

# Factors of Complexity for Managers of Projects of Information Systems

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## ABSTRACT

Even for the specific case of projects, the concept of complexity has no widely accepted definition. In the literature, this is associated to novelty, interdependencies, technology and to sets of variables as a whole. Some authors have an approach to complexity of projects based on subjective connotation.

This study aimed to identify factors related to the complexity of the projects in the area of information systems based on the perspective of their managers. It is classified as exploratory research and quantitative; and used a web-based survey with the participation of 140 Brazilian project managers of new information systems or of enhancements to existing systems.

The data analysis indicated that the complexity of projects managed by the participants can not be related to one factor or a specific group of factors, but possibly to different combinations of factors. Moreover, the scope of the project seems to be one of the most relevant contributors to the complexity of projects related to information systems.

**Keywords:** Project Complexity, Project Management and Factors of Complexity.

## 1. INTRODUCTION

The term "project" is used commonly with different meanings. Boutinet [1] refers to projects like figures ubiquitous in social life, defined by three core characteristics: uniqueness, materialization of the objective and identity. The PMI - Project Management Institute [2] adopts the concept that a project delivers products, services or results that are exclusive, non-repetitive or unique. Project is also temporary endeavor that starts with an idea and ends with the delivery of the materialization of this idea.

Archibald [3] states that the objective of a project, or the type of product that it generates, e.g. an information system, is one of the factors that defines how a project will be managed, differentiating it from others. However, even if different projects have similar goals, they will differ from each other depending on the context in which they are executed and on the degree of complexity it represents to their managers. According

to Shenhar and Dvir [4], the context can be evaluated according to the complexity, uncertainty and the degree of familiarity with the organization's projects. Thus, among the characteristics of projects, complexity is one that has received increasing attention. Williams [5] affirms that, in general, there are two basic reasons for this phenomena: extensions or improvements of previous generations of the products (e.g. additional features and greater inter-relationships); and increasing projects restrictions in respect to deadlines and expectations about the delivery of the products. As a consequence, specifically related to projects of development of information systems, the research results of Xia and Lee [6] indicate that the complexity is associated with delays, cost overruns, restrictions of system functionalities and reduction on user satisfaction.

The concept of systems is used to define important components of projects complexity related to interconnections and interdependences of organizations and technologies [7], [8], [9], [10]. According to Shtub *et al* [11], complexity is at the root of the concept of projects, since the factors that determine the realization of projects include the complexity never seen before in the design, development and implementation of a new system. Remington *et al* [10] agree that complexity is important for the management of projects because of difficulties associated with decision-making and achievement of goals. However, they indicate a lack of operational definitions for the concept of complex projects. Geraldi [8], Adlbrecht and Geraldi [9] and Williams [5] believe that it is necessary to look at the project and its problems holistically, considering not only the specific components, but also its effects. In general, the concept of complexity on the projects has been explored based on different theories and perceptions, inclusively having different positions in relation to the concepts of difficulty, uncertainty and complexity. One must consider, however, that despite the established concept of complexity in other areas such as physics and biology, the findings of this study are restricted, in theory, to the knowledge area of management and, more specifically, of management of projects.

An important issue on studying the complexity of the projects is related to the factors that generates or influences it. Baccarini [7], Williams [5] and Fitsilis [12] proposed a classification based on two types of complexity: the organizational and technological, which are operationalized in terms of differentiation and interdependence. Tatikonda and Rosenthal

[13] refer to the concept of project complexity as relating to the novelty of the product, its development process and performance objectives; and its technological interdependence and difficulty.

Geraldi [8] and Geraldi & Adlbrecht [9] proposed an approach that considers that complexity management should consider not only the unique characteristics of complexity, but also its standard, and developed the concept of pattern of complexity. They defined three main types of complexity: Complexity of Faith (related to uncertainty), Complexity of Fact (referring to the amount of interdependent and concurrent information), and Complexity of Interaction (related to the interfaces between systems, people and places).

Based on the analysis and classification of the factors related to the complexity of the projects, Remington *et al* [10] defined two groups of categories operationally: dimension of complexity (characterizes the nature or origin of complexity) and factor of severity (in what extent is a problem). In an even broader way, Fitsilis [12], Baccarini [7], Geraldi & Adlbrecht [9] and Remington *et al* [10] believe in a subjective connotation, which implies in difficulty in understanding and deal with the projects' complexity.

Although there are many studies on the issue of complexity of projects, it was not possible to identify a model that could indicate which factors, in particular, are responsible for the complexity of certain types of projects, since they deal with the theme only conceptually, or are limited to very specific contexts. The Table 1 below shows the main factors of complexity found in the literature.

