Revista de Gestão e Projetos - GeP
e-ISSN: 2236-0972
DOI: 10.5585/gep.v4i1.109
Organização: Comitê Científico Interinstitucional
Editor Científico: Roque Rabechini Júnior
Avaliação: Double Blind Review pelo SEER/OJS
Revisão: Gramatical, normativa e de formatação

ENTENDENDO E GERENCIANDO A COMPLEXIDADE DE PROJETOS

UNDERSTANDING AND MANAGING PROJECT COMPLEXITY

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ENTENDENDO E GERENCIANDO A COMPLEXIDADE DE PROJETOS

RESUMO

Decisões sobre quais ferramentas de gestão serão utilizadas a fim de alcançar os objetivos do projeto da maneira mais eficiente estão condicionadas às características específicas deste projeto, tais como objetivos, recursos e contexto. Uma das características mais desafiadoras é a complexidade do projeto. O objetivo deste estudo é contribuir para o conhecimento acerca do conceito de complexidade do projeto e das relações entre a complexidade do projeto e o uso de ferramentas de gerenciamento de projetos específicas. Um questionário foi enviado a 313 gerentes de projeto. A análise dos dados indicou que a complexidade dos projetos gerenciados pelos participantes é gerada pelo nível de dificuldade dos objetivos e pode influenciar a frequência de uso de processos e técnicas relacionadas ao planejamento de projetos e à gestão de pessoas.

Palavras-chave: Gestão de Projetos; Processos de Projeto; Ferramentas e Técnicas de Gestão; Complexidade do Projeto.

UNDERSTANDING AND MANAGING PROJECT COMPLEXITY

ABSTRACT

Decisions on which management tools will be used in order to accomplish project objectives in the most efficient way are contingent upon specific project features such as objectives, resources, and context. One of the most challenging features is the project's complexity. The objective of this study is to contribute to the knowledge on the concept of project complexity, and on the relationships between project complexity and the use of specific project management tools. A questionnaire was submitted to 313 project managers. The data analysis indicated that the complexity of projects managed by the participants is generated by the criticality of the goals and can influence the frequency of use of processes and techniques related to project planning and people management.

Keywords: Project Management; Project Processes; Management Tools and Techniques; Project Complexity.

1 INTRODUCTION

Project and project management may be defined from several perspectives. Boutinet (1993) refers to projects as ubiquitous figures in social life, defined by three core characteristics: uniqueness, materialization of the objective, and identity. The Project Management Institute (2008), on the other hand, adopts the concept that projects deliver products, services, or results that are exclusive, non-repetitive, or unique. In fact, projects are endeavors that can be explored from several perspectives. Project management involves decisions about planning, organization, execution, control, and conclusion of temporary undertakings (PMI, 2008). Each one of these processes encompasses quantitative and qualitative procedures that assist in the process of managing the project. Although there may be significant differences between different projects, the principles used in their management are the same. Project management is an approach or set of techniques that can be applied to specific situations, according to the intrinsic nature of the situation and conscious choice. Knowledge and practices of project management do not apply uniformly to all projects (PMI, 2008). However, Le Bissonnais (2003) says that the notion of process is independent of the size and complexity of the project, and serves to simplify the management by identifying the elements, tools, and resources needed for its management. According to Shtub et al. (1994), carrying out projects with skills not available in advance is one of the factors that determined the development of new methods for planning, organization, and controlling, which constitutes the essence of project management.

Even considering developments in practice, however, some researchers were still critical about the current conceptual base of project management for its lack of relevance to practice. Their main argument was not related to the extant project management body of knowledge involving concepts, methodologies, and tools, but rather was that new approaches were needed to enlarge and extend the field beyond its current status, and properly address the current challenges of contemporary project management practice [Winter; Smith; Morris, & Cicmil, 2006].

