project manager] can come up with the right solution, but it will not be implemented because powerful stakeholders don't like it."

This is the point in which the uncertainty comes into play for this type of *situation*: the managers don't really know how the stakeholders are going to react to the solutions proposed. And even if they did, they know that the solution they know to be the best will meet resistance from some stakeholders, and may ultimately not be implemented. The informant 1 said to this:

"[Stakeholder's reaction to] particular outputs can be hard to predict from the beginning, you may only realize the complexity once you are working on it."

And so, the main complexity *situation* for these type of projects puts a lot of strain in project managers. They have to deal with a lot of stakeholders with diverse ideas —a lot of final users that are hard to coordinate and please at the same time—, and they don't know exactly what their reactions to the product will be. So, even if they know what solution would be ideal, they are not sure it will be finally implemented. They will have to remain open to changes almost throughout the whole project.

From the informants we have seen that there is no one way to manage this type of *situation* and reduce the overall complexity. We have narrowed down the answers to two different ways of handling it. The first is a way that focuses more on the uncertainty than the structural complexity, but ultimately manages both. The project managers control the flow of information to the stakeholders in the projects, and this way they can show each stakeholder separately what they want them to see. For this, of course, a very good knowledge must be had before hand of what each stakeholder wants to get out of the project. To apply this solution the manager has to do this type of research. As the informant 1 said:

"The best weapon to fight this complexity is to have a very good overview of what stakeholders want from the beginning. If you know what a party is looking for it is easier to sell them the solutions you want."

By this approach you reduce the uncertainty of not knowing how the stakeholders are going to react to a solution, because the manager will be pitching the solution in a way that looks favorable to the stakeholders; some uncertainty of course remains, but it is greatly reduced. However, this solution reduces the structural complexity as well. The main strength of this solution lies in that when the manager knows well what the stakeholder wants, he can balance the solution beforehand, and not after having developed something and having it rejected. The diversity of the stakeholders will still be there, and it will have an influence on the project, but if you know what that influence is, you can handle it. By applying this solution the manager will be less likely to be surprised by the stakeholder's reactions, and therefore will be less inclined to make changes in the project; while still keeping everybody pleased with the final product. It can be difficult though: to work for every stakeholder's sake, and managing this balance between reducing uncertainty and structural complexity at the same time. As the informant 6 said regarding working with many different stakeholders:

"When you start a project, organizational complexity is a given, and there is little to do about it, you have deal with the way your company works."

On the other hand, there is a less flexible approach taken by other project managers. This consists of trying to lock the final product early on in the project, and then make the different departments adapt to the product (instead of the other way around), with few changes being done along the way. As illustrated by the informant 3, top management support is a key part of this strategy:

"*You should get support from the top management. They should know what you are doing and why you are doing it."*

When top management gets involved, the business unit's wishes get somehow overruled and they would have no choice but to comply with the deliverables of the project. This solution does much to reduce the structural complexity: there is only one final product and each stakeholder receives the same treatment; however flexibility is low, and thus uncertainty could become a complication. As the informant 2 illustrated:

"The change order system was very rigid, and so not many changes were made. There was not a lot of room for flexibility."

Still, with few changes done along the way, the uncertainty is also reduced. The problem would come when a change to the final product is imperative to a certain stakeholder. Then this system has a very bad way to react, and will probably not cope well. That's why it would be really important that before the final product is locked, it should at least comply with what every major stakeholder needs to function properly.

Each way of handling this *situation* is valid depending on what the project manager wants to achieve. In the case of the first: the product delivered will be very well fitted to the users and most will get what they wanted to get, however the process will be time consuming and many points of view will have to be taken into consideration. The second way is better for implementation under a short time frame and, perhaps, not having so many resources; however the final solution —while achieving its objective— will not have the best reception among users, and changes will be hard to implement.

Situation

Structural complexity in the form of many diverse stakeholders having to be accommodated by the final project deliverable. Uncertainty in the form of lack of predictability of stakeholder's opinion and their reactions to proposed solutions.

Solution 1

Reduce complexity by studying what stakeholders want early on in the project, managers can show their results in a favorable way and stakeholder's reactions will be more predictable.

Solution 2

Reduce complexity by locking a final solution early on, top management support is key to enforce it. This way stakeholders adapt to the final product instead of the other way around.

4.1.2 Situations in Client Engineering projects

Client engineering projects are a somewhat different matter. This are certainly R&D projects that can include most of the literature factors that make them complex, however they also have a defined client, who wants to get a product at the end of the project that has the functionality they desire. The managers we interviewed all agreed on the most complex *situation* for these kind of projects: to get the interface between all product components to work in the final product. The informant 5 discussed this point:

"The hardest thing is managing and being aware of a lot of elements at the same time, that are usually interacting with each other."

This view adds a lot of structural complexity to the project —that is consistent with the previously described component integration technology *element*. The projects involve many different components that have to be coordinated during the life cycle of the project, and, at the end, have to work seamlessly together; even if they involve fundamentally different technologies. An example was given by the informant 4:

"The problem with the computer system was that it was divided into 2 job packages: software and hardware, which were dependent on different disciplines."

To have to manage a large amount of structural complexity would not make these projects much different from other projects that are not R&D, but uncertainty also plays its part in this *situation*. Most managers stated that no matter how much planning you do before hand, when you assemble a final product —or even a part of it— testing will always reveal problems. So they are well aware that even if they can develop a prototype of the final product on time, they have to be ready for a lot of testing to finally iron out all of the functionality issues, which will be unexpected. The informant 9 said about this:

"To gain time on the testing we developed a larger testing lab —that allowed us to test for more functionalities than usual— to do most of the testing in-house. This was a big help."

And the informant 4 also reinforces this point:

"Creating a prototype is only half of the job. The other 50% will come in testing, because there is always something that is going to be wrong."

Added to that there is another part of uncertainty that is quite exclusive to these type of projects: client interference. Indeed, the clients can sometimes have a very good idea of what they want in the final product, and they try to make sure that the project delivers just that. This, however, can interfere greatly with the development process of the project team. The informant 8 stated thus:

“The client has a right to do changes, all kind of changes, even company procedures. For this we need to adapt to changes fast.”

The client, in this case, would clearly interfere with the development process, making changes (that they obviously believe will be beneficial to them in the final delivery) that disrupt the normal flow of the project team; creating unexpected situations to which they have to adapt.

As usual, there are several possibilities to manage this *situation* differently. What we have seen was a preferred option among managers is one that very smartly tries to deal with uncertainty and structural complexity at the same time. When having to deliver a final assembled product, the key lies at the organization of the project team in order to make this product work. It is very usual for project organizations that engulf so many different disciplines to be organized by area of expertise. That is to say, all the people from the same discipline are part of the same team, with their own personal agenda. When dealing with projects that include a large amount of interacting new technologies, that approach can prove to be a mistake, as it leads to the aforementioned complexity *situation*. To solve this problem a better organization by functionality, rather than discipline, can be used. This way the people working together in one whole function (or sub-product) will be part of the same team. The informant 4 said in this respect:

“The solution is to reorganize the project organization, and instead put all job packages that deliver a single product under one sub-project manager. Change the focus from discipline approach to final product approach.”

To accomplish this you don’t even need new people in the project, but a mere reorganization of the current members can be enough. The structural complexity gets diminished by reducing the number of independent parts the project has to produce and then assemble together. Instead, small whole products will be delivered: less in number, and with reduced interaction issues. This solution also helps quite a bit on the uncertainty part of the *situation*, as interaction between parts and processes will be tested to a certain degree before the final assembly of the product. The new organization will deliver working products that will be part of the whole, and so it is the interaction between these more finished deliverables that will be the focus of testing; instead of testing all possible systems for the first time.

