CRITICAL SUCCESS FACTORS IN NEW PRODUCT DEVELOPMENT PROJECTS IN A WEAK MATRIX STRUCTURE:

AN AEROSPACE CASE STUDY

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Abstract: Successful new product development (NPD) is needed for firms to remain competitive, especially for the high technology industry, where product lifecycles are relatively short. We use an empirical model to study the contribution of critical success factors on the performance of NPD projects in a high technology firm to find relationships between synergy and expertise of teams, managerial support, the use of a project champion, integrating mechanisms, and well as uncertainty's moderating effect on project performance, within the context of a matrix organization. Results show that communication and excellence, expertise, and team synergy have the greatest impact on project performance.

1. INTRODUCTION

In today's business world, the main goal of the industrial competition is developing new products (Lee, Woo, et al. 2017). Faster development of better products more efficiently is a top priority for companies all over the world (Pienaar, Van der Lingen, et al. 2019). The success of these emerging products in the current competitive and complex market depends on the response of a diverse customer base from various business and cultural environments. Therefore, new product development (NPD) strategies need to be developed to be able to effectively accomplish these goals. Competition among firms has intensified over the past three decades, particularly due to the globalization of the economy (Marzi, Ciampi, et al. 2020).

Consequently, there has been a proliferation of new products offered on the market. New product development has become an economic necessity for organizations that want to maintain a leading position in today's global marketplace. These new products constitute an important source of income, since, on average, they represent nearly 33% of the income generated by sales, all industries combined, and it is foreseeable that this proportion will continue to grow significantly in the years to come (Browning and Ramasesh 2007, Cooper 2011, Kou and Lee 2015, Cooper 2019). In the context of this competitive environment, firms must be both innovative and rapid in developing new products (Moatari Kazerouni, Achiche et al. 2011, Ulrich and Eppinger 2016).

Innovation makes up a major part of a firm's spending. For example, in 1991, research and development (R&D) spending across all industries reached seventy billion dollars in the U.S. and resulted in over 46% of profits. More recently, in a study done by Cooper and Kleinschmidt (2007), on average, 28.4 percent of annual sales were from new products that were introduced in the previous three years, and almost 57% of projects that were developed were successful on the market. In the aerospace industry, in particular, this amounted to approximately 3.9 billion dollars, with more than 90% profits (Cooper and Kleinschmidt 2007).

However, if the NPD is a critical element that can influence the competitive position of firms, it is considered a very high-risk investment. This risk is all the more important for firms working in the high-tech industry, because the life cycle of products is often shorter there than elsewhere, their obsolescence being moreover always planned (Salgado, Sanches da Silva et al. 2017, Chen and Lee 2018). Indeed, the cost associated with product marketing failures is connected to their relatively short life cycle and makes it more difficult to pay off development expenses (Glas and Ziemer 2009, Moatari Kazerouni, Achiche, et al. 2011).

In high-tech sectors such as aerospace, in order to avoid potential new product failures, firms have adopted various strategies such as innovative managerial methods. To increase new product success, firms have adopted methods to better manage the NPD process. The effectiveness of this process in terms of performance is influenced by a multitude of factors. Some studies have identified some of these factors, which are both internal and external to the firm (Glas and Ziemer 2009, Moatari Kazerouni, Achiche, et al. 2011, Jaifer, Beauregard, et al. 2020). These will be discussed shortly.

While many studies have focused on how to achieve success in NPD, few or none have given importance to the role played by a firm's organizational structure. In particular, a large number of aerospace companies have adopted the matrix model, which seems to be gaining popularity due to its great potential to manage projects (Galbraith 2008, Moatari Kazerouni, Achiche et al. 2011, Egelhoff and Wolf 2017). In this study, we, therefore, focus on critical success factors (CSF's) that contribute to performance in high-tech companies that undertake NPD within a matrix structure. Project managers of large, complex high-tech projects will gain a better understanding of what factors can help to drive the success of their projects, specifically in the context of matrix organizations. In the next section, we will talk about NPD and organizational structures, followed by a review of existing work. We then present our model, a discussion of the results, and conclusions.

2. NEW PRODUCT DEVELOPMENT

"New to the world products" are products that have never existed before. They represent a complete and radical innovation. This category comprises of the lowest percentage of all types of new products released. As for the "new product lines," they are not a technological invention on the market, but represent a set of new products never developed within a firm, which, for example, seeks to enter a new market. This category represents the largest proportion in the high-tech industry(Cooper 2011). The categories of new products titled "addition to existing product lines" and "improvement and revision of existing product lines" are two categories that use a technological concept already known within the firm. These are products that will allow the company to enter a new market or, in the case of the latter, to improve an already developed product. It is then a question of incremental innovation necessary to maintain or develop a position in a market. In terms of importance, these last two categories come in second position (Talke, Salomo et al. 2009, Cooper 2011, García-Alcaraz, Maldonado-Macías, et al. 2018).

The definition of "new products" retained in the context of this research is that proposed by Cooper "addition to existing product lines"(Cooper 2011). The particular interest in this category of new products has several reasons. First, this type of new product is more than 25% of all new product categories identified (Bhuiyan 2011, Cooper 2011); in other words, this category is large in volume and particularly affects the high-tech industry. Second, these new products are based on more defined development processes, which facilitates, among other things, the creation of performance measurement methods. Third, the life cycle of projects associated with the development of this category of new products is better circumscribed in time, as opposed to the process of developing new products in a context of pure innovation (Pinto and Pinto 1990, Cooper 2011). Finally, this last characteristic makes it possible not only to define a relatively controllable temporal research framework, but also enables us to distinguish between the projects which have been successful and those who have been less successful more easily. New product development processes can vary from firm to firm, and there is no common process standard for organizations (Crawford 2008, Lee, John, et al. 2018). However, the general steps required for the new product development processes are fundamentally similar (Ulrich and Eppinger 2016). In the context of this research, the process model serving as a reference is a generic model that highlights the different stages (of development) generally accepted by all researchers (Schilling and Hill 1998, Nihtilä 1999, Crawford 2008, Cooper 2011).

The generic process generally consists of the following phases: concept development, system-level design, detail design, testing and refinement, and production (Ulrich and Eppinger 2016).