In spite of that, a study conducted by Besner and Hobbs (2010) identified the existence of classes of practices of project management, i.e., professionals use tools and techniques in groups, which can be identified and studied empirically, as they are known and used in daily activities. The sets of project management tools are used in many different contexts, each one with its particular management problems, for which the practices of management projects have been adapted and the management skills developed to their use. Additionally, variations among the patterns of practices due to differences in the types of projects were identified. Even projects with similar goals may

differ from each other, depending on the context in which they are managed (Archibald, 2003). The context can be characterized, among other variables, by the complexity, uncertainty, and the degree of familiarity with the organization's projects (Shenhar & Dvir, 2007). Among these characteristics, complexity is one that has received increasing attention (Williams, 1999). The concept of systems has been used to define important components of project complexity related to interconnections and interdependences of organizations and technologies (Baccarini, 1996; Geraldi, 2007, Geraldi & Adlbrecht, 2007; Remington et al., 2009). Complexity is at the root of the concept of projects, because the factors that determine the realization of a project include complexity never seen before in its design, development, and implementation (Shtub et al., 1994). Nevertheless, there is a lack of operational definitions for complex projects. Some researchers believe that it is necessary to look at the project and its problems holistically, considering not only the specific components, but also their effects (Williams, 1999; Geraldi, 2007; Adlbrecht and Geraldi, 2007; and Williams 1999). The concept of complexity of projects has been explored from different perspectives. In the same way, there is a lot of research on the dimensions (i.e., factors, components or attributes that characterize complexity). Some examples of the diversity of approaches to the concept of complexity are presented in Table 1.

Table 1 - Types of project complexity

COMPLEXITY OF PROJECTS	AUTHOR
• Two types of complexity: the organizational and technological, which are operationalized in terms of differentiation and interdependence.	Williams, 1999; Baccarini, 1996; Fitsilies, 2009.
• Project complexity is related to the novelty of the product, to its development process and performance objectives; and to its technological interdependence and difficulty.	Tatikonda & Rosenthal, 2000.
• "Pattern complexity": minimal manageable "space" of complexity. 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 (with respect to the interfaces between systems, people and places).	Geraldi, 2007; Geraldi & Adlbrecht, 2007.
• Two groups of categories: dimension of complexity (characterizes the nature or origin of complexity) and factor of severity (to what extent is a problem)	Remington, Zolin & Turner, 2009.
• Subjective connotation, which would be the main reason for the difficulty in understanding and deal with the projects' complexity	Geraldi, 2007; Geraldi & Adlbrecht, 2007; Remington, Zolin, & Turner, 2009; Fitsilis, 2009.

2 METHOD

This study aimed to contribute to the knowledge on complexity of projects and the dimensions that complexity consists of, and to identify the project management processes and techniques that are most frequently used in complex projects. This study can be classified as non-experimental (Sampieri et al., 2006) and predominantly exploratory (Selltiz et al., 1974). The research had the participation of professionals working in Brazil as project managers, not limited to specific types of products or industry sectors. The sampling was non-random, by convenience (Fávero et al., 2009). The contact with the project managers was made by accessing discussion groups on the theme of project management that are established in social networks such as Yahoo Groups®, Google Groups™ and LinkedIn®. The survey instrument was an electronic questionnaire (Vasconcellos & Guedes, 2007; Kalantari et al., 2011) applied through a website (QuestionPro™).

Table 2 - Project management processes and techniques.

PROCESSES AND TECHNIQUES	REFERENCE
Project Charter	PMI (2008); Maximiano et al. (2010a, 2010b); Besner & Hobbs (2008); Mulcahy (2005); Streun (2006)
Kick-off meeting	Maximiano et al. (2010a, 2010b); Besner & Hobbs (2008); Mulcahy (2005); Le Bissonnais (2003)
Change control	PMI (2008); Mulcahy (2005); Streun (2006); Cleland (1999); Le Bissonnais (2003)
Identification of project requirements	PMI (2008); Besner & Hobbs (2008); Mulcahy (2005); Peels (2006); Le Bissonnais (2003)
Project scope statement	PMI (2008); Maximiano et al. (2010a, 2010b); Besner & Hobbs (2008); Mulcahy (2005); Mepyans-Robinson (2006)
WBS – Work breakdown structure	PMI (2008); Maximiano et al. (2010a, 2010b); Besner & Hobbs (2008); Mulcahy (2005); Turner & Cochrane (1993); Peels (2006); Mepyans-Robinson (2006); Le Bissonnais (2003)
WBS Dictionary	PMI (2008); Maximiano et al. (2010a, 2010b); Besner & Hobbs (2008); Mulcahy (2005); Mepyans-Robinson (2006a); Cleland (1999)
Resources estimate	PMI (2008); Houston (2006)
Project Schedule	PMI (2008); Mulcahy (2005); Houston (2006); Cleland (1999)
Cost estimate	PMI (2008); Maximiano et al. (2010a, 2010b); Besner & Hobbs (2008); Mulcahy (2005); Peels (2006); Abdomerovic (2006); Cleland (1999)
Project budget	PMI (2008); Mulcahy (2005); Abdomerovic (2006)
Earned value analysis	PMI (2008); Maximiano et al. (2010a, 2010b); Besner & Hobbs (2008); Ellis Jr (2006); Lambert (2006)
Quality management plan	PMI (2008); Peels (2006); Le Bissonnais (2003)