Importance is also given to the planning stage of the project, in which all possible interactions can be coordinated before hand. These would serve the same purpose as a different project organization: to get a better integration of the final product. The informant 5 talked about this:

"Projects are really large and involve so many competencies and expertise that have to match each other in the final product, that it is important to coordinate for everyone of them at the planning stage of the project."

This solution is a little bit less effective in its implementation, as the projects can face a lot of changes during the lifetime. Indeed, some of the projects that were described by our informants were lasting up to nine years, so it can be quite difficult to plan for every possible interaction issue from year one; apart from the fact that dealing with new technologies will always bring surprises. Still, this approach reduces uncertainty quite a bit, as the integration of parts would be planned well in advance, reducing the number of surprises that will show up at testing. And also helps with structural complexity by having a better oversight of every single component and technology that will be involved in the project, and some coordination between them done beforehand.

The client interference is still a factor that can have an impact in these projects, and the solutions for this problem have no special trick. Most managers agree that the only way to handle the client is to be open with him, and have constant coordination meetings together. That way they can talk about the direction the project is heading, involve the client in any major decisions, and keep themselves very well informed of any changes the client might want to make. The informant 8 said:

"We have weekly meetings with the client, looking at the situation, discussing the following week, and future actions of how to solve problems."

Another approach —that is quite similar to that of handling stakeholders in Internal Improvement projects— is to have a very good understanding of how the client operates and know what they want. This way a manager may be able to actually predict what the client will say to a certain decision or solution, and prepare for it before hand; reducing uncertainty and gaining valuable time. The informant 5 illustrated this point best:

"We have had to adapt to this situation by learning to take decisions without the time to consult the client sometimes, by watching every aspect of it very well."

Regardless of the solution chosen for handling these *situations*, the key lies —as in Internal Improvement projects— in balancing the reduction of uncertainty and structural complexity at the same time. The complexity has to be taken into account as a whole, otherwise problems will always remain to plague the project team. The strong point in this case is that most of these solutions can be combined. For instance: reorganization of the company and planning ahead can be done at the same time (to a certain degree, of course). This gives a somewhat more comprehensive solution to the *situation*, however this would also have to be balanced regarding the leadership style, which will be discussed later in this chapter.

Situation

Structural complexity in the form of handling many different technologies (some of them new), that have to be integrated into one final product. Uncertainty in the form of the impossibility of knowing every interface issue before final product assembly and testing.

Solution 1

Reduce complexity with a reorganization of the project team. Change focus from discipline to final product.

Solution 2

Reduce complexity by having a more comprehensive planning stage of the project, and foresee some interface problems that can possibly arise in the future.

Situation

Uncertainty in the form of client demanding changes in the middle of project development work. Number of changes can add to structural complexity as well.

Solution 1

Reduce complexity by having regular communication with the client, and be well informed of possible future changes.

Solution 2

Reduce complexity by studying what the client wants, early on in the project. As a result the client will be more predictable and changes can be foreseen.

4.2 Project manager's role and competencies

On this section we will discuss the project manager competencies that were highlighted by our informants. They can be applied to different types of projects, and to successfully implement different types of solutions. So, it might not be necessary to have all of these competencies in place to implement a particular solution, however it would still be required to master several of them at the same time to apply our presented solutions.

Most informants agreed on a single fact: that the project manager has to be able to keep a big picture of the project in his mind, and be able to see most of the consequences his decisions are going to bring. The way of getting this general overview is having a certain amount of technical knowledge about the project scope and purpose. The informant 1 said quite clearly:

"He [the project manager] has to have a sense of all the dependencies of the project. He should be able to see the big picture and know how some decisions of the project will affect other stakeholders."

Most managers insisted that in order to have this kind of big picture it was not necessary to be a complete expert in every technology the project uses, but have some general knowledge about everything that will allow the manager to understand well everything that happens on the project. As the informant 5 said:

"You don't necessarily have to be an expert, but have a reasonable understanding of everything."

In Internal Improvement projects, the knowledge about the project that the manager must have is harder to define, as these projects might involve a lot of different departments with very different responsibilities in the company. Understanding the general business of the company, however, was seen as a must. This way the manager will know very well what has to be achieved by delivering his project. The informant 2 stated:

"To be analytical is important: know very well what the project is trying to accomplish and why it is important to the business of the company."

On the other hand, for Client Engineering projects it was very clear for the managers to realize the type of knowledge they should have, since in these projects there was always a main type of technology that must be developed. For the type of projects we had contact with some sort of engineering background was of the essence. As the informant 8 stated:

"He [the project manager] must have a background (professional studies) related to the kind of project he is going to lead. It is not necessary that he is a technical expert [...], however he does require vast knowledge about the general theme of the project."

This competency has to be mostly used during the project execution phase, when the manager has to foresee what his decisions will mean to the project as a whole. It is an extremely important competency for most working managers, and it can be very useful in handling the compound *situations* we have previously described. It is a conciliatory competency taking the larger scale of things into account, and not only singular factors.

Competency
Understanding of whole project picture, and foresee consequences decisions can have in every aspect of the project. Knowledge required differs on the kind of project. Internal Improvement would require knowledge of the company business; Client Engineering would require knowledge of the engineering technologies involved.

R&D projects —as we have said in previous sections— have very often a lack of clarity in the deliverables. The main goals might be very well defined, however how to get there can be hard to figure out, based on newness of technology or other factors. For this, managers have said that it is important to be able to break down activities into manageable parts. The informant 3 said to this:

"Never take any work you don't clearly understand, always go into smaller parts you understand and can manage. Nothing comes out of vague work packages that are huge."

Indeed the informant 7 was also a strong defender of completing the project step by step:

"It is important to complete steps during the project. Get to finish deliverables all the time, not only focus on the end result, progress in between is important too."

This approach is a great handler of uncertainty as the smaller work packages become very definite and clear. A similar approach can also be taken for structural complexity: formalization of processes. The way every employee works can be standardized, that way managers will know exactly how —if not what—things are being done. After that it is just a matter of getting these procedures simplified to keep the project working as uncomplicated as possible. The informant 6 gave us the best quote in this regard:

“Two steps are highly recommended. First, to actually have processes for everything you do: that way you make sure that everybody is working the same way in the company. Second, you should work on making the processes simpler, more effective, and in general easier to do.”

Both steps described here have to do with an increased formalization on the project, both can be done at the same time, and between both they reduce uncertainty and structural complexity. This seems to be, however, a fairly standard project management competency. It is based on defining the tasks well (strong WBS) and standardizing processes for executing work packages and follow-up (planning and control). The best time to actually apply this is at the planning stage of the project, however managers who are skilled at it can do it during the execution phase.

Competency

Break down the project deliverables into manageable parts, deliver progress throughout the project execution phase, and not just on the final delivery. Have processes in place for all activities. Simplify the processes as much as possible.

A third competency that was highlighted, was to know the resources available very well. Flexibility is an important part of R&D projects, as they can come across many changes. However, flexibility is not necessarily altering work processes, or getting new resources to do new tasks. In a real project in can be the case that flexibility is performed by having the same resources do varied activities. In order to do this, though, managers should have a very good understanding of the resources they have available and what they can do. The informant 6 gives us an example of that:

“To do things in a non-standard way you must be very aware of what your resources can and cannot do.”

