

# Characterization of complexity in engineering projects

## Caracterização da complexidade em projetos de engenharia

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**Abstract:** The complexity of the projects has increased, boosting the demand in modern project management for new knowledge, tools, techniques and work models. However, the scientific community still seeks a definition for the complex project construct and the factors that characterize it. Therefore, the objective of this qualitative and descriptive study was to identify the factors that characterize the complexity in the vision of engineering project management professionals and from that, to propose a definition for a complex project. This characterization was based on the perception of 132 respondents, captured through the word evocation technique; treated and analyzed by the Vêrges technique with the support of Social Representation Theory and Complexity Theory. As a result, the central nucleus of the social representation that characterizes a complex project in the view of the professionals of the engineering area was constituted in descending order by: stakeholders, difficulty, risks, technology, large, scope, multidisciplinary and long. It is observed that complex projects are seen as a superlative system, in terms of quantity and quality of constituents, and stakeholders management gains protagonism.

**Keywords:** Complex projects; Complexity Theory; Social Representation Theory; Evocation of words.

**Resumo:** A complexidade dos projetos tem aumentado, impulsionando a demanda, no gerenciamento moderno de projetos, por novos conhecimentos, ferramentas, técnicas e modelos de trabalho. No entanto, a comunidade científica ainda busca uma definição para o constructo projeto complexo e os fatores que o caracterizam. Assim, o objetivo deste estudo qualitativo e descritivo foi identificar os fatores que caracterizam a complexidade na visão dos profissionais de gerenciamento de projetos de engenharia e a partir deles propor uma definição para projeto complexo. Essa caracterização se baseou na percepção de 132 respondentes, capturada por meio da técnica de evocação de palavras, tratada e analisada pela técnica de Vêrges, com apoio da Teoria da Representação Social e da Teoria da Complexidade. Como resultado, o núcleo central da representação social que caracteriza um projeto complexo na visão dos profissionais da área de engenharia se constituiu, em ordem decrescente, de: stakeholders, dificuldade, riscos, tecnologia, grande, escopo, multidisciplinar e longo. Constata-se que os projetos complexos são vistos como um sistema superlativo, em termos de quantidade e qualidade de constituintes, sendo que o gerenciamento de stakeholders ganha protagonismo.

**Palavras-chave:** Projetos complexos; Teoria da Complexidade; Teoria da Representação Social; Evocação de palavras.

## 1 Introduction

A lot of attention has been given to the Project Management theme, however, the historical of performance of the projects remains unsatisfactory (Thomas & Mengel, 2008; MPA, 2013). Delays, explosions of budget and not expected performances are common.

Consequently, in spite of the continued academic and practical efforts, the unsatisfactory performance of the projects has been leading the community of project management to look for new perspectives.

The studies on complexity of projects are aligned to this need.

The understanding of the complexity is being recognized as the key factor for improvement of the performance and understanding of project management (Aritua et al., 2009; Pinto et al., 2014; Chapman, 2016). For the Complexity Theory, projects are complex adaptive systems that require management and all the projects have some degree of complexity (Whitty & Maylor, 2009).

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These concepts can have deep implications in the current paradigm of project management, bringing the complementary form of thinking the phenomena of this field (Svejvig & Andersen, 2015) and opening possibilities for the application of new knowledge, practices, tools and techniques. Thus, to sail in the complexity, it is necessary to discover new ways of managing it (Vidal et al., 2011; Rensburg, 2012; Chapman, 2016).

Furthermore, it is noted that: (a) the apprentices of project management are in search of a guide to deal with the complexity (Geraldini et al., 2011) and (b) the academics are in search of a definition for the complexity in projects that can be used in a systemic way (Morel & Ramanujam, 1999; Xia & Lee, 2004; Maylor et al., 2008; Vidal et al., 2011; Chapman, 2016).

Due to this gap in the scientific literature, the objective of this article is to identify the factors that characterize the complexity through the point of view of engineering project management professional and from that propose a definition for “complex project”.

The research meets the objective by collecting the data through the technique of evocation of words with the application of online questionnaire. The data collection responses were treated and analyzed by the Vêrges technique with the support of Social Representation Theory and Complexity Theory.

