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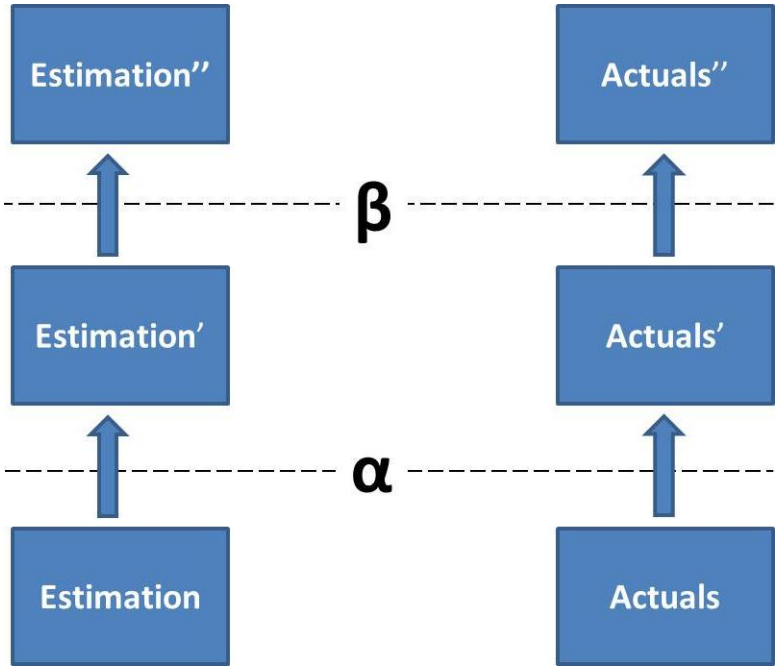

Exploring the Cost Estimation Process of a Global Product Development Organization

What are the influential factors behind cost estimates inaccuracy?

Master of Science Thesis in the Master's Programme Management and Economics of Innovation

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ABSTRACT

For decades, cost estimation accuracy has been a prevailing issue in project management. Despite many efforts to improve accuracy through the proposition of new estimation models and methods, project delays and overspendings continue to occur with the same frequency. Such difficulties to improve, coupled with the fact that cost estimation accuracy is crucial for the well-being of projects, make cost estimation an intriguing practice. This report aims to address such a challenge through the case study of a global product development organization. The purpose is to investigate the company's cost estimation process and to identify and unveil influential factors affecting the accuracy of cost estimates.

The term "accuracy", implying a comparison of estimates with a reference value, naturally led the present investigation to tackle both, cost estimation exercises and the recording activities allowing the calculation of actual project costs. In that regard, an analytical model has been proposed with respect to previous literature, and an empirical study based on interviews involving the company's line and project managers has been performed.

As a result, intentional and unintentional distortions of both cost estimates and actuals have been identified, implying that accuracy calculations themselves are questionable. While cost estimation errors have had the tendency to be exclusively attributed to cost estimates, the fact that distortions actually occur in both estimation and recording activities explains practitioners' difficulty to achieve an acceptable accuracy. Indeed, it is difficult to learn and improve when the reference values themselves are not reliable.

Therefore, in order to become an efficient learning organization benefiting from its past experience, the company must question its current governing variables and acknowledge the root causes initiating distortions. Only then, an improvement of its cost estimation accuracy would be possible. Given these circumstances and with respect to this study's analytical model, a few recommendations are suggested to overcome issues encountered in both estimation and recording activities.

Key words: *Project Management, Product Development, Cost Estimation, Actual Project Cost, Accuracy, Inaccuracy, Intentional Distortions, Unintentional Distortions, Organizational Politics, Organizational learning.*

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1 INTRODUCTION

The content of this chapter aims to introduce the research context of this study. To begin with, a brief description of the problems related to cost estimation practice is given. Then, the purpose and research questions are mentioned. Finally, the delimitations of the present research are presented.

1.1 BACKGROUND

Project delays and budget deficits are part of the inevitable problems faced by project managers in many industries (Maylor, 2010). Indeed, scholars refer to delays and overruns as being a "natural law" affecting project management (Engwall, 2002, p. 277). Further, significance of cost estimation accuracy is amplified along the progress of product development process (Tu et al., 2007). Hence, accurate cost estimation practice, being "the basis for project bidding, budgeting and planning" (Grimstad et al., 2006, p. 302), is critical for project organizations to overcome such major issues. However, in spite of the dedications made by both scholars and practitioners on this subject, most of which have focused on the development of tools and methods (Magazinius et al., 2012; Jørgensen and Shepperd, 2007), only little improvement of cost estimation accuracy has been achieved over the last 20 years (Grimstad et al., 2006). In this sense, cost estimation is considered both important and difficult to tackle for both practitioners and researchers.

Such a challenge being recognized, the problem needs to be further explored and examined in a pragmatic context, to better comprehend cost estimation accuracy and its influential factors. As articulated by Tu et al. (2007), "In a global manufacturing environment or an individual manufacturing company, product development cost estimation and control are an interdependent and correlated problem. It is influenced and dynamically determined/changed by a number of preconditions" (Tu et al., 2007, p. 29). As to say, cost estimation accuracy is closely correlated with the product development process and its performance. Herein, the studied company's cost estimation process is investigated to identify influential factors affecting its activities. Furthermore, some pre-identified organization and project management issues implied in product development, such as organizational learning, organizational politics, middle management and paradox of project control, are also taken into consideration, since these issues are correlated with cost estimation process and its accuracy and performance (Magazinius, 2012). All of these subjects will be further explored in the context of the researched organization, which is a product development department in a global manufacturing company.

1.2 PURPOSE

The purpose of this research is to explore the current cost estimation process in the studied organization, identify and investigate the influential factors affecting cost estimate accuracy, and with further attempts recommended to address these challenges in order to improve cost estimation accuracy. More specifically, the research purpose can be elaborated in three levels as the research progresses:

Phase 1: Study the current cost estimation and working effort process and summarize the general estimation protocols involved within the department.

Phase 2: Investigate the influential factors and resulting distortions affecting cost estimation accuracy.

Phase 3: Determine whether and how the studied organization could improve the accuracy of its cost estimates.

1.3 RESEARCH QUESTIONS

In line with the research purpose, the research questions are formulated as following:

RQ1: What are the factors and distortions affecting the accuracy of cost estimation in product development?

RQ2: How can these challenges be addressed by the studied product development organization?

1.4 DELIMITATIONS

"Although a relatively large number of papers and reports were found to address the cost estimate and control problems in various product development processes, these methodologies were normally developed based on cases in individual companies rather than in a global manufacturing environment" (Tu et al., 2007, p. 29). Similarly, hereby in this research, to ensure the in depth investigation to this significant and long-lasting issue of cost estimation and its accuracy, some delimitation are predefined. Only investigations are conducted within the studied product development organization with in the global company. Therefore, the later identified influential factors, distortions, and their counter measures are only valid within the studied organization. Generalization concerns can be expressed regarding this qualitative research. In that regard the authors intend to ensure analytical generalization through the introduction of an analytical model (Yin, 2013).

2 THEORETICAL FRAMEWORK

This chapter presents the theoretical framework used throughout this investigation. It begins with an introduction to the context of projects in product development organizations. This is followed by a presentation of cost estimation practices and a description of how the accuracy of this practice evolved over time. Later, this chapter introduces previous work tackling the issues of organizational politics and learning. Finally, it ends with the proposal analytical model contributing for the later discussion of this report.

2.1 PROJECT MANAGEMENT IN PRODUCT DEVELOPMENT

As observed by Maylor (2010), project delay, budget deficit or failure in deliverables, are phenomena that are inevitably experienced by every project manager in their daily work. These phenomena are prevailing in different sorts of projects and tend to be more evident with large project scales (Maylor, 2010; Buehler 1994). This tendency of project delays and overspendings also complies with Buehler's study (1994) on grand projects, showing that with an increase of project scale, there is a tendency that projects would be under-estimated, as illustrated Figure 1. Yet, in spite of knowing the majority of other similar projects running late, project managers have a tendency to be influenced by the optimistic bias that their own project will be on schedule (Buehler et al., 1994). Buehler (1994) termed this tendency as "planning fallacy" and indicated that the overly optimistic cost predictions can be deliberately underestimated by project proponents. In addition, manifested by both Maylor (2010) and Buehler (1994), the intrinsic uncertainties in terms of technology, complexity and other risks can excessively surpass their predictions, which is also deemed by Maylor (2010) as the one single root cause of project issues. Further, many instances in failing of managing these uncertainties are illustrated by Maylor (2010) and many other scholars and practitioners.

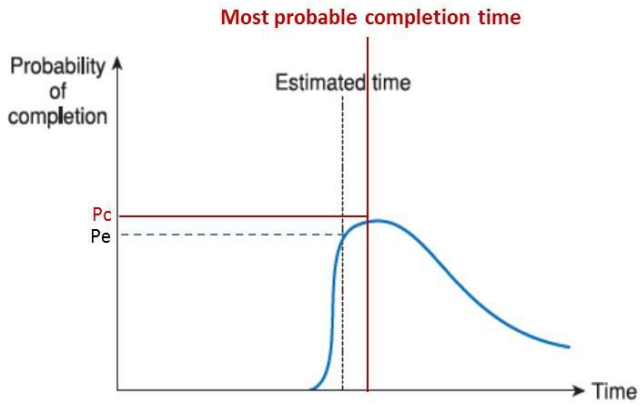


Figure 1: project completion time (Source: Maylor, 2010; modified by authors)

The Programme Evaluation and Review Technique (PERT) was developed with the aim to overcome such uncertainties and optimistic biases (Maylor, 2010). Instead of performing

single estimations, this programme suggests the implementation of the "three-point estimation" method, requiring estimations based on an **optimistic scenario (O)**, a **most likely scenario (M)**, and a **pessimistic one (P)**, as illustrated Figure 2 (Maylor, 2010). Afterwards, the final estimation is calculated based on the formula below (Maylor, 2010):

$$Final\ estimation = (O + 4M + P)/6$$

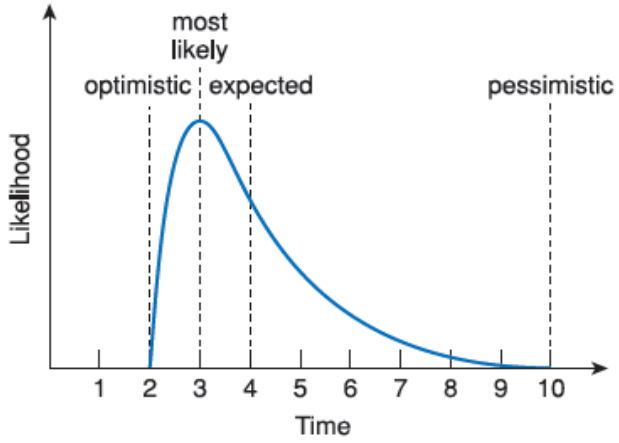


Figure 2: illustration of the three points of estimation (Source: Maylor, 2010)

While methods such as the three point estimates intend to overcome uncertainties and other optimistic biases, additional issues occurring along projects' critical path have been reported by scholars. Maylor (2010) defines the critical path as the longest sequence of dependent activities required for a project to be completed. He identifies the causes of ubiquitous problems in project management as being caused by seven issues related to the critical path (Maylor, 2010). A brief introduction to all of them is provided, as follows:

1. The planned objectives are rather poorly met, due to the intrinsic uncertainties and the quality of estimates based on which the goals are built.
2. The estimates provided often comprise a large safety margin, which is considered as non-beneficial to accomplish tasks on-time.
3. Some non-critical tasks can be built with a latest start time. Consequently, they could become critical if these tasks are running late. With the number of critical paths increasing, there are greater chances that projects could be delayed.
4. Due to the dependencies among tasks, the delays can be accumulated and passed on the following tasks while, the advances in preceding steps are often wasted in vain.
5. The measurement of time and project completion by percentage is considered as erroneous. Some mistakes could be possibly ignored, and it could be too late by the time it is corrected.
6. As a consequence of the issues 1 to 4 above mentioned, it has been identified that the time spent on different tasks has the tendency to be consumed, and this, even though a safety margin is added. This phenomenon can be referred to as the "Parkinson Law" or "Student Syndrome".

7. Multi-tasking increases lead-time for all projects. With the interruptions from other tasks, the total lead-time for the project will be eventually prolonged, which can be illustrated in Figure 3:

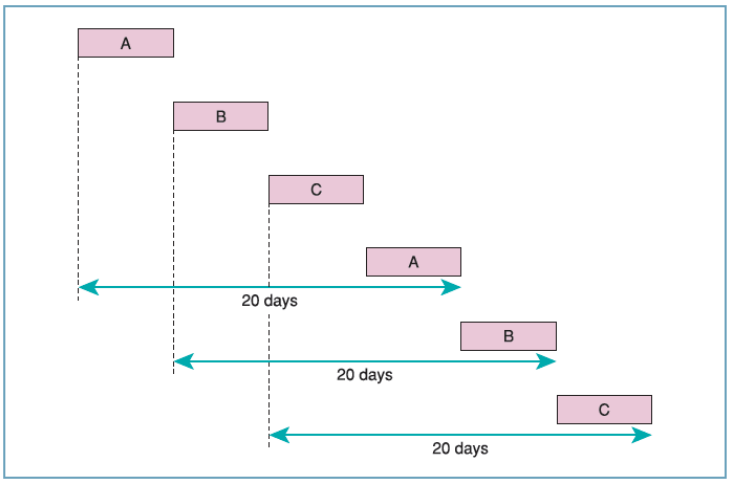


Figure 3: Effect of multitasking on lead-time (Source: Maylor, 2010)

In order to address the seven issues previously mentioned, Goldratt (1997) advocates the Critical Chain method, which relies essentially on the application of the Theory of Constraints. This theory presented by Goldratt (1984) in *The Goal*, can be summarized as the identification, the exploitation, the prioritization and the elevation of the constraints of one system (Goldratt, 1984). These constraints can vary enormously from a specific competence of a particular individual to technical or financial assets (Maylor, 2010). Initially, the Theory of Constraints was supposed to address a manufacturing context, but Goldratt (1997) later proposed an application to project management with the Critical Chain Project Management method. Instead of adding safety margins in each activity of a project, this theory suggests the buffer to be centralized (Leach, 1999; Maylor, 2010; Goldratt, 1997). Thanks to this, it would be possible to overcome the aforementioned issues of the Parkinson Law and of the Student Syndrome. At the same time, the method proposes to set up buffer management principles that would allow project managers to steer their projects with greater control and reactive power (Goldratt, 1997). As indicated by Leach (1999) and Maylor (2010), the critical chain method would enhance project performance and control and would solve several issues currently reported to exist in project management, namely overestimation; student syndrome; failure to pass positive deviations; project delay; multi-tasking and loss of focus (Leach, 1999).

Product development is depicted to be a very complex activity which undergoes an important amount of issues (Maylor, 2010). While authors such as Leach (1999) and Goldratt (1997) intended to address these issues, others, such as Cooper (1983), have described a generic product development process with the aim to urge practitioners that innovation should be steered by a focus on customers. The stage-gate model presented by Cooper (1983), as a new product development process model, is indeed strongly market and customer oriented (Cooper, 1983). From such a perspective, viewing product innovation as a process, the stage-gate model employs process-management methodologies and incorporates seven stages and

quality control points, called "gates" (Cooper, 1983; Cooper, 1990). These seven stages comprise the entire development process, initiating from idea generation to the final market launch, which can be presented as follows in Figure 4 (Cooper, 1983; Cooper, 1990):

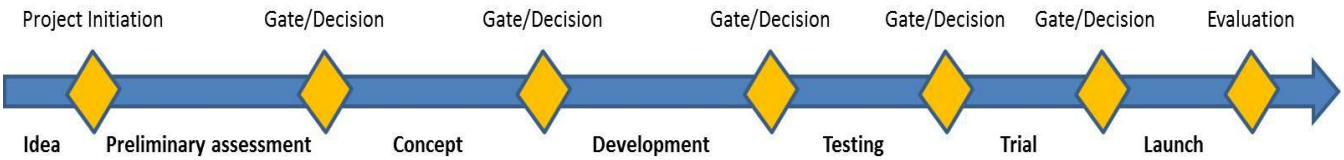


Figure 4: Cooper's stage-gate model with seven stages (source: Cooper, 1990, modified by authors)

Following a specific process, such as the one presented above, companies adopt specific organizational structures while performing projects in a product development environment. Galbraith (1971) explains that functional organizations, such as the one illustrated Figure 5, provide operational efficiency, economies of scale and specialization, but lead to poor horizontal coordination (Galbraith, 1971; Maylor, 2010). On the other hand, Maylor (2010) adds that project organizations provide better coordination at the cost of efficiency and quality. As a result, matrix organizations were invented to combine both advantages of specialization and coordination thanks to the setup of dual authorities (Maylor, 2010).

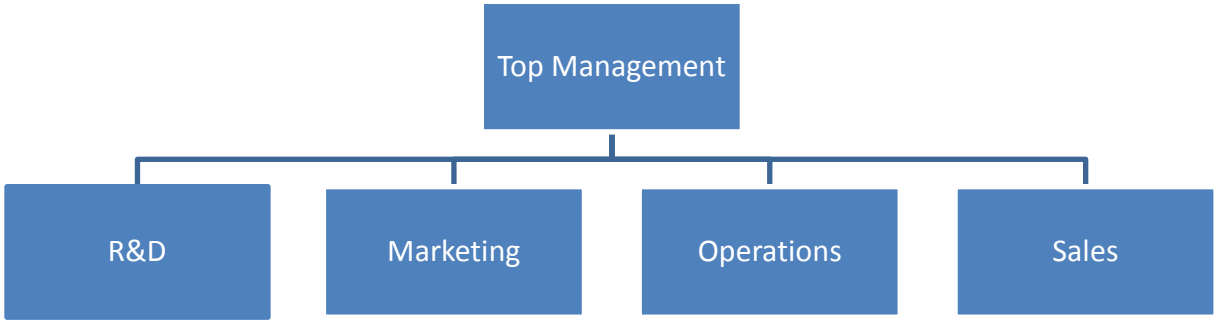


Figure 5: Functional organization (Source: Galbraith, 1971, modified by authors)

Project and line managers, being middle managers in matrix organizations, also face difficulties to cope with constraints coming from both their superiors and subordinates (Uyterhoeven, 1989). As elaborated by Uyterhoeven (1989) and Bourne and Walker (2005), project managers are general managers located at an intermediate organizational level, and in many aspects face arduous situations due to both management pressures coming from upward and challenges coming from their peers and subordinates. Middle managers' relationships are therefore a threefold task, requiring them to constantly act as subordinates, equals and superiors (Uyterhoeven, 1989). With limited authority and flexibility, it is of great difficulty for project manager to yield the desired outcomes in the setting of the traditional organizational paradigm (Bourne and Walker, 2005). Given the complexity of matrix organizations, project managers and their teams are required to be politically astute and sensitive (Bourne and Walker, 2005; Pinto, 2000). Intriguingly, as pinpointed by Bourne and Walker (2005), this creates a so-called paradox of control occurring in a "zone" of decision-making located between top management and middle management. In Bourne and Walker's (2005) investigation, such a murky "zone" is considered as "a highly complex and dynamic

organism", which requires project managers to operate agilely with a comprehensive understanding, not only on their project but also regarding the chaotic organizational environment (Bourne and Walker, 2005). As illustrated in Figure 6, any strategic objective or command from top management could be delivered and implemented directly by project managers and their teams.

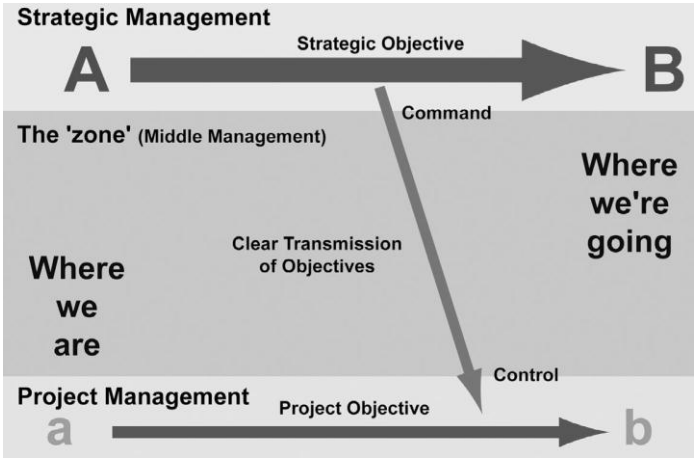


Figure 6: Theoretical command-control across the "zone" (Source: Bourne and Walker, 2005)

However, in the reality, illustrated in Figure 7, top management commands are faced by the apparition of counterforces, meaning that only part of the command will be put into action (Bourne and Walker, 2005).

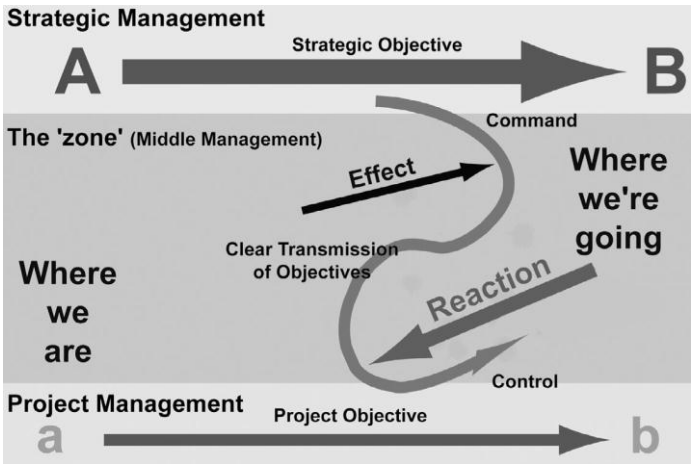


Figure 7: Effects and reactions affecting command-control (Source: Bourne and Walker, 2005)

As mentioned by Olson and Eoyang (2001), "The traditional paradigm of organizational change holds deep, largely unconscious assumptions and values about efficiency and control" (Olson and Eoyang, 2001, p. 5). In other words, the change approach adopted by strategic management usually possesses a linear structure with clear and strict start, planning, and desired goals. However, the outcomes do not often turn out as predicted, which is often deemed as "out of control" by top management, and could naturally lead to commands aiming at increasing this so-called control (Bourne and Walker, 2005). As a consequence, counterforces from the project teams would react in a manner that produces undesired side effects (Boonstra, 2004; Bourne and Walker, 2005). With such conclusions, Bourne and

Walker (2005) claim that "a paradigm shift in management thinking is needed to succeed in managing projects and their teams within the turbulent environment of a modern matrix organization" (Bourne and Walker, 2005, p. 157). Therefore, while on their side, project managers need to be both flexible and vigilant in terms of managing relationship with different stakeholders to succeed in the dynamic environment of such matrix organizations (Uyterhoeven, 1989) top management, on the other side, need to be aware that any attempt of imposing and gaining control will lead to more uncertainties and unpredictable outcomes (Bourne and Walker, 2005).