3. NPD IN THE HIGH-TECH INDUSTRY

The high-tech industry is distinguished by a rate of new product development that is significantly higher than the average for other industries (Cooper 2019). This industry, in which product lifecycles are generally short, is characterized by a rate of innovation that is much greater than other industries, and as such, is exposed to a greater risk of failure associated with NPD, where failure is in terms of delays, and cost overruns, and/or loss of revenues to name a few sources. One classic study on high-tech products showed that a delay of six months in getting a product to market, but within budget, it resulted in a loss of 33% of revenues for the five years after market launch (Vesey 1992). If the product was on the market on time, but 50% over budget, a loss of only 4% in revenues would have been experienced by the company. Speed to market is clearly more important than being within budget. The electronic industry is a very good example of high-tech industries (Cooper 2011).

4. ORGANIZATIONAL STRUCTURE

The organizational structure adopted by a firm highly influences the success of NPD. A matrix is a form of organization structure that includes two or more dimensions (e.g., functions, products, regions, etc.) where people have two bosses (Galbraith 2008, Egelhoff and Wolf 2017). The modern concept of matrix first appeared in the aerospace industry in the 1960's, but it has its roots in the scientific management era of the early 1900's (Galbraith 2008). Fredrick Taylor first proposed the idea of functional foremanship, where he outlined the benefits of having multiple bosses. He proposed that the labor force has an administrative boss, a quality boss, a schedule boss and so on. His idea was to bring in specialist skills. However, the idea of multiple bosses was not well received because it was thought to cause confusion (Galbraith 2008). One of the earliest definitions of the matrix structure is offered by Davis and Lawrence in their classic study of 1977. They define a matrix as a "multiple commands" or "two bosses" structure where they constitute an overlaying of two or more elementary structures (Davis 1977). For example, multinational corporations have a worldwide functional division structure, an international division structure, a geographical region structure, and a worldwide product division structure as their elementary structures. However, in any of these elementary structures, authority and communications follow one primary hierarchy or structural dimension. For instance, the head of a subunit can report to a country manager and they, in turn, can report to a lower-level manager in a worldwide product division headquarters. In a matrix organization, resources are assigned to projects temporarily and while they report to a functional manager, and the project manager has greater power. Generally, project managers are grouped together under the Project Management Office (PMO) (Egelhoff and Wolf 2017).

In recent years, matrix management and organization has gained popularity due to its potential flexibility, which is lacking in conventional, single-line-of-command organizations. This flexibility allows for coordination and economies of scale, which are the strong points of large organizations (Galbraith 2008, Egelhoff and Wolf 2017).

The matrix structure is an important dimension of this study, as it is adopted by more and more high-tech firms. This structure has several advantages for projects that require a mix of competencies, such as better functional integration, which in turn requires better communication and use of human resources. However, resource sharing tends to be a source of conflict in terms of assigning priorities to activities among the departmental manager and the project manager. In other words, a matrix structure tends to increase organizational complexity since employees reporting to two or more managers may be confused as to how to manage the priority of tasks to be accomplished. This, in turn, contributes to added project time and costs.

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5. LITERATURE REVIEW

In this section, we will review the important literature that is connected to the present study. The performance of an NPD project is impacted by a series of internal and external factors linked to the firm itself (Spivey, Munson, et al. 1997). Typically, these factors can be defined as elements that influence the final objective of the product development process, as for example, leadership, resources, or customer expectations. The literature review revealed the existence of several models developed and used in the context of research related to CSF's.

Some exhaustive studies highlighted a framework in which the project teams, the tools, and the technological strategies deployed have a significant impact on the performance of the development process (Schilling and Hill 1998). The results of some studies indicate that in many cases, the integration or the synergy across the functions of the firm play the most important role in innovation success (Roberts 1979, Kanter 1985, Moenaert and Souder 1990). Furthermore, the majority of the authors consider it critical to establish high-quality communication within the project team (Cooper 1979, Souder 1989). Yang et al. found that increasing levels of project manager leadership, which enhances team relations, and teamwork significantly affect project performance (Yang, Huang, et al. 2011). However, Turner et al. have found, in a review of the literature on project success factors, that the project manager and his/her leadership style or competence is rarely if ever, mentioned (Turner and Müller 2005). Another study that looks at product development in the aerospace industry proposes an original framework that characterizes and organizes effort and time drivers in aerospace product development. The goal of the framework is to identify and support the understanding of the most relevant drivers for aerospace product development effort and time. The authors validate the final list of the frameworks' drivers through a survey assessment. The study concludes that, in additions to risks and uncertainty, technologies maturity, degree of change in design, ambiguity of requirements, functional decompositions, severity of standards, process overlapping and the variety of key stakeholders drive effort and time as complexity drivers while processes maturity, experience with technology, risk management, change management, level of trust in suppliers and team skills drive effort and time as proficiency drivers (Jaifer, Beauregard et al. 2020).

Some other studies indicate the importance of the implementation of an adapted project management structure, and the capability of getting the benefits from the lessons learned (Bessant and Francis 1997). Also, Craig and Hart demonstrated that the support of the top-management and the existence of a champion are both factors that influence the performance of a project and play a key role in its success (Craig and Hart 1992).

Moreover, a flexible process structure that can be adapted to an organization's needs for managing NPD projects can have a positive impact on the outcome of projects. Other factors, such as leadership, the role of the champion or the efficiency of the project team are positively impacted by the existence of a project management structure. In a study on the identification and prioritization of CSF's in NPD projects in biotechnology companies (as an example of high-tech industries), Salgade et al. (2017) used a survey questionnaire to assess a sample of 31 Brazilian biotechnology companies. They found that interpersonal skills/relationships of the project leader and technical skills are significant critical factors for successful NDP. However, they acknowledge that CFS's for NPD for companies from other high-tech sectors (such as the aerospace industry) may not correspond to the CFS's in the biotechnology industry (Salgado, Sanches da Silva, et al. 2017).

Cooper and Kleinschmidt studied critical success factors at the business unit level and found that the main drivers of product performance are a high-quality process, a clearly defined strategy, and adequate resources, i.e., people and money (Cooper and Kleinschmidt 2007). Cooper has established that a firm's technical and marketing activities are critical (Cooper 2011). Furthermore, if the availability of qualified human resources is combined with the availability of financial and material resources, the probability of project success increases significantly (Emmanuelides 1993). Other models highlight factors such as those related to the market, customers, or competition, external to the organization that affects NPD project performance (Zirger and Maidique 1990, Cooper 1994). These external factors involve a certain level of uncontrolled influence independent from the CSF's.

In a study on the role of product, market and organizational characteristics on NPD, the authors have devised a structural equation model that links three CSF's for NPD. Their model covers market, product and organizational characteristics (as independent variables) and benefits gained by customers and companies (as dependent variables). They found that the best way to increase profits is for the company to guarantee the benefits for their customers, because the relationship between these variables is statistically significant and not significant with others (García-Alcaraz, Maldonado-Macías, et al. 2018).