PROCESSES AND TECHNIQUES	REFERENCE
Project organization chart	PMI (2008); Maximiano et al. (2010a, 2010b); Peels (2006); Le Bissonnais (2003)
Responsibility assignment matrix	PMI (2008); Maximiano et al. (2010a, 2010b); Besner & Hobbs (2008); Towe (2006); Cleland (1999)
Team-building	PMI (2008); Maximiano et al. (2010a, 2010b); Besner & Hobbs (2008); Mulcahy (2005); Dinsmore (2006); Le Bissonnais (2003)
Project communication plan	PMI (2008); Maximiano et al. (2010a, 2010b); Besner & Hobbs (2008); Mepyans-Robinson (2006b)
Stakeholders management	PMI (2008); Mepyans-Robinson (2006b); Englund (2006)
Project performance reports	PMI (2008); Maximiano et al. (2010a, 2010b); Besner & Hobbs (2008); Mulcahy (2005); Peels (2006); Mepyans-Robinson (2006b); Lambert (2006); Le Bissonnais (2003)
Maintenance of project registers	PMI (2008); Besner & Hobbs (2008); Mulcahy (2005); Peels (2006)
Matrix of risk analysis	PMI (2008); Maximiano et al. (2010a, 2010b); Besner & Hobbs (2008); Hillson (2006)
Strategy to risk responses	PMI (2008); Maximiano et al. (2010a, 2010b); Mulcahy (2005); Hillson (2006)
Procurement management plan	PMI (2008); Le Bissonnais (2003); Mulcahy (2005); Woolf (2007)
Contracts management	PMI (2008); Maximiano et al. (2010a, 2010b); Mulcahy (2005); Edwards (2006)
Register of lessons learned	Maximiano et al. (2010a, 2010b); Besner & Hobbs (2008); Mulcahy (2005); Edwards (2006)
Client's statement of acceptance	PMI (2008); Maximiano et al. (2010a, 2010b); Besner & Hobbs (2008); Mulcahy (2005)

The main question of this research refers to the relationship between the complexity of projects and the use of the project management processes. Thus, in this relationship, project management processes are the dependent variable. The project management processes (and techniques) adopted by this research are presented in Table 2.

One of the independent variables studied is related to the dimensions of the complexity of the projects managed by the respondents. In spite of the established concept of complexity in other areas, such as physics and biology, the definition adopted by this study is restricted, in theory, to the knowledge area of management and, more specifically, of management of projects. Although there are many studies on the theme of complexity of projects, it was not possible to identify a model that could indicate which dimensions are specifically responsible for the complexity of certain types of projects, thus a selection of the most relevant dimensions was completed. Table 3 shows the main dimensions of complexity found in the literature and adopted in this study.

Table 3 - Dimensions of project complexity

DIMENSION OF COMPLEXITY	REFERENCE
Uncertainty about the scope of the project	Tatikonda & Rosenthal (2000); Turner & Cochrane (1993); Remington et al. (2009); Scranton (2008); Williams (1999); Baccarini (1996); Shtub et al. (1994).
Uncertainty about the product of the project	Tatikonda & Rosenthal (2000); Turner & Cochrane (1993); Remington et al. (2009); Scranton (2008); Williams (1999); Baccarini (1996); Shtub et al. (1994).
Significant change in the scope of the project during its implementation	Geraldi (2007); Geraldi & Adlbrecht (2007); Remington et al. (2009); Williams (1999); Fitsilis (2009); Turner & Cochane (1993).
High difficulty to achieve performance goals	Williams (1999); Maximiano (2002); Tatikonda & Rosenthal (2000); Baccarini (1996); Fitsilis (2009).
High number of stakeholders with influence on the project	Williams (1999); Remington et al. (2009); Fitsilis (2009).
High interdependence between firms involved with the project.	Baccarini (1996); Williams (1999); Geraldi (2007); Remington et al. (2009); Fitsilis (2009).
Novelty of the technology	Baccarini (1996); Tatikonda & Rosenthal (2000); Fitsilis (2009); Williams (1999); Geraldi (2007); Remington et al (2009).