To sum up, projects have been reported to experience an important amount of unexpected issues. Scholars have tried to propose methods to address these issues while others have emphasized on the importance to adopt a market-driven perspective in product development. Further, a few organizational structures related to project management have been briefly introduced and Bourne and Warner's (2005) paradox of control and its implications for middle managers have been explained. The next section introduces previous research on cost estimation practice in product development projects.

2.2 COST ESTIMATION PRACTICE

As defined in previous works, cost estimation is a forecast of the development effort needed for accomplishing a task using information available at the time it is performed (Magazinius et al., 2012; Lederer and Prasad, 1991). Being the basis for the later project selection, planning, and evaluation, cost estimation is a crucial practice for organizations. In that regard, there have been multiple intents to improve cost estimation accuracy, with a majority focusing on the estimation tools, methods and techniques (Jørgensen and Shepperd, 2007). The aforementioned definition further highlights the fact that information that was not initially available, might affect cost estimation throughout implementation and therefore lead to deviations and budget issues (Magazinius et al., 2012). As explained by Magazinius and Pernstål (2008), several studies led from 1984 to 2008 have reported important percentages of overrunning projects (Jenkins et al., 1984; Yang et al., 2008). Even though estimation terminology has been defined as non-standardized and imprecise and even though the reference values taken for assessing projects overruns and underruns may differ from author to author (Grimstad et al., 2006), their results still show that estimation accuracy has been a constant issue in project management. Thus, despite the important focus of previous studies on tools and methods (Jørgensen and Shepperd, 2007), estimation models have still been unable to improve cost estimation accuracy. Jørgensen (2007) argues that such models are not even objective, as their inputs themselves are subjective in nature (Jørgensen, 2007). Then, what is the reason for estimation inaccuracy? Why was it not possible to improve? Jørgensen and Shepperd (2007) claim that the present issue must be addressed from an organizational context, where a human-centered approach is needed to identify the underlying reasons. Indeed, by following a human-centered research approach, several authors found that most of the reasons for estimation inaccuracy are human-related and involve issues, such as

deviations encountered in the process of the product development work (Magazinius and Pernstål, 2008; Lederer and Prasad, 1995). Further, several studies pointed out the existence of cognitive and unintentional aspects leading to cost estimates inaccuracy (Aranda and Easterbrook, 2005; Jørgensen and Grimstad, 2008), while other authors identified conscious and intentional causes (Lederer and Prasad, 1995; Magazinius et al., 2012; Magazinius and Feldt, 2011). These two categories, namely intentional and unintentional, are presented in greater details in section 2.5, but when it seems natural that cognitive and unintentional aspects can affect cost estimation accuracy, the intentional causes are certainly less straightforward. Why would estimators consciously and intentionally distort their estimation? The authors of this study intent to address this issue through the presentation of organizational politics theories.

2.3 ORGANIZATIONAL POLITICS

As previously mentioned, "in a matrix organization the project manager has limited authority over the project team" (Bourne and Walker, 2005, p. 173). The only authority that project managers possess is qualified as "project authority" where they are responsible to inform and steer the deliveries, as opposed to "supervisory authority" which implies much stronger influence in command and decision-making (Bourne and Walker, 2005). As a result, in order to bridge the "authority gap", project managers need to be politically astute and sensitive, to incorporate adequate management relationships, and to find ways to exert more influence over the project team and other stakeholders (Bourne and Walker, 2005; Pinto, 2000).

The role of politics and political behaviors are further articulated by Pinto (2000) as pivotal and decisive in distinguishing the success or failure of project management. Yet, hitherto, the research field of organizational politics is still remaining as much unexplored (Buchanan, 2008). Buchanan (2008) has reported the existence of many instances of political behaviors in organizations and has consolidated a list of tactics, strategies and other political behaviors undertaken by individuals to serve their own interests. Although facing the fact of pervasive political behaviors in any modern corporation, the attitudes and perceptions of politics from practitioners are generally subjective, limited, and even hostile, rather than objective, comprehensive, and judicious (Pinto, 2000). Nevertheless, when practitioners come to admit the existences of organizational politics and political behaviors, their alternative attitudes are categorized into three categories by Lynch and Kordis (1988) and Pinto (2000), as summarized in Table 1.

Table 1: Characteristics of political behaviors (Source: Pinto, 2000)

Characteristics	Naive	Sensible	Sharks
Underlying Attitude: ``*Politics is...."*	Unpleasant	Necessary	An opportunity
Intent	Avoid at all costs	Used to further project's goals	Self-serving and predatory

Techniques	Tell it like it is	Network, expand connections, use system to give and receive favors	Manipulation, use of fraud and deceit when necessary
Favorite tactics	None, the truth will win out	Negotiation, bargaining	Bullying, misuse of information, cultivate and use ``friends'' and other contacts

More specifically, according to Lynch and Kordis (1988) and Pinto (2000), none of the extremes "naive" or "shark" would induce any positive side-effect to success in project management. As the purpose of political behavior is to cultivate and maintain power, both of these two attitudes are deemed as "equally misguided and equally damaging to the likelihood of project implementation success" (Pinto, 2000, p. 88).

On the other hand, according to Lynch and Kordis (1988) and Pinto (2000), the category "politically sensible", suggesting an appropriate use of political tactics, would contribute to the successful implementation of project goals. This is also advocated by Ollila (2001) who adds that it is of great significance for project leaders to manage adequately organizational politics to yield successful outcomes in product development. Further, Pinto (2000) highlights political tactics with positive side-effect for project management success. These can be summarized into the following main points:

- First, "understand and acknowledge the political nature of most organizations" (Pinto, 2000, p. 87). Instead of adopting a naive attitude and disregard any political activities, it is necessary to first acknowledge the existence and the impacts of organizational politics.
- Second, learn to cultivate `appropriate' political tactics (Pinto, 2000, p. 88). As illustrated in Table 1, "shark" attitudes towards organizational politics are not recommended, but the adequate political sensibility and tactics can influence and facilitate the completion of projects.
- Third, "understand and accept different stakeholders' self-interest when facing new projects. To overcome this, time and care could be spent on employing politics effectively. Project managers need to build up a relationship with powerful stakeholders in order to implement the project.
- Fourth, project managers' official authority should be accrued. As mentioned before, there is an "authority gap" in project management. Project managers could, for instance, have the authority to evaluate the performance of project team subordinates.
- Fifth, establish a sustainable influence throughout the organization. Essential aspects in establishing and maintaining managerial influence as project managers are mentioned by Keys and Case (1990), namely, develop a reputation as an expert;

prioritize social relationships on the basis of work needs; develop a network of other experts; choose the correct combination of influence tactics; influence with sensitivity, flexibility and communication (Keys and Case, 1990).

- Sixth, develop negotiation skills, which are inevitable for all project managers. The tricks and ploys used by opponents must be recognized and learned, in order to develop corresponding responses. In addition, "The key is to use a form of principled negotiation, in which you search for fairness, Win-Win outcomes, and mutually acceptable solutions" (Pinto, 2000, p. 90).
- Last but not least, recognize and understand the conflicts as a natural process occurring project management. However, as conflicts are more contingent and conditional, no optimal solution can be suggested. Project managers need to determine and tackle them accordingly.

Having confirmed the existence of multiple tactics, strategies and political behaviors, Buchanan (2008) further adds that 84% of practitioners admit that they would use politics if necessary (Buchanan, 2008). In that regard, organizational politics theories could contrast with Goldratt's (1997) proposal to centralize the buffer of a project, as this might not be in line with individuals' self-interests.

Magazinius et. al (2012) reported that respondents tend to unconsciously redirect reasons for estimation failure to something and something else. In order to understand why people in general tend to blame others and never themselves, Argyris' Organizational learning theory has been introduced and discussed in the next section.

2.4 ORGANIZATIONAL LEARNING

According to Argyris (2002), continual success in an increasingly severe business environment depends on persistent learning. However, most modern corporations have tremendous difficulties in becoming a learning organization, and the main reason leading to their failures is their misunderstanding of learning and how to conduct it. Further, Argyris (2002) elaborated on the two main mistakes that usually prevent corporations to become a learning organization. First, learning is commented to be too narrowly associated to problem-solving, where the focus is to identify and correct errors (Argyris, 2002; Argyris and Schön, 1994). Argyris (2002) categories this type of learning, issued from implementation of actions, as being "single-loop" learning, as illustrated Figure 8. However, to maintain learning in a sustainable manner, highly skilled managers and other professionals must critically reflect inward on their own behaviors, for the reason that their problem solving oriented manners can inadvertently lead them to contribute to the organization's problems (Argyris, 2002). This category of learning, called double-loop learning consists in the proper understanding and improvement of the values that drive individuals' actions in their organization, namely "governing variables" (Argyris, 2002). By arguing that practitioners tend to focus on single-loop learning, Argyris (2002) comments that ironically, this fact hinders their ability to develop double-loop learning. This would therefore explain why people do not to accept their

own failures but instead, would tend to put the blame on someone or something else (Argyris, 2002).

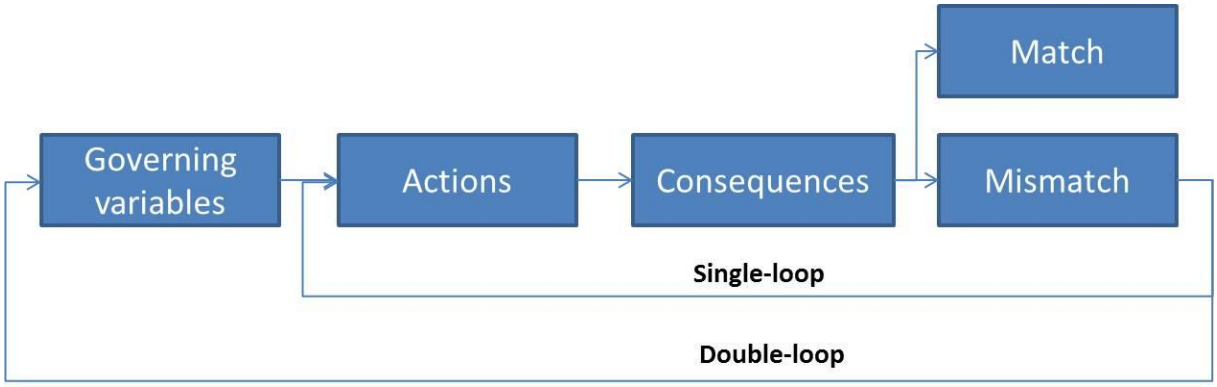


Figure 8: Double and single-loop learning (Source: Argyris, 1999, p. 68)

The second common mistake mentioned by Argyris (2002) is that, this defensive reasoning employed by practitioners, substantially blocks both learning and any possibility to trigger any real changes in action. Practitioners "project the blame for any problems away from themselves and onto what they said were unclear goals, insensitive and unfair leaders, and stupid clients" (Argyris, 2002, p. 5). However, this cognitive rule of defensive reasoning or organizational routines governing their behaviors is sometimes not even consciously known by themselves or the organization (Argyris, 2002). This makes the required organizational changes difficult if one wants to establish a learning organization (Argyris, 2002). Similarly, Balle and Balle (2005) explain that in order to exert better outcomes, it is critical that managers start to "question themselves seriously on their tacit approaches to knowledge creation" (Balle and Balle, 2005, p. 22).

Due to the fact that theories driving practitioners actions, namely "theory-in-use", are often divergent from theories believed to be reflecting their actions, or "espoused theories" (Argyris, 1999), Marmgren et al. (2013) stressed that the relationship between "governing variables", "actions" and "consequences" are crucial for organizational learning. However, as illustrated in Figure 9, while governing variables dictate both espoused theories and theories-in-use, these two tend to diverge and are hard to correlate to each other (Marmgren et al., 2013). Thus, it is easier to document espoused theories than actual theories-in-use.

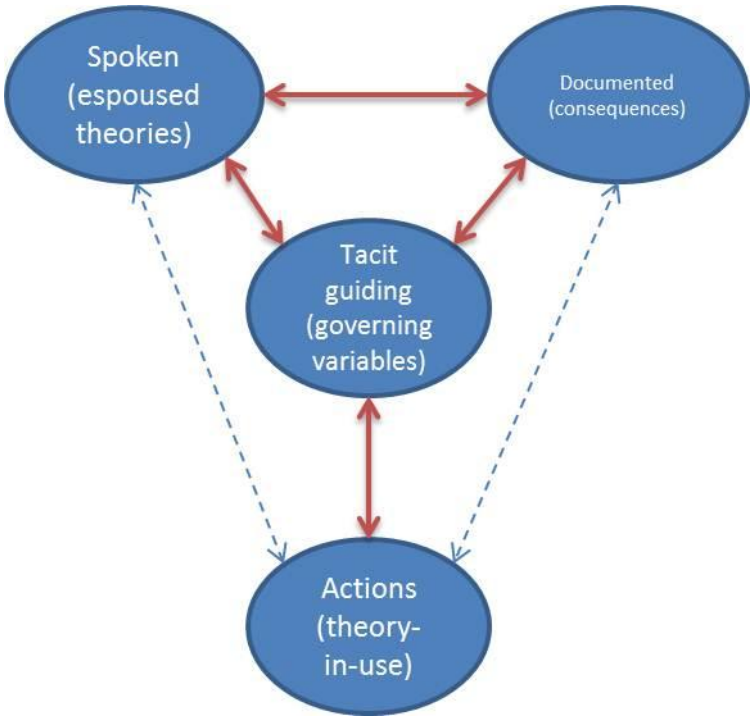


Figure 9: Framework of relationships (Source: Marmgren et al., 2013; modified by authors)

Argyris (2002) further advises counter measures to solve the learning dilemma in all organizations. Effective double-loop learning reflecting on the underlying values behind undertaken actions is necessary for corporations to successfully achieve organizational learning and continuous improvement programs (Argyris, 2002).

Thus, after having introduced theories on organizational politics, justifying the existence of intentional distortion of estimates (Magazinius and Feldt, 2011), and on organizational learning, explaining the reason why practitioners have the tendency to put the blame on something else (Argyris, 2002), the authors of this study present an analytical model in the following section.

2.5 PROPOSED ANALYTICAL MODEL

In section 2.2, unintentional and cognitive reasons for estimation inaccuracy have been mentioned. Magazinius et al. (2012) specified that cognitive biases, occurring unconsciously, are most of the time unknown by the estimators themselves and, therefore, very difficult to identify. This category of aspects affecting cost estimation inaccuracy truly requires an adequate methodology. Jørgensen and Grimstad (2008) performed four experiments in which irrelevant and misleading information was given to subjects who had the role of performing an estimation task. Participants of two of their studies were even warned not to use this specific piece of information (Jørgensen and Grimstad, 2008). In the first of these studies, Jørgensen and Grimstad (2008) provided three experiment groups with different values of the clients' cost expectations, specifying not to take them into account, but instead to estimate the most likely effort needed. Then, the experimenters compared the median value obtained by each group with the one from a control group, which did not receive such misleading

information. These results clearly showed that each of the experiment group has been influenced by the misleading client's cost expectation (Jørgensen and Grimstad, 2008). Similarly, Jørgensen and Grimstad (2008) found out that subjects were also unconsciously sensitive to variation of wording in the description of the task, to future opportunities proposed by the clients, and to neutral and irrelevant information, such as unnecessary features (Jørgensen and Grimstad, 2008). Further, the experimenters concluded that the only way to avoid unconscious effects of irrelevant and misleading information on the estimation was to have requirements that are as neutral as possible, and which only present relevant information (Jørgensen and Grimstad, 2008). Aranda and Easterbrook (2005) made an experiment leading to the similar conclusion that anchoring and adjustment act as a cognitive bias, which can significantly change the resulting estimates, and so whatever the method used. Another identified cognitive bias affecting cost estimation was the optimistic bias (Jørgensen and Grimstad, 2005; Buehler et al., 1994), but while cognitive biases are part of unintentional distortions, Magazinius and al. (2012) identified other unintentional factors in their study, such as, inexperience of the estimator and misunderstanding of the requirements. These latter are not cognitive biases, but are still unintentional and will be considered as such in the proposed analytical model of this study.

To complement these unintentional reasons, other authors reported conscious distortions. Lederer and Prasad (1995) identified 24 causes of inaccuracy in cost estimation. Among these, their study mentioned several factors referring to intentional distortions, namely pressure from others to reduce estimates; reduction of project scope or quality in order to stay within the estimate; removal of padding by management; and red tape (Lederer and Prasad, 1995). Later, Magazinius and al. (2012) conducted interviews of developers, line managers, project managers, product planners and high managers to investigate extensively intentional distortions of estimates. By drawing their investigation on organizational politics theories, Magazinius and al. (2012) identified several reasons for intentional distortions of estimates by practitioners. Estimators have been reported to intentionally distort their estimates in case they want to hide other activities; to avoid overspending situations; to secure jobs for their colleagues; to sell their ideas or if they adopt a myopic perspective; adapt their estimate to a predetermine budget or voluntarily disregard efficiency (Magazinius et al., 2012). Magazinius and al. (2012) also reported that pressure from management to reduce and cut the budget affect the estimates and lead to underestimation. Magazinius and Feldt (2011) further provided a list of politically related tactics affecting the estimation practice: accumulation and control of resources; bargaining aggressively; forming coalitions and informal teams; maintaining flexibility; anticipating and preparing for others' actions and reactions; managing career; Managing functionality and disregarding uncertainty (Magazinius and Feldt, 2011). These authors all identified several reasons behind intentional distortion of estimates (Lederer and Prasad, 1995; Magazinius et al., 2012; Magazinius and Feldt, 2011). While most of their findings provide redundant and common explanations, there are seemingly intentional reasons from which the classification differ from study to study (Lederer and Prasad, 1995; Magazinius et al., 2012; Magazinius and Feldt, 2011). Such distinctions have to be attributed to the differences in settings, research methods and interpretation of the results and will be discussed in greater details in 6.1.

Thus, both cognitive and unintentional aspects (Aranda and Easterbrook, 2005; Jørgensen and Grimstad, 2008), on the one hand, and organizational politics and other intentional reasons (Lederer and Prasad, 1995; Magazinius et al., 2012; Magazinius and Feldt, 2011) on the other hand, can be at the origin of cost estimation distortions. In that regards, based on the results obtained by previous researchers (Magazinius et al., 2012; Jørgensen and Grimstad, 2008; Aranda and Easterbrook, 2005), the authors of this study present the first half of their proposed analytical model[1], illustrated Figure 10.

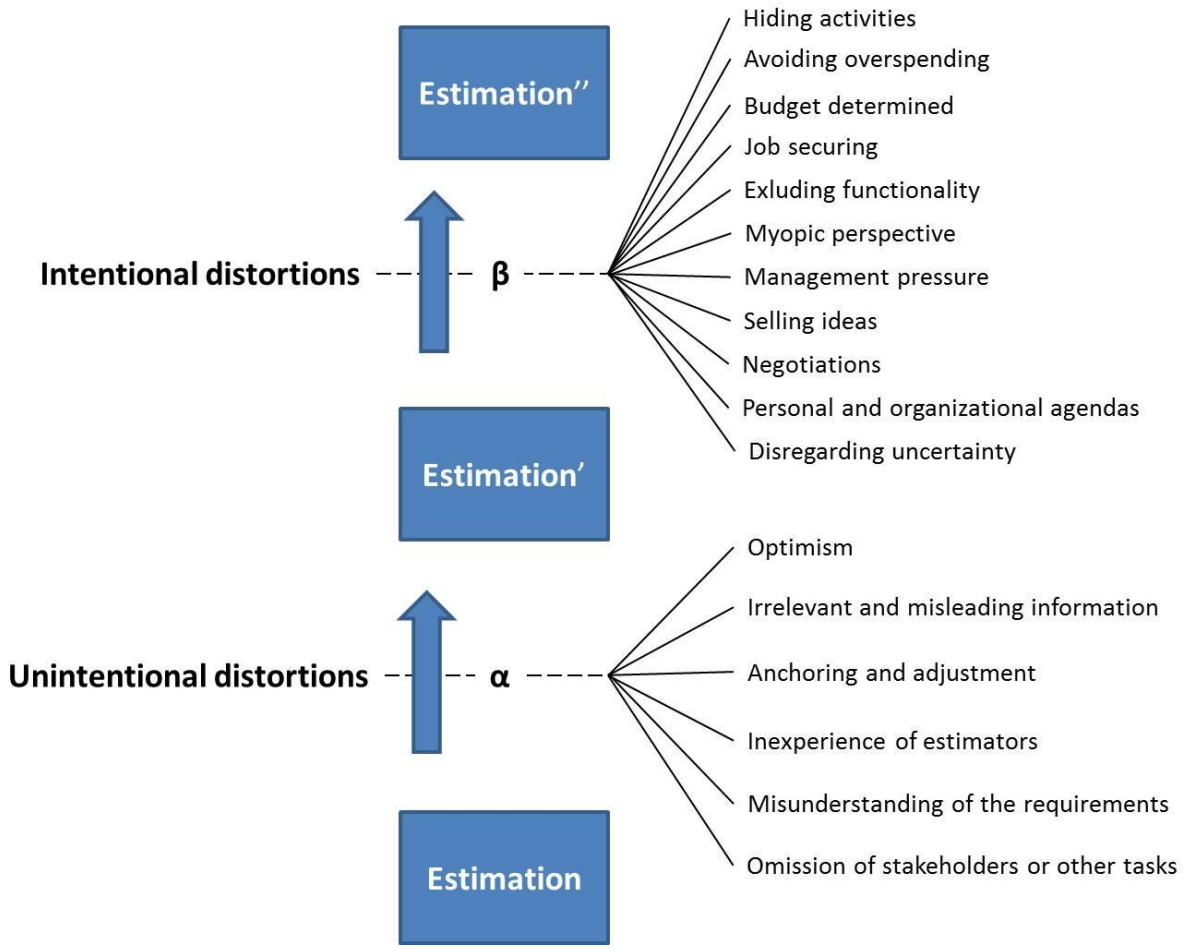


Figure 10: First half of the analytical model

The present analytical model suggests the existence of three states of estimation, each of which is defined as follows:

- **Estimation**: estimation of the most likely effort needed, purely based on neutral, relevant and consistent information, and excluding any form of biases, might they be intentional or unintentional.

[1] This is based on a framework presented by Jan Wickenberg at SIMULA, Oslo, Norway in Feb 5, 2009. Wickenberg' s framework includes a third level of distortion, Gamma, which consists of the intentional adding of a (often covert) cost margin when offering a product or service on a market. Since this thesis deals only with in-house estimation practices, the Gamma level is not included here.

- **Estimation'**: estimation of the most likely effort affected by unintentional and cognitive biases, excluding any type of conscious distortions.
- **Estimation''**: estimation of the effort needed, affected by both unintentional and intentional factors.

The value **Estimation** is a theoretical concept, as it is impossible to filter it out from unconscious cognitive biases, which all vary from estimator to estimator. **Estimation'** and **Estimation''** are therefore most likely representing the real values issued from estimation exercises.