Often a manager does not get to choose the team that will get to work with him, which makes having a way to know the people more important in this point. He will also have to lead them in an efficient way. The informant 7 said in defense of leadership abilities:

"If you have a project manager that leads people then he delivers results [regardless of his theoretical knowledge of project management], but if you have a project manager that just sits in the office, makes documents, reports; he does not deliver results."

It is then of importance for managers to have at least some connection with their people, this will help lead them better and also identify well the capabilities of the resources, which can be critical in achieving greater flexibility. Managers won't often know the team until they are working together, so this competency comes in handy during the execution phase of the project. It is interesting to note that a manager would not really have to look for flexibility outside his project team, but having good control over the resources, and knowing well what they can do will grant a manager a large amount of flexibility.

Competency
Know the project team very well. This will help in communication and to achieve higher flexibility.

Another competency that was well cited by managers working in Client Engineering projects, was to have a good understanding of the scope, and be very aware of not overdoing it. In R&D projects it is sometimes easy for the technical experts of the project team to deliver something that is beyond the scope of the project. They can add functionality, or improve quality without anybody having asked for it; simply for the sake that they feel it is better to do so. This can be detrimental to the success of the project (especially in client driven projects, where time is such an important factor), as the project can be lengthened and become more expensive; and clients will not be inclined to pay for something they did not ask for. The informant 4 explained this point best:

"It is important to deliver just what the client is asking and not something better, it is usual for engineers to say that they can deliver something much better than what is required, but the manager has to restrain them to what is necessary only."

In these projects the functionalities are initially sold to the client, and it is only the client who can make changes to it in the run of the project. Otherwise the project team runs the risk of delivering something the client did not need (reducing satisfaction), or something for which the client will not pay (increasing cost for nothing). The informant 9 said about this:

"When a project is sold to a client it is done so in a timeframe that is very expensive to break, so the manager has to do everything he can to deliver the project in time, and of course with the functionalities the client has asked for."

This competency can be seen as opposed to what R&D is really about: delivering new solutions that are innovative; but projects that have a clear scope should stick to it. It is an important success factor that the manager knows the scope very well, and can make his people deliver what is asked; nothing more, nothing less. This is a problem the managers will come across during the execution phase, so it is then that they have to look out the most for scope creep inserted by their own team.

Competency
Clear scope knowledge to deliver the exact product that is needed.

We discussed leadership a little bit before, but this is a competency so well cited by all managers that we have decided to leave its detailed discussion for last. Decision-making seems to be the ultimate competency for a project manager. It is a very important part of the job, and this is not different in the case of R&D projects. What impresses most is that managers have linked decision making with the ability to be a leader as well. The informant 4 said:

"Do not be afraid of making decisions and prioritizations. It could be demotivating to the team if you hesitate all the time, and do not have any sort of priority."

A manager is the leader of a team, and in order for things to work well in the project he has to be so in practice as well as in paper; and to be a leader you have to act like a leader. Communication is also a very important aspect of this: the manager must be able to get to his own people (and motivate them), as well as other stakeholders that might be involved in the project. The informant 8 talked about this particular competency:

"[A project manager] must show leadership and have influence on the project team. He must be a good communicator for his relationships with the client, other executives of the company, and the project team."

Leadership is, however, an illusive concept. Still, we believe that our informants have given us some keys for being a leader in a project context. Be decisive and act like a leader, communicate with your team, and always try to be a motivator. Being a leader can be one of the most important qualities a manager can have in any kind of project. The informant 7 stressed this point the most:

"They need a person, a project manager, who is at the same time manager and leader."

Also in his previous quote he stated that a leader will get results, even if he is not technically skilled, but not the other way around. This competency should engulf all the phases of the project life cycle, and be present in the application of any solution to complexity. If the manager is not the leader of the project, then he cannot be an effective project manager.

Competency
Leadership through: acting like a leader will enhance the manager's leadership in the eyes of the project team. Being a good communicator will enhance the manager's leadership in the eyes of the project team, and other stakeholders.

Closing all the skills mentioned before the informant 10 words are summarizing them:

"It is really important to get in place all the things you have learned at the start of the project: success criteria, rules, client wants, what we expect from the client, and a general understanding of the whole project. Use time to establish necessary things."

4.3 Leadership style

We have decided to have a findings section apart from project manager competencies that discusses the different leadership styles used by the managers we have interviewed. The reason for this is that the competencies seemed to depend on personal characteristics and general best practices of the managers and, while the leadership style can indeed be personal, it seemed to depend more on the main goal of the project. The examples we have seen have been dependent on whether the quality of the solution is the most important success criteria, or delivering on time is the most important success criteria of the project. All projects would consider quality, time and costs as being important, but it is a rare example in which they all have the same priority. As such, we have seen that in Internal Improvement projects the emphasis is more on the final quality of the product. The informant 2 —involved in internal improvement projects— illustrated this point:

"Delivering the right product is the most important thing; the functionality of the final delivery […] has to be an improvement to the workings of the company."

Whereas in Client Engineering R&D projects the emphasis is mostly put on delivering on time. The informant 4 stated:

"Time was the most important. The time has impact on the cost. If you are delivering on schedule usually you are not spending more money than planned."

In the first case (functionality more important than time and cost), the leadership style that works the most is a flexible one; where discussion is much encouraged and gives the experts a lot of freedom in order to find the best possible solutions. The manager would usually just give the direction in which the project should go, what the solution has to be able to do; and let the team work on how to achieve that quite freely. The informant 1 stresses this point:

"An open leadership style is used, in which there is a lot of discussion. The manager usually points the way the project should go, and lets the experts take the best solutions to get there, by discussing them between them."

And so, this more horizontal and democratic approach is usually best suited to achieve higher quality results —while taking less consideration of the time and costs of the project (but, of course, never really forgetting about them). In the second case (time more important than quality and cost), the leadership style most preferred is one that is very much focused on achieving the deadlines, allowing the team less freedom, and push them for deliverables all the time. Always move forward, and avoiding any delays at all costs is the focus here. As the informant 5 says:

"Sometimes you have to swallow your own stubbornness, or a camel [do what you don't want to do], else you get stuck in the project. […] you have to always be able to move forward."

The managers in Client Engineering projects have admitted, however, that at the beginning of the project —when all the deliverables are not yet completely clear— discussion among the team is encouraged, and a style more like the previous is used. As soon as the deliverables are established, the deadlines are locked and the team begins working in a more vertical way; the manager interested in achieving those deadlines at all costs. The informant 5 again made this point best:

"The normal style is to start with a lot of discussion amongst everybody. Then the biggest deadlines, packages, etc. are identified. […] Then be very strict in keeping that date [deadlines], and take measures if it is not kept."

As a further argument that the leadership style is more based on the main goal of the project than on actual personal taste of the manager, we can say that we saw examples from our informants in which the role was reversed. For instance the informant 7, used to work on Internal Improvement projects —and therefore with a more horizontal style of leadership—, was involved in a project that changed its main goal from quality to time:

"After the crisis meeting, time became more important than quality. […] For the second part of the project the project manager became like a dictator, he was only interested in pushing forward and getting results."

On the other hand the informant 8 usually works on Client Engineering projects, but uses a more open leadership style when the client puts more stress on quality than time:

"The leader has to be democratic, open the way to discussions and be open minded to suggestions. This, of course, goes hand in hand to the final quality of the product."