Toor and Ogunlala found that on the traditional measures of time, budget, and meeting specifications are no longer applicable to large-scale public sector development projects (Ogunlana 2010). They found that other performance indicators are gaining importance, and these include safety, efficient use of resources, effectiveness, satisfaction of stakeholders, and reduced conflicts and disputes are increasingly becoming important.

Milosevic and Patanakul studied firms that make use of standardized project management (SPM) in high-velocity industries (Milosevic and Patanakul 2005). They found that increased standardization of some project management factors, a standardized project management toolbox and/or a standardized but flexible process can improve project performance.

In the aerospace industry, the high uncertainty levels make it difficult to plan activities with the required accuracy. In a recent study, the authors explore uncertainty evaluation issues in NDP in the aerospace industry based on existing research papers and ongoing experience where they examine complexity drivers regarding the features and issues of aerospace projects and successfully introduce an integrated evaluation and measurement approach of uncertainty and complexity with a focus on planning improvement. Then the authors go on to illustrate this measurement method via a case study from a major aerospace project, which helps to understand the introduced method. The study concludes that the determinant effect of uncertainty and complexity factors on project performance necessitates the integration of these factors to improve the accuracy of project planning in NDP (Jaifer, Beauregard et al. 2017).

In a recent study by Cooper, the author classifies success factors from a wide variety of research studies into NPD performance in the industry. The paper identifies three categories of success drivers. One category encompasses the success drivers which explain the success of individual new-product projects and capture the characteristics of new product projects, such as certain executional best practices such as building in voice-of-customer, doing the front-end homework; and adopting a global orientation for the project. This group also includes the factors that correspond to the nature of the product itself, such as a compelling value proposition. A second category includes the drivers of success at the business level and consists of organizational and strategic factors, such as the business's innovation strategy, how it organizes for NPD, leadership and climate and culture. Finally, the third category of success divers identified in this study is the systems and methods that a company incorporates for managing NPD. Gating systems, agile development approaches, and ideation methods fall into this last category.

The article outlines some 20 success drivers and their managerial implications (Cooper 2019).

Despite the fact that the various studies described highlight some specific factors more than others, researchers agree on the existence of a large number of factors that affect NPD project performance. The literature review shows that there are management factors that include elements such as communication, management structure or system, activities and leadership, as well as factors that group together with resources such as information, human and financial resources (Spivey, Munson, et al. 1997, Cooper 2019). Sicotte studies the impact of CSF's, integrating mechanisms, and communication as a moderating variable, on the performance of NPD projects (Sicotte 1996). In this study, there was no particular consideration of the organizational structure within the projects, rather the focus was on innovation with communication as an important dimension of development activities. **Table 1** presents a synthesis of previous studies and a meta-analysis conducted by various authors on the determinants of new product performance, on which Sicotte bases her research (Sicotte 1996). The list groups 19 determinants divided into four categories: market environment, strategic factors, factors associated with development processes, and organizational factors.

Table 2 also shows the relationships between CSF's and performance, which was adapted from Sicotte (Sicotte 1996). The main variables and factors of interest in this study were obtained from this study. This study was based on extensive research that contained all of the important elements of interest in our study. Our model differs from Sicotte's in three important ways. First, our study focuses specifically on the aerospace industry. Second, in our study, communication is a CSF that directly impacts performance, as opposed to a moderating variable. Third, we focus on projects that are specifically undertaken in a matrix structure.

The influence of CSF's in the context of NPD in a matrix organization, as well as their impact on performance in the high-tech industry, has not been given much attention in the literature. Since a large number of high-tech firms that undertake NPD work in a matrix organization, this is an important topic to study.

Table 1. Determinants of new product performance

Montoya-Weiss et Calantone, 1994 taken from Sicotte (1996).

Strategic factors	Product advantage Technological synergy Resources Strategy Marketing synergy
Market factors	Market potential Competition Environment
Factors associated with development processes	Technical excellence Marketing excellence Development protocol or methodology Support and ability of upper management Excellence of pre-development activities Speed to market Financial/corporate analysis Costs
Organisational factors	Internal/external relations Organizational factors Upper management support

Some exhaustive studies highlighted a framework in which the project teams, the tools, and the technological strategies deployed have a significant impact on the performance of the development process (Schilling and Hill 1998). The results of some studies indicate that in many cases, the integration or the synergy across the functions of the firm play the most important role in innovation success (Roberts 1979, Kanter 1985, Moenaert and Souder 1990). Furthermore, the majority of the authors consider it critical to establish high-quality communication within the project team (Cooper 1979, Souder 1989). Yang et al. found that increasing levels of project manager leadership, which enhances team relations, and teamwork significantly affect project performance (Yang, Huang, et al. 2011). However, Turner et al. have found, in a review of the literature on project success factors, that the project manager and his/her leadership style or competence is rarely if ever, mentioned (Turner and Müller 2005). Another study that looks at product development in the aerospace industry proposes an original framework that characterizes and organizes effort and time drivers in aerospace product development. The goal of the framework is to identify and support the understanding of the most relevant drivers for aerospace product development effort and time. The authors validate the final list of the frameworks' drivers through a survey assessment. The study concludes that, in additions to risks and uncertainty, technologies maturity, degree of change in design, ambiguity of requirements, functional decompositions, severity of standards, process overlapping and the variety of key stakeholders drive effort and time as complexity drivers while processes maturity, experience with technology, risk management, change management, level of trust in suppliers and team skills drive effort and time as proficiency drivers (Jaifer, Beauregard et al. 2020).