In previous studies, the presence of the so-called α and β distorters, listed in Figure 10, have been reported to affect cost estimates accuracy (Magazinius et al., 2012). However, how can such a dual distortion, made at an initial stage, affect the final accuracy of a project? What is the meaning of accuracy of an estimate? Is it the comparison between the value of **Estimation** and **Estimation''**? Or, is it the comparison between **Estimation''** and the actual cost of a project? In fact, whatever the value of an estimate, it still remains a forecast of the most likely effort needed to accomplish a task (Magazinius et al., 2012; Lederer and Prasad, 1991). This means that both the values of **Estimation** and of **Estimation''** can be affected by scope changes and deviations, described as inhibitors by Magazinius and Pernstål (2008). In that regard, estimation accuracy is considered in this investigation as the comparison between estimation and the actual costs of a project, as illustrated by the following formula:

$$\text{Cost Estimate Inaccuracy} = \frac{|\text{Reported Actual Costs} - \text{Estimated Costs}|}{\text{Estimated Costs}}$$

Grimstad et. al (2006) addressed the issue of the lack of clarity and precision in estimation terminology. They stressed that estimation of the most likely effort should not be confused with planning, budgeting or pricing, and that accuracy should be assessed by ensuring that estimates and actuals can be comparable (Grimstad et al., 2006). A proper assessment of cost estimation accuracy therefore depends on the values taken as a reference, but while cost estimates have been extensively discussed, the reported actual cost of projects seem no to have been addressed with a similar focus. Magazinius and Pernstål (2008) reported in their study that due to dependencies between projects, it happened that resources were borrowed from project to project, without keeping any record of it, resulting in a mismatch between estimates and actuals. Further, Magazinius and Pernstål (2008) mentioned that the tracking of the actual project costs is incomplete and specified that the development time spent is not always reported properly (Magazinius and Pernstål, 2008). Due to the fact that both estimation and actuals have been described by previous studies as being questionable (Magazinius and Pernstål, 2008), the authors of the present investigation formulate the hypothesis that α and β distorters could not only be involved at the time of the estimation, as it has been established previously, but could similarly have an impact on the recorded actual cost of projects. Hence, the authors propose the following analytical model, shown in Figure 11, to illustrate the formulated hypothesis and address the issue of cost estimation accuracy in its whole:

Hypothesis: "Reported actual cost of projects are also affected by intentional and unintentional distortions"

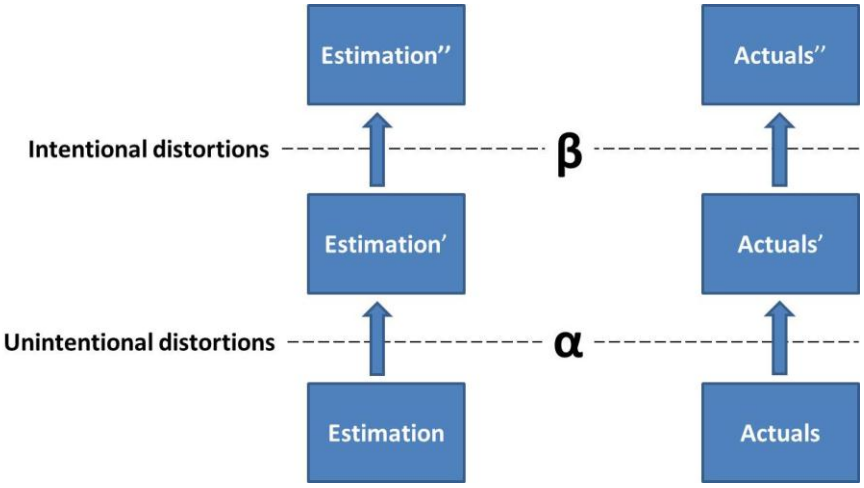


Figure 11: Hypothetical model

As previously described for the values of estimations, this model suggests the existence of three distinct values of actuals, which can be defined as follows:

- **Actuals** represent the real cost of a project, recorded perfectly and not including any mistakes, confusions or other intentional modifications
- **Actuals'** is the reported cost of a project including unintentional distortions, such as mistakes or memory problems.
- **Actuals''** is the reported cost of a project including both unintentional and intentional distortions.

According to Magazinius and Pernstål (2008), practitioners assess estimation accuracy by comparing distorted estimation and distorted actuals. This would mean that accuracy is determined through the comparison of this model's **Estimation''** and **Actuals''**. Obviously, such comparisons, if validated, would imply the existence of errors at multiple stages. This study therefore aims to test and assess the validity of the present hypothesis and analytical model in section 6.2.

3 METHODOLOGY

The following chapter elaborates on the research methodology implemented by the authors throughout the study. The research topic and strategy are described to support the selected research design. Then, an emphasis of the instances involved is justified and the choice of the employed research methods is motivated. Lastly, this section supports the reasons behind the selection of the data analysis tools used to process the collected data.

3.1 RESEARCH TOPIC AND QUESTIONS

This investigation, first, focused on the exploration of the cost estimation process in place in a company's product development with the aim to identify any influential factors and distortions affecting the accuracy of estimates. Second, the validity of the hypothesis and analytical model proposed by the authors in Section 2.5 has been tested and assessed. Third, the authors intended to determine whether and how the studied organization can improve the accuracy of its cost estimates.

Considering such a research topic, this report's research questions are formulated as follows:

RQ1: What are the factors and distortions affecting the accuracy of cost estimation in product development?

RQ2: How can these challenges be addressed by the studied product development organization?

As a consequence, the research type of this study can be defined as practice-oriented since the outcomes are expected to identify potential solutions to a specific problem (Bryman and Bell, 2011) In that regard, this research's methodology has been elaborated in the following sections.

3.2 RESEARCH STRATEGY AND DESIGN

To assess the above presented research questions, a qualitative research strategy has been implemented by the authors (Bryman and Bell, 2011). The purpose of exploring and highlighting unknown factors and behaviors in a specific social system makes the present empirical study having a descriptive perspective (Bryman and Bell, 2011). Therefore, due to the epistemological and ontological considerations of the connection between theory and

research with a qualitative view, and as this study addresses issues related to social systems, the authors adopted an interpretivist epistemology towards the data collected during the investigation (Bryman and Bell, 2011). Regarding the ontological orientations, an effort is made to consider the social phenomena studied as being in a constant state of revision, as organizational structures, product development processes and estimating tools evolve over time, hence the adoption of a constructionist perspective along the investigation (Bryman and Bell, 2011).

Cost estimation consists of a forecast based on the available information at the time it is performed (Magazinius et al., 2012; Lederer and Prasad, 1995). As expressed in 2.2, there are many approaches developed to perform this exercise, meaning that each and every individual have their own perspective and judgment on how to estimate. Therefore, it can be assumed that the authors' perception, values and beliefs may bias the recommendations proposed by this investigation and it is suggested that the reader's interpretation of the later presented conclusions should take this possibility into account. Regarding the practical limitations, this research has faced important time constraints that influenced parts of the data collection and analysis of this study.

By leading this investigation in the course of an industrial placement, the authors made the decision to adopt the research design of a case study. Therefore, the present report focuses exclusively on the cost estimation process of the hosting company. As mentioned previously, this study has been performed within one of the global organization's product development department, which develops, produces and sells mechanical products all over the world.

In addition to the above mentioned limitations, the authors had dual objectives. The first objective being to perform the present research, the second was to deliver standardized cost estimation tools and process to the company. The latter objective was not reported in this dissertation. However, this needed to be taken into investigation during the interviews. Consequently, this would eventually compromise the concentration and exploration of the research questions during the interviews.

3.3 SELECTION OF SAMPLE

Even though nor visits neither travels were scheduled during the research, the authors made an important effort to involve as equally as possible all the geographical sites belonging to the department throughout the investigation. In that regard, the selected sample was composed of respondents from all locations, who preferably had experienced more than one of the positions presented in the matrix organization in Section 2, or, who had work experience at more than one sites. Such a selection of sample could provide more comprehensive view and feedback during the investigation. Another criterion of selection was to have respondents able to provide a contrast between small and large-scale projects in relation to the cost estimation process. Thus, with the intent to get a sample as representative to these criteria as possible, the authors made requests to both the line and project organizations' top management of all sites to provide a name list of suitable project and line managers. The choice of such a non-probability sample selection is justified by two reasons (Bryman and Bell, 2011). First, the

authors' lack of knowledge of the department's employees made it difficult to properly select employees corresponding to the above mentioned criteria. Second, as advised by their company's supervisor, they decided to involve top management in the sample selection in order to benefit from their influence and to reduce as much as possible the non-response rate (Bryman and Bell, 2011).

In total, data collected from 38 respondents of the company's department, with a response rate of 95%. The selected sample represents 24% of all the line managers and 53% of all the project managers currently working in the studied development department. Such a triangulation of sources supports the credibility and internal validity of the present results and provided the authors with relevant contrasts between both sides of the matrix organization (Bryman and Bell, 2011). In addition, previous studies addressing similar purposes and methods obtained similar results to the ones presented in this investigation (Lederer and Prasad, 1995; Magazinius et al., 2012), supporting its external reliability (Bryman and Bell, 2011). However, being a case study following a qualitative strategy makes any generalization of the following findings difficult. Therefore, such a fact compromises the external validity of this paper (Bryman and Bell, 2011).

3.4 DATA COLLECTION AND ANALYSIS

Due to their lack of knowledge on cost estimation topics and on product development in global organizations, the authors adopt an explorative approach for data collection and analysis (Bryman and Bell, 2011). Besides, thanks to an initial literature review of previous studies, several areas of investigation had identified. In that regard, it had been decided to perform semi-structured interviews for data collection (Bryman and Bell, 2011). Such a choice allowed the authors to address specific topics presented by the literature and to compensate their lack of initial knowledge by asking a set of open questions. However, this research method is not adequate to address cognitive level of distortions on both cost estimates, due to the fact that cognitive factors, being unconscious, are even unknown by interviewees themselves in the cost estimation process (Magazinius et al., 2012).

Out of the 38 respondents of this study, 35 participated in semi-structured interviews, each of which was scheduled to last approximately 2 hours. Some of the interviews took place in two phases of one hour each, due to jet lags or to the usually tight time schedules of managers. In addition, not being able to travel, the authors performed 28 interviews out of 38 with respondents from other sites through e-conferences. This constraint of not having the opportunity to meet face-to face with most of the respondents can present both disadvantages, due to the fact that the visual part of human interaction was missing; and advantages, as respondents might have felt more comfortable to answer sensitive questions addressing political aspects. Among the 35 interviews, 31 were fully recorded while 4 were particular exceptions. One out of the four exceptions was caused by a respondent's demand not to be recorded while the three others were caused by technical issues.

3 of the 38 respondents were interviewed with open questions before the semi-structured interview session. Each occasion respectively lasted for 2 hours, 1 hour and half, and 30

minutes and can be considered as open-interviews, as no specific guides were designed at the time. By providing the authors with initial knowledge on the department's activities and its cost estimation process, these interviews significantly contributed to the design of the interview guide. Both authors took notes during and after these interviews. These notes were then summarized and revised before data analysis.

Further, in addition to these 38 interviews, the authors took part of several informal discussions with local managers in order to confirm specific points of the investigation and to deepen the understanding of particular aspects of the cost estimation process. Such discussions occurred in corridors, during lunch times or coffee breaks and presented the advantage of being informal. In such settings, interlocutors were usually feeling more comfortable to express themselves than in a meeting room for an interview. In that regard, the authors really valued the information acquired through these numerous discussions.

After completion of the interview session, 24 of the 31 recorded interviews were thoroughly re-listened and transcribed into texts that included answers and comments from the interviewees. The transcription was not reflecting literally the wording, phrasing and pauses of the respondents and the authors, at times, used their interpretation to select the information that seemed to be relevant. Therefore, it cannot be qualified as a "full transcription", which requires a thorough documentation including every single word, pauses and tones (Ives, Edward D., 1984; Bryman and Bell, 2011). The reason why the transcription was not complete is that this practice usually requires about six to eight more time than the length of interviews (Bryman and Bell, 2011). This means that it would have required between 380 and 500 hours for the authors to fully transcribe 31 recorded interviews, which were each 2 hours long. Due to important time limitations, the decision was made to interpret part of the answers given by respondents. Time limitation is also the reason why the authors did not transcribe 7 of the recorded interviews, but instead wrote summaries based on their notes, their memories and rapid reviews of the recordings. This implies that there might have been cognitive biases from the authors towards part of the data collected. Nevertheless, the answers to all interview questions tended to become convergent at the end of the session, which means that the qualitative interviews conducted by authors were valid and reliable with adequate amount of data collected (Bryman and Bell, 2011).

The qualitative data gathered and transcribed from both open and semi-structured interviews had been centralized and listed by respondents in a single document. However, "transcripts and notes are the raw data of the research. They provide a descriptive record of the research, but they cannot provide explanations. The researcher has to make sense of the data by sifting and interpreting them." (Pope, Catherine et al., 2000, p. 114). In that sense, a typology method, aiming to create a system of classification and categorization has been implemented (Bryman and Bell, 2011). Each and every part of the transcribed text was classified and assembled into a set of specific tags in a second document. A coding of each set of answers has been setup to replace the interviewees' names and to ensure that the whole analysis was performed anonymously. Indeed, certain topics being relatively sensitive and because it was preferable to avoid any unnecessary comparisons between the different sites, the authors made the choice to completely cover any distinctive signs giving away identity or site specific

information. Afterwards, an interpretation of each category was conducted, and summarized into a thick description, before finally selecting, structuring and aligning these descriptions to build up the present result chapter. Based on the contents of the interview results, some relevant literatures and theoretical framework were employed in order to further analyze and discuss upon the empirical findings before finally presenting several recommendations and their implications.

4 COST ESTIMATION CONTEXT

For confidentiality reasons and due to the sensitivity of the research topic, all information and terminologies having the potential to reveal the identity of the company and its employees have been covered and replaced with conceptual terms introduced in the previous theoretical framework. In respect to these constraints, this chapter has the purpose to present the context in which cost estimation is performed. First, it starts with a presentation of the organizational structure of the company and of the studied department of this investigation. Second, the product development process used by the company is described in order to better understand at what stages are the exercises of cost estimation and recording of the actual cost of projects performed. Third, the criteria in use to perform project evaluation are presented before finally introducing the corporate roles of the different stakeholders involved in the cost estimation process.

4.1 ORGANIZATIONAL STRUCTURE

Due to its important size and the diversity of products it manufactures, the present global corporation is structured along a strategic business unit organization. Each of these business units are themselves structured along a functional organization similar to the one presented in the section 2.1 of this report. As illustrated below in Figure 12, the department in which this study has been led is part of the R&D organization of the business unit and focuses on development of new products.

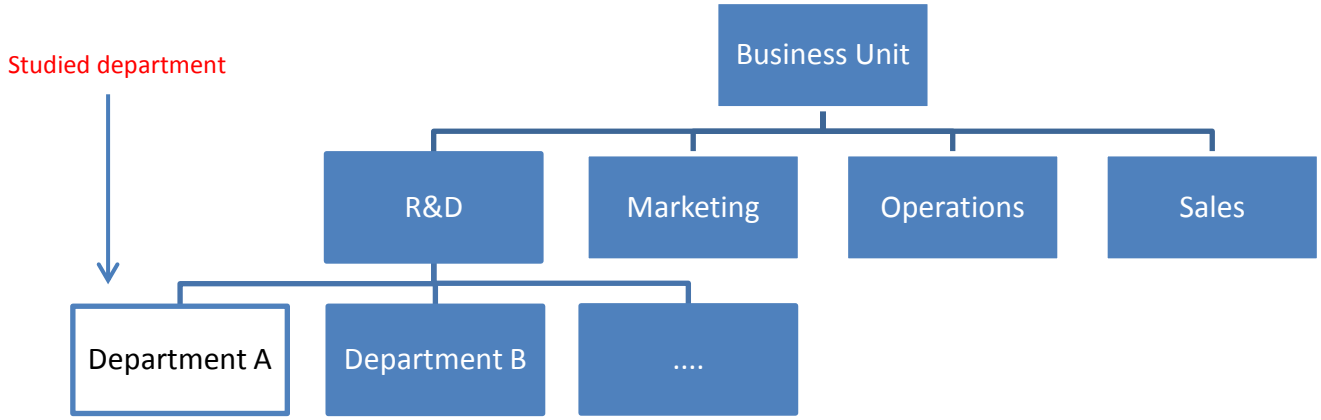


Figure 12: Functional organization of the Business Unit

Most of the large product development projects undertaken involve the intervention of a chief project manager responsible for coordinating the needed cross-functional activities between each departments of the R&D organization. As long as it concerns their projects, chief project managers are also responsible to coordinate cross-functional activities between R&D departments and other entities of the business unit, such as Operations or Sales organizations. Further, within each of the R&D departments, a project manager, reporting to the aforementioned Chief Project Manager, is in charge of coordinating the cross-functional

activities needed between each of the department's technical sections involved in the project. In that regard, the Project Management Office of each department assigns project managers according to a matrix organization, as illustrated Figure 13.

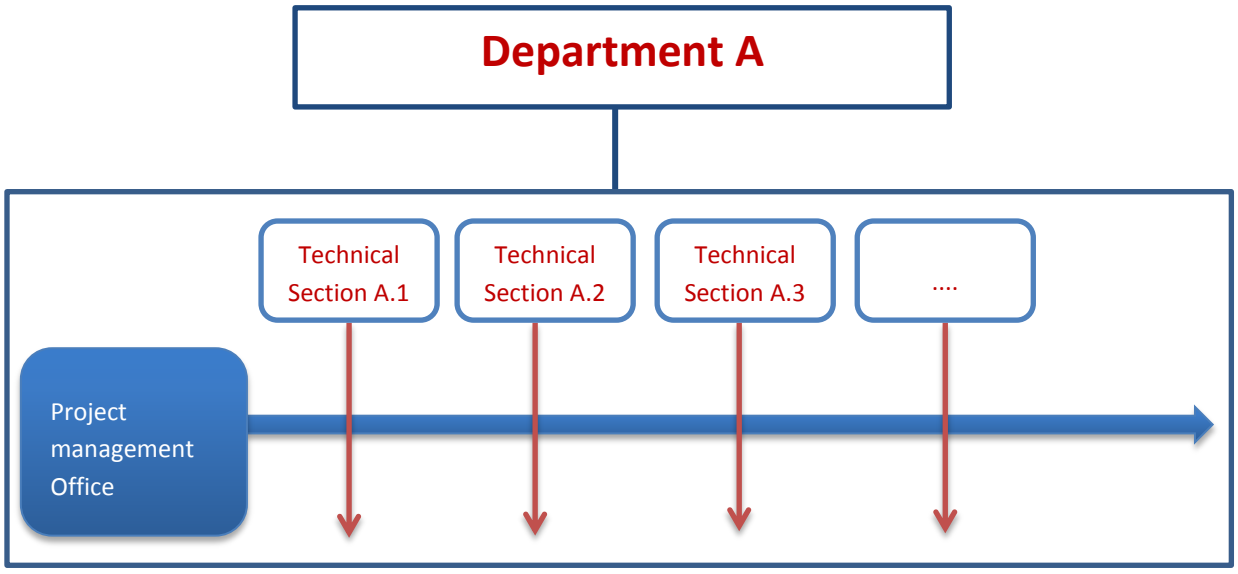


Figure 13: Matrix structure at the department level

Each project manager therefore interacts with the line managers of the technical sections involved in their project. These line managers are responsible for the allocation of their engineering resources and for delivering components to the project. Within a department, there are two hierarchical positions of line managers, namely technical section managers and group managers. The division in technical sections and groups purely follows a functional organization structure, as illustrated in Figure 14. In short, technical sections are responsible for particular systems of the final product, which are broken down into sub-systems delivered by groups.

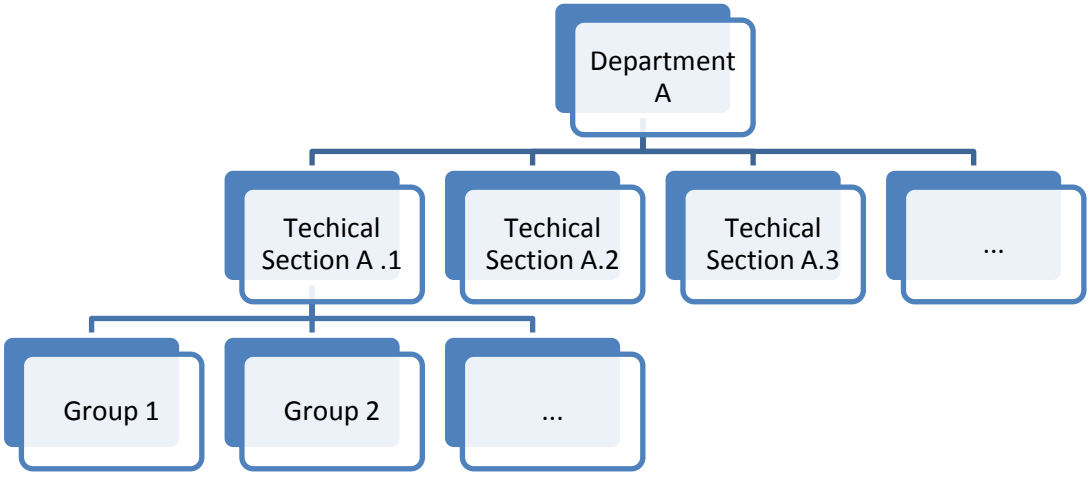


Figure 14: Line organization

4.2 PRODUCT DEVELOPMENT PROCESS

The company uses a development process based on Cooper's stage-gate model (1983) to deliver its projects. This model, illustrated in Figure 15, divides product development activities in seven phases and covers the entire project lifecycle. A brief description of each phase is given in this section in order to describe at which stages of the process estimation-related activities are performed:

Phase 1: *Idea* phase—In this phase, any department or individuals can initiate a project proposal for which an initial cost estimation is conducted. Based on the initial cost estimates and on a market analysis, a profitability forecast is established to support project selection. While some proposals are passed to project initiation, others are withdrawn, or kept in a waiting list.

Phase 2: *Preliminary Assessment* phase—This phase starts just after project initiation with the aim to understand the project objectives and to develop alternative concepts. Before the end of the preliminary assessment, detailed cost estimation is performed along with comparisons using previous projects cost as reference.

Phase 3: *Concept* phase—In this phase, alternatives concepts are analyzed and tested, up until the final selection of one of them for further development. Before the end of the phase, an update of the previous cost estimation of the project is performed and consolidated.

Phase 4: *Development* phase—This phase mainly includes design, documentation and test activities. Another update of the cost estimation is coupled with project cost comparisons. The resulting estimation from the development phase is set to be the reference estimate for estimation accuracy assessment.

Phase 5: *Testing* phase—In this phase, product solutions are built, verified, validated and refined. Simultaneously, another cost estimation update is performed.