Based on all the examples we have seen, we believe that the leadership style to be used in a particular project has to be based on what the main goals of the project are. This would really be an important context for selecting the solutions to the complexity *situations*. Not only complexity needs to be diminished, but be done in a way that helps achieve the main project goal. We believe the leadership style to be very important in balancing this. For instance —regarding Internal Improvement projects—, when quality would be more important than time, the preferred solution to managing the stakeholders would be to get to know them and predict their behavior. To achieve this, the leadership style has to be a more flexible one and allow for discussion and changes in the project team. The opposite works as well: when time would be more important than quality the other solution (lock the product and enforce it with support from top management) would be preferably applied, and a more hierarchical leadership style would be adopted. In Client Engineering projects the same could be said: when time would be the main goal, the solution of reorganizing the team with the focus on functionality would be preferred, and require more of a hierarchical leadership style. Whereas the solution of planning well ahead would require a more flexible leadership style, and would favor quality over time. Like we said, all the solutions are not necessarily exclusive, so the leadership style will be key in balancing them together, and reduce complexity while achieving the best possible result.

Leadership style
When functionality is more important than time and cost, the leadership style is a flexible one, allowing the experts flexibility to find the best possible solution. When time is more important than quality and cost, the leadership style is a hierarchical one, allowing the team little freedom and pushing them for deadlines all the time.

Before moving on to our next chapter of discussion we summarized the findings chapter and put the most important details in a table. There are shown in it three *situations* and the ways to manage them with their required competencies; assuming that the leadership competency is a main one for each *situation*, and it will, therefore, not appear on the table.

Table 3: Summary of situations and solutions with needed competencies to handle them

Situation	Solution	Competencies
Dealing with stakeholders with power on final product decision (end users). -Structural complexity: many diverse stakeholders -Uncertainty: unknown reactions of stakeholders to solutions	Manage each stakeholder separately, controlling the flow of information closely	Understanding of whole project picture. Emphasis on stakeholder wants
		Know project team well, in order to attain maximum flexibility
	Lock final delivery early on. Help stakeholders adapt to final solution	Top management support
		Break down project deliverables. Simplify processes
		Clear scope knowledge
Dealing with many different components and technologies for final assembly of product. -Structural complexity: many different technologies. -Uncertainty: impossible to know all interface issues before testing	Reorganization of project team. From discipline focus to functionality focus	Understanding of whole project picture. Emphasis on final product
		Know project team well in order to attain maximum flexibility
		Break down project deliverables. Simplify processes
	Emphasis on planning stage of the project, to make sure integration works well on assembly	Understanding of whole project picture. Emphasis on leading technologies
		Break down project deliverables. Simplify processes
		Clear scope knowledge
Dealing with the client as main stakeholder. Client interferes with normal flow of project. -Structural complexity: number of scope changes. -Uncertainty: unknown impact of scope changes	Constant communication with client. Being well informed, and in due time, of possible changes	Good communication with stakeholders. Diplomatic approach
		Know project team well in order to attain maximum flexibility
	Great understanding of client. Be able to predict or overrule changes	Understanding of whole project picture. Emphasis on stakeholders wants
		Clear scope knowledge

5 Discussion

We have started our study with a literature review; to see what the literature discusses, and to create our own complexity framework, which we have applied and approved during chapter 4- Findings. In this chapter we are going to compare how our findings match the literature, what kind of differences it has, and how it could be finally improved to come up with more comprehensive solutions to complexity *situations* in this scenario.

5.1 Organizational structure

A point we would like to raise early on in this section is one that was addressed by the literature, but was a non-issue in the empirical research. Organizational structure is often quoted as an important success factor in the literature. Larson and Gobeli (1989) had a whole article about it, with their findings pointing to a strong project structure having better results than a line structure. We do not believe this to be of little importance, however it seems to be a lesson already learned for project based companies. All of our informants worked in companies that had a strong matrix structure in place, and none mentioned the organizational structure as a limitation. It was a rare case when it was mentioned as a factor at all. Managers are so used to having an empowered structure that they take it as a given, and so they don't experience any issues related to organizational structure. We believe that the literature is correct in defending a strong matrix and pure project structure as the way to get better project results, however this seems to be something companies are already aware of, and so not an active issue from the manager's perspective; as they already have a great share of autonomy.

A more interesting point for discussion is a comment made by one of the informants (informant 4) about this subject. He said that it was always preferred to have people dedicated a 100% of their time to the project. In a matrix structure it can be usual that people split their time between several projects and line activities, however this informant was strongly against this, saying that he rejected before-hand people who were going to spend less than 50% of their time in his project:

"If the people are going to be involved less than 50%, I do not involve them into the project. It is not useful to me to have somebody who will not put complete attention to the project. It will be easy for them to make excuses if they don't deliver on time, because they can always blame the other project."

The reason for this (as clearly stated by the informant) is one of efficiency of the resources. A person whose time is divided between two tasks will invariably not concentrate fully on either one. What's more: the worker will have an excuse for not performing accordingly as well; because he can lay blame on one project for not performing on another. It is certain that most managers will want people focused fully on their project, but most will just take the help in whatever way it comes (as most of our informants did). However, this may not be the best for the project effort, as having many man hours assigned in the form of people not fully dedicated can be less effective than having less man hours assigned, but in the form of people fully dedicated to the project at hand.

5.2 Internal Improvement and Client engineering projects

We have seen both a little of what the literature had to say about R&D projects, and a more in-depth investigation of what practitioners are facing. It is quite obvious that there are differences between the two, but there is also much common ground that will be interesting to discuss.

The first point to discuss is the type of projects we have encountered in our empirical research. We were clear in that there were two main types: Internal Improvement, and Client Engineering projects. In this sub-section we will try to explain them in terms of the literature, so that we can later more easily compare the literature with the findings when it comes to analyzing the complexity *situations*. Both are, of course, about developing something new and innovation (to different degrees), which was precisely our previous definition of R&D projects. There are, however, some differences to what was discussed in the literature, as these projects do not deliver their new product to an open market. Both Internal Improvement and Client Engineering projects have a definite client from the start, and are not meant to hit a new market; they are rather about delivering a customized solution to a particular need.

That is not to say that there is no strong link between the literature and the empirical research in this point. Indeed, Lager (2002) discusses Internal Improvement projects almost exactly as we have seen them. They are meant to be an improvement to old company processes, and those examples we had from 5 of our informants. This type of R&D project is definitely inside the scope of what the literature discusses, and the complexity that Lager (2002) finds is not so different to what was challenging the informants. Lager (2002) said that these projects became more complex based on two parameters: the level of innovation of the new process (to the world), and how difficult it would be to implement in the company. The parameter of difficulty to implement in the company is aligned to what managers found complex in the empirical study (changing the way the company works). The reason for this was based on the resistance the stakeholders showed to the new process, which impaired the company's capability to implement the new process. Basically, the main complexity of these projects would lie in their stakeholders, and the resistance they will always show to change. What makes it an even bigger challenge is the diversity of opinion from the stakeholders, as we had from our informants that they might want different—even opposing—results out of the project; and this would have to be balanced by the project manager.

With Client Engineering projects the link is not so clear, however we believe the literature has addressed the main point that affected these projects in our empirical research. This is mainly the coordination between departments and technologies that are involved in a single project. Moenaert et al. (1995) and Carbone (2005) talk about the inter-departmental coordination in order to make these projects a success. In Moenaert et al. (1995) an upstream coordination is described (link to the marketing department to ensure the right product is delivered). There is no marketing department in these projects, as they are already sold to a client; but the client can take the form of it in Client Engineering projects. It is certain that the client has a strong link to the future success of the project, as the client is the one who will judge if the product delivered is useful or not. Therefore, we believe that this upstream coordination Moenaert et al. (1995) talks about is with the client in this case. On the other hand, Carbone (2005) talks about a downstream coordination, in the form of the manufacturing department, that will eventually have to assemble the final product. Nothing was mentioned of this by the informants, the reason for this —we believe— being that it is not their problem how the company will go about manufacturing the final product. Their job as project managers ends when they have finished the final product, and it becomes ready for production. However, this does not mean that there is no downstream communication in Client Engineering projects, just not as far as manufacturing per se. The whole technology and discipline coordination, and the final assembly plan of the product is indeed downstream coordination. All the little necessary parts, that the product requires to achieve good functionality, need to be coordinated in advance. So, coordination upstream with the client is necessary to know what to deliver, and possibly receive changes to the product plan along the way. Then, downstream coordination to the technical departments to be able to actually deliver what the client has required. The main complexity points of Client Engineering projects lie in the coordination and balance between these two dimensions, as we have seen from our informants that the most complex challenge was to get all the final pieces of technology to work together (with no surprises) in a way that would satisfy the client. (See Figure 1.)