High interdependence between the technologies	Geraldi (2007); Geraldi & Adlbrecht (2007); Remington et al. (2009); Williams (1999); Remington (1996); Pollack, 2007; Baccarini (1996); Fitsilis (2009); Tatikonda & Rosenthal (2000); Ireland (2007).
High multidisciplinarity	Baccarini (1996); Geraldi (2007); Geraldi & Adlbrecht (2007); Fitsilis (2009).
Large number of different activities to be performed	Baccarini (1996); Williams (1999); Fitsilis (2009).

3 RESULTS

The projects managed by the respondents in the last 12 months were distributed, in percentage terms, by the degree of complexity perceived by the respondents. Table 4 shows the distribution of the average percentage of projects managed among the different levels of complexity.

Table 4 - Descriptive statistics: distribution of projects by level of complexity

	WITHOUT COMPLEXITY	LOW COMPLEXITY	MEDIUM COMPLEXITY	HIGH COMPLEXITY	VERY HIGH COMPLEXITY
Mean	5.3%	16.0%	29.4%	30.2%	19.1%
Median	0%	10%	30%	25%	10%
Mode	0%	0%	50%	20%	0%

The data presented show that, on average, 19% of the projects managed were classified as of "very high complexity." If this percentage is added to the percentage of projects rated as of "high complexity," it will represent almost half of the projects managed (49%).

The survey also identified which dimensions were considered by the respondents to be the most important contribution to the complexity of the projects managed during the last 12 months of work. For this purpose, we applied a question considering 10 different dimensions (see Table 2),

which were evaluated by the respondents according to a Likert-type scale of 5 points, ranging from "without complexity" to "very high complexity." The results of the analysis of the responses are presented descriptively in Table 5.

Table 5 - Complexity dimensions – 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 complete 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
Responses		298	296	293	298	297	300	300	300	298	300	299	293
Not applicable		5	7	10	5	6	3	3	3	5	3	4	10
Mode		3	3	3	3	3	3	3	4	3	4	3	3 and 4
Percentiles	25	3	2	2	2	3	3	3	3	3	3	3	3
	50	3	3	3	3	3	3.5	4	3	4	3	3	3
	75	4	4	4	4	4	4	4	4	4	4	4	4

The criticality of the goals and changes in the project scope (both mode = 4) were considered by the respondents to be of the highest intensities of complexity in the projects managed. More than 50% of projects were considered to be high or very high complexity regarding these dimensions. This result was not expected considering that project performance goals regarding time, cost, scope, and quality are cited only by a few studies in the literature, although it may be treated as a matter of difficulty instead of complexity. One of them is Remington et al, (2009), that includes the high-level goals among the key themes of the complexity of the projects. Changes in project scope during the execution phase are indicated as an important contributor to project complexity by different researchers (Geraldi, 2007; Adlbrecht and Geraldi, 2007; Remington et al., 2009; Williams, 1999; Fitsilis, 2009; and Turner and Cochrane, 1993). Frequently, these changes result in redefinitions, preplanning, and insecurity (PMI, 2008). On the other hand, when the scope is changed, there will be re-planning and rework, which normally lead to increased costs and time, thus resulting in further pressure on the goals.

The correlation analysis (Spearman's correlation coefficient) between the degree of complexity of the dimensions in the projects managed and the distribution of projects, in percentage terms, among the different degrees of projects complexity, is represented in Table 6.

Table 6 - Relations between the dimensions of complexity and distribution of projects by degree of complexity.