In addition to this introduction, the article then presents the literature review, addressing the theories and knowledge that support the research, that is, the studies on complexity and social representation. Then the methodological procedures are elucidated, the type of research is identified, the subjects of the research are defined, the instrument is detailed, the strategy is defined and the techniques for data treatment are pointed out and, finally, the approach to data analysis is clarified. Next, the results are presented and discussed. As a closing, the conclusions, recommendations and limitations of the work are presented.

## 2 Complexity in projects

The Complexity Theory can be understood as the study of how order and pattern arise from chaotic systems and, conversely, how complex structures and behaviors emerge from simple rules (PMI, 2009). This theory is concerned with the behavior of certain complex systems over time, and has been widely applied in several types of research in different branches of knowledge (Cooke-Davies et al., 2007; Ponchirolli, 2007; Thomas & Mengel, 2008; Aritua et al., 2009; PMI, 2009; Serva et al., 2010).

The work of Baccarini (1996) pioneered the application of Complexity Theory to project management. In 2014, project complexity was recognized as a key factor in determining the organization’s ideal maturity level in projects by moderating the relationship between maturity in project management and the

success of the projects (Albrecht & Spang, 2014). Thought corroborated by Chapman (2016) when he states that complexity management is relevant to project performance.

For the presented, one of the main contributions of Complexity Theory to the management is the unique form of facing the reality of the organizations (Ponchirolli, 2007). From the perspective of management, there is a certain consensus that Complexity Theory offers an opportunity to reexamine the thought that the world is predictable, in favor of a more holistic approach (Cooke-Davies et al., 2007; Aritua et al., 2009; Tarride, 2013). This expanded perspective of reality opens up possibilities for problem solving, decision making improvements, definition of behaviors in organizations and for project management.

However, there is no unified understanding of complexity in projects in the academic community (Vidal & Marle, 2008). Despite this, some authors presented their definitions (Chart 1).

## 3 Social representation

The Social Representation Theory (SRT) was formulated by Serge Moscovici, social psychologist, in his work *La Psychanalyse, son image et son public*,

Chart 1. Definitions of Complexity in Projects.

Definition of Complexity	Author(s)
The complexity in projects is the number of different disciplines or departments involved in the project, as well as the complication of the design itself.	Larson & Gobeli (1989)
“Complexity in projects consists of many, varied and interrelated parts and can be operationalized in terms of differentiation and interdependence.”	Baccarini (1996, p. 202)
Complexity in projects is characterized by the number of elements and their interdependencies, including multiple objectives and multiplicity of stakeholders, as well as the uncertainty of methods and goals.	Williams (1999)
“Complexity in projects is the property of a project that makes it difficult to understand, predict, and to keep its overall behavior under control, even if there are reasonably complete information about the project system.”	Vidal et al. (2011, p. 719)
“Complex design is the one that exhibits a high degree of uncertainty and unpredictability, derived from the project itself and its context.”	Chapman (2016, p. 938)

launched in 1961 in France. Until 1961, theories led to the belief that the laws governing perceptual phenomena at the individual and collective levels were independent (Wagner, 1999; Farr, 2002).

Moscovici chose to leave open the definition of social representation. That is why this mission was entrusted to his predecessors. A well-accepted definition is that of Denise Jodelet (2001, p. 22), who defined social representations as:

[...] a socially elaborated and shared form of knowledge, with a practical objective, and which contributes to the construction of a reality common to a social set.

Thus, social representation involves concepts of a psychological and sociological nature, being this a form of social thought (Alves-Mazzotti, 2008).

In today’s society, people have to deal with a great volume of information. This informational burden raises questions, and to make sense of the world, people try to understand what is happening based on their reference history (eg, knowledge, myths, beliefs, and historical-cultural heritage) and seek to provide explanations that are shared in their social environments. Shared explanations form “consensual universes” that lead to the creation of collective “theories” of everyday life, which shape group identity and guide individual behaviors (Alves-Mazzotti, 2008; Wachelke & Wolter, 2011). This process of creating social representations is shown in Figure 1.