Phase 6: *Trial* phase— In the trial phase, the industrialization system will be installed, prepared and verified before product launch and commercialization. The last cost estimation update is performed at this stage of the project.

Phase 7: *Launch* phase—in the last phase, the project is delivered by the project team. Experiences and other relevant information are summarized and reported before project closure. This is later followed by a project evaluation is organized along specific criteria defined by the company.

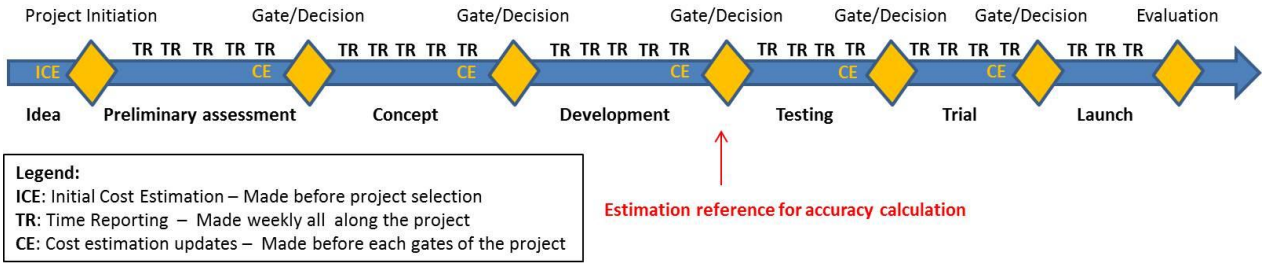


Figure 15: Current product development process (Source: Cooper, 1983, modified by authors)

Within the department, costs are divided and estimated according to three categories: engineering hours, prototyping material expenses and bought services. The first category is the time spent by stakeholders on project-related activities. This cost is collected in hours by project managers, who then use a conversion rate, specific to each site, to change them into a cost in their local currency. Prototyping material expenses represent the cost of the material needed to perform different validation tests scheduled along the product development process. Finally, bought services include outsourced developments, external consultants and stress tests realized by other departments of the company. Estimators provide cost estimation of all three categories, which are then consolidated by project managers to determine the estimated cost of their project. In average, project costs of the studied department are composed of about 85% of cost of engineering hours, 10% of bought services and 5% of material costs. This indicates the importance for the company to perform accurate estimations of engineering hours.

As illustrated in Figure 15, cost estimation updates are performed in all phases of the product development process. This allows project budgets to be updated and approved at each gates. To be able to follow the evolution of project costs, every week, all employees involved in the product development process are asked to report their time spent on each activity in the budget administration system of the company. This is how the actual cost of projects are measured and calculated when it comes to engineering hours. Later, at each gate, project teams are required to report the evolution of the project cost in contrast to budget deviations encountered. All along their implementation, projects are evaluated according to their quality, delivery time, cost and features. Cost estimates have an impact on the cost criteria, where profitability forecasts, such as payback and Internal Rate of Return are made and used as decision support at each gate of the product development process. In order to support decisions, it has been defined to setup minimal limitations for projects' profitability forecasts. This information serves top management to decide whether to continue, to stop or put projects on hold.

5 RESULTS

The following chapter aims to report the results obtained throughout the interviews led during this investigation. First, a description of the current cost estimation process is provided, in which the interactions among stakeholders and the methods, rules and objectives related to estimation are presented. Second, the company's aim to improve its cost estimates accuracy is discussed before introducing influential factors affecting the process and generating distortions of both estimation and time reporting. Finally, current methods used for organizational learning and accuracy improvement are described.

5.1 DESCRIPTION OF THE COST ESTIMATION PROCESS

5.1.1 INITIAL COST ESTIMATION

Prior to project selection, an initial cost estimate is consolidated for each idea of project proposal. Based on these ideas and very little information, line managers of the department are responsible for providing rough estimates of their needs in engineering hours, materials and bought services to carry on the project if it is selected. Respondents of this study shared that due to the very brief and vague descriptions they are provided with, their estimation at this stage are made quickly, can include wrong assumptions and are rough. The procedure in use to perform these initial cost estimations varies from site to site. In some cases, the leader of the project management office (PMO) holds a meeting and collects inputs from line managers. In other sites, line managers receive the project proposals by email and send back their quotation to a colleague in charge of the consolidation. The only purpose of this estimation is to calculate an initial profitability forecast, in the form of Internal Rate of Return (IRR) and payback values. This forecast serves as one of the most important criteria used by the company for project selection and evaluation.

5.1.2 COST ESTIMATION AFTER PROJECT INITIATION

Once projects are initiated, a project description in which the initial cost estimates are conveyed, the project prerequisites, the technical scope and other preliminary information is delivered to the assigned project manager. Based on this, a time plan specifying the dates of important milestones is prepared and the project manager shares all this information to the line organization before requesting their estimation. At that stage, there is no common procedure defining project and line managers' interactions. While some project managers would exchange almost exclusively by email, others would organize review meetings with their stakeholders. There are no common practices neither as to who would be the project manager's interlocutor in each technical area. Project managers have the choice between contacting section managers, group managers or directly the engineers of the department, but whichever way is used, project managers' contacts from the line organization finally provide

them with an estimation of the engineering hours, material and bought services needed to perform the required activities. At times, project managers make their own analysis in which they assess the technical involvement of the different groups of the department, make comparisons with their previous projects and use their previous experience. Once the figures are collected and consolidated, project managers decide either to accept the estimation proposed by the line managers or to question and challenge them. Such challenges, when they are triggered by project managers, are mainly justified by their feeling or experience that part of the estimates can be reduced or increased. In these cases, they schedule a meeting with the concerned line managers to obtain more details about the estimates' underlying assumptions and expectations. At the end of these discussions, project and line managers come to an agreement regarding the cost estimation of their project and the consolidated figures are handed over to the chief project manager who then requests approval from top management. The relationships and interaction between each stakeholders of the cost estimation process is illustrated in Figure 16.

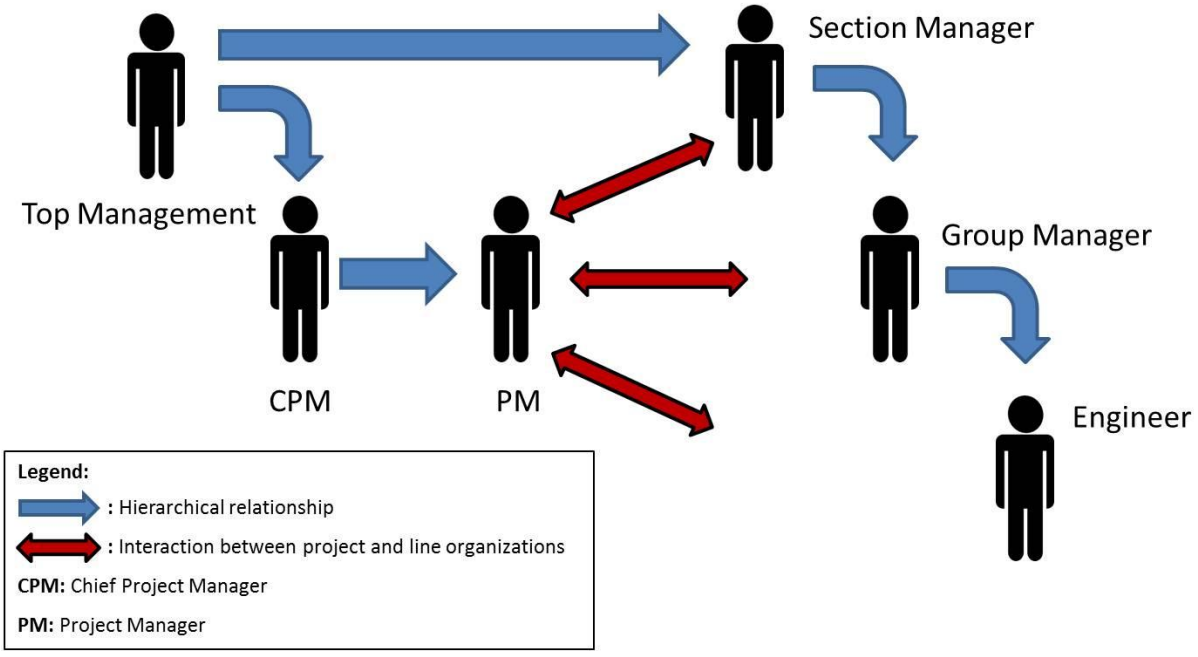


Figure 16: Actors involved in the cost estimation process

Chief project managers are responsible for consolidating the cost estimation of all the departments of the company. They therefore review all the estimates from each department to evaluate the total estimated cost of their project. In that regard, chief project managers have also the possibility to question and challenge each project manager of their teams. Once an agreement is reached among all the stakeholders, chief project managers consolidate the overall cost of the project and submit it to top management and the finance department for calculation of profitability forecasts and receive an approval regarding the requested budget. Top management has the possibility to approve the budget or question and challenge the cost estimation. As a result, a project can be challenged and requested to reduce its budget from different layers of the organization. In general, to answer a challenge, line managers have to re-assess their estimation, make sure they properly understood the prerequisites, and propose

alternative scenarios or reductions of the scope. Respondents described this type of challenges as being frequent in large-scale projects.

On their side, line managers are responsible to perform a cost estimation of each project in which their teams are involved and to provide their quotations back to project managers. In that regard, respondents of the interviews described that engineers or group managers in charge of estimating must understand completely the prerequisites and scope of the project in order neither to be confused nor to omit any required members of their teams. Once the impacted technical areas are known, some line managers have a meeting with their engineers, in which they share their estimates through the use of templates generally sorted by function groups and activities. During their review, they question their quotations and try to assess the risks capable of affecting the project. Sometimes, to support their estimation, a former project is taken as a comparison to evaluate the total size of the project. Then, by contrasting the different activities and by adding some modifications according to the new situation, they would use these additional inputs to build their cost estimate. According to the respondents, the advantage of such inputs from historical comparisons is that it complements the important degree of details given by estimation templates, which sometimes can lead to unrealistic values. Once group managers and their teams have completed their cost estimates, the values are reviewed in meetings by their section managers who have the responsibility to coordinate the overall response back to project managers. If during their review meetings, line managers have the feeling that their cost estimate is more expensive than it should be, they try to rework together by making sure that a mutual understanding of the scope is shared. At times, they are able to identify which designs are not necessary and therefore to reduce their estimation. To know how much should be the value of an estimate, a line manager usually relies on his past experience, but for various reasons, there is no clear system and the history of previous cost estimation exercises made within the department is neither structured nor properly documented. According to a respondent, this is due to several facts. First, some technical components require a very little frequency of modifications over time, such as once every twenty years. Second, most of the time, the technical changes required are very important and often new for line managers. Third, it is very seldom that the same development is done twice. Thus, each project because of the content being different, the scope being different, or the geographical location being different makes it difficult to estimate based on historical values.

Such a process can vary among different sites. In some cases, line managers focus their estimation around the number of new components that will be needed to design. Then once, they get the total estimate by function group, they will distribute it over-time according to the release dates given by the time plan. Such an indication, given by the amount of new components, has been noticed to be used by several line managers in different sites. Actually, it is even used officially in the estimation process of one of the department's sites where the common bottom-up is coupled with a one-dimension parametric tool, taking as variable the amount of new components.

5.1.3 COST ESTIMATION UPDATE

In front of every gate, the cost estimate is updated by project managers, who request the line managers to re-estimate and re-express their needs of engineering hours. The former quotation of each group is provided as a reminder of the last estimations. At the moment of the update, respondents shared that when there are changes of the cost estimates, it is most of the time an increase. Once the updated cost estimate is consolidated and approved by top management, project managers enter the new budget into the budget administration system of the department. This software has been described as a rigid and non-user-friendly tool in which project managers have to enter each value given by each of their stakeholder manually. This activity alone has been said to occupy between several hours to several days. Once the estimation is updated on the budget administration system, project managers consider the severity of the deviation. In case of an important deviation, they have to prepare a request submitted by their chief project managers in a meeting with top management representatives. It has been defined as a rule that such requests are accepted in the department until what Cooper (1983) defines to be the development gate. Prior to summon top management, chief project managers always try to question and challenge such increases, but according to the respondents, most of the projects require budget augmentations regularly along the project to be able to continue. Usually such requests are not very well perceived by top management, who will question very toughly the chief project manager. Such experiences are really not comfortable for chief project managers. Their reputation is said to depend on the reasons of the deviations, as well as amount and the frequency of their requests. Thus, this is a part of the cost estimate process that most of the chief project managers would try to avoid going through.

5.1.4 CHALLENGES ON COST ESTIMATION

In general, before presenting to top management, project managers can always challenge and question whether some of the line managers really need extra hours, they can also balance their budget within their frame, or they can use their own buffer in case they had some, to unlock the situation. In these particular cases and others that will be discussed later, project managers can avoid going through presentations with top management. However, line managers do not officially have similar flexibility when it comes to the budget and are always supposed to refer to the responsible project manager in case of budget issue. Alike the project manager, chief project managers can balance their budget among the different product development departments, ask to reduce the project scope, challenge their teams to reduce their cost, or they can as well use their own buffer, in case they have some, to solve overspending situations.

At times, the chief project manager or top management will not provide any answer to the project manager regarding whether they should reduce the scope of the project, or get an approval for budget increase. This situation has been reported to be a struggle for line and project managers, as they end up being blocked by the organizational process itself. The lack of clear answer, in general, leads project and line managers to informally take decisions on

their own. One of the possible measures is simply to continue working on the deliveries and willingly overspend until obtaining a clear reaction from other stakeholders. In addition, it seems complicated for line managers to foresee overspendings, as there are no structured processes and tools for them to formally review their needs of hours. Indeed, when an issue is escalated to a project manager or to a chief project manager, thanks to the flexibility they have with the budget, they can take the decision to balance the budget from department to department or from group to group. In these cases, the cost estimate is not updated in the budget administration system and even though an agreement has been given, the situation will still look like an overspending. Therefore, respondents complained about the lack of visibility and traceability of such agreements in the budget administration system, making the cost estimate more difficult to follow-up. As a result, the project might seem to be overspending where it is actually confirmed and agreed that it is under an updated budget frame.

5.2 CURRENT IMPRESSIONS ON COST ESTIMATION ACCURACY

In most of the sites, interviewees considered relatively being able to achieve satisfying cost estimation accuracy. Usually, if the deviation is within -/+ 5%, then the accuracy is considered to respect the objective, which in turn means that project managers have done a good job in terms of scope control, timely decision-making, and etc. As reflected by project managers, the accuracy of estimates differs from project to project, which can be both over and under- estimated occasionally. Also, the estimates received from line management also vary team by team or by section, for instance, some engineers are always prone to over or under-estimate. In this case, project managers have to learn their individual estimation manners personally, and adjust the estimates correspondingly.

However, the cost estimates accuracy is not always affected by the estimates solely. More importantly, there are many other aspects during the project implementation will have considerable impacts on the cost estimation accuracy. In the case if something fails in cost estimates, the profitability level will be re-calculated and evaluated. With the budget increased, however the profitability is still sufficient, then the project will be continued, and vice versa.

In some instances, the interviewees find it very difficult to answer the question. For the reasons that most of time, once the project is accomplished, they usually do not turn back to the cost estimates they provided for budget approval; and as the cost estimate evolves along the project, they neither do not know which estimates should be used as reference to compare with at the end of the project. Some line managers keep track of the spending on a monthly level, as to say, if the spending corresponds to the estimation on a monthly basis, then it is considered as an accurate estimate. Yet, some more question could not be answered during the interviews, such like, should the cost estimation accuracy be controlled and evaluated on a time periodically basis or at the conclusion of the project?

Given consideration to these doubts, furthermore, it would be sensible to question the incumbent criteria for cost estimation accuracy evaluation. Could the deviations, namely the matching between estimates and reported actual costs, eventually reflect the “accuracy” level?

In the formula above, it can be easily seen that both the two decisive parameters are maneuverable variables, which means that by intentionally distortions or unintentionally mistakes, the accuracy could be enhanced with mitigated deviations between this two factors; however, the presented results can deviate even further from the actual facts in terms of accuracy.

On the other hand, even without any intentional distortions to both parameters, the so-called "accurate estimates" could also be questioned that can they be the "leanest" estimates without any unnecessary margins padded and accordingly consumed? Unfortunately, the answer is not a firm "yes" from most of the interviewees. In this sense, by examining the "leanness" of the incumbent cost estimation, cost estimation accuracy could probably be more thoroughly comprehended and further improved.

5.3 INFLUENTIAL FACTORS AFFECTING THE ACCURACY OF ESTIMATES

As described earlier in 2.2, overruns are quite frequent in project organizations. One of the objectives of this investigation has been to study this phenomenon and to highlight the influential factors affecting the accuracy of estimates. Throughout the data collection, several aspects of product development projects in a global organization were found to influence the accuracy of estimates.

Limited initial investigation and unclear prerequisites have been considered as a struggle for line managers while estimating. Forced to develop their own complementary assumptions about the company's expectations, their estimates are exposed to the later changes caused by scope clarification coming from project requesters. Such an issue has been mentioned many times by line managers who complained that *"at the end of the day, we spend a lot of time trying to understand each other"*. According to them, project prerequisites documents, no matter how long they are, present specifications that are either unclear or incompatibles to each other. As a consequence, line managers are not even certain that they understand what they have to estimate on. Therefore, it has been commented that there are normally many ambiguities and uncertainties in the prerequisites regarding the technical complexity, dependencies, unknown risks, etc., which indeed lead to omissions, under-estimations or estimations based on misunderstanding in many occasions.

Simultaneously, it has been noted that there is an important amount of uncertainty regarding development activities. Even though knowledge increases along project execution, unforeseen problems occur and need to be solved. In many circumstances, line managers need to work cross-functionally with different stakeholders and with different departments. Due to many functional dependencies involved in the development process, the work of a designer can be largely affected by other team members, other groups or even other development departments. In addition, important cooperation between teams from different geographic sites is often needed even though, at times there is no clear statement of responsibilities. As a consequence, estimations from different teams can include overlapping of the expected work content. Such

problems are frequent and often cause an increase of engineering hours' consumption. If, for any reasons, a group, a department or a requester decides or is forced to change the scope by adding or suppressing features or modifying the predefined architecture of the product, there will certainly be affected teams needing to rework and comply with the new requirements. Striking examples are the multiple validation tests scheduled for every project. As soon as a test fails, each of the function groups involved has to perform root-cause analyses to understand the origin of the failure. These analyses are followed by additional loops of tests up until the results are sufficient. Product development is therefore truly an iterative process, making it difficult to estimate, as it requires assumptions on the amount of loops to consider. These assumptions have been described as too optimistic by some line managers, while others complained that their teams performed too much unnecessary tests.

Cost estimate accuracy has been noted to be dependent on the considerations made at the moment of the estimation. As commented by several project and line managers, in many instances, engineers do not have a deeper understanding of the current Product Development Process, which often leads to negligence regarding non-core but required activities. At times, line managers can forget to include support activities, such as meetings or presentations in their estimates, but as these activities need to be reported in the budget administration system, they end up providing underestimated figures. A similar issue occurs before project initiation, when line managers consider the involvement of their teams in the activities of each project. If any of the functional stakeholders is omitted, then the project will suffer from budget issues. Thus, omissions of involved stakeholders or needed activities at the moment of the estimation often result in later requests of budget increase.

Another critical influential factor leading to cost estimate inaccuracy has been identified to be the increasing pressure from top management to cut cost. Line managers commented that over time, the company has had more and more focus on non-acceptance of cost increases. They added that it is a struggle today to get the necessary funding to be able to deliver their components and that overspending is really badly seen and taken very seriously by most of the stakeholders. Indeed, budget deviations hinder the efficiency of the product development department. According to top management, overspending has for consequences that new projects cannot be started and that project profitability is deteriorated, while underspending postpones their start. Clearly, by being stricter on budget, top management intends to increase efficiency by compensating with the slack presumed to be added by estimators, and by slightly overloading the department in comparison to its stated capacity. Such measures aiming at compensating overestimation are perceived as pressure by the line organization. Being pressured for budget cuts by top management and unable to receive approval for their demands, they naturally seek for alternative solutions.

Finally, respondents commented that plans themselves were rather linear and optimistic, as they are made with the assumption that nothing will go wrong. In reality, the department's product development process is iterative, as each failure or deviation requires consequent rework. One respondent commented that the more advanced is the stage of a project the more expensive will be any deviation. That is why he added that interactions with manufacturing

are really sensitive, as any issue encountered at that stage could consequently affect the cost of a project.

To sum up, several aspects have been identified as influential factors affecting the cost estimation process of the organization. These influential factors can be listed as follows:

- Unclear requirements
- Uncertainty and risks
- Interdependence among different stakeholders
- Multi-tasking
- Pressures from top management

5.4DISTORTION OF ESTIMATES

This section introduces respondents' explanations regarding distortions of estimates. As effectuated by previous authors (Magazinius et al., 2012), these distortions have been classified according to the degree of consciousness of estimators. Cognitive and other unintentional explanations are reported before introducing conscious and intentional behaviors.

5.4.1 UNINTENTIONAL

As mentioned in Section 2.5, cognitive distortions of estimates are even unknown from estimators. This means that respondents would not be able to properly describe and explain their cognitive biases during an interview session and previous authors covered extensively this topic in their investigation with appropriate research methods (Aranda and Easterbrook, 2005; Jørgensen and Grimstad, 2005; Jørgensen and Grimstad, 2008). However, even though the present methodology was not suited to collect data related to unconscious factors, at times, respondents commented that they could be too optimistic in their estimations. Others explained that inexperience of project managers, engineers and/or line managers could lead to serious underestimations. Indeed, any omission of required stakeholders or activities affects the budget of a project. Finally, line managers make assumptions on the expected scope of the project, when they do not find the relevant information in project documents. While making such assumptions, some commented having misunderstood the project prerequisites.

To sum up, identified reasons for unintentional distortions of estimates can be listed as follows:

- Optimism
- Inexperience
- Omission of required stakeholders or activities
- Misunderstanding of project requirements

5.4.2 INTENTIONAL

Throughout the interviews, it has been discovered that each and every actors presented in 5.1.2 may have incentives to pad their estimates. Initially, some project managers commented that their colleagues from the line organization would always try to get margins while the latters considered that the project organization would never have such an interest. This impression that project managers and chief project managers do not have any incentives to pad estimates was certainly due to the fact that they were at the same time the actors responsible for challenging and pushing for budget reductions. In fact, under specific circumstances, even project managers and chief project managers may make the decision to create an additional buffer. Such a situation certainly does not signal cost efficiency, as noted by one respondent: *"If all levels in an organization add buffer, you can imagine what happens, you reserve a lot of money somewhere just in case"*.