From this points we validate the type of projects we have seen during the empirical research. These may seem different (specially Client Engineering projects) from what the literature has been discussing, but the issues are not so different; and so the link between literature and practice can be made and further discussed.

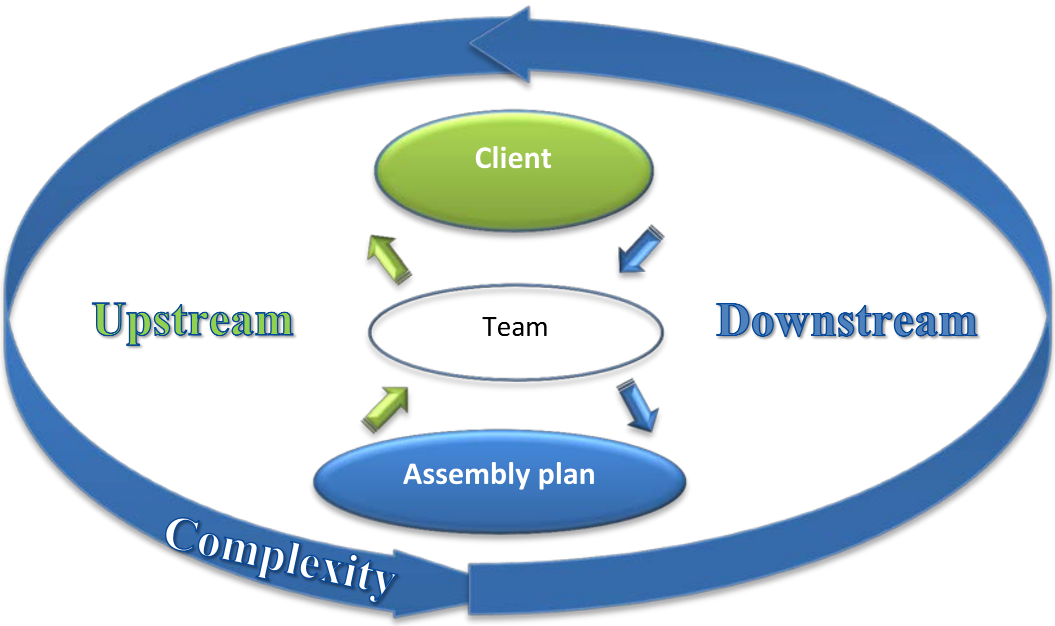

Figure 1: Upstream and Downstream coordination with the team, complexity in coordination

5.3 Complexity situations

Coming to the main point of this whole thesis, we can discuss the differences and similarities between the literature and the empirical findings regarding the complexity *situations* in R&D projects. There are many things that the literature addresses quite correctly in relation to complexity in these kind of projects. Technology is one such factor, as this is completely related to the main sources of complexity; both in Internal Improvement and Client Engineering projects. Component integration —defined as a technology factor by Kim and Wilemon (2003)— is definitely one that hits the mark of what we have seen as a complexity *situation* in Client Engineering projects: many different technologies require integration and coordination. Technological newness (Kim and Wilemon, 2003) was another technology factor that also had relevance in the empirical research, as in Internal Improvement projects the end users created resistance to the new solutions implemented by the project team. It is certain that in projects such as R&D, in which innovation is so important, technology will always be part of the complexity challenge in one way or another.

Much has been said during our previous chapters about structural complexity and uncertainty. These definitions show the heart of what we have seen are the challenges for project managers, and have been validated throughout our whole work. However, managers are not familiarized with these terms, and when asked about project complexity, they just describe what they believe has been really complicated in their projects in a regular basis. The literature has made very good work in trying to classify these concepts, and individualize the root causes for most complexity *situations*. So we speak about structural complexity and uncertainty as separate concepts, each having different roots, and different solutions. A working project manager, however, does not deal in those terms, and so we come to the main difference that, we believe, exists between the literature and our empirical study regarding complexity *situations*. The literature attempts to isolate the *situations*, and its causes, from each other. In practice the *situations* are not only not isolated, but compound each other into creating one massive *situation* that is way more complex than any root *element* by itself. We have examples of this in both main *situations* we discovered in the project types we researched. On Internal Improvement projects, the main *situation* was related to stakeholders; with structural complexity and uncertainty being part of that *situation*. Neither is the root cause, but both make the whole *situation* what it is, and work linked together: the former seen in the number of stakeholders and their different expectations; the latter in the lack of predictability of the stakeholder's reactions. The same can be said of Client Engineering projects, where product coordination was the main complexity *situation.* Having structural complexity in the number of parts to coordinate, and uncertainty in the lack of knowledge of how they would work together. (See Figure 2.)

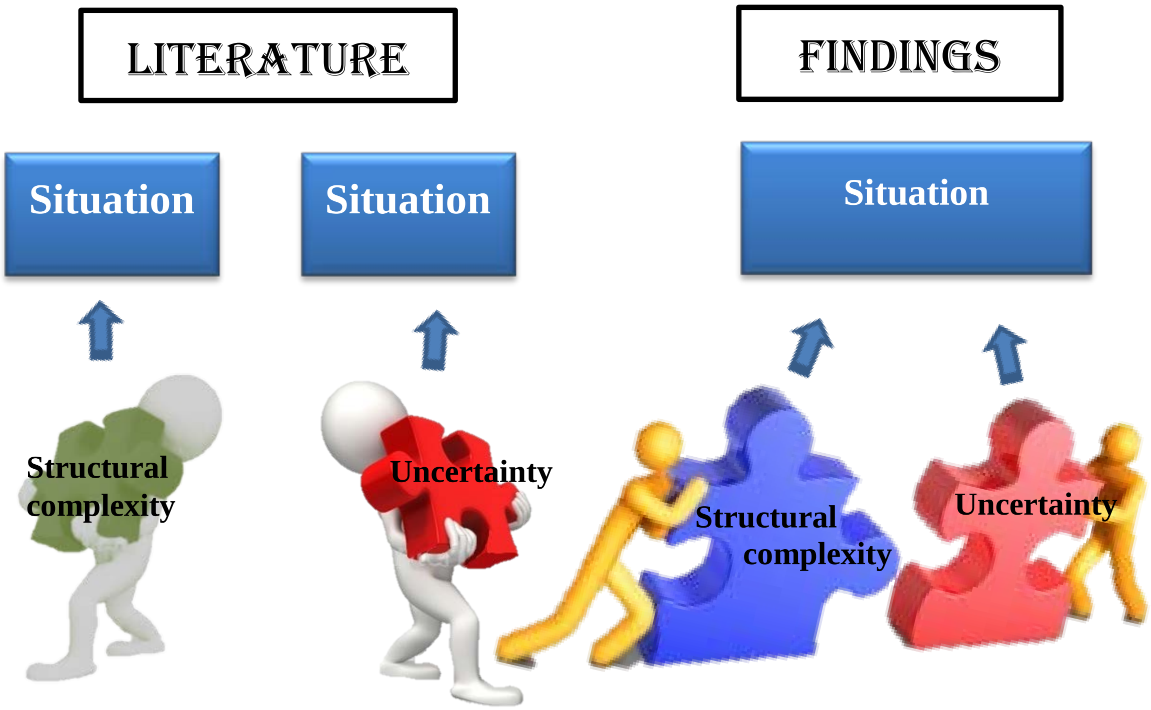

Figure 2: Literature and Findings comparison in regards to complexity *situations*.