The SRT investigates how do referral systems used to classify people, groups, and to interpret reality work (Alves-Mazzotti, 2008). Therefore, it studies the symbolic exchanges developed in social environments and how these symbols influence the construction of knowledge and culture.

Therefore, according to SRT, different individuals can construct mentally and assign different meanings to the same object. After all, subjects can have symbolic activities, live contexts and establish differentiated social relations. For this reason, social representations may not be consensual.

To deal with the difference of perceptions of social representations, in 1976, Jean-Claude Abric presented an approach proposing that the set of perceptions is organized into two subsystems: central and peripheral.

In the central system, the meaning of social representation is agglutinated and hierarchized in few elements. This thickening of meanings was called the central nucleus. Next to the central nucleus is the peripheral system with the least significant representations of a given reality.

The central nucleus is the most stable element of social representation, since it forms an interface between the concrete reality and the central nucleus (Sá, 2002); The peripheral system is the sensitive and flexible part of the structure of social representations (Sá, 2002; Wachelke, 2012). Therefore, the transformations in the representation of the object are perceived, first, in the peripheral system.

The evocation of words is a technique commonly used by researchers to capture the words of the central nucleus and peripheral system, while the Vèrges technique is widely applied for the treatment and analysis of the evoked words (Vergara, 2012).

In sequential terms, the steps for treatment and analysis of the collected data, according to the Vèrges technique, are (Vergara, 2012):

1. After evocation, words are listed and classified into semantic categories that have close meanings;
2. Words that are not significant are neglected according to the criterion established by the researcher. For example, we can eliminate the words quoted only once, since social representations are aimed at capturing the collective views on a given object;
3. The average recall order of each category is calculated. It indicates in which range of recall the word was quoted; Wachelke & Wolter (2011) suggest that the cutoff point for the average recall order is equal to half the frequencies of

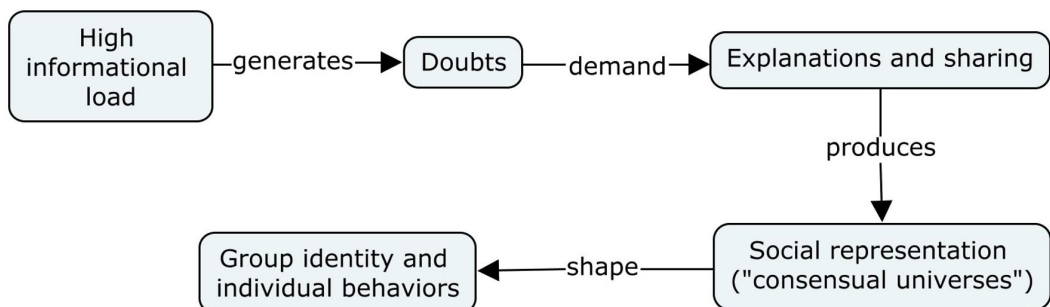


Figure 1. Process of Creating Social Representations. Source: Authors.

the evoked words. For example, if five words are spoken of, by rounding, the average would be three;

4. Next, the mean of the average recall orders is calculated. For example, for N words, the frequency is first multiplied by 1, frequency is secondly multiplied by 2, frequency is third multiplied by 3, and so on until the frequency in Nth place is multiplied by N. Then Sum up these plots and divide the result by the sum of the frequencies of the category. Equation 1 (Vergara, 2012) illustrates the formula:

$$\frac{(f^{1^o \text{ place}}x1) + (f^{2^o \text{ place}}x2) + (f^{3^o \text{ place}}x3) + \dots + (f^{N^o \text{ place}}xN)}{\sum f} \tag{1}$$

5. Then, the average evocation frequency is calculated through the mean or median of the frequencies, and the results are allocated in a four-quadrant diagram that implements the Vergès four quadrant technique as shown in Figure 2.