**Table 1 – Factors related to the complexity of projects.**

Factors of project complexity	References
- Uncertainty about the scope of the project	[7], [13], [14], [15].
- Uncertainty about the product of the project	[5], [10], [14], [15].
- Significant change in the scope of the project during its implementation	[5], [8], [9], [10], [12]; [15].
- High difficulty to achieve performance goals	[10].
- High number of stakeholders with influence on the project	[5], [10], [12].
- High interdependence between firms involved in the project.	[5], [7], [8]; [10].
- Novelty of the technology	[5], [7], [8], [10], [12], [13].
- High interdependence between the technologies	[5], [7], [8], [10], [12], [13].
- High multidisciplinary	[7], [8], [9], [12], [16].
- Large number of different activities to be performed	[13].

## 2. METHOD

This research aimed to identify the factors that are related to the complexity of the projects, according to the managers of project of information systems. This research can be classified as non-experimental, conducted at a single time and having a quantitative approach [17]. It is predominantly exploratory [18].

This research had the participation of professionals working in Brazil as managers of information systems projects. There was no differentiation among the different industries. The sampling was non-random, for convenience, in conjunction with a snowball type sampling [19]. The contact with the project managers was made by using discussion groups on project management in social networks such as Yahoo!®, Google™ and LinkedIn®. The survey instrument was an electronic questionnaire applied through a website (QuestionPro™ - <http://GP.questionpro.com>) [20], [21]. Descriptive statistical techniques were used for the analysis of survey data. The Spearman correlation coefficient was employed to analyze the association between the level of complexity of projects managed and factors of complexity [17]. The quality of responses was verified by test-retest and calculating the Kappa index.

## 3. DATA ANALISYS

The application of electronic questionnaire obtained the participation of 313 professionals. Of this total, 140 professionals have managed projects of new information systems, or enhancements in existing systems. The profile of the participants is characterized by the experience in project management, since more than 90% of the 140 respondents have more than 2 years of experience in project management and more than 60% have more than 6 years of experience. In addition, more than 37% have some professional certification in project management.

The projects managed by the respondents in the last 12 months related to new information systems or enhancements in existing systems were distributed, in percentage terms, by the degree of complexity perceived, i.e., without complexity, low complexity, medium complexity, high complexity and very high complexity. Table 2 below shows average distribution of the projects managed, in percentage, among the different levels of complexity.

**Table 2 - Descriptive statistics: distribution of the projects by level of complexity**

Statistics	Level of complexity of the projects				
	Without	Low	Mediu m	High	Very high
N	140	140	140	140	140
Mean	4.5%	16.4%	31.6%	30.4%	17.2%
Median	0.0%	15.0%	30.0%	25.0%	10.0%
Mode	0%	0%	30%	20%	0%
Std. Deviation	8.83%	15.79%	19.85%	22.11%	21.49%
Minimum	0%	0%	0%	0%	0%
Maximum	60%	80%	100%	100%	100%

The data analysis presented in Table 2 shows the following:

- On average, 17.2% of the projects managed were classified as of "very high complexity." If added to the percentage of

projects rated as of "high complexity", they will represent together almost half of the sample, i.e. 47.6%.

- Relatively small portion of the projects managed (20.7% on average) were considered by respondents as of little or without complexity.

In order to analyze the respondent's understanding about the concept of complexity of projects, it was applied a question about situations that occur on a project and that are related to its complexity. These conditions were defined based on the factors related to the complexity that were found in the literature and by assigning values to them, in order to characterize how they contribute to the complexity of the projects in practice. In order to assess the contribution of each of the proposed situations to the complexity of the projects, it was used a Lykert type scale of five points, from "not contribute" to "contributes fully". The results of data analysis by using descriptive statistics are presented in the Figure 1 and the Table 3 below:

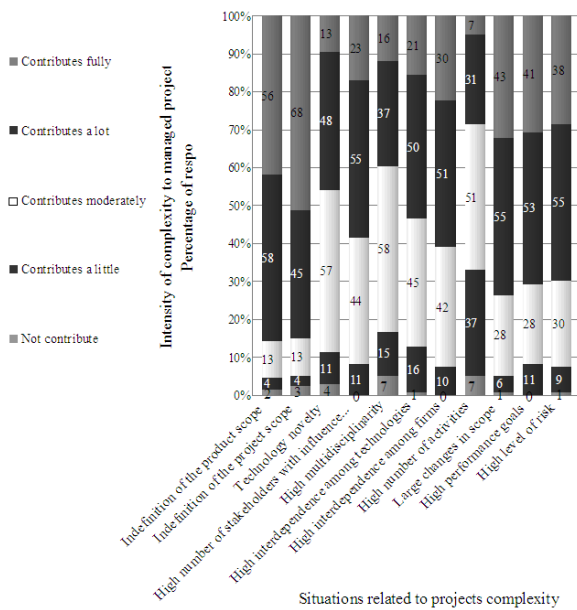


Figure 1 - Contribution of situations of projects to the complexity

Table 3 - Descriptive statistics: the contribution of situations of projects to the complexity