By stating that *"today [top management] would cut out our buffer wherever they find it"*, line and project managers in general take the decision to mask their margins directly in their activities and in other costs types, such as materials or bought services. Such situations have been noted at several occasions throughout the semi-structured interview sessions, but this varies from manager to manager. Some mentioned voluntarily trying to be optimistic in order to motivate their teams and improve their performance. By avoiding adding buffer, these managers signal their situation each time they face budget issues, but as cost increases are often rejected and as budget cuts are frequent, these respondents are the most exposed in the cost estimate process. Thus, the interviews confirmed that every actor in the organization could have the incentive to add hidden buffers in their estimates to avoid them being cut out from other stakeholders, as illustrated by the following: *"Of course we need to have some margin but what I would like from line managers is to have this margin visible. […] The problem is that if they make it visible, then we have the possibility to remove it"*. Why isn't it possible to centralize and make such margins transparent? What are the causes of such intentional distortions? Why do line and project managers pad their cost estimation?

> *" There are probably a lot of hours floating around without project, but it needs to be like that. We need to be flexible."*

Line and project managers both provided several reasons behind their decision to pad their estimates. First of all, several complaints from line managers have been given towards the prerequisites of projects. Line managers' understanding of these documents is one of the influential factors identified previously. At times, when details are missing, or when technical inconsistencies are present, line managers decide to intentionally increase their estimation. A respondent complaining that he was sometimes requested to estimate on very fuzzy descriptions said that he applied a buffer 10 to 15% times more important than usually when the scope is unclear. Line managers justify this additional buffer by arguing that when they don't have a clear understanding of the prerequisites, they are forced to make their own assumptions and estimate based on incomplete information. They therefore add this important margin to be able to react when the scope will be clarified.

As mentioned previously, unforeseen events, deviations and scope changes are also important influential factors affecting the accuracy of cost estimates. Each deviation actually makes all the previous estimations obsolete. Indeed, due to important dependencies, each change not only affects the team making modifications, but can also concern groups, or departments that were initially not involved. Therefore, line managers decide to pad their estimates by in the form of risk considerations. Usually, the size of these margins depends on the perceived complexity of the activities, the dependences with other stakeholders and the project phase. Project and line managers know they will always face changes and unforeseen events, and even commented that they usually face more issues than initially expected. They further explained that due to such a fact, they always tend to consume their entire contingency buffer.

Respondents mentioned the important workload and multi-tasking undergone by engineers. Such frequent transitions from project to projects decrease their efficiency, and in turn increase their hour consumption. For this reason, it has been argued from some of the respondents that estimates had to be padded to take such constraints into account. The more projects there are, the more margins are added in the different projects to be able to cope with this issue.

Most of the aforementioned reasons behind intentional distortion of cost estimates are intents to cope with the different uncertainties and constraints presented by product development activities. However, these reasons were not the only ones presented by the respondents of this study. There are intentional distortions that can be characterized as issued from political behaviors and self-interests.

The increasing pressure from top management to reduce project cost and to cut budget has been previously introduced as an important influential factor affecting the accuracy of cost estimates. Such measures initiated by top management and carried by chief project managers and project managers are realized with the intent to increase efficiency and compensate overestimations from line managers and engineers. However, being constantly pressured in some of their projects, line managers are sometimes forced to cut their cost estimation and to provide unrealistic figures, leading to overspending in later stages. As a result, line management, on the one hand, tends to anticipate these pressures by inflating artificially their estimates. On the other hand, project managers complained that on top of leading to such anticipations, their challenges give a signal of distrust and can compromise the later interactions between the line and the project organization. Therefore, these pressures and emphasis on cost efficiency, being intents from top management to push for efficiency, are actually creating undesired reactions as side effects: *"Yes, I think this increasingly strict situation will cause increase of buffer in estimations. I've also started to raise my estimates"*. Respondents from both sides of the organizational matrix compared these situations with typical bargaining discussions occurring in market places, commenting that the estimation exercise is changed into a "salesmen game" and referring to the intentional distortion related to this specific influential factor as a "negotiation" buffer.

In line with its overall focus on cost efficiency, top management is increasingly stricter towards overspending situations. Respondents mentioned the struggle it was to obtain

approvals to increase their budget in these situations, some even used figuratively words such as “punishment”, “yelling” or “harassment”. In fact, although there are neither blames nor sanctions in place in the organization towards overspending, there is actually a general frustration of project and line managers while communicating these situations. Therefore, both line and project managers intentionally add buffer to avoid overspending and to compensate with expected negative answers.

> *“If you get punished for an overrun, even if you did your best, then next time you add some buffer. It’s easy to think about how to avoid the punition for the next time”*

In addition, padding estimates to avoid overspending can also be a way to preserve one’s reputation within the department, as can be illustrated by the following: *“At the end of the day, you look good if you underspend”*. To sum up, avoiding overspending through intentional distortions of estimates provides project and line managers with the multiple advantages of compensating with expected negative answers regarding requests for budget increases, relieving them from the frustrating reactions of other stakeholders, and preserving their reputation within the department.

Another type of intentional distortion, this time specific to line managers, is issued from their responsibilities regarding their resources. If line managers find out that during the project execution that they are facing a lack of engineering resources to deliver on schedule, they need to request additional team members. However, at times, these requests are unfruitful or lead to the decision to export labor to other sites of the company. In addition to this, every year the budget estimated allows top management to attribute internal and external resources to each functional section, which mean that cost estimations have an impact on the headcount of the department. In that regard, some line managers expressed that they could take the decision to pad their estimates in order to secure the resources currently working in their team. They justified these decisions by the fact that experienced engineers and consultants work significantly faster than newcomers, insisting on the difference of efficiency in hour consumption. In such contexts or when they simply want to make sure to have enough resources in the future, line managers can decide to pad their estimates. However, intentional distortion of estimates is not the only way to achieve such ends and other instances of resource securement have been reported throughout this investigation. Line managers’ resource plans are actually affected by budget cuts, as these situations require resource reallocation. Project delays have the same effect. If a project is delayed, and a part of the budget transferred to a later calendar year, resources issues need to be handled by line managers. As a result, it has been found out that not only padding of estimates, but also deliberate addition of features in the project, were both possible solutions to assess such resource issues. Indeed, by creating work within a team, its initially unallocated resources can contribute to its activities, even though this type of deviations often leads to project cost increases.

After having mentioned several reasons for intentional increases of estimates, one can wonder whether line and project managers can have incentives to deliberately decrease their estimates. Actually, some respondents mentioned that with the objective of keeping a project

alive, to increase the chances of project selection or simply because they just want to influence the development of a particular feature, they could decide to underestimate on purpose. Such distortions aim at fulfilling the minimum values required in the profitability forecast to obtain approval at decision gates. Once approval is given, requests for additional funding are expressed by the time the budget is spent. This practice becomes harder to implement, as top management is stricter towards budget increases. It seems therefore to be less frequent to intentionally shrink an estimate than to pad it.

Thus, as a synthesis, reasons behind the decision to intentionally distort estimates can be listed into 7 different categories, namely:

- Intents to cope with Unclear prerequisites
- Intents to cope with Unforeseen events, deviations, test failures and scope changes
- Multi-tasking of engineers
- Challenges and pressures pushing for budget reduction
- Anticipation of pressures from other stakeholders
- Avoidance of overspending:
    - Professional reputation
    - Avoidance of frustrating discussions
- Resource securement
- Facilitation of the acquisition of approvals

Some of these categories present several underlying root causes justifying line and project managers' decisions, such as reputation or frustrating interactions. Again, it is important to note that such practices are not used by all the employees of the product development department and that there are managers that prefer not to intentionally distort their values. Being a qualitative study, this report provides different explanations without having the pretention of quantifying them.

5.5 DISTORTIONS OF TIME REPORTING

As expressed earlier, accuracy is determined by the difference between the initial estimates and the actual costs of projects. In fact, actuals are the basis for project follow-ups, profitability forecasts and project evaluations. These values, when it comes to engineering hours, are determined by the consolidation of each employee's time reporting in the budget administration system. This activity is then at the source of most of the budget measurements effectuated along the product development process. However, the interview session showed that even actuals can be distorted at the moment of time reporting. These distortions are presented in the present section.

5.5.1 UNINTENTIONAL

For each project in which they are involved, project managers, line managers and engineers are given activity codes. By time reporting within each of these codes, the spent of each

project is progressively recorded, giving an overview of the budget consumption rate. This activity is supposed to be done weekly, but the frequency actually varies from individuals to individuals and it occurs that time reporting is done monthly. Respondents, while explaining the reasons for distortions of time reporting, mentioned that it is impossible to be efficient 100% of the time while performing activities and that efficiency depends on specific circumstances and individuals. Further, they explained that at the end of the week, or of the month, it is very complicated to remember all the activities they performed and how much time was spent for each of them. In fact, engineers have to perform an estimation of their spent according to their memories. Both managers and engineers are said to make a lot of approximations during this exercise. Such approximations have been reported to be continuously affecting the accuracy of time reporting.

As previously mentioned, engineers constantly deal with several activities at the same time, and are constantly interrupted. Often, they also work for a single activity responding to several projects. This means that boundaries between the different activity codes in place are questionable. Worse, there are also many obsolete activity codes still open for reporting in the system, and still used by employees. Besides, project and line managers commented that engineers have usually an important amount of activity codes to report on. As a result, the fuzziness of boundaries and the complexity given by the large amount of codes lead to confusions, and engineers sometimes do not remember the correct codes or simply do not know which one they should use. These confusions regarding activity codes lead to distortions of the actual costs of projects and have also been reported to be frequent. Despite such issues being commonly known, respondents of this survey commented that engineers entered themselves manually each of their activity codes in the budget administration system. In total, they are supposed to remember and enter more than ten codes and fill in their hour consumption for each of them, for the whole week or the whole month. In fact, engineers are not even supposed to manually perform such a tedious task, but part of the project managers, unwilling to use the budget administration system due to its lack of user-friendliness and its long loading times, do not use the features making this procedure automatic.

Respondents mentioned that these confusions will be reduced in the coming months by an important simplification of the codification in the department. Indeed, it has been decided to merge the codes corresponding to all the small-scale projects into about three activity codes in total. This will have for effect to simplify the time reporting activity, but on the other hand, will make it impossible for project and line managers to follow-up the spent of their small projects.

As a synthesis, reported intentional distortion of the actual cost of project can be listed as follows:

- Difficulty to be efficient 100% of the time
- Memory issues
- Re-estimation and approximation of what has been spent
- Complexity of activity codes and confusions
- Non-user friendly system in which everything is done manually

5.5.2 INTENTIONAL

Unfortunately, not all the distortions of time reporting are unintentional. At some stages, individuals, whatever their position, from top management to engineers, can deliberately decide to falsify the actual costs of projects. Of course, as it has been said previously, the behaviors described in this section are not generalizable to all the employees of the department. Several respondents have clearly stated being against intentional distortion of actuals, where others shared using them in specific circumstances. This report does not aim to quantify the occurrence of such actions, but results from the interviews provide an initial scale of the problem. While most of respondents were in the same line by saying that memory issues and confusions were frequent within the department, their judgment on the frequency of intentional falsifications varies from individual to individual. Some commented that these behaviors occurred as frequently as the unintentional causes. Others said that intentionally providing wrong time reporting happened, but not that often. In general, line managers having declared using these practices estimated that their distortions are limited within 5 to 10% off of the real time they spent on a project in a year. Why such practices are in use at all organizational levels? What are their effects on the cost estimation process?

It has been reported that engineers, due to the previously described tediousness of time reporting and their important amount of activities, tend to take shortcuts. Part of the project and line managers, having started their career as engineers, could comment that they used to perceive budget and administration activities as boring and uninteresting. Therefore, being forced to enter each activity code manually in a non-user-friendly system, investing up to 30 minutes to perform a presumed boring but necessary task, having troubles to remember their spent and to find the correct codes to report on, all contribute to the fact that engineers naturally tend to neglect time reporting activities. Their core function is to design and deliver components and in that regard, they may not want to be bothered by tedious tasks and may simply take the decision to report most of their hours in the project having the biggest budget. Besides, engineers usually work on a certain amount of small-scale projects in which they do not have big budgets. This gives them very little contingency margins and when they run into technical problems and deviations, they may decide to continue working and report their hours in a bigger project. Thanks to this, engineers are able to avoid time consuming and uncomfortable discussions regarding their small projects at the cost of an intentional distortion of actuals. This issue is often noticed by the concerned project managers, but quite often they do not have possibilities to apply corrective actions:

> *"First, you see that a group is overspending and when you question, maybe they'll say 'but we haven't spent that much'. Then it's another function that spent money on their account. But then it's too late, then it's already spent."*

Some respondents described engineers' intentional distortions of actuals as following a similar pattern year after year. They explained that in general, engineers would tend to report a lot of hours on projects having large budgets in the first half of the year. Then, within the last three months, when the budgets of large projects are consumed, engineers intend to

spread out their time reporting among the smaller projects of the department. To illustrate this point, a line manager showed a document used to track the spent of his teams. Before the middle of the year, he explained that they already spent 70% of the yearly budget allocated in their biggest project, while several of their smallest projects' budgets were not consumed at all. He further added that the activities to deliver for these small projects were in progress, but it was simply that nobody was reporting on them.

As said previously, engineers are not the only one responsible for intentional distortions of actuals. Respondents interestingly mentioned that there is a belief in top management that projects should absolutely not overspend. These situations are considered to deteriorate projects' profitability forecasts and to prevent the department from starting new projects. With such concerns, it has been reported that top management sometimes requires the whole department to stop reporting on a specific project and to report on maintenance instead. This way, profitability forecasts remained seemingly interesting and everyone involved in the project could continue working on their deliveries.

It has been mentioned from several respondents from the line organization that project managers and chief project managers also sometimes advise intentional distortion of time reporting. When a project manager has 5 to 6 projects, he knows by his follow-ups, which projects are in a good state and which are suffering from budget troubles. In that context, and for the same purpose as top management's, namely avoidance of overspending, project managers can ask their line managers to report on another project which do not suffer from budget issues. As for the chief project manager, being responsible for the overall cost of a project and being the only actor reporting and requesting budget increases to top management, makes this employee the most exposed actor to the strict reactions described earlier. In that regard, chief project managers refuse to present requests of budget increase due the important frustration to be involved in such discussions and advise their project team to perform wrong time reporting.

This belief that overspending is unacceptable coupled with top management's desire to push for efficiency has been shown to influence distortions of estimates in 5.4. As a matter of fact, it is sometimes for the exact same reason that line and project managers take the decision to distort the values of the actual cost of the project. Indeed, when they are about to overspend, line managers have two options, as expressed by the following:

> *"To complete the year, regarding the deliveries that we have to do, we may be short in hours. How can we do? Should we discuss with the project manager if we can overspend and let him do the balance between the [function groups]? Or should we by ourselves decide to spend more time on product maintenance codes? "*

This line manager further explains that most of the time, he prefers to overspend but by making this choice, there is a risk that the project manager is actually unable to transfer budget from another group. In that case, this line manager's teams would be forced to stop working on the project until a budget increase is obtained. To avoid overspending and the struggles of requesting budget increases, line managers can alternatively ask their engineers to

report on projects where the budget is unused. On the one hand, respondents described that requesting additional budget involves more discussions, more justifications, more explanations, and takes more time and effort. On the other hand, they commented that falsifying their time reporting is fast and can solve problems in both a project that is overspending and another one that is underspending. As a complementary justification, line managers add that their decision to influence time reporting helps to compensate the unintentional and intentional distortions originated by their engineers. Complaining that their employees tend to report too much on the bigger projects, line managers would try to react and rebalance the situation by influencing the same engineers to wrongly time report on the smaller projects as well. This creates layers of successive influences and distortions of what is supposed to be the actual costs of projects.

These behaviors are not only in use to cover overspending situations. At times, due to reasons previously explained, line managers accumulate too much buffer in a project. Being about to underspend, they use the opportunity given by their collected buffer to distribute their time reporting and artificially respect their budget targets in several projects simultaneously: *"As a group manager, I try to see if I can balance my buffer across all my projects"*. This cumulative use of distortion of both the estimates and the actuals can be extremely convenient for line managers to be seen as accurate and efficient individuals. Indeed, being able to respect their budget frames allows line managers to both preserve their reputation and avoid pressure from top management. This fact was already given as a reason for distortion of estimates in 5.4. Actually, distortion of actuals can serve the same purpose, as illustrated by the following:

> *"You avoid a lot of hard discussions if you're actually showing that you're doing a good job, and you have better career possibilities. There are more drivers to fix the numbers than actually to be honest and have the possibility to learn. Then you need to have that culture in the company to encourage learning instead of punishing someone."*

Besides, as explained for the distortions of estimates, line managers are also able to secure their resources for the coming year by falsifying their time reporting. Indeed, every year, resources are reallocated among the different groups of the department. If a group has been underspending, it is interpreted as if part of its resources were under loaded. As a result, at the term of the reallocation, this group might lose engineers or consultant in favor of others. To cope with this resource issues, line managers can deliberately take the decision to overspend by influencing their engineers' time reporting. This way, they are able to show that they fully used all of their resources and increase their chances of securing them for the next years.

Another instance that has been commented to potentially influence the time reporting of employees is the requirement to report at least 40 hours of work per week with an overall ratio of billable hours of 90%. Everyone in the department spends non-billable hours, such as meetings or budget activities, but if the ratio of these hours is too high, then managers could

react and warn their subordinates. In that regard, some employees could intentionally make sure that their time reporting respects this ratio.

As a synthesis, reported intentional distortion of the actual cost of project can be listed as follows:

- Negligence of budget activities and shortcuts taken by engineers
- Intents to cope with shortcuts taken by engineers
- Avoidance of overspending
- Avoidance of frustrating discussion
- Request from other stakeholders
- Simpler and faster resolution of budget issues
- Reallocation of buffer from project to project
- Resource securement
- Requirement in terms of minimum billable hours

5.6 ORGANIZATIONAL LEARNING

5.6.1 LOG AND TRACE OF HISTORICAL DATA

Starting from the project initiation and until its termination, the cost estimates and reported working hours from the existing projects, are supposed to be stored and updated into a project cost and budget management system by project managers at each gate along the product development process. Whereas, it is advised by the project managers that the cost estimates changes and evolution should be stored in the same template utilized during the cost estimation process. In the template, there should be some folders for each gate and one folder for tracking the changes between each gate, which is done nowadays via email without any documentation for it.

After the conclusion of project, there is project data storage system, where all the relevant documents should be uploaded and an experience summary document should be compiled by each project team. The experience summary document, will be documented by the chief project manager with assistance of project managers with all the positive and negative experiences, as well as recommended proposals from all team members in the entire project. Later, the experience summary document will be reviewed together the chief project manager and target groups, and further distributed to top management and other concerned stakeholders. The intended purpose of such experience summary document is to offer possibilities for the later project teams to learn from the mistakes and successes of previous projects, in order to better implement future projects.

Regarding knowledge transfer among projects, it is considered as inconvenient and time-consuming to utilize the incumbent project data storage system for miscellaneous reasons. First of all, the project data is deemed as confidential in the organization. As a result, no explicit searching is supported by this system; the only way to search for some project is

through its project identity. Whereas, in most cases, it is impossible to know the project identity in forehand, either some target project is embodied in some large-scale project. Even if the target project is found, sometimes, the previous cost estimates could be difficult to abstract from all the documents, or omitted to storage in the system. Subsequently, comparing to the benefits and the time devoted in searching, it is considered generally by project managers as no added-value to do so.

Moreover, the facts collected from interviewees indicate that the current organizational learning in the global organization is not as desirable as it was intended to be. Most of the interviewed project managers, they do not deem it worth time-spending to search and refer to the historical data. Only few interviewed project managers eventually spending more time on searching in the project data storage system and exploiting the historical data from previous projects. As they said, "There is lot of bureaucracy that breaks your interest (to search for the historical data)." More than 50% amounts of the project managers do not browse nor store any project document into this system. They either preserve the project documents on their own computer, or only store in their own team document system at local servers with limited access right. Or, even if the data and experience is documented to it, in fact, only the success story will be highlighted, rather than truthful descriptions with both successes and failures. Yet, as advised by some project managers, they can learn and benefit on a massive scale from other project's failures; and there should be a procedure in the cost estimation process to check the project summary document from some similar projects before conduct the cost estimates.

At the line management side, most of the interviewed line managers will not search and refer to the previous project data and experience, nor do they store the accomplished project data to this system. Some line managers deem it is not feasible to share such documents, since they think it is mostly irrelevant with other team or department without involving in this project.

On the other hand, the current knowledge transfer among projects is mostly done individually based on personal working experience or transferred among individuals or within their teams as tacit knowledge, which incorporates both the official professional knowledge in project management, i.e. the experience and actual data from previous projects; and the unofficial knowledge, i.e. how to take the some shortcuts and some political behaviors in balancing with the time reporting and budgets, etc. Both these two kinds of knowledge should be appreciated as very valuable intangible assets in line with tangible assets of project deliverables. However, unfortunately, neither of them is properly documented and stored in an easy-to-use manner; nor some falsified data derived from the political behaviors could be traced or corrected to avoid further misusages in forthcoming projects.

Having advised from both project and line managers, they should surely consult the data from previous or existing projects to assistant with cost estimation. And a data storage system is advised by many managers, which should be easier to access, and with structured categories of projects or design components. Thus, some database with previous project data is under construction at one site, in which the projects are categorized into different categorizations.

During the entire project, they will update and store their estimates and reported working hours at three specific gates, which reveal a full picture of the cost estimation evolvement.

5.6.2 USAGE OF HISTORICAL DATA

Given the recent introduction of the usage of historical data is substantially exercised and reinforced. The philosophy of these comparisons is basically by reviewing and investigating the cost estimates and reported working hours and other costs from similar projects, the cost estimates for current project can be better performed with higher accuracy. However, the primary concern from project managers is that, at present it is difficult to find the "similar" projects or corresponding components to compare with. Mainly for the reason that, neither the exactly same project will be implemented again, or the ways of working and cost estimation process vary a lot among different sites globally. Also, the incumbent project data storage system is not applicable or user-friendly for data tracking. Instead, these comparisons are still conducted by project managers for the most part based on own experience from previous projects. This is deemed as not in a scientific or systematic way by project managers, and it does not essentially differ from the current cost estimation manner in practice without historical comparisons. In this sense, the preliminary prerequisite to implement these comparisons properly is to have the historical data from pervious project stored and categorized in a systematic and easy-to-access way at each site.

Furthermore, some other suggestion from project managers is that it should be the line managers' responsibility to perform historical comparisons, due to that both the cost estimates and reported working hours are initially provided by them based on their engineering tasks. It is also advised by project managers that some more transparency is needed from the line. However, it could be quite controversy that the safety margins added by line management should be visible to project management and officially accepted by top management. As this safety margin is inevitable in regard with uncertainties and risks, the better acceptance to it could eventually mitigate the political behaviors and corresponding distorted project data, which will benefit the organizational learning in a long-term perspective. In contrast, the current situation is that both the cost estimates and reported actual hours are in an opaque status, which makes the possibility to learn from previous projects a very small chance.