While the literature has done well in isolating these concepts, and maybe design ways to handle them independently, we believe one more step is still required to fully comprehend how complexity works in actual projects. From our empirical research we have seen that *elements* simply don't appear in isolation. They strengthen each other into creating larger *situations* (in a sort of synergy effect) that are not really based on one single *element*, but present characteristics of both.

We have the example of Iansiti (1995) with the flexible approach to project management, which can be likened to the stakeholder management in Internal Improvement projects. The flexible approach encourages managers to lock the final product as late as possible in order to be able to implement the most possible changes in it. The stakeholders in Internal Improvement projects would force a manager to do this by trying to make changes to the final product all the time. This approach, we saw, was used sometimes by managers, and we believe it is a great way of handling the uncertainty in these *situations*, but what about the structural complexity? This approach shows no solution to that, and could even make it worse by trying to accommodate every single stakeholder request. So, as good as it is, it is not enough to tackle the whole *situation* that practitioners face.

Another example in this regard is the solution we saw presented by Chiesa (2000), that deals with projects that have many technology centers around the world. This can be linked to the *situation* faced by Client Engineering projects, in which the coordination between all the different technologies and disciplines proves to be the challenge. Chiesa (2000) has the very smart idea of organizing the project by technology: one department to have main control if they have the main technology of the project; or developing a network of departments if there are no predominant technologies. In practice this is what managers usually do by organizing their departments by discipline, and it can really help with the structural complexity of the project, but —again the same question as before— what about the uncertainty? Nothing is done in that regard, and we saw from the informants that this approach was very bad in regards to uncertainty, as the final product does not work well together without a lot of testing to iron out the problems. Once again we see that the literature, although having great ways to manage a single *element*, falls short when it comes to manage the whole *situation* we have seen in our empirical research.

Worse yet, these solutions seem to really upset the balance of the *situation*; making good on a single *element*, but probably enhancing the problem in the other one. As good —and smart— as these solutions are, they do not seem to be the way to handle a large complexity *situation* in working projects. Or, at least, they don't address the whole problem, and therefore are not complete solutions to the *situations* we encountered. (See Figure 3.)

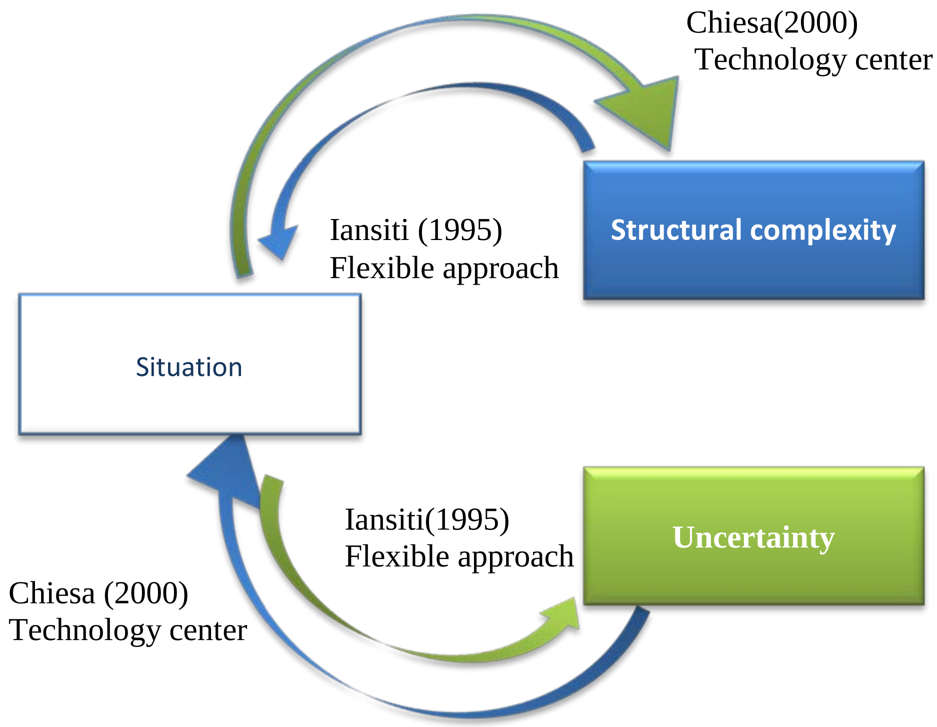

Figure 3: The singular literature solutions and their relation to complexity *situations* (green arrows helps to solve situation and blue ones impair)

5.4 The Project Manager's Role, Competencies and Leadership style

Some very interesting findings have been made regarding the competencies a project manager should have, and the dependence of the leadership style on the main goal of the project. It illustrates how the project manager will have to perform —and some characteristics he should have as a professional— in different project situations (or different projects altogether). This can be very well combined with the solutions to complexity *situations* we have discussed before; they would actually require some of the competencies we have mentioned in chapter 4 – Findings to work. From what we have seen in the literature there are many points that have been mentioned by authors before. We believe there is a close link between the literature and the competencies we have seen in our empirical research, however one of the main competencies talked about by practitioners was not really mentioned in any literature we have seen; namely the understanding of the whole project picture. We can start, however, by discussing the findings which do have a background in the literature.

It was seen as a good competency among practitioners to be able to break down the whole project scope into manageable parts, and from that to be able to meet deadlines constantly and get deliverables midway through the project life as well. From all our findings, we believe, this one seems to be the closest to by-the-book project management —working with a good WBS and having mid-project progress with deadlines, or a project plan that constantly finishes tasks, is pretty much covered in every project management course or text. The literature, therefore, has great support for this, but we wanted to quote a couple of articles here that were based on actual projects; and show how applying these concepts actually works. On Giezen (2012), the author describes the successful execution of a metro line in the Netherlands. The prerogative for the success of this project was to make it as simple as possible. A great look at the tasks was taken, and each was made as simple as possible; each task had to be analyzed with a focus on keeping uncertainty to a minimum. This is consistent with breaking the project down into manageable parts, as was stated by the informants. Lindkvist et al. (1998), give the description of a project Ericsson had in Japan that had a difficult time constraint. This project was also a success and the authors speak of a new system the company used to deliver the project, highlighting the use of deadlines to have constant mid-project progress. Both these examples of successful projects point to the importance of this particular competency. This is basic project management, but practitioners defend this concept, and the literature shows that it is constantly used successfully in actual projects, so it is always important to keep in mind. After all, a project manager must have some project management knowledge.

Regarding flexibility in the project organization, we have seen that our findings point to the manager being able to recognize the capabilities of the resources, be able to relocate them, or order them different tasks that they know they can perform. Tatikonda and Rosenthal (2000) have stated something very similar, by saying that flexibility comes from the resources, rather than from actual lack of formality in the processes. They believe this can be more easily achieved by the project manager, if he has freedom to allocate the resources as he wants, which is something the informants also mentioned. This works well in combination with a strong project organizational structure (either strong matrix or pure project), that we have seen most companies already use, identifying it as a major success factor. Also, Chronéer and Bergquist (2012) —in an article about the complexities faced by production companies when doing development projects— identified as a key factor that the manager needs to be very aware of who is doing what in the project. This would also be important in order to be able to use the different competencies of the resources to the project's advantage. We can be certain then, that this particular competency about flexibility and knowing the resources at their disposal, is something which has been discussed in the literature.