	Indefinition of the product scope	Indefinition of the project scope	Technology novelty	High number of stakeholders with influence on decisions	High multidisciplinary	High interdependence among technologies	High interdependence among firms	High number of activities	Large changes in scope	High performance goals	High level of risk
N	140	140	140	140	140	140	140	140	140	140	140
Mode	4	5	3	4	3	4	4	3	4	4	4
Percentiles	25	4	4	3	3	3	3	2	3	3	3
	50	4	5	3	4	3	4	3	4	4	4
	75	5	5	4	4	4	4	4	5	5	5

Within the situations presented, which was considered with the greatest contribution to the complexity of projects of new systems, or enhancements to existing systems, was the vagueness or uncertainty of the project scope (mode = 5, median = 5). Authors such as Tatikonda and Rosenthal [13], Maximiano [14], and Turner and Cochrane [15] also indicate the uncertainty as important component of project complexity. Following, in descending order of degree of contribution, appears the uncertainty regarding the scope of the product of the project (mode = 4, median = 4). This factor is mentioned by Williams [5], Remington *et al* [10], Maximiano [14] and Turner and Cochrane [15] as a component of uncertainty of projects.

With a contribution a little smaller (mode = 4, median = 4) shows up the changes in the scope of the project during its implementation, the difficulty to achieve the goals of the project and the high level of risks, followed by the large number of stakeholders with influence on the project, the high interdependence among technologies and the high interdependence among the firms participating in the project. The change in project scope is also indicated as an important factor that contributes to the complexity of projects by Williams [5], Geraldi [8], Adlbrecht and Geraldi [9], Remington *et al* [10], Fitsilis [12] and Turner and Cochrane [15]. However, the performance goals related to the projects results, specifically in relation to meeting deadlines, cost, scope and quality, are cited only by a few studies. One of the authors is Remington *et al* [10] who includes high-level goals among the key themes of the complexity of the projects.

Regarding the high interdependence among the firms involved in the project, its relatively lower association with the complexity of projects was not expected, considering the importance given to it, most notably by Williams [5], Baccarini [7], Geraldi [8] and Remington *et al* [10]. This perception of the respondents may be related to the type of project they manage normally, which could be essentially internal, without considerable participation of other companies. The type of project managed by the respondents could have influenced the answers and thus could be the reason for the relatively low importance given to the complexity of situations regarding the technologies (novelty and high interdependence between the technologies involved in the projects) if considering the high importance given by Williams [5], Baccarini [7], Geraldi [8], Remington *et al* [10], Fitsilis [12] and Tatikonda and Rosenthal [13] to this factor.

The high multidisciplinary of the participants of the projects and the large number of different activities to be performed on the project are among the situations considered of the lowest degree of influence on the projects complexity. Contrary to the results of this research, the multidisciplinary of the project participants is a factor of complexity highlighted by authors such as: Baccarini [7], Geraldi [8], Adlbrecht and Geraldi [9], Fitsilis [12] and Maximiano [16].

The number of project activities is one of the indicators used to evaluate the project size, especially in the case of new systems that can be sized based on the number of lines of programming. This low contribution to the complexity of projects is in accordance to the literature, since few authors consider it in the list of the most important factors.

The survey aimed to identify which factors were more complex in the projects managed by the respondents during the last 12 months of work. For this analysis it was used a Likert type scale of 5 points, from "without complexity" to "very high complexity". The results of the analysis of the responses received are presented descriptively in the following Figure 2 and Table 4.