More importantly, the accuracy of the cost estimates and reported working hours in storage is very important to the effectiveness of historical comparisons as well. For some instances expressed by project managers, in the case of some experienced projects, it is possible for them to distinguish the distorted records from any political behavior in the storage; however, if they did not participate in the project, it would be misleading when referring to the previous project data. Yet, having the distortions form previous data taken consideration, it is still believed by most of project managers that, in long-term perspective, it will be more accurate and beneficial, given more references from similar projects by gradually constructing the database of historical data.

6 DISCUSSION

This chapter contains discussions regarding the investigation led throughout this research. It begins with a comparison between the present findings and previous related studies, in which several minor distinctions in interpretation are presented. Then, the authors question the validity of their hypothesis concerning the proposed analytical model of this report, before elaborating on the conditions required for the studied department to implement a beneficial organizational learning and improve cost estimation accuracy. This is followed by the authors' recommendations and the presentation of two alternative options which possibly could help the studied organization to improve its cost estimation practice.

6.1 INFLUENTIAL FACTORS AND DISTORTIONS OF COST ESTIMATES

As explained in 2.5, Magazinius et al. (2012) found that not only cost estimation practice was affected by cognitive and unintentional factors (Aranda and Easterbrook, 2005; Jørgensen and Grimstad, 2008), but that there was a set of conscious and intentional motives justifying distortions of estimates. As a matter of fact, the findings issued from the present study confirm previous authors' conclusions. Even though semi-structured interviews are not the most adequate method to test the existence of cognitive and unintentional factors, respondents of this study mentioned that their cost estimates could be inaccurate due to the fact that estimators might have been too optimistic, that they misunderstood the project prerequisites, that they omitted to think about a certain task or simply that they did not have enough experience. Further, respondents explained using the values of initial cost estimations as a reference to build the first project cost estimation. The authors of this report consider this to lead to unintentional distortions and this, due to three different reasons. First, values given by initial cost estimations are actually used by the company to perform profitability forecasts and to support project selection decisions. In that regard, they are not development-oriented and might be affected by behaviors non-covered in the present study. Second, respondents commented that, being often based on a few sentences of description, such estimations were made very quickly and roughly. Hence, initial cost estimations certainly include errors. Third, it was also reported that the estimators performing initial cost estimations are also responsible to re-estimate the same projects a few months later. The authors of this study therefore argue that initial cost estimations have potential effects, similar to the "irrelevant and misleading information" described by Jørgensen and Grimstad (2008) in their experiments. Indeed, initial cost estimation values are both not neutral, as they are performed and re-used by the same estimators, and are not entirely relevant, as the very poor description given requires a lot of interpretation from estimators who, in return, provide rough and quick estimates. Aranda and Easterbrook (2005) argue that anchoring and adjustment act as a cognitive bias in cost estimation. In that regard, initial cost estimation clearly has the potential to unconsciously

affect and mislead estimators' conclusions and this is obviously the case for each of the other cost estimation updates performed along the company's product development process.

Intentional distortions of cost estimates have mainly been introduced to be related to political tactics (Magazinius et al., 2012; Magazinius and Feldt, 2011). Magazinius et al. (2012) introduced the issue called "disregarding uncertainty", which corresponds in this report's findings to the intents from estimators to compensate with "unforeseen events, deviations, test failures and scope changes". "Disregarding uncertainty" reflects to the intentional choice of the company to use point estimates instead of intervals (Magazinius et al., 2012), and are described by Magazinius and Feldt (2011) as political tactics that include "expectations that estimates will correspond to actuals" and "the uncomfortable discussions" about budget deviations. The authors of this report adopted a distinct interpretation regarding this specific issue. First, the company's will to require point estimates instead of intervals has not been questioned. Second, "disregarding uncertainty" or intents from estimators to compensate with "unforeseen events, deviations, test failures and scope changes" were not perceived as being issued from self-interest incentives. Third, although the present study confirms Magazinius et al.'s (2012) findings that "top management tends to expect that estimates will correspond to actuals" and that there are "uncomfortable and frustrating discussions", both these issues have not been associated to "disregarding uncertainty". Instead, they have been classified and interpreted as being part of the root causes leading practitioners to distort their estimate to "avoid overspending". However, even though there are several distinctions in interpretation regarding this particular issue, in line with Magazinius et al. (2012) and Magazinius and Feldt (2011), the authors of the present study argue that the company should not disregard uncertainty. In that regard, a discussion around two alternative solutions is proposed in 6.5.2 and 6.5.3. It is also important to emphasize the distinction between political and non-political distortions. On the one hand, intents to cope with "unclear requirements" and "unforeseen events, deviations, test failures and scope changes" are not considered to be political in nature. On the other hand, any intentional distortion induced by the following reasons are qualified as political: "reduction of the workload"; "challenges and pressure pushing for budget reduction"; "Anticipation of pressures from other stakeholders"; "Avoidance of overspending ;"professional reputation"; "avoidance of frustrating discussions"; "Resource securement"; "Facilitation of the acquisition of approvals". A last distinction between previous and the present investigations concerns one of the reasons for intentional distortions mentioned by Magazinius et al. (2012), where estimates were found to be intentionally distorted due to the fact that estimators could plan to "hide activities" of smaller projects in bigger project or to hide the development of "additional functionalities". While "hiding activities from project to project" is later discussed in 6.5.1, "hiding functionalities" has not been explicitly mentioned by respondents of this investigation.

To sum up, the results obtained throughout this study regarding distortions of cost estimates were in line with those obtained by Magazinius et al. (2012) and confirmed the existence of two levels of distortion of estimates. In that regard, the first half of the analytical model presented in 2.5 has been adjusted to the findings of the present investigation, taking into account all the considerations enunciated in this section, as follows in Figure 17:

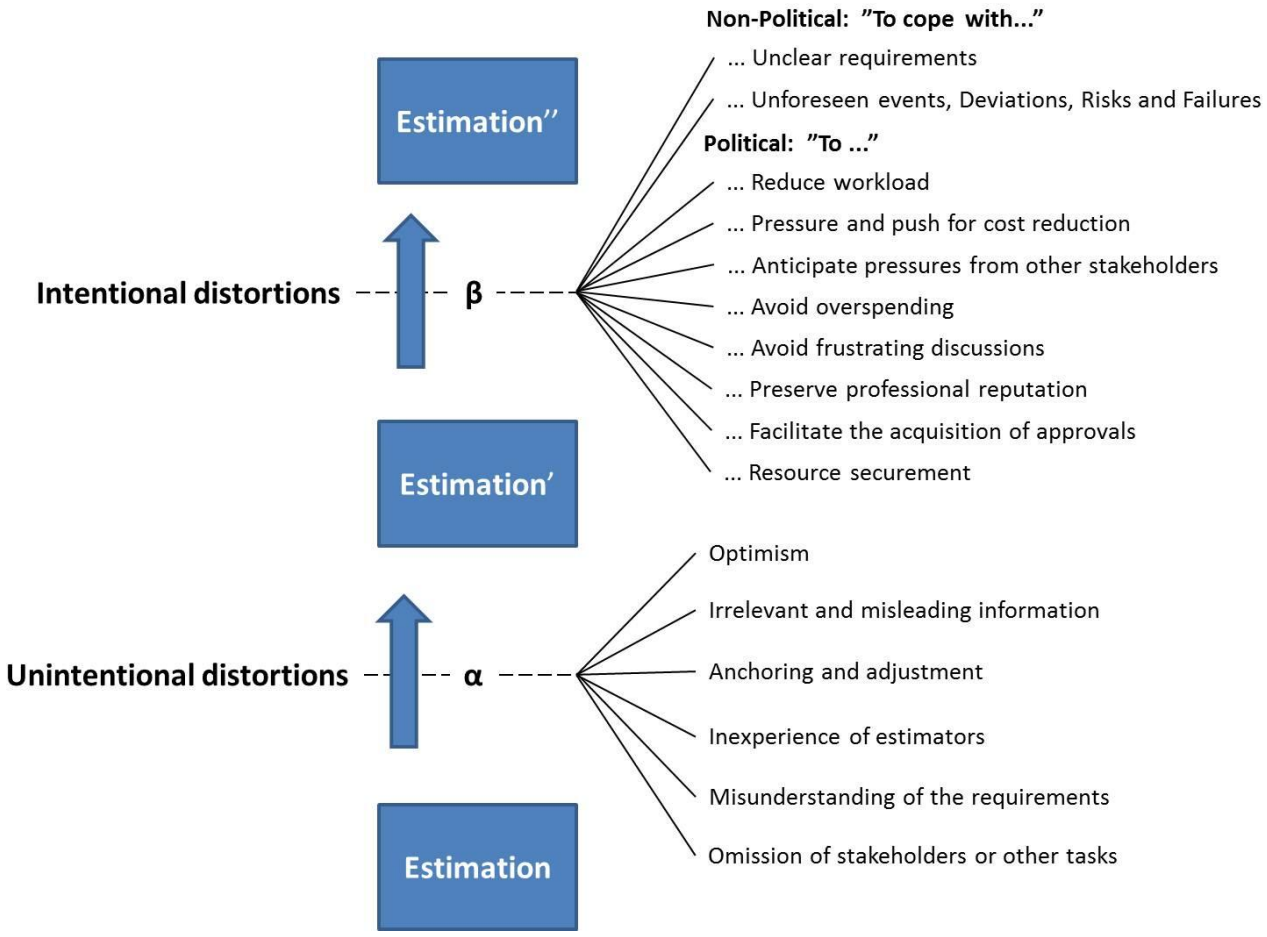


Figure 17: Analytical model for the distortion of estimates

As explained in 2.5, the value of **Estimation** is the theoretical value of estimates not being affected by unintentional and intentional factors. Having access to such a value would not increase cost estimation accuracy as such, but would allow estimators to objectively improve over time. Unfortunately, the presence of α and β distorters hinder cost estimation practices, as the former are unconscious and the latter are not traced and registered. As a consequence, estimators provide **Estimation''** to project managers, but later, even themselves do not remember the value of **Estimation'**. The authors of the present study argue that non-political β distorters are necessary in the cost estimation process and that their existence allows the company not to fully "disregard uncertainty". However, these distorters are often badly perceived by top management who usually push for efficiency and cost reduction.

6.2 ASSESSMENT OF THE HYPOTHESIS

In the section 2.5 of this report, the authors formulated the hypothesis that, what has been extensively studied and discussed regarding cost estimation practice (Lederer and Prasad, 1995; Magazinius et al., 2012; Magazinius and Feldt, 2011), could be applied to the activities used by the company to track the actual costs of their projects. In other words, are the reported actual costs of projects affected by unintentional and intentional distortions? This hypothesis was motivated by the intent from both authors to address the topic of cost estimation accuracy in its whole, the term "accuracy" implying a comparison with a reference value. Additionally,

it was inspired by Magazinius and Pernstål's (2008) explanation that "the tracking of the actual project cost is incomplete, leading to difficulties in comparing them to the estimated costs". In that regard, an analytical model was suggested and its validity has been addressed during the investigation. As mentioned in 4.2, to determine the actual cost of projects, employees involved in projects, might they be engineers, project managers or line managers, are responsible for reporting the time they spent on project activities in the budget administration system of the company. As a matter of fact, the present study clearly indicates the existence of flaws in the way these costs are consolidated. In the section 5.5, the authors intended to classify these flaws into two categories, namely intentional and unintentional. On the one hand, time reporting activities have been reported to be distorted by unintentional factors, such as "memory issues"; "approximations and re-estimations"; "complexity of the activity codes and related confusions"; "Negative perceptions regarding the budget administration system of the company"; "irrelevant information" and "the student syndrome and Parkinson law". On the other hand, intentional distortions of time reporting have been mentioned by respondents: "negative perception of the budget administration system"; "negligence of budget activities and decisions to take shortcuts"; " avoidance of overspending"; "avoidance of frustrating discussions"; "requests from other stakeholders"; "simpler and faster resolution of budget issues"; "Intents to cope with engineers' decisions to take shortcuts"; "Reallocation of buffer from project to project"; "Resource securement"; " Company's requirements for the proportion of billable hours to perform". Therefore, the authors confirm the existence of unintentional and intentional distortions of the actual project costs and validate their hypothesis in the particular context of the present product development department. The analytical model proposed by the authors has been validated and a summary of the mentioned distortions of actuals has been illustrated in Figure 18.

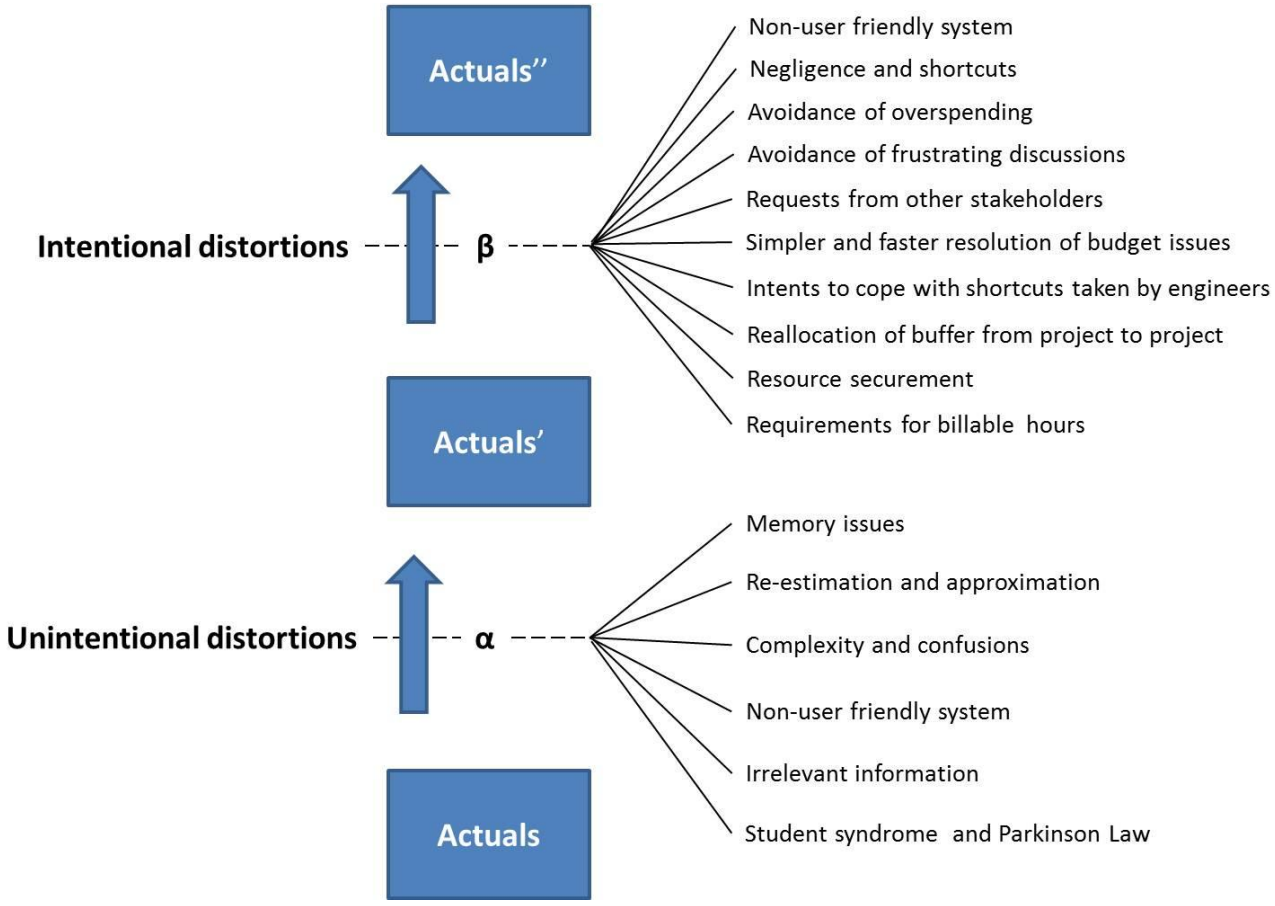


Figure 18: Analytical model for the distortion of actuals

As explained in 2.5, cost estimation accuracy is truly dependent on both the cost estimation values and the recorded project costs. In respect to Figure 19, the authors argue that accuracy should be determined by the comparison between the values of **Estimation** and **Actuals**. However, both values being affected by α and β distorters, justify the existence of errors in accuracy calculations. The problem is that such errors are exclusively attributed by the company to cost estimates. Actually, there seem to be a belief that actuals are reliable, unchangeable and reflect the true cost of a project. This belief has been proven to be wrong by the present investigation and the authors argue that while intending to improve cost estimation accuracy, practitioners should not omit to question the reference values. The reliability of actuals is actually essential for estimators to improve over time, as they explained using previous experiences while estimating new projects.

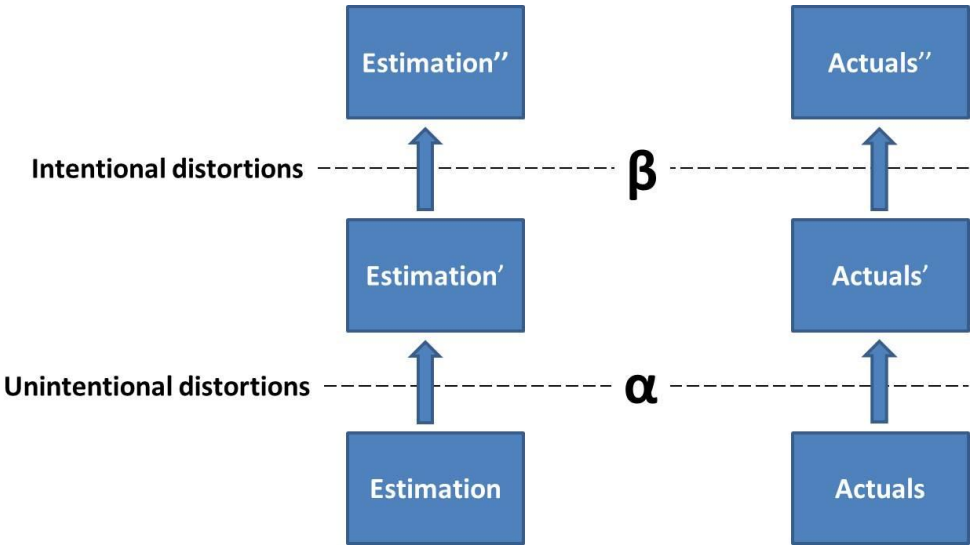


Figure 19: Analytical model

Thanks to the validation of their analytical model, the authors of the present study argue the existence of four problematic areas to be tackled separately in order to improve the accuracy of cost estimation. These areas are studied in greater details in sections 6.4 and 6.5. The following section will cover an important implication resulting from the validation of the present analytical model, namely organizational learning.

6.3 ORGANIZATIONAL LEARNING

As manifested by Argyris (2002), organizations encounter tremendous difficulties while intending to become learning organizations. This is due to their predominant focus on problem solving and single-loop learning (Argyris and Schön, 1994; Argyris, 2002). Today, in order to solve accuracy issues, the company tries to revise estimation methods and tools, disregarding the existence of **Estimation''** and **Actuals'**', and disregarding the facts that errors in estimation include errors in time reporting. As a result, as illustrated in Figure 20 below, all the efforts devoted in the single-loop will eventually be vain due to the fact that "theories-in-use" and actions seldom lead to beneficial "consequences" without any shift of "tacit guiding" (Marmgren et al., 2013). The analytical model of this study does not only suggest the need for new methods and tools for problem solving, but also requires changes in the company's governing variables. Indeed, while accuracy calculation consists in comparing actual cost of projects with the values determined from cost estimation, the results of the present study showed the existence of several steps of distortions of both estimates and actuals. In that regard, in order to become a true learning organization and improve cost estimation practice over time, the company should also revise its governing variables to get their current **Estimation''** and **Actuals''** as close as possible to the values of **Estimation** and **Actuals**, as defined by the authors' model. This will only be possible after obtaining a clear understanding of the root causes behind the presented distortions. The company must understand and comply with the underlying reasons behind the four problematic areas identified. Argyris' (2002) double-loop learning is therefore necessary to truly become a

learning organization and improve estimation accuracy. Only then, the right problem-solving actions could be implemented and could improve its cost estimation practice over time.

Figure 20: Organizational learning concepts (source: Marmgren et al., 2013, Argyris, 1999; modified)

A striking example of inefficient single-loop learning is top management's intent to increase accuracy by being stricter towards overspendings. Actions undertaken in this direction aim to preserve efficiency and to signal employees that accuracy must be improved. However, the reasons for distortion identified in 5.4 and 5.5 are not taken into account by such actions, which later lead to undesired reactions and political intentional distortions. As a result, the organization obtains the values of **Estimation''** and **Actuals''**, and even estimators themselves do not remember this and therefore are unable to learn from their past mistakes.

To sum up, the current use of historical data aims to improve future cost estimation accuracy, but as discussed in this section, the outcomes of these implementations are still questionable. As long as problem-solving actions do not take into account both α and β errors, initiatives for learning will not have beneficial effects. The authors of the present study therefore advocate double-loop learning and suggest a set of recommendations for each problematic area in the next section.

6.4 UNINTENTIONAL CAUSES OF ESTIMATION INACCURACY

Unintentional causes of estimation inaccuracy have been proven to exist in both estimation and time reporting activities. How can such challenges be addressed by the present product development department? This section focuses on unintentional distortions of both actuals and estimates and presents the authors' recommendations to improve the department's practice.

As mentioned previously, reliability of actuals is essential for the company. However, these have been found to suffer from several types of unintentional distortions, as shown in Figure 21. First, there are obsolete activity codes still being open for time reporting in the budget administration system. This "irrelevant information", added to the frequent "complexity and confusions", increases the likelihood of distortion of project costs. Respondents further stated being unable to remember exactly which activities they've been working on and the time spent on each of them. Due to these "memory issues", they often have to "re-estimate and approximate" the values they report in the system. In that regard, the authors make the assumption that the cognitive biases identified by Jørgensen and Grimstad (2008) and Aranda and Easterbrook (2005) could affect time reporting activities the same way they affect the estimation practice. Second, most of the respondents addressed complaints regarding the budget administration system of the company. Due to this general negative perception, project managers, line manager and engineers generally tend to avoid using the tools provided by the system as much as they can, resulting in a complication of time reporting activities. Indeed, as explained previously, project managers do not use the feature allowing their colleagues to enter activity codes automatically in the budget administration system. This forces engineers to perform this operation manually and increases the chances of "confusion". Last, but not least, is an interesting question raised by one of the respondents: "If we work 10 hours, how much time in these 10 hours are we really efficient?" This comment is actually in line with what Maylor (2010) qualifies to be the student syndrome or Parkinson Law, explaining that the time allocated to deliver a task is often fully consumed. Cognitively, practitioners can be more or less efficient depending on the circumstances, pressure or stress, and this affects the actual amount of time used to deliver a task. How can the department tackle such issues and reduce the effect of unintentional distortions?