As for having a clear scope knowledge (a competency that we saw was important in Client Engineering projects), it is something that in general project management could be easy to defend. However, in R&D projects, is something that could be sometimes seen as to go against the aim of the project: the development of something new can be seen as something which should not be restricted in scope. Still, this competency can be linked to having the goals and objectives of the project clear, as they will define the whole scope of the project. In Murmann (1994) —an article about reducing time in development projects for the mechanical industry—, the author states that having a clear project objective is an important success factor for R&D projects. The PM should have a very clear knowledge of the objective of the project, from that be aware of the scope, and then make sure the team stays within the boundaries of the scope. This is something that could be more important in Client Engineering projects (and indeed Murmann (1994) is interested in time as a success factor, which is generally more important in these type of projects), but still a competency that should never be ignored in any kind of project.

A concept as elusive as leadership, which was extremely important to most informants, is also well mentioned in the literature; so far we have not seen anyone dismiss leadership as a minor competency. In our empirical findings it was interesting to see that leadership, although a skill you might not be able to train for, had some elements that were important. One of them was acting as a leader, which practitioners identified as being a good decision-maker: making people understand you are in charge by constantly making decisions and assigning priorities. Geraldi (2008) —in an article that was mostly about how to differently deal with structural complexity and uncertainty— stated that it was important for the manager to make a decision when it was critical to do so, regardless of the situation. This is consistent with showing the team leadership by being leader-like. On the other hand, there was the motivation part. Practitioners also agreed that a leader not only "barks" orders, but tries to keep the spirit of the team high by constant motivation. Assigning priorities, explaining how they are important to the project effort, or giving praise —where praise is due— were seen as ways to increase the motivation of the team. Söderlund (2002) (based also on an empirical study), spoke of this concept as well. Among his main findings was that managers had to try to make the team feel important to the project. The idea behind this, for Söderlund (2002), was to try to bond the team to the project, and so get better performance from them, but this would definitely also help with the team’s motivation.

It would be lengthy indeed to keep quoting articles and authors that have defended the importance of leadership in a project manager. What we feel is interesting from our findings is that leadership is not presented as a concept that is unreachable for people who are not natural leaders. Being a natural leader helps a lot when actually leading people, but even if a person does not have that attribute, there are still things that person can do to lead the team properly. Acting like a leader, and being a motivator to the team helps a project manager lead the team better, even if his natural leadership abilities are not great. These two small concepts could be seen as keys to becoming an effective leader.

We have illustrated, so far, how the literature has indeed been discussing some of the most important competencies project managers should have. We must, however, now come to the one that the literature does not really discuss. The understanding of the big picture of the project —that is: to know what the project is about; have knowledge of how every part of it interacts with each other, the company, and other stakeholders— is something that is interestingly not discussed in depth by any author. This competency was, along with leadership, the main one that practitioners identified and defended. Every informant highlighted the importance of this, and we can see how it can be critical for handling complexity as we have presented it. The *situations* are big, they not only deal with one *element*, but several at the same time, and their impact can carry over a long way. Therefore, the manager must know very well what the project is about, and what consequences each decision can have in a broad scenario. We have seen already that something similar was the case with the complexity *situations*: the literature is very accurate when dealing with single *elements*, but is lacking when dealing with big compound *situations* (like the ones we found in our empirical research). This competency is very much linked to these kind of *situations*, and it is critical in handling them correctly. So, this is another point in which the literature has focused well in identifying individual *elements* —this time singular competencies—, however has not really paid much attention to the greater scenario; as we see with this last competency.

The leadership style findings are one of the most interesting points we have come across in our empirical research. The leadership style seems not to be an actual competency of the project manager, but something that derives from the overall goal of the project; it becomes the context in which the project manager will apply solutions and competencies. In R&D

projects, when a manager is leading the team in an authoritarian way —being very strict with deadlines, keeping priority on moving forward, and limiting the creativity of the project team— it could be easily assumed that this was only his personal style. It is very interesting that most practitioners don't really see it that way; what they see when a manager is leading like that, is one that is hardly pressed for time. On the other hand, when a project manager is open to discussion —ready to accept new ideas and input on the product by the project team, and encourages comprehensive work even if it means missing deadlines— practitioners did not see a very relaxed person, but a manager that is concerned about final product quality. As we have seen, the leadership style is not really dictated by the personal preference of the project manager, but by the main goal of the project.

Projects don't usually have an equal priority for their main success criteria, even if all are important. From our empirical research, we saw that Client Engineering projects usually had a stronger focus on time, rather than final quality. This is a pressure that comes from the client himself, as for most of them time is money. The sooner they have a product they can be selling, the more profit they stand to make, so they press the project managers into delivering on time more than anything else. Of course, quality cannot be left aside, but the quality has to be just enough to fulfill the client's need. In order to meet this demand, project managers adapt their leadership style to one that allows less freedom to the project team. The tasks are not open to discussion, and the manager is just interested in getting them delivered on time; if not, measures are taken to correct this right away. The project manager will make decisions quickly, even decisions they wouldn't normally make, but they have the need to keep moving forward. If a decision happened to be the wrong one, it doesn't matter; they make a new decision to correct that later. They will also demand constant feedback on the status of the project work.

On Internal Improvement projects the focus was otherwise. The client in these projects was (in most cases) the company performing them. The main goal was to deliver a product that would be beneficial to the company procedures, something that would be valuable and useful. As they were their own clients, time was not the biggest issue in this case, but the final quality of the product was; and this would be the focus of the project managers. The style the manager would adopt in this case is one that is more flexible. Most deliverables would be open for discussion, the project team having freedom to make changes to the product if they see they can make improvements to functionality. The manager will not be so worried about deadlines, but very worried about how the product is shaping up to be, and if it actually fulfills the need of the company. The manager in this case will just lead the team to what the product needs to achieve, but allow the experts the freedom to get there as they see best.

The most interesting thing is that the leadership style can change during the same project — which makes an even stronger point for the most pressing goal being what actually counts in the leadership style, rather than the personal taste of the manager. At the beginning of Client Engineering projects, when development is just starting and the final product is not yet so clear, the managers adopt the flexible leadership style. This allows the team to define the scope of the project well, come up with the deliverables of the project, and make sure they deliver what is required by the client. In other words: the focus is on the quality of the product. We saw, also, the example of an Internal Improvement project in which time became critical. The system needed to be in place before a certain date or the company would just not be able to function. In this case, according to our informant, the manager adopted the hierarchical leadership style completely, and kept focus solely on the deadline.

There is also literature that supports these findings. Clift and Vandenbosch (1999) conducted an empirical research into how product development projects were being done. Their findings showed (among others) that complex projects had a more open, horizontal leadership style; while simpler projects had a more authoritarian, less flexible leadership style. This is consistent with our findings as more complex projects would tend to focus on quality and on getting the deliverables right, while simpler projects could put the focus on finishing quickly. (See Figure 4.)

The importance of the leadership style cannot be stressed enough. We have seen it is absolutely critical to the project’s success (as it is a direct by-product of the success criteria). However, to complexity it can also be critical, as the leadership style, like we said, defines the context in which the project will be handled. This has a direct connection to the type of solutions that will be implemented to reduce complexity. It would also serve as a tool through which managers could strike the balance between the *elements* producing the *situation*; and so tackle the whole *situation* at a time, instead of just parts of it.