Factors	Independent variables	Direction of relationship	Authors
Industrial context	Competition	(-)	Lilien and Yoon, 1989.
	Important and growing markets	(+)	Cooper, 1990, 1994; Oakey and Cooper, 1991; Zirger, 1991; Zirger and Maidique, 1990.
	Uncertainty	(-)	Lilien and Yoon, 1989.
Project uncertainty	Technological and task uncertainty	(-)	Millson et al., 1992; Chang and Yong, 1991.
Team excellence	Functional	(+)	Baron, 1990; Cooper, 1979, 1990, 1994; Dwyer and Mellor, 1991; Kleinschmidt and Cooper, 1991; Souder, 1987; Zirger and Maidique, 1990.
Managerial support	Support Involvement Leadership	(+) (+) (+)	Lilien and Yoon, 1989; Maidique and Hayes, 1984; Maidique and Zirger, 1985; Pearson, 1990; Rothwell et al. 1974; Schon, 1963; Zirger, 1991; Markham, 1998.
Resources	Material Time	(+) (+)	Maidique and Zirger, 1985; Zirger, 1991; Belout, 1998.
Champion	Technical champion Executif champion	(+) (+)	Cooper, 1990; Hise et al., 1990; Pearson, 1990; Markham and Griffin, 1998.
Structure	Latitude Autonomy Motivation	(+) (+) (+)	Kanter, 1984; Maidique and Hayes, 1984; Pearson, Pearson and Ball 1989; [16] Souder, 1987; Lester, 1998.
Product value	Technical superiority, responding to customer needs	(+)	Cooper, 1990, 1992; Cooper and Kleinschmidt, 1991; Hopkins, 1981; Souder, 1987; Zirger, 1991; Zirger and Maidique, 1990.
Source of ideas	Customer/marketing R&D	(+) (-)	Cooper, 1979; Munro and Noori, 1988; Hise et al., 1990; Voss, 1984; Zirger, 1991
Synergy with existing competencies	Market, technologies, product	(+)	Cooper, 1990, 1992, 2001; Cooper and Kleinschmidt, 1991; Erickson et al., 1990; Frohman, 1985; Roberts and Berry, 1985; Zirger and Maidique, 1990.

Table 2. Relationships Between CSF's and Performance

Adapted from Sicotte (1996).

6. CONCEPTUAL MODEL

In this paper, we identify the CSF's that contribute to performance in the context of a matrix organization. In order to identify these factors, a case study was undertaken at a Canadian high-tech company in the aerospace industry, which develops new products in a matrix organization. Our conceptual model is shown in **Figure 1.**

The dependent variable is project performance, measured in terms of success or failure. The independent variables are integrating mechanisms and CSF's; both selected based on studies that have deemed them to be important and to have a major influence on performance..

7. INTEGRATING MECHANISMS

The integrating mechanisms are defined as a group of organizational methods that enable the integration of resources and activities needed to complete the project (Jones 2013). These mechanisms can be categorized as follows: structure, project management, and technologies used in the context of the project. In terms of structure, in a matrix organization, the project team is under the direction of a project manager that exerts leadership on the resources and also influences the performance of the project. This type of structure tends to favor entrepreneurship, decision-making, and the ability to adapt (Lester 1998, Jones 2013). Among the structural mechanisms that are being studied, attention should be paid to the project team, which operates in a matrix structure and which is in charge of the complete management of the project. The project team is made up of three to four people who share authority and responsibility for organizing and modifying the tasks to be performed on the project.

This team is relatively dependent on the organizational environment, since the human resources working on the project report directly to a department head (vertical function). In a matrix organization, the project team operates under the direction of a project manager (horizontal function) who exercises some leadership over human resources and thus attempts to influence the performance of the project. The matrix structure thus seems to favor entrepreneurship, decision-making and the capacity for adaptation (Jones 2013).

This type of organization thus combines vertical mechanisms (functional units) and horizontal mechanisms (project teams). The project manager is responsible for developing, controlling, directing, coordinating and reviewing the project plan and work schedule. It is the responsibility of the project manager to negotiate with the department managers, human resources who will be working on the project. These employees are temporarily assigned to the project, a method that promotes knowledge transfer (Adler 1986, Nonaka 1990, Jones 2013). This movement of personnel also provides for the need for training of personnel, through continuous training or parallel to daily tasks, who will occasionally be assigned to the project and employees who will be so throughout its duration. The elements that mainly make up the "structure" variable are as follows:

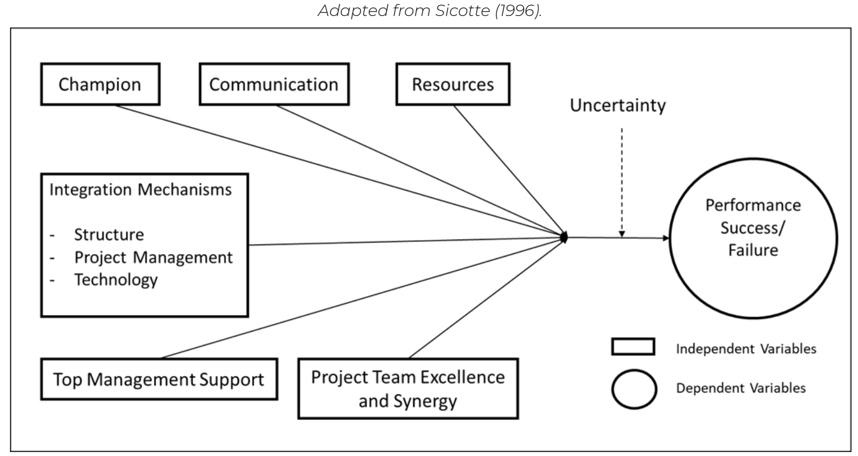
- Board of Directors;
- Stakeholder meetings;
- Managerial control;
- Team assigned to project;
- Matrix structure;
- Temporary assignment of personnel

Based on the above, we hypothesized the following:

Hypothesis IM 1: A matrix structure is positively related to project performance for NPD projects (where the subscript IM refers to integrating mechanisms).

Table 2. Relationships Between CSF's and Performance

Adapted from Sicotte (1996).



Among the important steps in planning a project, there is the breakdown of the project into deliverables or tasks, known as Work Break-down Structure (WBS) (PMBOK® Guide) (www.pmi.org). Given the uncertainty inherent in NPD projects, various decision points, or gates are used at the end of project phases. These gates constitute critical steps whereby various stakeholders can influence the direction of the project. They provide focus on common goals to the various functional groups involved in the project and help them to realign on the goals. Project management, in this sense, is a discipline that allows for the increase in the efficiency of the management of tasks through planning at each phase of the process. At each of these steps, documents are produced to measure performance in terms of the management of costs, time and quality of the project (PMBOK® Guide) (PMBOK, 2000). The elements that are part of the project management factor are:

- Progress reports;
- Financial planning (earned value);
- Task sequence planning;
- Work breakdown structure;
- Use of performance measure (financial, quality).

Our second hypothesis is:
Hypothesis IM 2: Project management is positively associated with NPD project performance.

The use of technology allows for the computerization of certain activities, which translates into increased speed and capacity with which information can be accessed and used, which in turn can increase the reliability of the information used. Our next hypothesis is, therefore:
Hypothesis IM 3: The use of technology is positively associated with NPD project performance.