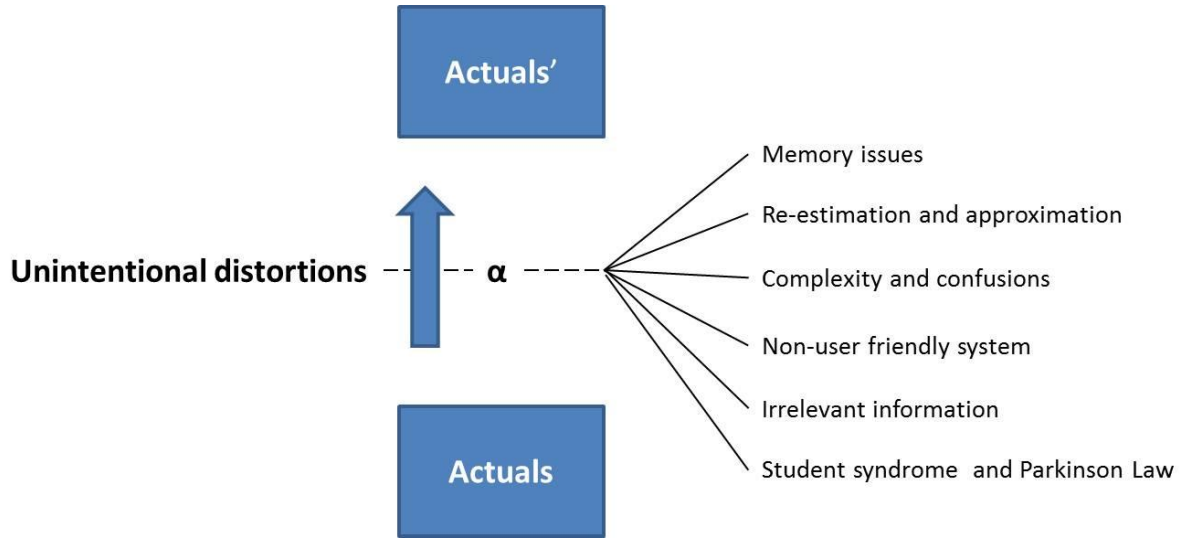


Figure 21: Unintentional distortions of actuals

Complexity, confusions and memory issues have been reported to be quite frequent by several respondents. In order to cope with these issues, the department is about to simplify the codification of small-scale projects in the budget administration system. This simplification has several implications. On the one hand, it will help employees to reduce the amount of

errors in time reporting. On the other hand, this simplification will prevent project managers to track the evolution of the actuals in small-scale projects. Therefore, this decision implies a tradeoff between traceability and simplicity. Another issue reported by respondents concerned the budget administration system itself, which is negatively perceived by most of the respondents due to its lack of user-friendliness and its long loading times. As a consequence, several employees do not use its features, making time reporting activities more complex for their colleagues. In that regard, the authors recommend the company to replace or improve the current budget administration tool, and to sensitize employees to use the specific features entering activity codes automatically. This would help to reduce the amount of errors and confusions in time reporting. Last, as previously explained, employees often do not remember the time they spent on their activities and make approximations when they report. To reduce the effects of this issue, the authors advise the company to find a way to keep track on the time spent more regularly. A problem is that engineers feel bothered by time consuming activities, some of them even reporting monthly. In that case, asking them to report daily instead of weekly would not be beneficial for the company and might not change employees' reporting habits. Therefore, the authors recommend the setup of a simple and personal timer that employees could use to record their time spent on different activities and save summaries in the form of text documents. This measure, illustrated Figure 22, could reduce the effect of memory issues.

Figure 22: Time recorder

Regarding unintentional distortions of estimates, cognitive biases have been extensively discussed previously. Estimators receive irrelevant and incomplete information at the beginning of their projects. At times, line managers found important information to be either missing or contradictory in the prerequisites document. In other occasions, they simply make mistakes and misunderstand their role in the project. Further, inexperience of the estimators and omissions also cause unintentional distortions of the estimation, as illustrated in Figure 23. How can the department reduce the effect of α distorters and improve the values of **Estimation'**?

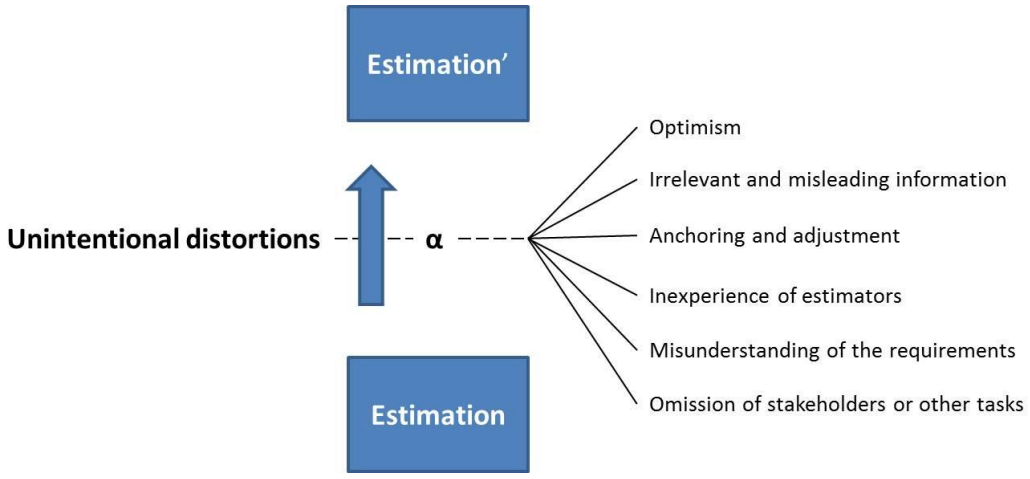


Figure 23: Unintentional distortions of estimates

In order to improve in this specific area, the authors formulated four recommendations. First, in order to avoid misunderstandings of project prerequisites and other omissions, it is recommended to improve the quality of project requirement documents. According to Jørgensen and Grimstad (2008), these documents should contain exclusively clear, neutral and relevant information. Reviewing the content of these documents and bringing clarifications upon what is requested could help line managers to estimate better. Second, it has been mentioned earlier that initial cost estimation values could negatively anchor estimators, as suggested by Aranda and Easterbrook (2005). The authors recommend that project and line managers avoid the use of these values while performing their first cost estimation after project initiation. Third, as articulated by Buehler et al. (1994) and Jørgensen and Grimstad (2005), both line and project managers responded that estimations were often too optimistic, and that early completion was seldom. In order to reduce the effects of such a phenomenon, Maylor (2010) suggests the use of the "three-point estimation", presented in the section 2.1 of this report. By estimating according to an optimistic, most-likely and pessimistic scenarios, estimators could attenuate the effect of the optimistic bias. The authors therefore recommend the use of such a method, as it also forces estimators to take risks and uncertainties into consideration. Fourth, in order to increase the amount of relevant information accessible by estimators, the authors recommend the company to improve documentation regarding the evolution and lifecycle of each project. Centralized, summarized and accessible information explaining the different issues encountered and the resulting deviations, as illustrated Figure 24, could be very valuable for next cost estimations and project executions.

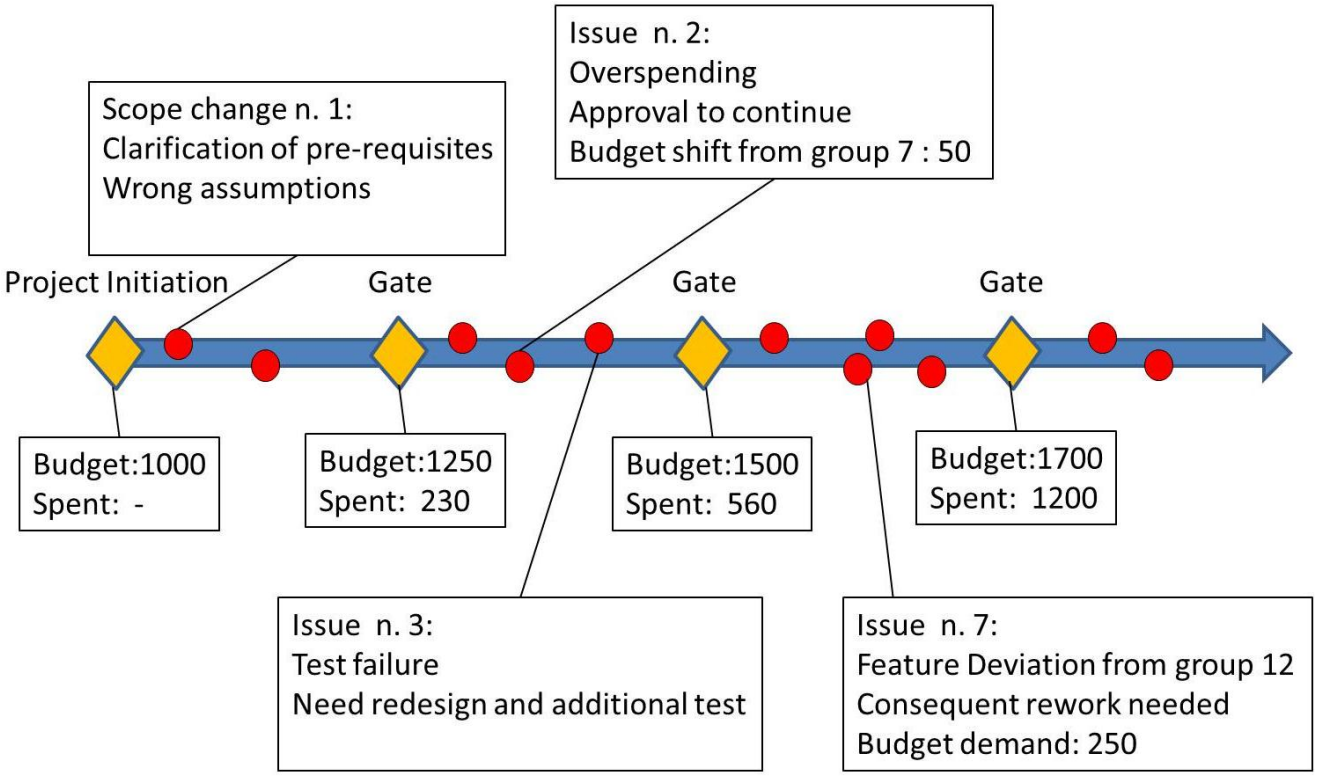
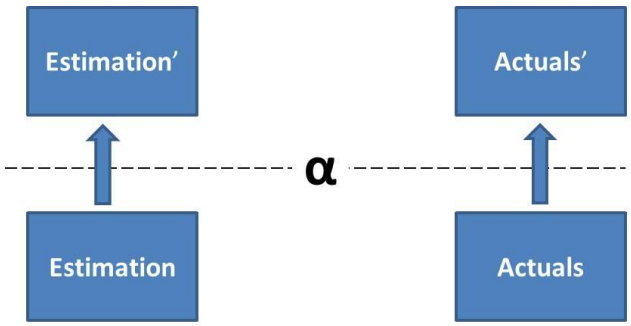


Figure 24: Summarized documentation of project evolution

Figure 25 sums up the authors' recommendations to reduce the effect of α distorters for both actuals and estimates. In the next section, a similar discussion regarding β distorters has been elaborated.



Improve clarity, relevance and neutrality of requirement documents	Simplify the activity codes
Avoid using initial cost estimation values after project selection	Improve or replace the budget administration system
Use the "three point estimation"	Sensitize employees to use the system's features
Document the evolution of projects	Setup a simple and personal time recorder

Figure 25: Recommendations to reduce the effect of α distorters

6.5 INTENTIONAL CAUSES OF ESTIMATION INACCURACY

Intentional causes of estimation inaccuracy have been found to exist in both time reporting and cost estimation practices. How can the department address intentional distortions? These two distinct areas are discussed in the present section.

6.5.1 INTENTIONAL DISTORTIONS OF ACTUALS AND ESTIMATES

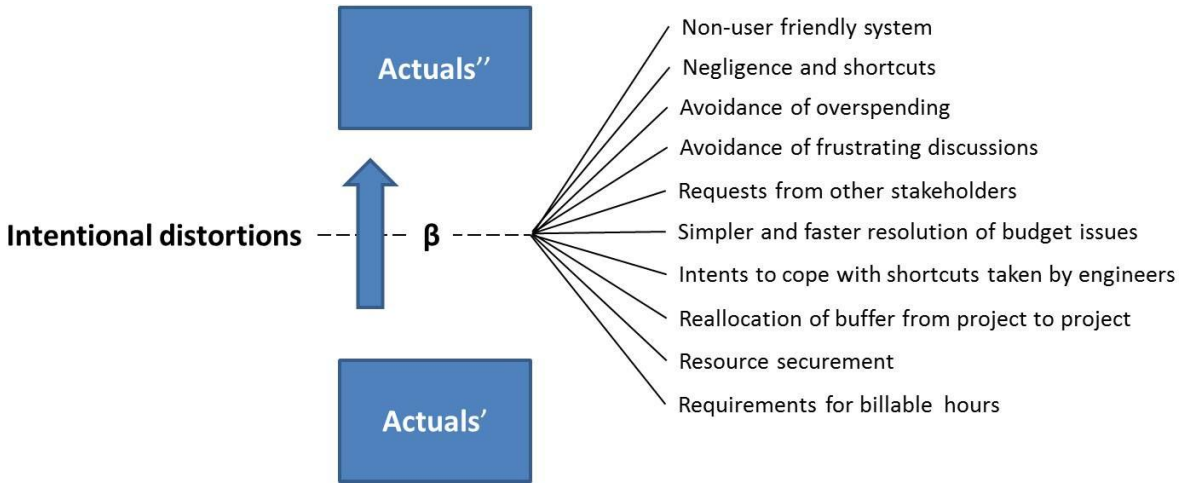


Figure 26: Intentional distortions of actuals

Regarding distortions of actual cost of projects, illustrated Figure 26, it has been reported that due to the lack of user-friendliness of the budget administration system and the negligence of engineers toward budget activities, employees take shortcuts and tend to report more hours in larger projects. Line managers further explained that in order to cope with such shortcuts, they intent to balance by asking their engineers to wrongly report on small-scale projects. In order to reduce employees' deliberate shortcuts, the authors recommend the company to improve or replace the current budget administration system, as already mentioned in 6.4. This system is actually source of both unintentional and intentional distortions.

In addition, distortions of actuals have been described by line managers, as being simpler and faster actions to solve budget issues than what has been defined in the formal process of the company. It also allows practitioners to avoid overspending, to preserve their professional reputation, to secure their resources and to avoid related frustrating discussions. These last reasons have actually been reported as causes for intentional distortion of estimates as well. Respondents explained that thanks to the buffer accumulated after their cost estimation, they had the possibility to reallocate their margins from projects to projects. This practice is very close to Magazinius et al.'s (2012) "hiding activities" factor, as intentional distortion of estimate is used conjointly with distortion of time reporting activities. Therefore it seems that both type of distortions are interrelated and need to be addressed together.

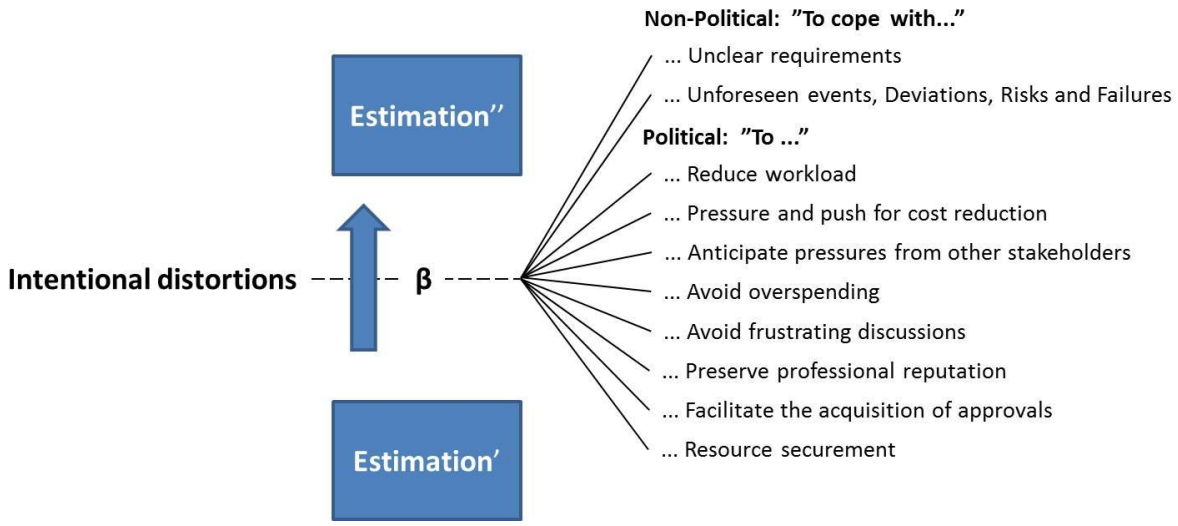


Figure 27: Intentional distortions of estimates

Indeed, as illustrated Figure 27, several of the identified reasons for intentional distortions of estimates are common with those previously mentioned for actuals. Establishing the existence of common causes for intentional distortions of both actuals and estimates is not insignificant. Some respondents mentioned having the possibility to combine both efficiently. The authors of the present investigation qualify such combinations of intentional distortions as "the two games of distortion", one game occurring beforehand, while the other taking place during project execution. Both strategies can be used jointly or separately to reach similar ends. The early game of distortion executed at the moment of the estimation has the drawback to be exposed to uncertainty and deviations, while the later game of distortion solve problems faster but is not ethical and make the reliance on historical data even more difficult. Their main distinction is that while intentional distortion of estimates can be categorized into issued from political and non-political behaviors, β distortions of time reporting are exclusively political, as they are all motived by self-interests. In that regard, how can the department address the issues presented by these β distorters?

Projects are organized following a matrix structure in which project and line managers may have conflicting objectives and constraints, requiring them to be politically astute (Pinto, 2000). Both project and line managers also have to cope with a threefold relationship with top management, peers and subordinates (Uyterhoeven, 1989). As mentioned by respondents, project and line managers frequently face top management pressures toward budget reductions. These pressures coupled with the increasingly strict reaction towards overspending are justified by the will of top management to compensate with the effects of β distorters and to increase efficiency within the department. However, the resulting outcomes are questionable. Bourne and Walker (2005), argued the existence of a murky "zone" between top and project management, illustrated Figure 28, in which there will always be counterforces acting against intents from top management to gain more control (Bourne and Walker, 2005; Sotiriou, D. and Wittmer, D, 2001). The presence of such a zone is clearly what explains the existence of β distorters. Project and line managers, being responsible to deliver their projects and components are constrained by the current command-control actions exerted by top management, and therefore react through the use of intentional distortions in

order to compensate this effect. A striking example of this can be the β distorter "anticipate pressure from other stakeholders" in which estimates are padded in case of later pressure to reduce project cost. To describe this situation, one respondent made the analogy with typical negotiations in market places. However, it seems natural that estimates should not be negotiated by any stakeholders, as they are supposed to represent the most likely effort needed to accomplish specific tasks. Therefore, Bourne and Walker's (2005) paradox of control coupled with the present results that intentional distortions in both actuals and estimates affect the accuracy of cost estimation practices indicate the existence of a tradeoff between efficiency and transparency. Top management acts to improve efficiency, but these initiative are countered by reactions inducing a loss of information and inaccuracy issues. The authors strongly recommend top management and project and line managers to recognize such a tradeoff and to avoid its implied undesirable effects. It is impossible to push for efficiency and at the same time to obtain accuracy and transparency from project and line managers. Indeed, as mentioned previously, actuals are essential for cost estimation improvement because many estimators use their previous experiences to estimate new projects. If intentional distortions are caused because top management is stricter toward budget increases and enter into frustrating discussions with their employees, then the transparency of having proper actuals will be lost and cost estimates will end up not being accurate. Top management should therefore moderate its pressure and challenges and be sensitized to the political behaviors resulting.

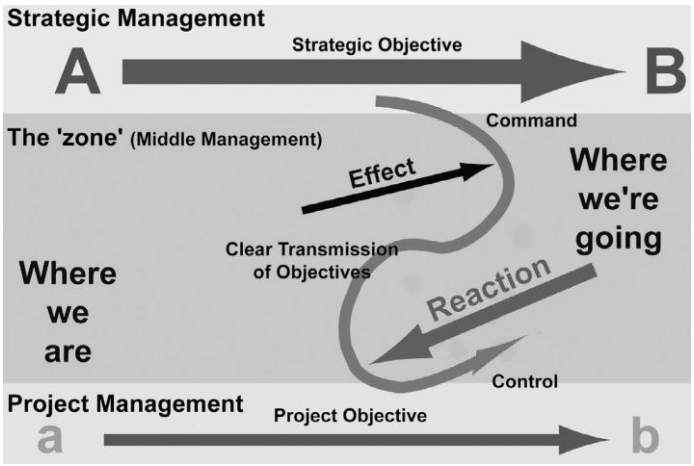


Figure 28: Effects and reactions affecting command-control (Source: Bourne and Walker, 2005)

In section 6.1, the authors made a distinction between non-political and political β distorters. While the latter have been addressed in the previous paragraph, the former are covered by the following. Indeed, estimators in an attempt not to disregard uncertainty add safety margins to cope with possible unforeseen events, deviations, failures or other scope changes. These intentional distortions of estimates are not political tactics.

Engineers, line and project managers usually work on 4 to 10 projects simultaneously. As manifested by Maylor (2010), this could considerably increase the lead-time of all projects and eventually impact cost estimation accuracy as soon as project delays occur. Indeed, multitasking implies that different stakeholders are likely to finish their project tasks at different points in time from each other. As a result, given the constant interdependencies

involved along a project, any trouble encountered by a group risks to force other groups to rework on task that were assumed to be completed. This would consequently lead to overspendings and delays. As explained by Goldratt (1997) and Maylor (2010), multitasking and interdependencies are sources of important issues in project management. These issues coupled with risks and uncertainties to face unforeseen events and failures, make the estimation practice a complex task. When projects face such problems, cost estimates become obsolete and must be revised. In that regard, the company must understand the constraints and uncertainties involved in projects and must avoid disregarding uncertainty and pushing for overoptimistic efficiency. The authors of this study, in line with Goldrath (1997), advocate the existence of non-political intentional distortions, also called safety margins. Estimators should have an explicit right to address risks and uncertainties while estimating, but due to Parkinson Law and student syndrome, these safety margins risk being wasted along the completion of project tasks (Maylor, 2010). That is why Goldratt (1997) suggests the use of the Critical Chain Method to centralize project buffers and margins. However, such a method requires all estimations to be performed honestly, overtly, and to exclude the presence of covert buffers. The authors believe that, while the Critical Chain method would correctly address non-political β distorters, it would not help the company to deal with political distortions. Today, due to the fact that safety margins are being cut off most of the time, estimators take the decision to hide these margins within their estimates of the most likely effort. As a consequence, the company and the estimators themselves lose any possibility to trace and distinguish between buffer and the estimation of the most likely effort.