According to Sá (2002), the four quadrants are:

- a) **Central Nucleus:** located in the upper left quadrant, it contains the most important words cited; Therefore, those that attribute meaning to representation. These are the most cited words (frequency of evocation greater than or equal to the IRF - Intermediate Recall Frequency) and more readily quoted (ARO - Average Recall Order lower than its own average);

- b) **Contrast Zone:** located in the lower left quadrant, it contains words that are important only for a small group of subjects. These are the least-quoted words (evocation frequency lower than IRF - Intermediate Recall Frequency) and more readily quoted (ARO - Average Recall Order lower than its own average). The words of this quadrant are closely related to the central nucleus;
- c) **First periphery:** located in the upper right corner, it contains the very quoted words, but with little importance for the subjects. These are the most cited words (frequency of evocation greater than or equal to IRF - Intermediate Recall Frequency) and later cited (ARO - Average Recall Order greater than or equal to its own average). The words of this quadrant are closely related to the central nucleus;
- d) **Second periphery (peripheral system):** located in the lower right quadrant, it contains words of less importance and irrelevant to the representation. These are the least-quoted words (evocation frequency lower than IRF - Intermediate Recall Frequency) and later cited (ARO - Average Recall Order greater than or equal to its own average). The words of this quadrant keep distant relationship with the central core.

### 4 Methodological procedures

Given the fact that this article aims to characterize complexity in projects and propose a definition for “complex project”, we opted for a qualitative approach with descriptive research. For Cervo &

Frequency of evocation	<b>CENTRAL NUCLEUS</b>  Higher frequency and more readily quoted evocations  (frequency of evocation $\geq$ IRF and ARO $<$ mean ARO)	<b>FIRST PERIPHERY</b>  Higher frequency and later quoted evocations  (frequency of evocation $\geq$ IRF and ARO $\geq$ mean ARO)
	<b>CONTRAST ZONE</b>  Less frequency and more readily quoted evocations  (frequency of evocation $<$ IRF and ARO $<$ mean ARO)	<b>SECOND PERIPHERY (PERIPHERAL SYSTEM)</b>  Less frequency and later quoted evocations  (frequency of evocation $<$ IRF and ARO $\geq$ mean ARO)
Average mean of evocation		

Figure 2. Diagram with allocation of evoked words. Source: Adapted from Vergara (2012).



Bervian (2002), studies that aim to identify the social representations via SRT are commonly descriptive in character.

The research subjects were formed by project management professionals from the engineering area chosen by the accessibility criteria, therefore a non-probabilistic sample, implemented by the snowball method, in which the researcher accesses known persons who indicate other known people to respond to the research (Biernacki & Waldorf, 1981). Thus, the study embraces the sector of people with some experience as a project management professional, trained or active in the field of engineering.

The respondents were accessed from the following professionals: (1) affiliated with institutions that foster the growth of the project management area; (2) who are undertaking postgraduate courses, preparatory courses for certifications and training in the area of project management.

The questionnaire was distributed in two ways: internet and delivered personally. Through the internet, the distribution channels used were: mailing lists of project management, LinkedIn, mailing lists of friends and acquaintances, as well as discussion groups of project management associations. In addition, the questionnaire was delivered in printed form to gather response from professionals that fulfilled the research profile.

During 40 days of collection, 243 respondents were obtained; 140 (57.6%) respondents had training or engineering performance, which were the criteria adopted in this research to qualify a respondent. However, eight (3.2%) respondents were discarded because they had no experience as a project management professional. Therefore, 132 (54.4%) valid respondents remained for the survey. Chart 2 summarizes the characteristics of the sample.

All questionnaires must pass through a quality test before being sent to potential respondents (Vieira, 2009). Thus, initially, the questionnaire was applied to 30 project management professionals for pre-test purposes. The application was attended by

one of the authors of this article to provide guidance, withdraw doubts and observe the response dynamics of the respondents. The 30 questionnaires were considered valid due to their correct completion. The pre-test pointed to the need for improvements in the questionnaire to increase clarity.

Then, data collection was implemented through the word evocation technique with the support of an online questionnaire and handled by the EVOC software. The word evocation technique aims to collect data from an inductive expression suggested by the researcher, which is a reference for the spontaneous generation (oral or written) of a certain number of words by the research subjects (Vergara, 2012). In the literature, the word evocation technique has been constantly used in studies that are based on SRT (Vergara, 2012). In this article, the word evocation technique was implemented by asking the research subjects to mention, in a spontaneous flow, the first five different words related to the inductive expression "complex project".