8. CRITICAL SUCCESS FACTORS

Critical success factors (CSF's), as suggested by their name, are the areas of performance that are essential to the organization in order to complete its mission. Satisfactory results in these CSF's leads to successful competitive performance for individuals, departments, and the whole firm. (Rocha and Delamaro 2012).
In her research, Sicotte identified seven CSF's that influence NPD project performance (Sicotte 1996). Five of these are studied in this research; they were selected based on their importance in project management as well as the ease with which they could be measured through the questionnaire used in this study. They are project champion, communication, top management support, excellence and synergy of teams, and resources. These are described below.
The project champion plays a leadership role in a project and influences the way in which decisions are made, and generally directs the project in general. The role of the champion is often attributed to the project manager or the program manager. The importance of a champion in influencing NPD project performance has been identified by many researchers (Zirger and Maidique 1990, Craig and Hart 1992, Barczak 1995, Walter, Parboteeah, et al. 2011, Shim and Kim 2018). The literature review helped to identify three important variables that are addressed in three questions in the questionnaire. Our next hypothesis is as follows:
Hypothesis CSF 1: The presence and the influence of a project champion are positively associated with NPD project performance (where CSF refers to critical success factors).
In an innovation process, communication is related to the human and technological aspects, as well as to the organizational climate. Thus, communication plays an important role in a project (Spivey, Munson, et al. 1997, Chan, Chan, et al. 2004). The networking of different organizational groups involved in a project is also of prime importance (Gupta and Wilemon 1996). Since communication plays a significant role in reducing environmental uncertainty and uncertainty of tasks, (Daft and Lengel 1986, Lester 1998, Sicotte and Bourgault 2008), sharing of information in the different departments is critical in the NPD process. Communication in projects allows teams to be stronger and more efficient (Strieter and Tankersley 1998, Chan, Chan et al. 2004). Thus, our next hypothesis is as follows:
Hypothesis CSF 2: Communication positively influences NPD project performance.
Top management support also plays an important role in the performance of the project team. Managerial support also manifests itself through actions such as removing political barriers or any other obstacles (as for example, inertia in the company) that the project team might face during the project (Chan, Chan, et al. 2004). The importance of their early and constant support leads to our next hypothesis:
Hypothesis CSF 3: NPD project performance is positively associated with the level of managerial support obtained.
The abilities of the various functional groups (R&D, engineering, etc.) significantly influences the quality of the results of a project (Dwyer and Mellor 1991, Chan, Chan, et al. 2004). The eventual success related to customer satisfaction implies that the organization possesses key competencies (Spivey, Munson, et al. 1997). The team synergy, combined with the competencies needed to manage the project increase the chances of success (Cooper 2000, Chan, Chan, et al. 2004). The next hypothesis is:
Hypothesis CSF 4: The knowledge and expertise combined with the synergy of the project team are positively associated with NPD project performance.

Resources are allocated to a project based on the needs spelled out in the project scope. Sicotte stated, in her study, that there were gaps between the real needs and those planned for dedicated teams (Sicotte 1996). The model proposed in this study seeks to determine if such a relationship is valid in projects that evolve in a matrix structure. Our next hypothesis is:
Hypothesis CSF 5: The availability of resources is positively associated with NPD project performance.

9. MODERATING VARIABLE

The moderating variable in this study is uncertainty, which represents a dimension that is present in NPD, especially in high tech companies where development risks are quite high (Merrifield 2000, Sicotte and Bourgault 2008, Lasso, Cash, et al. 2020). Our next hypothesis is:
Hypothesis Cont 1: Uncertainty is a factor that influences project performance.
The methodology is briefly discussed in the next section.

10. METHODOLOGY

The research strategy objective set is the collection of factual and perceptual data related to the characteristics of the NPD projects and to the participating individuals, all from the point of view of performance, organizational structures, project management, and critical success factors such as communication.
The data comes mainly from project managers responsible for carrying out new product development projects. Other sources, such as historical factual data on the performance of past and completed projects, were accessed through the information systems of the site selected for the research.
Two main tools were used for data collection: the interviews and the questionnaire. This study examines the contextualization of the gathered data in a matrix environment as well as their interrelation dynamics. In this sense, a mixed qualitative (observation and collection of secondary data and interviews) and quantitative (distribution of a questionnaire) approach is feasible.
The company selected for the study is a multinational aerospace company, which, under the pseudonym Aerodata, employs several thousand of people that are grouped into departments. Aerodata designs and develops complex aerospace products and operates under a weak matrix structure, where project managers do not have direct authority over the resources allocated to a project. Both qualitative and quantitative data were collected. Our main data collection instrument was the survey, followed by interviews. To supplement the results of the survey questionnaires, we used other sources of data, including information systems and historical data from past projects from the company's enterprise resource planning (ERP) system, and attendance at team meetings.

The survey used was based on the one developed and validated by Sicotte based on a study similar to ours, but done within a different organizational context than our study (Sicotte 1996). The research framework for which this questionnaire was used presents a certain degree of similarity with the present study, which allows using a large part of it. The development of a new version of the questionnaire required the repetition of the pre-test steps of the French and English versions of the questionnaire. These steps were carried out separately with project managers actively involved in the development of new products, in order to obtain their feedback on issues such as understanding the questions and the amount of time required to complete the questionnaire. As a result of these pre-tests, a number of questions were "adjusted", and others removed to reduce the time required to complete the questionnaire.
A list of completed projects that met the research selection criteria (product commissioning date) was extracted from the company's information system, involving the various managers who had participated in the targeted projects.
The list in question was relatively long since it included nearly two hundred and fifty projects completed in the last seven years (the project had to have been completed within the last three years but could have started earlier). The list was reduced when the second selection criterion, relating to the characteristics of the project leader, was applied to this first "fishery".
In fact, the choice of respondents was determined according to two criteria: the respondent had to be a project manager who had participated at least in the product integration and certification phases or who had managed the project as a whole. The respondent could either be part of the military or commercial project management group. In both cases, these two groups are required to manage the development of new products in an already existing product line. Finally, the questionnaire was handed out with the list of projects on which this research wanted to focus; they were presented according to their performance evaluation: the project manager, therefore, chose between one project qualified as successful, the other as a relative failure (or one that had encountered difficulties).
Overall, managers did not seem to have any difficulty discussing projects that ended in failure. The climate of confidentiality and trust that surrounded these investigations made it possible to assess, in the context of the questionnaire, this particular type of project, which is all the more important given that the responsibility for failure is often shared between several departments of the same company. All of the interviews conducted did not exceed the ten-minute threshold in terms of duration, which was occasionally interspersed with very brief visits from the manager's colleagues. Although the interview data were not used directly in the analysis, they nevertheless helped confirm many of the results of the empirical analysis.