Intentional distortions of estimates, unlike the distortions discussed in 6.4, are issued from individuals' self-interests. The authors categorized β distorters, as either non-political or political. One the one hand, political distortions are unfortunately unavoidable, but can be reduced through an in-depth understanding of the tradeoff between efficiency and transparency. These political distortions affect learning and improvement, as the reference values used by the company, namely the recorded actuals, are not fully reliable. The company must therefore find the right balance to attenuate the undesirable side-effects created by what Bourne and Walker (2005) describe as the paradox of control. On the other hand, as it is important to properly address uncertainty and the influential factors identified in 5.3, the authors advocate the existence of safety margins, or non-political distortions, with the condition that these margins are traceable. Therefore, the authors propose two alternatives aiming to cope with uncertainty. Either, the non-political distortions should be kept overt and traceable or covert and traceable. These alternatives are further discussed in 6.5.2 and 6.5.3.

6.5.2 OVERT ALTERNATIVE

In contrast to the current situation, where buffers are hidden by estimators, who are concerned by the risk of being pressured and forced to reduce their estimation, a first alternative would recommend the setup of an overt and traceable way of dealing with safety margins. A proper risk assessment, justifying the existence and size of each margin, would be handed-in by estimators to project managers, who in return, would make sure that these margins are registered and respected by the organization. Through such a compromise, and under the

condition of having performed a detailed risk assessment, the company would accept not to cut off the buffer requested by estimators without having an objective and critical discussion leading to a common agreement.

Obviously, as any other method, this alternative presents several implications, advantages and drawbacks. As a prerequisite, the implementation of such an overt and traceable system requires a strong revision of top management's governing variables. Indeed, top management would need to stop disregarding uncertainty, but instead, should accept the presence of non-political β distorters in the organization. In such circumstances, it would be possible to trace and distinguish safety margins from estimations of the most likely effort. In other words, the organization would have access to the values of **Estimation'** and **Estimation''** defined by this study's analytical model. Estimators and other stakeholders could therefore use this information and adapt their estimation accordingly by asking themselves: What was missing or unnecessary in their previous estimates? By being able to trace how they estimated in the past and by comparing with the issues they encountered along the product development process, estimators could improve their estimation practice in the long run. Nevertheless, this practice also present disadvantages. As aforementioned, the existence of political behaviors could justify estimators' will to cover at least part of their added buffer. There could be more incentives to keep buffers covert than to communicate and share them openly within the department. It can therefore be assumed that political β distorters would affect this alternative. Furthermore, as a tradeoff between efficiency and transparency has been identified in 6.5.1, and as this method is in favor of an increase of transparency, top management's pressures to increase efficiency could hinder this method to be implemented successfully. A balance must be set and respected or the organization would eventually remain trapped into Bourne and Walker's (2005) paradox of control. If management pressure persists, there would probably be a shift back towards covert, hidden and untraceable buffers, resulting in incapacity to learn efficiently in the long run.

6.5.3 COVERT ALTERNATIVE

The second alternative proposed by the authors would be the setup of a covert system to face the challenges of β distortions of estimates. In principle, to improve the estimation practice over time, estimators would benefit from keeping a trace of the values of both **Estimation''** and **Estimation'**. Thanks to this, they could know the size of their previous padding and adapt this information to improve their next estimations. However, as non-political and political β distorters are undistinguishable, and as top management's pressures aim to compensate with intentional distortions, it is very unlikely that estimators would communicate overtly both their values of **Estimation'** and **Estimation''** to other stakeholders. In that regard, the present alternative intends to be politically sensitive and suggests a way to perform an efficient organizational learning with respect to the distorters and influential factors discussed in 6.5.1.

This alternative suggests that estimators could be allowed to distinguish and record their buffers and dry estimates covertly. This means that they would be the only actors who could have access to this information, while the rest of the organization would only have a access to **Estimation''**. The reason behind such an alternative is that estimators are actually the only

individuals who would objectively benefit from an access to this information in the long run. Thanks to this method, they would not need to hide their buffer and lose all traceability, and could improve their estimation practice in the long run.

As opposed to the previous alternative, this one does not especially require a change in mindset from top management, but would need them to reconsider their position regarding the identified tradeoff between efficiency and transparency. Indeed, management would need to accept having information being kept covert by their employees in order to be able to preserve both the capacity to learn and improve estimation practices. This method also present the advantage of being politically sensitive and take into consideration the existence of self-interests and particular behaviors and tactics that are usually kept covered. On the other hand, approval from top management might be difficult to obtain and it might not be feasible to ensure privacy to employees within a company. Would top management respect privacy? Would they allow having buffer hidden? Could it attract more pressure from top management? As long as there is such a tradeoff, there is no optimal solution. The department must understand this tradeoff, revise its governing variables and take decisions accordingly.

Figure 29 sums up this section, intentional distortions of estimates and actuals have been discussed to hinder the accuracy of estimation and to disrupt the opportunities for organizational learning. While non-political distortions, such as safety buffer, have been advocated and two alternative solutions have been presented, the authors could not give recommendations regarding political distortions. The company must understand the implications of the existing tradeoff between efficiency and transparency.

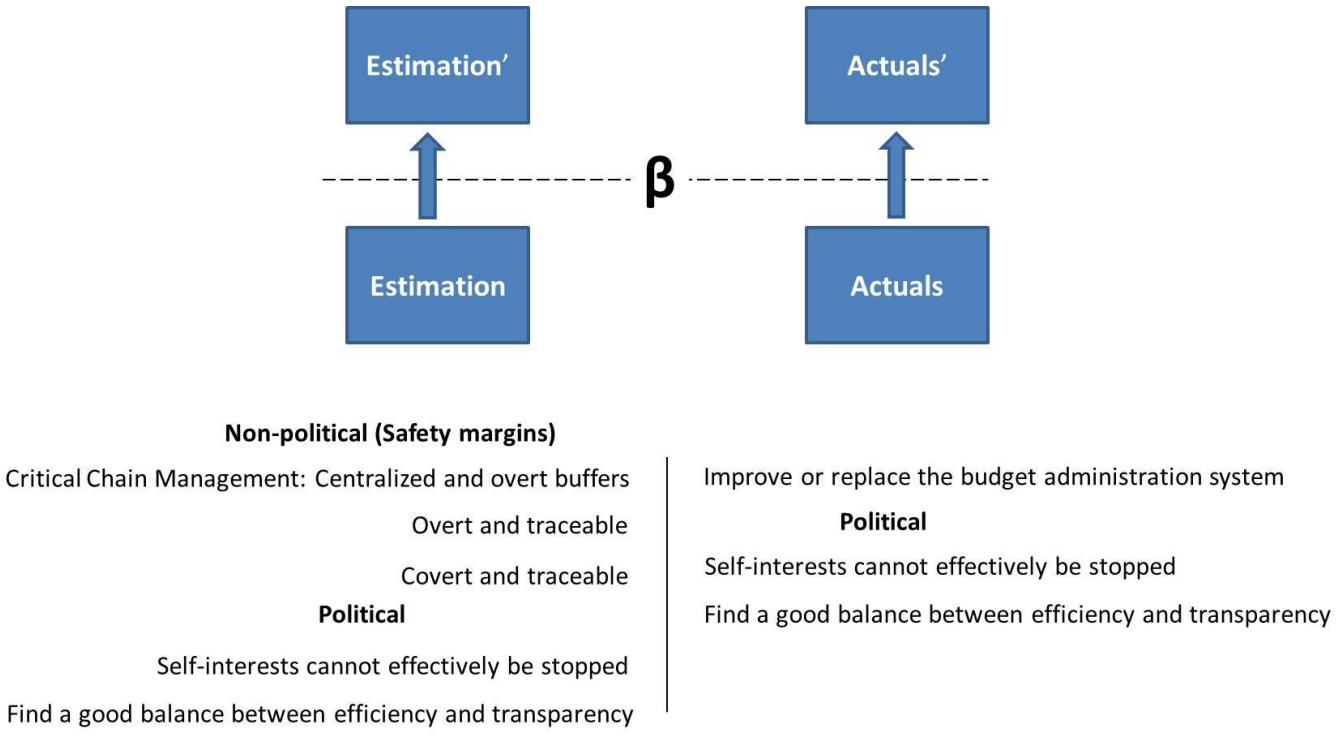


Figure 29: Recommendations to reduce the effect of β distorters

7 CONCLUSION

The purpose of this research is, first, to explore the cost estimation process in place in the studied organization, second, to identify the influential factors and distortions affecting the accuracy of cost estimates, and third, to determine whether and how the company could improve its estimation practice. Based on a theoretical framework of previous literatures, on the empirical findings of the interview sessions and on the outcomes of the discussion chapter, the present conclusion answers both the research questions formulated in 1.3.

RQ1: What are the factors and distortions affecting the accuracy of cost estimation in product development?

Inspired by previous research, the authors of the present investigation consider that the terminology "accuracy of cost estimation" requires a consideration of both the estimates and the reference values used in accuracy calculations. In that regard, data concerning both estimation and time reporting activities have been gathered along the present study.

The authors identified the existence of influential factors affecting the accuracy of estimates. Product development projects usually involve complex, interdependent and uncertain activities, and face numerous issues, scope changes and deviations. Top management, responsible for budget approvals, has also been reported to be strict toward budget deviations and to pressure and push for project cost reductions. These factors definitely affect the cost estimation practice of the studied organization. Indeed, the authors could confirm the existence of unintentional and intentional distortions of both actuals and estimates. These findings come to support the proposal of an analytical model, highlighting four problematic areas inhibiting improvements of cost estimation accuracy, each of which involving distinct types of distortions. The authors' analytical model further suggests the existence of several theoretical values of actuals and estimates, because of which accuracy calculations, when performed with distorted values, include undesirable errors.

Unintentional distortions of estimates and actuals have been classified in two categories. On the one hand, previous scholars have shown that estimators are affected by cognitive and unconscious biases at the time of the estimation exercise, while, on the other hand, the empirical findings of this report highlight the existence of misunderstandings and other confusions. Similarly, the authors later classify intentional distortions into two categories: "non-political" and "political". While safety margins can be considered as non-political, intents to anticipate pressure from top management or to secure specific resources have been categorized as political. To sum up, cost estimation accuracy in product development is

affected by both intentional and unintentional distortions of estimates and actuals, as illustrated by the analytical model illustrated Figure 30.

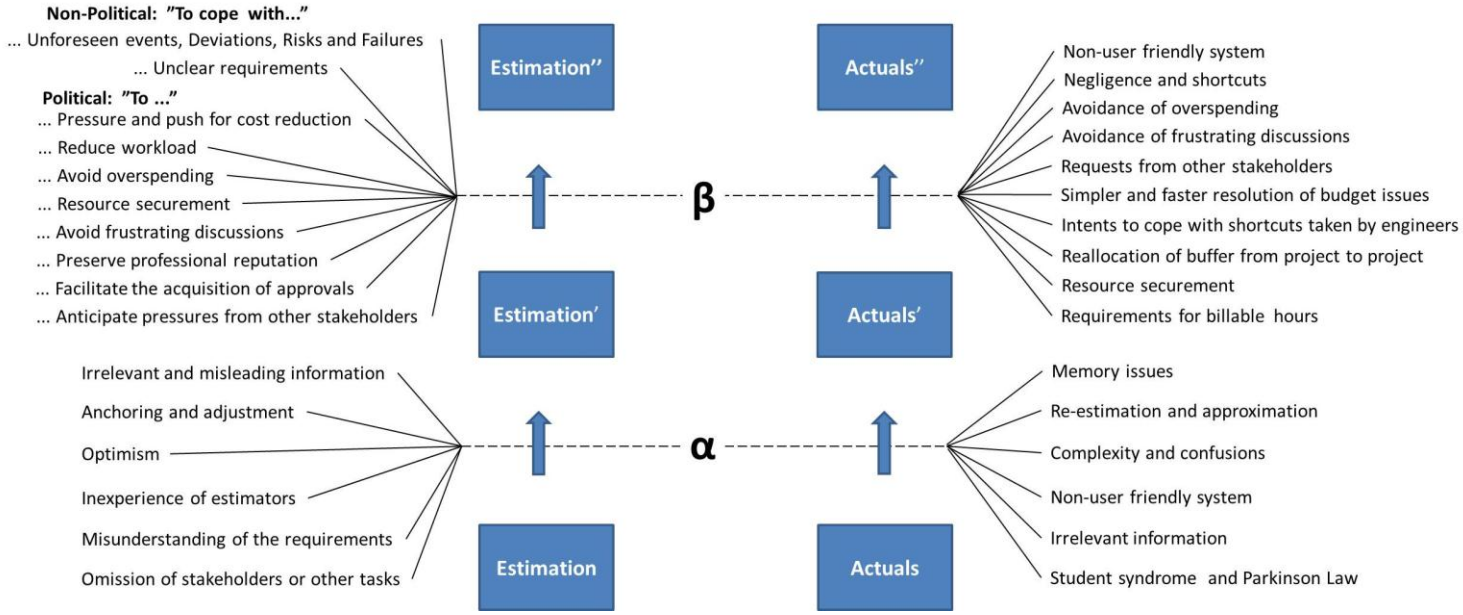


Figure 30: Analytical model summarizing all the identified distortions

The present analytical model illustrates all the identified issues affecting the company's cost estimation accuracy. Through their second research question formulated in 1.3, the authors have reflected on which potential actions could be implemented by the product development organization to address the challenges of these distortions.

RQ2: How can these challenges be addressed by the studied product development organization?

As explained in 6.3, to improve accuracy of cost estimates, the company currently implements problem-solving measures that have the tendency to disregard the influential factors identified in this report. These measures do not take into consideration the facts that, first, both estimations and actuals can be distorted, and second, that errors in actuals are usually accounted as errors in estimates. By not questioning the reliability of its reference values and by not reflecting on others of its governing variables, the company inadvertently applies inadequate problem-solving measures and do not benefit from an efficient organizational learning. The authors argue that in order to improve the accuracy of its cost estimates, the company must consider the implications given by the existence of the four problematic areas illustrated by this study's analytical model. While intentional distortions are undesired within an organization, it is of importance to properly understand the root-causes of these distortions

to be able to efficiently reduce their frequency of occurrence. As a matter of fact, intentional distortions are currently covert and untraceable. The authors argue that the company should find a way to trace and distinguish efficiently dry estimates from safety margins, but that in order to succeed, it is necessary to understand the tradeoff between efficiency and transparency discussed in 6.5. Only then, could the recommendations and alternative solutions discussed in the present report be applicable and beneficial for the company.

FUTURE RESEARCH

The authors believe that interesting research topics could be developed to further complement the present study. Indeed, being a case study following a qualitative strategy, the present investigation cannot be generalized to all product development departments of all global organizations. Nevertheless, by developing an analytical model categorizing the reasons for estimation inaccuracy, the authors intend to establish an analytical generalization (Yin, 2013). Further quantitative studies would be appreciated to assess the validity of the proposed analytical model. Indeed, it would be interesting to establish whether such a model is applicable to other companies and industries and whether the impact of each of the four problematic areas identified could be quantified.

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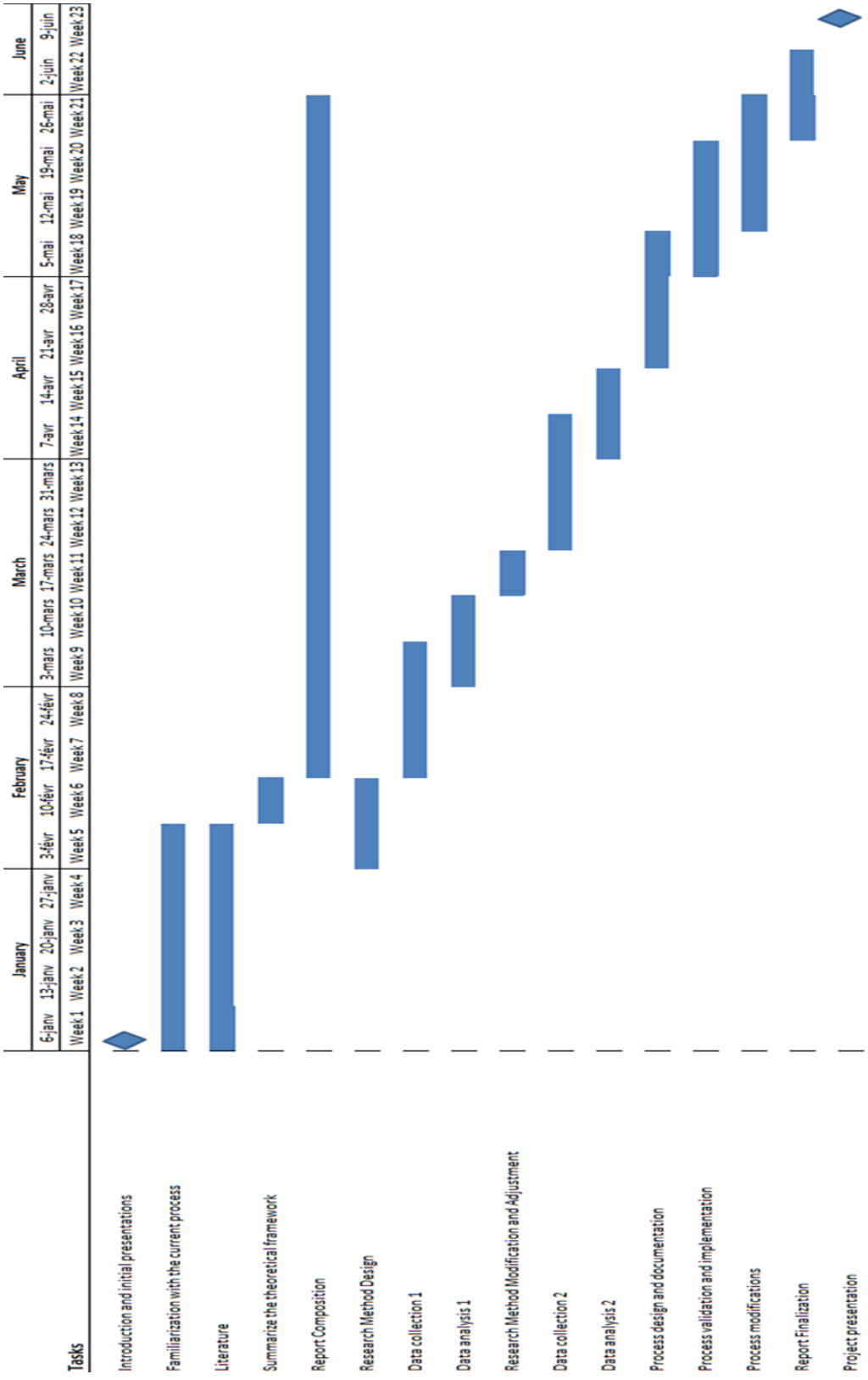
APPENDICES

APPENDIX I: GANTT CHART OF THE THESIS WORK



Draft of Interview Guide

Introduction: *Thank you very much for your time and allowing us to conduct this interview! Our overall purpose of this interview is to investigate influential factors affecting cost estimates, and the robustness and traceability, to further develop an efficient and simple cost estimation tool to support both PMs (*project managers) *and LMs (*line managers). *The interview will be kept as anonymous. We might ask for your permissions for recording the interview, but only for our own use, which will be deleted once after the thesis work is finished.*

1. **Cost estimation process**

1.1 Can you tell us about a recent project? How did you build your cost estimates? Please explain step by step.

1.2 What are the roles of other actors related to the CE (cost estimation) process? E.g. different line managers, SMs (section managers), GMs (group managers) or engineers.

1.3 What are their responsibilities? What are their interests in relation to CE?

1.4 What are the differences in the CE process between the different types of projects?

1.5 Which instructions and methodology are defined by the department regarding cost estimates?

1.6 Do you follow these instructions for all types of projects?
If not:

1.6.1 What do you do differently?

1.6.2 What is lacking in the current methodology? How can it be improved in your opinion? Why?

1.7 What is the role of the Chief Engineer in this process?

1.8 What are the roles of the CPM and top management (TM)?

1.9 Can TM have an impact on your CE? How?

1.10 How does TM build their decision-making before approval/refusal? What are the decisive factors in their decision- making process?

2. **Possible influential factors (e.g. Pressure, responsibility, culture...)**

2.1 How exact do you think are the current estimates? Yours? Those of others?

2.2 What are the reasons behind estimate inaccuracy (over-estimation, under-estimation)? Please list out possible influential factors, and give some examples about them.

2.3 Do you think it always come out of purely technical causes (scope, components conflicts, requirements,..)?

2.4 Can the errors in estimates result from interaction with involved colleagues and/or committees?

2.5 Which other causes can affect the estimates?

2.6 What are the consequences when actuals and estimates do not match? For you? For the CPM? For the line managers? And all the involved actors?

2.7 What do you do to avoid this situation to happen?

2.8 What can be done, in your opinion, to improve the accuracy of the CE?

3. **Template**

3.1 What template do you currently use to build your cost estimate? Can you show it to us and describe it?

3.2 Why do you choose to use this template?

3.3 What are the advantages of this template? Please explain

3.4 What are the problems regarding to use this template? Please explain.

3.5 What do you think of the amount of time spent on the template

3.6 Do you use this template for all type of projects?

If not:

3.6.1 Which other template(s) do you use regarding to each type of project?

3.6.2 Can you show it to us? (and ask for any links)

3.6.3 Why do you choose them for each type of project?

3.7 Do you use any other templates as a complement? For what purpose(s)?

3.8 How do you expect the template to be improved or simplified? Any recommendations?

3.9 What are the most important features you expect from the template? (list them, and give some examples)

4. **Actuals**

4.1 Can you tell me about the latest "time reporting" you performed? How did you do it?

4.2 How are you supposed to use actuals? Both as a PM and for yourself?

4.3 Do you personally use the actuals as a reference? To what extend? Why?

4.4 What do you think are the problems with time reporting? What are the good things for time reporting?

4.5 If we would like to improve the time reporting, what do you think we should do?

5. **Log an traceability**

5.1 How do you log the history of your cost estimate?

5.2 How do you log changes concerning your projects/components?

5.3 Do you keep track on who are the responsible contacts for each specific task? How?

5.4 What knowledge is transferred from project to project? Is it shared among peers?

5.5 Would it be possible to use data from former projects? How?

5.6 What can be done to ensure the traceability of the CE?

5.7 Would you be willing to spend time on such an activity? How much?

5.8 How do you log changes regarding the scope of your projects (PM)/ component(Eng)?

6. **Dependences among projects**

6.1 Do you usually know the amount of projects sharing the same engineering resources?

6.2 How can you get access to this information today?

6.3 Can this information be useful to you?

6.4 Is dependence among project resources taken into account when estimating?

End words: *Please remind us if any parts you want to exclude from the interview. Here is our contact information, please don't hesitate to send us any follow-up information. We would like to ask your permission for some follow-up questions. Thank you very much again for your time and information!*