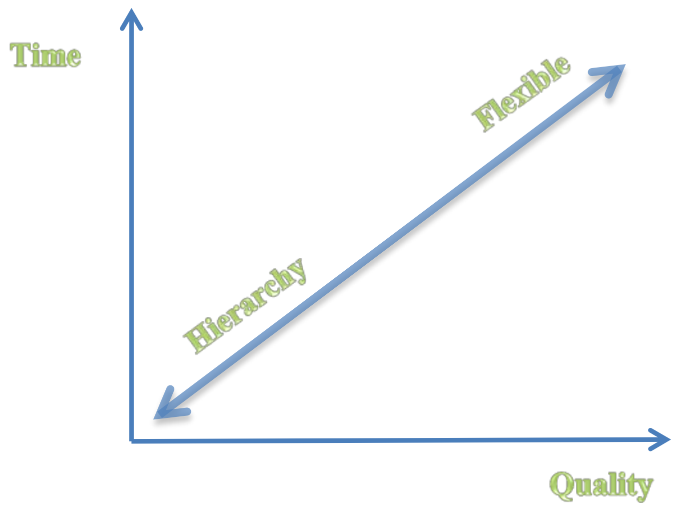

Figure 4: Leadership style depending on time and quality.

From these examples— both in the complexity *situations* and in the project manager competencies—, we see the main weakness in carrying over the literature solutions to the practitioner's side. The literature focus is somewhat narrow, and we could see that complexities in actual projects are nothing but broad. This is something which definitely requires more attention in the future. A further look at this compound effects of complexity *situations*, that the literature is failing to address; and the understanding of the project as a whole, that is such an important competency. On our side we have listed a few solutions — that we got from the empirical research— that are a shot at handling the two main *situations* we were involved with. Our solutions try to tackle the whole *situation*: both structural complexity and uncertainty at the same time, but they are very specific solutions to very specific problems. More research would be required to understand more *situations* in the working world, and the solutions, combined with competencies, that would come with that.

6 Conclusions

Our master thesis has started on the premise of, basically, three main tasks (combined from the original five in the thesis assignment). First, to conduct a literature review about complexity in R&D projects, and find out as much as possible of how the literature is treating this scenario: their *elements* and *situations*. Second, to do an empirical research along the same lines: this time to identify real complexity *elements* and *situations*, along with possible solutions to them. Lastly, to analyze the role of the PM in this scenario, what they can do, and what possible competencies they require to handle complexity right.

Some limitations were present in our work. The biggest ones having to do with the link from literature to empirical findings. The project types mostly discussed in the literature were destined to hit an open market, however none of our informants worked in such a project. Theirs were about developing custom solutions to an already known and particular client. Also on this subject, our informants were not great in number (10), nor very diverse in nature (only two types of projects were described, several from the same company). We have validated our research in a qualitative manner, and we were able to find the necessary links from the literature to the findings to come up with our most important conclusions.

So, even with our limitations, we believe we have addressed all of the original tasks throughout the thesis work. Our empirical research was inclusive with the framework we had previously developed about project complexity. We saw that the literature found that R&D projects had special challenges in the intercompany communication field, namely upstream and downstream of the process. That these projects were hard to appraise as a whole in the company, as overall project performance was not so easy to see as in normal projects—some R&D projects fail while others succeed, but the failed ones can also contribute to the successful ones. That technology always played a mayor role in these project's complexity, as they are always about developing something new, no matter how small the upgrade. Lastly, we saw that the authors could do good work in defining how the *elements* structural complexity and uncertainty affected R&D projects. We even found some solutions to these possible *situations*; however the solutions were only presented as helping with the complexity of a single *element*.

Our empirical findings, on the contrary, showed that complexity *situations* can be very much inclusive, and that the *elements* of structural complexity and uncertainty can compound each other and form a much larger complexity *situation*. We narrowed down our findings to two different kind of projects: Internal Improvement, and Client Engineering. In both we could identify the main complexity *situation* that affected them, and possible solutions for each. What was most important, however, was precisely what was lacking in the literature: that in order to truly aim at reducing complexity, all the dimensions of the *situation* had to be addressed. Else the managers really got no proper solution, and had to contend still with, at least, half of the problem unsolved.

As for the manager's role in all of these *situations*, we saw that the competencies needed by the manager might differ depending on the kind of project and *situation* they had. For instance, in Internal Improvement projects it was normally quoted that a PM had to have good knowledge of the capabilities of the project personnel in order to achieve maximum flexibility (hand them different tasks and get more creative solutions), and come to the best possible final product. In Client Engineering projects, however, it was very important to have good scope knowledge, and make sure that the project team did not "overdo" the scope, but only delivered what was necessary and asked for by the client. Two very important, universal competencies were singled out though: understanding of the whole project picture, and leadership. These are both a must for successful PMs. The most interesting finding, however, came in what we called the leadership style. This had not to do with a PM's natural preference of running the project, but was dependent on the main success criteria of the project. When the main goal of the project was to deliver a more comprehensive quality solution, and time was not particularly short, the leadership style was a flexible one: allowing plenty of discussion, and giving the experts the freedom to come up with the best possible solution. When time was of the essence, however, the leadership style was a very hierarchical one: the manager prioritizing moving forward most of all, making decisions quickly —even if they meant not the best possible quality—, and allowing the team little freedom to make changes. Internal Improvement projects favored the more flexible style, and Client Engineering projects the more hierarchical one, however this was also seen to be interchangeable if the priorities changed.

All these findings certainly would come to work together. It is first important to identify the complexity *situation* that a project manager is dealing with, which will be most likely a big compound *situation* made out of several *elements*. Then the manager tries to come up with a solution to the *situation*, and in order to implement this solution he has to have certain competencies in place. Everything is kept within the frame of the leadership style dictated by the main goal of the project, and the solution proposed has to be consistent with this. A manager has to be able to keep all of these things working together at the same time, and — while they can be identified independently— the most important thing is to combine them to tackle the whole *situation*, and not just a small part of it. This could be the most important lesson we have learned from our empirical research, and the main point in which the literature is failing. It is indeed quite helpful to break the problem into parts to understand it better (we actually do the same by separating into *elements*, *situations*, solutions, competencies, and leadership style); however these parts alone will not help solve complexity issues. What's more, the literature has already done a great job identifying most of the single *elements*. What is missing now, is to start combining these solutions to come up with ways to reduce the impact of complexity in big, compound *situations*.

Our biggest contribution in this regard, comes in the way of two possible solutions to two of these larger *situations*. One for the large stakeholder *situation* of Internal Improvement projects, either by: understanding clearly what they want and so be able to predict their reactions, at the same time avoiding excess changes in the project; or locking a good working product early on and enforce it with top management support. And another for the large technology interface *situation* of Client Engineering projects, by: reorganizing the project team into a functionality focus, which would reduce the interface problems in both quantity and functionality; plus more thorough planning at the project's early phase. The literature, we believe, already has a strong basis for identifying the greatest complexity *elements* in R&D projects; however it is lacking when it comes to identifying the possible *situations* and solutions to them. The future research would have to come in this form. Focus more on seeing different complexity *situations* and come up with more comprehensive solutions that could really help project managers. There is much to be done in this regard, we have only shown two *situation* types of probably many possible, even more perhaps arising when the largest *situations* (like the ones we discussed) are discovered and solved, hidden behind the larger problem. Every single input can help project managers in their day-to-day practice and become a contribution to larger project success overall.

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