The present research is limited to the problem of the development of new products in the aerospace industry, and the investigation was conducted on a single site. This approach made it possible to limit the impact of environmental factors (market and economic context) on the various dimensions that were analyzed and to dissect in detail the factors specific to the company that were under investigation. The possibility of extending this research to other sites in the short term was considered: not only was the sampling of projects available at Aérodata large enough to highlight interesting results, but the in-depth knowledge of the company militates in favor of choosing a single site.
Eighty questionnaires were distributed to potential respondents, of which 58 were completed. The twenty-nine questionnaires that were completed collected information on fifty-eight projects broken down as follows: twenty-nine successful projects and twenty-nine less successful projects. The target population works in a project management department specializing in a product line. Using the corporate information system, only completed projects, whose performance data was available in the information system, were considered.
These questionnaires used a seven-point Likert scale to help collect information on 58 NPD projects. The majority of the respondents were project managers that were responsible for completing the NPD projects; the rest were equally divided among project engineers and project administrators. Respondents had an average of nine years of experience in an industry similar to their current positions. Data was also collected on completed projects through the company's information system.

11. CONSTRUCT RELIABILITY

Cronbach's alpha was used to measure the reliability of the constructs. At the same time, the literature indicates that the coefficient should be close to 0.80 or more to be assured of a minimum of measurement error. Given the sample size in our study, it is acceptable to use an alpha of 0.50. If, in most cases, alphas close to and greater than 0.80 have nevertheless been obtained, certain constructs have values closer to 0.50, which remains acceptable. (Taber 2018). Statistical data analysis methods such as comparison of means, regression, or correlation test were used. Cronbach's alpha was applied to measure the reliability of the questions used for each of the variables. The paired test of means was used between successful and less successful projects to observe whether the results obtained between these two groups of projects were different.
The interviews were compiled and coded to allow for qualitative data analyzes. Associated with these, observations and various reports were acquired in the field in order not only to consolidate the factual dimension of the qualitative analysis but also to strengthen that resulting from the data collected with the questionnaires.

The integrating mechanisms are composed of three sub-groups. The variables are presented in **Table 3**, where SP and LSP denote 'successful projects' and 'less successful projects,' respectively

The alpha for Structure, composed of four items, is rather surprising. Looking at the means obtained for SP and LSP, a minimal difference is found; this may be explained by the weakness of the standard deviation. Project management groups six variables that measure as much the degree of use of project management methods as it does the type of method that is applied. The result of the reliability test is quite high (alpha=0.78). The variable Technology attempts to identify which type of technology was used in the projects. As was the case for the other variables, the Likert scale was used. The responses were weak or not present either because the technology was not available, or it was, and the respondent did not make use of it. Among the most popular technologies used, regardless of the type of project, were email, intranet, and project management tools.
The CSF's were made up of five variables. Sixteen items make up this construct, each taken from the research hypotheses, which are supported by the literature. **Table 4** presents an average obtained for each CSF for SP and LSP as well as its alpha value.

The overall means for SP and LSP show that the factors do indeed have an influence on performance. A value of p=0.001 was obtained for the comparison test of the means, which signifies that the probability that the overall means are not different is very low. The alphas were all high, which indicates strong construct reliability. Performance is the dependent variable and was defined as the combination of various important dimensions of management, such as cost, time, quality, technique, and goals. These dimensions can be found in **Table 5**.

The Cronbach alpha for the variables that make up performance indicates relatively good construct reliability. The alpha level is once again higher for SP (0.82), which shows that respondents classified their projects well and that the variables are an indication of performance. On the other hand, a lower alpha for LSP (0.64) seems to indicate that respondents could not properly identify which elements affected the performance of these projects. Overall, the means obtained for both types of projects suggest that the respondents made a good association between project performance measures such as quality, deadlines, and budget, and the notion of performance. Even if this association is not a difficult issue to conceptualize, it is important that it be properly assimilated by the respondents since any bias would result in a dichotomy between SP and LSP.

Variables Integrating mechanisms	Successful Projects – **Less Successful Projects**		Combined (SP, LSP)	
	Mean – *standard deviation*		Mean	Alpha
Group of mechanisms (23 items)	4.70 /*0.83*	**4.33 /*0.84***	4.13	0.77
Structure (4 items)	4.02 /*1.23*	**3.71 /*1.23***	3.80	0.43
Project Management (6 items)	4.71 /*1.04*	**3.96 /*1.30***	4.25	0.78
Technology (13 items)	5.37 /*1.50*	**5.34 /*1.51***	5.35	1.50

Table 3. Summary of integrating mechanisms

nSP=29 ; nLSP=29

Variables **CSF**	Successful Projects – **Less Successful Projects**		Combined (SP, LSP)	
	Mean – *standard deviation*		Mean	Mean – *alpha*
Group of CSF's (16 items)	4.77 /*0.59*	**3.99 /*0.59***	4.20	0.68
Champion (3 items)	3.92 /*1.57*	**2.88 /*1.23***	3.40	0.64
Communication (5 items)	5.62 /*0.58*	**4.03 /*1.14***	4.80	0.85
Management support (2 items)	5.14 /*1.22*	**4.39 /*1.35***	4.77	0.70
Team excellence and synergy (4 items)	5.24 /*0.88*	**4.06 /*1.17***	4.70	0.72
Resources (2 items)	3.51 /*1.41*	**4.33 /*1.66***	3.90	0.58

Table 4. Summary of CSF's

nSP=29 ;nLSP=29

Variables **Performance**	Successful Projects – **Less Successful Projects**				Combined (SP. LSP)
	Mean – *standard deviation*				Mean/alpha
General Performance (5 items)	5.96	*0.65*	**4.00**	***1.13***	4.99 / ***1.35***
Quality	5.93	*1.07*	**4.39**	***1.73***	5.18 / *1.62*
Technique	6.14	*0.92*	**4.03**	***1.97***	5.11 / *1.85*
Schedule	5.97	*1.38*	**3.32**	***2.01***	4.67 / *2.17*
Budget	6.38	*0.86*	**3.64**	***2.00***	5.04 / *2.05*
Goals	6.38	*1.18*	**4.21**	***2.13***	5.32 / *2.02*

Table 5. Performance

Alpha SP: 0.82 ; Alpha LSP: 0.64

12. RESULTS AND DISCUSSION

This part of the analysis aims to study the effect of integrative mechanisms and critical success factors on the performance of successful and less successful projects. Table 6 presents the means and standard deviations for each variable that constitutes the integrating mechanisms and the CSF's for both SP and LSP. The values for the means are considered strong if they are over 4 (on the Likert scale of 1 to 7). The t-test results show the existence of a significant difference between SP and LSP when they are below 0.5.
Table 6 shows higher means for SP than for LSP, as expected. Overall, the influence of integrating mechanisms and the CSF's are clear, with the exception of Resources, whose mean is lower for SP than LSP. The most significant differences can be found between Management support and Excellence and synergy of teams, two of the most important dimensions in project management at Aerodata. Table 7 presents the correlation coefficients between integrating mechanisms and performance and CSF's and performance. The description of the relation between the independent variables on performance follows the norm suggested by Sawyer and Ball: a coefficient below 0.13 is considered small, between 0.13 and 0.26 has medium influence, and above 0.26 reveals a strong correlation (Sawyer and Ball 1981). The following sections, combined with the correlation results, allow for an analysis of each variable in the conceptual model.