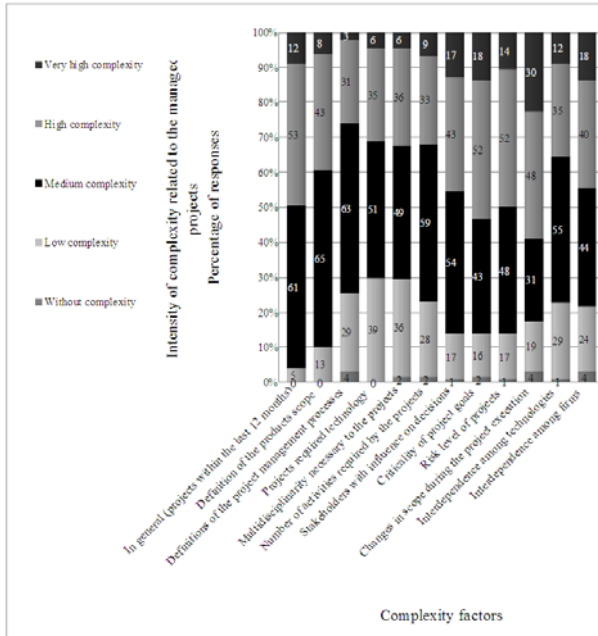


Figure 2 – Complexity factors and their intensity in the projects managed

Table 4 - Descriptive statistics: complexity factors – intensity in the projects managed

	In general (projects within the last 12 months)	Definition of the products scope	Definitions of the project management processes	Projects required technology	Multidisciplinarity necessary to the projects	Number of activities required by the projects	Stakeholders with influence on decisions	Criticality of project goals	Risk level of projects	Changes in scope during the project execution	Interdependence among technologies	Interdependence among firms
N	140	140	140	140	140	140	140	140	140	140	140	140
Mode	3	3	3	3	3	3	3	4	4	4	3	3
Percentiles	25	3	3	2	2	3	3	3	3	3	3	3
	50	3	3	3	3	3	3	4	3	4	3	3
	75	4	4	4	4	4	4	4	4	4	4	4

The criticality of the goals and changes in project scope (mode = 4, median = 4) were considered of the highest complexity in the projects managed by the research participants. More than 50% of projects were considered of high or very high complexity regarding these factors. It is plausible to consider that the criticality of the goals actually exerts great pressure on

project managers if they are too restrictive to their performance, since they can generate uncertainty and risk. Scope changes during the execution of a project always result in redefinitions, replanning and insecurity with respect to the development of the project itself [2]. These two factors have some feedback relationship, since changes in project scope may result in pressure on the project goals. On the other hand, when the scope is changed there will be replanning and rework, which, in general, leads to increased costs and time, thus resulting in further pressure on the goals. Somehow, this relationship is related to the factor with the third highest intensity in complexity, which is the level of risk (mode = 4, median = 3).

On one level a little below appear the interdependence among firms and the influence of stakeholders. These factors seem to indicate that in practice the complexity is much related to factors that are out of the action of the project manager, in the sense that it depends on others, although there are also ways to influence them, as indicated by Cleland [22] in relation to stakeholders.

These last two groups of factors, except for the number of necessary activities, are opposite in relation to the higher importance given to these factors by other authors such as: Williams [5], Baccarini [7], Gerdali [8], Gerdali and Adlbrecht [9], Remington *et al* [10], Fitsilis [12], Tatikonda and Rosenthal [13] and Maximiano [16].

Figure 3 - Comparison among the situations and factors contributing to complexity.

Situation that contributes to the complexity of the projects (conceptual)	Contribution to complexity	Factors of complexity in the projects managed
- Indefinition about the project scope - Indefinition about the scope of the product	HIGH	
- Significant changes in the scope - Difficult to achieve the performance goals - High level of risks		
- High interdependence among the firms - High number of stakeholders with influence - High interdependence among the technologies	↑	- Changes in the scope during the project - Criticality of the goals - Level of risks
- Novelty of the technologies - High multidisciplinarity		- Stakeholders with influence on the project - Interdependence among the firms
		- Interdependence among the technologies - Definition of the scope of the products of the project - Number of activities
- Large number of activities to be undertaken by the project		Low

Although these two groups of data did not use variables with identical descriptions, however there are correspondences between them. The differences between what is perceived conceptually and in practice in relation to the complexity of the projects are presented in the Figure 3 above, that aligns the degrees of contribution to the complexity of projects, comparatively higher or lower as the values of the modes and percentages presented in the Tables 3 and 4, and in the Figures 1 and 2. This comparison considers that, in general, the contribution to the complexity of projects is reached more frequently in higher scores. Thus, Figure 3 shows the factors with equivalent scores on the same lines.

The evaluation of the complexity of the managed projects have the average of the relative frequencies, in general, smaller than the average achieved by the relative frequency of the perception in conceptual terms, at the highest points on the ordinal scale. This difference was expected because, in the case of conceptual evaluation, the situations that were presented aimed to represent more clearly the occurrence of complexity source. Another reason is related to the level of complexity of projects managed, since not all of them were considered highly complex. However, this difference does not preclude making some comments regarding the order they appear in both analyses.