In relation to word ordering, there are two possibilities: (1) to ask the participant to indicate the most important words among those mentioned or (2) to understand that the order of mention is the same order of importance of the words (Vergara, 2012). In this article, the subjects were instructed to mention the first five words that came to the head in descending order (from the most important to the least important). The last step was identification in the central nucleus and peripheral system with EVOC software support.

In terms of the validity and reliability of the research, the recommendations of Yin (2001) and Patton (1999) were followed. In addition to the word evocation collection, the respondents' understanding of a complex project was also collected using an open question in the online questionnaire. The text of this question made it possible to clarify and confront the veracity of the words quoted. In addition, the data were analyzed by more than one researcher through information shared in a repository in the "cloud" and based on a research protocol.

**Chart 2.** Characteristics of the researched sample.

Characteristics	Description of research subjects
Age and experience time	Average age of 37.46 years and average experience time of 10.10 years
Gender	16.7% women and 83.3% men
Project management, participation in complex projects and engineering projects	78.8% already managed or currently managed a project, 71.2% participated in a complex project, and 93.2% acted or worked in engineering projects as project management professionals
Project Management Methodology	72.7% work in organizations that do not adopt a project management methodology
Number of employees and type of organization	35.6% work in organizations with more than 5,000 employees, with private organizations standing out with 76.5%
Organizational Maturity in Project Management	28% of organizations surveyed are in level 2 and 25% are in level 1 of project management maturity

Source: Authors.

### 5 Results obtained by EVOC

In the questionnaire the respondent was asked to give five words when he came across the expression “complex project”. Consequently, for the 132 respondents, it was expected to obtain 660 words; But 655 (99.3%) words were obtained, since five (0.7%) words were filled with blanks and, therefore, were not considered.

With the help of EVOC, the 655 words were imported and the database of the words evoked was prepared. Then all of the evoked words were poured into lowercase, the accents and chisels were removed, and expressions with more than one word were concatenated by a hyphen to compose a word only (eg, “many people” in “many-people”).

Following the process, the standardization criteria suggested by Kalache et al. (1987) were used to categorize the words with: (1) grammatical bending of gender and number, for example, the similarity between words like “conflict” and “conflicts” and (2) semantic synonyms and similarities, for example, the similarity between words such as “uncertainty” and “uncertain”.

In the categorization of words, the word with the highest number of evocations between the disputed words was chosen as criteria. For example, between the words “diversity” (three evocations) and “diverse” (an evocation), the word “diversity” was chosen due to the greater number of recalls.

Next, EVOC eliminated words with just one evocation. The elimination of unitary evocations is justified since the social representations are constituted

by the collective vision and not of only one individual (Moller, 1996).

Continuing, the generation of the four quadrants of Vergès among them: the central nucleus and the peripheral system of the social representation. However, prior to this, three calculations should be made for further information to EVOC: (1) calculate the minimum average frequency that each word must have to be considered for the average recall order (ARO) calculations; (2) calculate the mean of the average recall orders (mean ARO) and (3) calculate the intermediate recall frequency (IRF), which can be calculated based on the mean or median evocations.

Regarding the minimum average frequency, EVOC suggests as a standard the value of five evocations; that is, the words will be considered in the calculation only if they are recalled at least five times. This value can be adopted to execute the EVOC for the first time, but it is possible to use the value that represents the average of the words evoked since the social representations are aimed at capturing the collective thought.

The average of recall words can be discovered by analyzing the table generated by EVOC in the RANGMOT subroutine. This table shows the accumulated values in ascending and descending order of the relation between the number of words evoked and the frequency with which they were evoked (Reis & Sarubbi, 2013). In the case of social representation for complex projects, Table 1 was generated by EVOC.