Independent variables	Performance						
	Successful Projects (SP)		Less Successful Projects (LSP)		T-test Sign.	Combined (SP. LSP)
	Mean	Standard deviation	Mean	Standard deviation		Mean/ Standard deviation
Group of mechanisms	4,70	0,83	4,33	0,84	0,014**	4,52 / 0,75
Project management	4,71	1,04	3,96	1,30	0,002***	4,34 / 1,02
Structure	4,02	1,23	3,71	1,11	0,127	3,90 / 1,04
Technology	5,37	1,50	5,34	1,51	0,811	5,35 / 1,47
Group of CSF's	4,52	0,52	3,86	0,54	0,000***	4,33 / 0,67
Champion	3,92	1,57	2,88	1,23	0,004***	3,40 / 1,09
Communication	5,62	0,58	3,98	1,14	0,000***	4,80 / 0,58
Management support	5,14	1,22	4,39	1,35	0,034**	4,77 / 0,93
Team excellence and synergy	5,72	0,88	4,44	1,17	0,000***	3,94 / 1,01
Resources	3,43	1,41	4,28	1,66	0,012***	3,81 / 1,37

Table 6. Means and standard deviations of variables associated with integrating mechanisms

***p<0,01; ** p<0,05; * p<0,10 ; nSP=29 ; nLSP=29

Independent variables	Performance		
	Successful Projects (SP) n=29	Less Successful Projects (LSP) n=29	Projects (SP) & (LSP) n=58
Group of mechanisms	0,10	-0,64	0,25
Project management	0,35**	0,17	0,334***
Structure	-0,31**	-0,27*	-0,106***
Technology	0,17	-0,58	0,025
Group of CSF's	0,38	0,20	0,087
Champion	-0,13	0,15	0,296*
Communication	0,23*	0,42**	0,595***
Management support	0,50***	-0,30	0,324***
Team excellence and synergy	0,74***	0,42**	0,610***
Resources	-0,18	-0,26*	0,338***

Table 7. Correlation coefficients between integrating mechanisms and performance and critical factors of success and performance

1 Significance level of the test : *** p<0,01; ** p<0,05; * p<0,10

13. IMPACT OF INTEGRATING MECHANISMS ON PERFORMANCE

Table 6 clearly shows a significant difference between the means between SP and LSP for the Project management variable. This is not surprising as most teams regularly invest time in the follow-up and control of project activities. These are daily tasks in fact. They cover the management of risk, financial data, planning, control of specifications, and even status meetings with different key stakeholders. These are routine activities that take place throughout the project lifecycle, the end of which is typically marked by two important activities: the transfer of product responsibilities to customer service, as well as a post-mortem presentation. Nevertheless, during interviews, a large number of respondents expressed having followed a less structured project management methodology and are less adapted to business needs. These respondents also seemed less familiar with project management practices and focused more on the technical aspects of the project.

Among the integrating mechanisms, Structure is represented by the variable whose means are the weakest. In isolation, this variable does not influence the success of a project. In fact, at Aerodata, all NPD projects take place within the same organizational context, which is characterized by similar corporate activities and practices (meetings of project and department leaders. assigning human resources temporarily to another service or project. or establishing common objectives to different services by upper management). The means associated with Structure and Technology are relatively similar for SP and LSP.

Overall, the variables that constitute the integrating mechanisms suggest a significant difference between the means for SP and LSP.

Table 7 shows that, in general, the integrating mechanisms were not found to be highly influential on NPD project performance. The organizational structure showed a weak relationship with performance. In fact, the functional managers at Aerodata seemed to have more control over the members of the project team than did the project managers. This tended to create a more conflictual climate between the two managers in terms of the goals that needed to be achieved. The matrix structure at Aerodata can be characterized as weak, given that the functional managers-maintained authority over their resources, while the project managers had only limited influence. Given that most respondents were project managers, it is thus not surprising that they did not associate the matrix structure to project performance.

Aerodata's matrix structure does however, have some advantages. In fact, it allows for better resource allocation by allowing different resources to be assigned to different mandates of differing priorities. This diversification of tasks is generally perceived in a positive light by employees since it reduces the monotony of their work and allows for better professional development. The matrix structure also offers greater flexibility in coordinating employees and facilitates communication among them, as much at the project level as within their department. This context makes it possible to transfer knowledge acquired within a project to the department. Among the main disadvantages related to this type of structure is that the project managers often highlight the presence of the decision-making conflict with the functional managers, especially when it comes to assigning priorities to resources working on several important projects. Finally, because each employee reports to two different authorities, the matrix structure duplicates the tasks in the management of human resources, which translates into high administrative costs.

Project management has only a moderate correlation with project performance. This is not surprising: at Aerodata, project cycles are well-defined and constitute a relatively solid management framework. Given the complexity of the products, project leaders consider project management to be very important since it encourages the use of methods to follow-up and controls the product throughout its development.

Interestingly, the use of technologies has no impact on project performance. Yet, the use of technologies is perceived as being critical tools to achieve proper management of projects. While the survey did not capture this, interviews and meetings did capture this important dimension.