An important difference between the two scales is at the definition of the project scope and the products scope that are in the top of the list of situations that lead to complexity of projects in conceptual terms. In this research, the definition of project management processes is considered to be equivalent to the scope of the project, since it is defined as the work that needs to be done to deliver a product, service or result with the specified features and functions [2]. The low frequency of the contribution of the definition of management processes to the complexity of the projects managed indicates that, in practice and in general, there is weak relationship between the complexity of the projects and the project management processes, as indicated by Yugue [23].

**Table 5 – Relation between the factors of complexity and the distribution of projects by degree of complexity.**

Complexity factors	Distribution of the projects managed by degree of complexity					
	Without	Low	Medium	High	Very high	High + Very high
In general (for projects managed).	-0.312	-0.521	-0.467	0.258	0.540	0.681
Definition of the scope of the products..	-0.234	-0.369	-0.269	0.213	0.423	0.472
Definition of project management processes.	-0.057	-0.085	-0.020	0.046	0.127	0.120
Technologies required to develop the project.	0.116	-0.048	-0.047	0.023	0.071	0.036
Multidisciplinarity	-0.074	-0.176	-0.182	0.053	0.238	0.235
Number of activities necessary for the project.	-0.129	-0.179	-0.140	0.036	0.351	0.248
Stakeholders	-0.234	-0.184	-0.164	0.097	0.218	0.253
Criticality of the goals.	-0.152	-0.232	-0.165	0.130	0.245	0.290
Level of risks.	-0.079	-0.169 <sup>a</sup>	-0.193	0.016	0.321	0.239
Changes in scope during the project execution	-0.066	-0.222	-0.234	0.098	0.264	0.273
Interdependence /of technologies.	0.030	-0.150	-0.239	-0.026	0.339	0.264
Interdependence among the firms.	-0.092	-0.135	-0.201	0.042	0.278	0.262

The correlation analysis (correlation coefficient Spearman - level of 0.05) between the degree of complexity of the factors in the projects managed and the distribution of projects (in percentage terms) among the different levels of complexity enabled the construction of Table 5.

An expectation of this study was that with a few and better defined variables, and for a specific type of projects, it would be possible to characterize the complexity of the projects. However, the data analysis found correlation between the percentage of projects managed with high or very high complexity and the complexity of projects in general ( $r = 0.681$ ), which seems to indicate that, probably, the complexity of the projects considered in this research is not due to a specific complexity factor, but rather a set of factors. This conclusion is in line with other authors such as: Williams [5], Geraldi [8], Geraldi and Adlbrecht [9] and Remington *et al* [10], who believe that one must look at the complexity of the projects holistically.

Another factor that presented positive correlation with respect to the high complexity of the projects was the definition of the scope of the products of the projects ( $r = 0.540$ ). This datum indicates that the definition of scope is one of the biggest problems faced by project managers. The reason may lie in the concentration of many features of complexity in the planning phase of the project scope as it covers the definition of project objectives, identification of risks, the assumptions, constraints and goals to be achieved [2]. Also are considered at this stage: the necessary technologies, the interdependencies and the goals already set, which are characteristics related to complexity of the project too.

#### 4. CONCLUSIONS

This research found that the projects performance goals are considered by respondents as of relatively high contribution to the complexity of the projects, but are rarely indicated by other authors. However, one must consider that this factor may be treated a factor of difficulty and not a factor of complexity. Anyway, this result indicates the need for greater attention from organizations for this factor. This research also indicated that changes in the scope of the project are also important factors of complexity, both conceptually and in relation to projects managed in practice.

It was hoped that, in general, the analysis of the factors of complexity of projects and the distribution of the projects managed by the level of complexity would indicate a more precise characterization of the complexity of the projects. However, the correlation analysis found only two relationships. The main of them points to a relation to the factors of complexity as a whole. Based on that, it is plausible to consider that this data is indicative that the complexity of the projects actually not due to a specific factor, but the set of factors, reinforcing the idea of the holistic approach.

The second relationship was found between the percentage of projects managed with high or very high complexity and the complexity of projects related to the definition of the scope of the products of the projects. In this case, it seems reasonable to assume that this relationship is indicative that yet during the definition of project scope it would be possible to perceive its

level of complexity, since, in its process, are considered or analyzed most of the characteristics of complexity of a project.

Considering that this research is exploratory, not random, and thus, not possible to be generalized, the results of this research can be contributive to the formulation of better constructs suited to the study of the complexity of projects and their management. The conclusions, however, ask for further research on the criticality of the goals as a component of difficulty or complexity of projects and about the ways to approach the planning of the project scope in order to reduce its complexity and to facilitate its management.

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