	DISTRIBUTION OF THE PROJECTS MANAGED BY DEGREE OF COMPLEXITY					
Complexity dimensions	**Without**	**Low**	**Medium**	**High**	**Very high**	**High + Very high**
Scope of the products	-0.24	-0.35	-0.31	0.30	0.41	0.53
Project management processes	-0.09	-0.14	-0.12	0.08	0.24	0.24
Technologies required	0.00	-0.05	-0.08	0.09	0.10	0.14
Multidisciplinarity	-0.10	-0.25	-0.25	0.14	0.29	0.36
Number of activities necessary for the project	-0.16	-0.26	-0.20	0.10	0.34	0.35
Stakeholders influence	-0.15	-0.17	-0.15	0.08	0.25	0.30
Criticality of the goals.	-0.11	-0.22	-0.22	0.13	0.26	0.34
Level of risks	-0.13	-0.19	-0.23	0.11	0.36	0.36
Changes in scope	-0.09	-0.19	-0.17	0.11	0.30	0.29
Interdependence of technologies	-0.03	-0.16	-0.15	0.06	0.27	0.26
Interdependence among the firms	-0.07	-0.28	-0.24	0.13	0.33	0.39

The data analysis found a significant and positive correlation with respect to the complexity of the projects and the definition of the scope of the products of the projects (r = 0.53). Based on that, one can infer that the definition of scope is one of the biggest challenges faced by project managers when dealing with complex projects. One of the reasons may lie in the concentration of many features of complexity in the definition phase of the project scope as it covers the definition

of project objectives and identification of risks, assumptions, constraints, and goals to be achieved (PMI, 2008). At this phase, it is also important to consider that this is when decisions and definitions are made about the necessary technologies, interdependencies, and goals. In this case, it seems reasonable to assume that this relationship is indicative that during the definition of project scope it would be possible to perceive its level of complexity, since, during that process, most of the characteristics of complexity of a project are considered or analyzed.

Because of the number of the project management processes and techniques selected for this research, 22 in total, a factorial analysis was performed in order to reduce it to a restricted number of variables that would enable the study to explain the facts. The best solution obtained by the statistical treatment is composed of eight factors (Table 7).

Table 7 - Factorial analysis of project management processes and techniques.

FACTOR 1	
- Project budget	**Cost Management**
- Cost estimate	
- Resource estimate	
FACTOR 2	
- Matrix of risk analysis	**Risk Management**
- Strategy to risk responses	
FACTOR 3	
- Contracts management	**Procurement Management**
- Procurement management plan	
- Quality management plan	

FACTOR 4	
- Project schedule	**Planning**
- Kick-off meeting	
- Project scope statement	
FACTOR 5	
- Responsibility assignment matrix	**People Management**
- Project organization chart	
- Project communication plan	
FACTOR 6	
- Identification of project requirements	**Requirements Management**
- Team-building	
- Stakeholders management	
FACTOR 7	
- WBS Dictionary	**Scope Management**
- WBS – Work breakdown structure	
- Earned value analysis	
FACTOR 8	
- Maintenance of project registries	**Controlling**
- Project performance reports	

The Kruskal-Wallis test was performed in order to study the relationship between the project's complexity and the frequency of use of the project management processes and techniques. The results are presented hereafter (Table 8).

H0: C1 = C2 = C3 (C: level of projects complexity –without/low complexity; medium complexity; high/very high complexity)

Ha: at least two levels of complexity differ from each other regarding the frequency of use of the project management processes and techniques.

The results of the Kruskal-Wallis test indicate that the frequency of use of the project management processes and techniques related to the factors of planning, and people management varies in accordance with the complexity levels of the projects managed. The other processes and techniques did not present any significant difference in their frequency of use given the different levels of project complexity.

The data from the two relationships encountered were submitted to a multiple comparison test and the results are shown in Table 9.

Table 8 - Level of complexity and project management processes and techniques

KRUSKAL-WALLIS TEST (A = 0.05).

	COSTS	RISKS	PROCUREMENT	PLANNING	PEOPLE	REQUIREMENTS	SCOPE	CONTROLLING
χ^2	4.071	2.497	4.285	6.508	11.45	0.67	0.318	5.25
P	0.131	0.287	0.117	0.039	0.003	0.715	0.853	0.072

Independent variable: in general, complexity of the projects managed during the last 12 months.