14. IMPACT OF CSF'S ON PERFORMANCE

Table 6 shows that the means obtained for SP are very high for all variables except Champion and Resources. It is interesting to note that Champion does not seem to have a great influence on either type of project. Nevertheless, this variable does show more importance in SP than in LSP. It would be interesting to further explore the relation between Champion and uncertainty: Sicotte and Langley have shown that its influence changed based on the level of uncertainty involved, and vice-versa (Sicotte and Langley 2000). Communication is one of the variables with the highest means for SP, which suggests that communication is an essential determinant for an SP. The literature reveals that Management support and Excellence and synergy of teams are important factors that influence the success of projects (Clark and Fujimoto 1991, Sicotte and Bourgault 2008). This is corroborated by the results in the table. In fact, these two variables have high means, especially Excellence of teams. They both have much lower means for LSP. As for Resources, this factor is the weakest among all independent variables for SP, but one of the strongest for LSP. This surprising result may be explained as follows: on the one hand, it should be reiterated that resources are very important for large-scale projects, but this is not sufficient for success. On the other hand, in the context of the nature of projects at Aerodata, mobilizing resources takes place only when there are technical problems with the product. Thus, it is not surprising to note that a strong mobilization of resources is associated more with LSP. Overall, the means for the CSF's are higher than those for LSP.

The literature is particularly rich in studies on CSF's for project performance and their importance is generally acknowledged by most researchers. Often considered as key in the literature (Markham 1998, Cooper 2000, Nybakk and Jenssen 2012) the project champion who has a critical leadership role is the one who brings a project to completion with the goal of reaching the project objectives. The champion's contributions to the project are generally considered critical to the success of the project (Craig and Hart 1992, Shim and Kim 2018). **Table 7** shows that, for Aerodata, the role of a champion does not benefit from the same importance as the one described in the literature. This aspect can be explained mainly by the weak matrix organizational structure in which the champions are generally project managers whose influence are overshadowed by departmental managers.

Communication has been found to have a strong positive influence on NPD project performance. This is not surprising since communication has been recognized as being extremely important in NPD projects(Gupta and Wilemon 1996, Egelhoff and Wolf 2017).

The technical complexity of products and the involvement of many functional groups in projects encourage horizontal communication and necessitate a climate that is favorable to exchange. This observation goes along with the importance of synergy of project teams, which was discussed earlier, and is supported by previous studies (McDonough, Kahn, et al. 1999, Sicotte and Bourgault 2008). The strong and positive influence of communication on project performance is recognized as being important (Moenaert, Caeldries, et al. 2000).

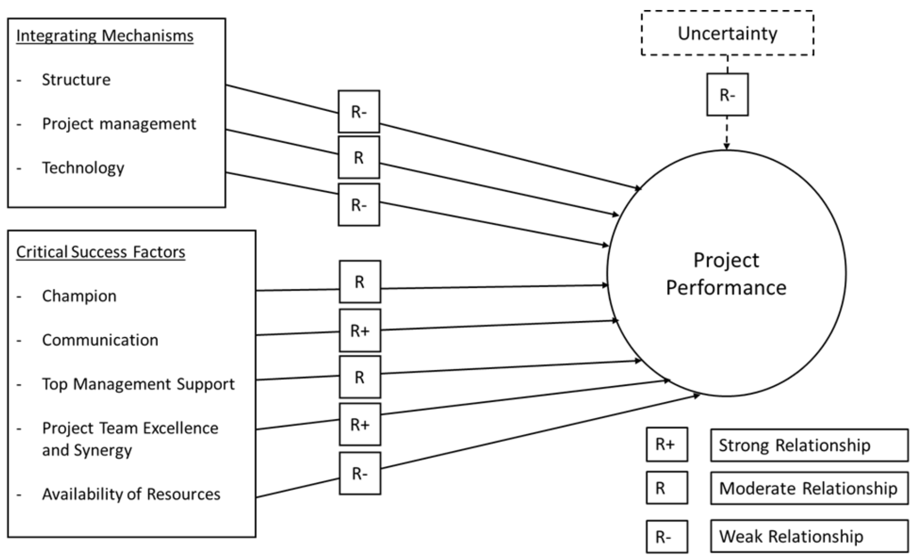
At Aerodata, two dimensions show the strong relationship between communication and performance. On the one hand, the complexity of development products requires important information exchange among the project leaders, who are responsible for meeting the general objectives of the project (such as managing the specifications), and the functional managers who are in charge of translating the specifications into technical solutions. These exchanges are frequent and often require large teams. On the other hand, the project manager, not having official authority over the resources assigned to the project, must be an excellent communicator in order to have an efficient influence over them. This talent is also often needed in the development of team synergy.

Managerial support had a moderate influence on project performance. Zirger and Maidique showed that the support of an executive champion who possesses adequate power and authority could improve the chances of success, specifically by controlling resource allocation (Zirger and Maidique 1990). Management can stimulate communication and cooperation among the different functional groups that are a part of the product development process (Schilling and Hill 1998, Shim and Kim 2018).

Several studies focus on the management of project teams, which are often structured differently according to the organizational context within which they evolve (Spivey, Munson et al. 1997, Chan, Chan et al. 2004). In the case of the company under study, the excellence and synergy of the teams have a positive influence on project performance. For highly complex products, it is not surprising that the team members' technical expertise and the information-sharing capabilities of the team require group synergy.

The availability of human resources has been recognized as an important dimension in NPD (Griffin and Belliveau 1997, Cooper 2019). At Aerodata, this factor showed a moderate negative influence on performance. This may be explained in two ways: first, project performance includes the dimensions of cost and project hours spent. Adding resources (at Aerodata) creates an increase in costs without any measurable benefits in terms of performance. Second, due to the highly complex technical nature of the products at Aerodata, it is possible that the performance of such projects are most sensitive to the quality of the resources (in terms of expertise and synergy) than to the quantity of resources available or assigned to the project. **Figure 2** provides a summary of the relationships among the variables.

Figure 2. Summary



15.CONCLUSION

Although CSF's have the subject of many a study, the literature does not reveal any that have emphasized the relationships between these determinants and performance within the context of a matrix organization. In this research, we tried to fill this gap through an in-depth study conducted at a high-tech company in the aerospace industry. In terms of managerial implications, this study brings to light three points: first, our study showed that simply adding resources to a project will not translate into better project performance, so managers should exercise caution when turning to this practice. Second, it is important to establish and select the proper skills in the resources assigned to the projects. And third, promoting teamwork and communication among team members can contribute to increasing project performance.

This study did not consider intra-project interaction in the firm. In a company such as Aerodata, a multitude of projects share the same resources and are undertaken simultaneously. This sharing of resources will no doubt cause additional constraints (Scott 1997). The interaction among these projects generates significant competition for human resources, which can cause additional delays. This may be due to the lack of resources, but also by the learning curves that employees must go through every time they are transferred from one project to another. Finally, the external environment was excluded from this study. It would be interesting to study the impact on the performance of factors external to the firm, such as the customer, the market, and suppliers, all of which have a recognized impact on NPD performance.

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