Table 9 - Multiple comparison tests for the different levels of complexity

FACTOR	IN GENERAL (PROJECTS MANAGED DURING THE LAST 12 MONTHS)	n	AVERAGE SCORES
Planning	Without/low complexity	16	91.31
	Medium complexity	114	142.09
	High/very high complexity	135	130.27
	Total	265	
People Management	Without/low complexity	16	81.81
	Medium complexity	114	125.91
	High/very high complexity	135	145.05
	Total	265	

The planning factor is composed of three components: project schedule, kick-off meeting, and project scope statement. These processes and techniques of project management are among the most used by the research participants and are mainly associated with early stages of a project, which is when some of the most critical decisions on projects occur. This phase is defined by Tatikonda and Rosenthal (2000) as complex, iterative, and often unstructured. The initial phase of a project is also characterized by the Complexity of Faith, as defined by Geraldi (2007) and Geraldi and Adlbrech (2007), which is more intense, considering that the objectives and means are not well-defined, the team is new, and the problems are still unique.

Another possible reason for this relationship has to do with the criticality of the project goals. In this specific case, project goals that are hard to achieve invariably involve time constraints. Thus, this may be another justification for having schedules among the most used components for the management processes used in the cases of complex projects. Based on these data, it is plausible to think that it would be possible to know the level of complexity of a new

project since its initial stage, when the main information about the product or objective of a project and its restrictions are revealed.

The other factor correlated with the level of complexity of the projects managed is people management. This factor is composed of the responsibility assignment matrix, the project organization chart, and the project communication plan. People management or human resources management is not a subject widely discussed in the literature on the complexity of projects, but only on specific aspects such as interdependence and multidisciplinarity. However, Geraldi (2007) and Geraldi and Adlbrech (2007) addressed the soft skills of managers when talking about the complexity of interaction. For them, the number of physical interfaces, the schedule, time pressure, and stress were responsible for a greater complexity of interaction in the project, especially in its final phase. Baccarini (1996), in his turn, points out that the differentiation and the interdependencies of the projects are managed by integration (i.e., communication, coordination, and control). Thus, the author claims it acceptable to say that integration is the rational and essential role of project management.

4 DISCUSSION

One significant first result is that, in general and in practice, the projects managed by the respondents have performance goals as the most important dimension in terms of contribution to the project's complexity. While defining project scope it would be possible to perceive its level of complexity, because, in this process, most of the characteristics of the complexity of a project are considered.

The relationship between complexity dimensions and the distribution of the projects managed according to their level of complexity is indicative that the project's complexity is not actually related to specific dimensions, but to a set of dimensions, reinforcing the idea of using the holistic approach mentioned by other researchers. Furthermore, it also seems to be plausible to consider personal aspects as part of the perception about the complexity of a given project. The project objectives can be considered very complex by one project manager and perceived differently by another project manager, even with the same background and resources, which is due to subjective connotation of the complexity. Considering this, maybe the real challenge is not the characterization of the complexity of a project, but the possible and best ways of dealing with it.

Finally, the results of the analysis on the effects of the level of complexity of the projects on the frequency of use of the processes and techniques of project management showed that there are relationships regarding the planning and the people management factors. According to these data, attention has to be given to the initial phases of the projects, which involve the scope and schedule decisions, and to the relationships, people management, and communications. No other significant relationships were found regarding the other factors of project management processes and techniques, even for the scope management factor. This result suggests that projects, both complex and simple ones, are managed using the same processes and techniques of project management. But it is possible to consider that specific processes and techniques, other than those normally used to manage the project, are used in the case of the complex projects. Furthermore, it is plausible to consider that the frequency of use of the different processes and techniques or project management may be only one of the variables to be considered in order to identify eventual differences among the various types of projects or their complexity. Based on this, a possible issue for new research would be to consider other variables, such as the way or intensity in which the processes and techniques are used by the project managers. Even considering the research limitations, this points out that the scope, people, and communications management are the keys to dealing with complex projects.

The conclusions of this research, considering it is exploratory, not random, and thus, not possible to be generalized, are expected to contribute to the understanding of complex projects and their management. The conclusions, however, indicated further research is needed on the complexity of projects.

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Data do recebimento do artigo: 19/12/2012

Data do aceite de publicação: 07/02/2013