**Table 1.** Calculation of the mean of the evoked words.

Frequency and number of evoked words	Cumulative values in ascending order	Cumulative values in descending order
1 x 112	112 17.1%	655 100.0%
2 x 34	180 27.5%	543 82.9%
3 x 16	228 34.8%	475 72.5%
4 x 9	264 40.3%	427 65.2%
6 x 8	312 47.6%	391 59.7%
7 x 2	326 49.8%	343 52.4%
<b>8 x 1</b>	<b>334 51.0%</b>	<b>329 50.2%</b>
9 x 7	397 60.6%	321 49.0%
10 x 2	417 63.7%	258 39.4%
13 x 1	430 65.6%	238 36.3%
17 x 1	447 68.2%	225 34.4%
18 x 1	465 71.0%	208 31.8%
20 x 2	505 77.1%	190 29.0%
21 x 1	526 80.3%	150 22.9%
25 x 1	551 84.1%	129 19.7%
32 x 1	583 89.0%	104 15.9%
35 x 1	618 94.4%	72 11.0%
37 x 1	655 100.0%	37 5.6%

Source: EVOC software.

Table 1 shows that the value approaching 50% in the column “cumulative values in descending order” is 50.2%, that is, the 20 different words (sum of the words quoted between frequencies 8 to 37 in the first column) represent 50.2% of the evocations. Therefore, they are the 20 most significant words among the 655 total words evoked. This value is associated with a frequency of eight evocations, as highlighted in bold in Table 1, and was adopted as the minimum mean frequency instead of the five evocations suggested as the standard by EVOC.

Regarding the calculation of the mean of average recall orders (mean ARO), the EVOC identified 201 distinct words and an average recall order of 2.98, with the EVOC rounded to 2.90 for greater consistency in the analysis. Regarding the calculation of the intermediate recall frequency (IRF), the EVOC identified 201 distinct words out of the 655 evoked

words, of which 20 met the criteria of minimum frequency of eight evocations.

The average and median evocations of the 20 distinct words were, respectively, 16.45 and 11.5. The median was adopted because, according to Reis & Sarubbi (2013), it seems to be the best measure for the intermediate recall frequency, since the frequencies of evocations do not distribute uniformly. Since the EVOC allows only integers, then the median is rounded to 12. Figure 3 shows the flow to determine the four quadrants of Vergès.

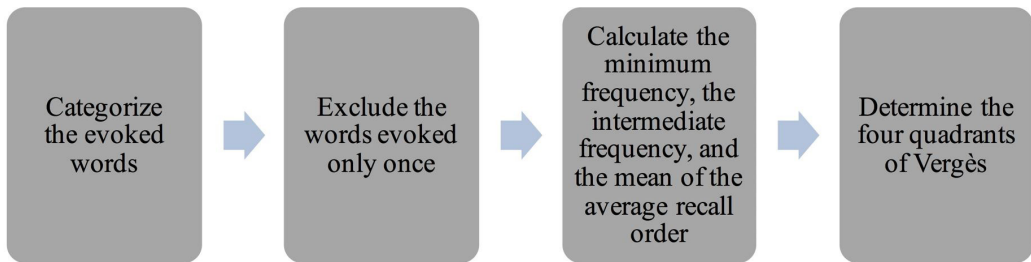
In sum, for the generation of the four quadrants of Vergès by through the EVOC software, first were calculated: (1) the minimum average frequency that each word must have to be considered in the calculations of the average recall order (ARO), being the value equal to eight; (2) average recall order equal to 2.9 and (3) the intermediate recall frequency (IRF) equal to 12 (median). Chart 3 presents these three values in detail and Chart 4 shows the four quadrants of Vergès with the words that were evoked.

On Chart 4, next to each word is indicated the frequency it was recalled by the research subjects and the Average Recall Order of each word. Taking that into consideration, the words that structure the

**Chart 3.** Calculations requested by the EVOC program for the creation of the four quadrants of Vergès.

<b>Minimum Average Frequency</b>	8
<b>Intermediate Recall Frequency</b>	12
<b>Mean of Average Recall Order</b>	2.9

Source: Adapted from EVOC software.



**Figure 3.** Flow with the steps to determine the four quadrants of Vergès. Source: Authors.

**Chart 4.** Distribution of the evoked words on the four quadrants of Vergès.

	<b>Average Recall Order under 2.9</b>	<b>Average Recall Order equal or above 2.9</b>
<b>Frequency equal or over 12</b>	<b>CENTRAL NUCLEUS</b> Stakeholders (37) Difficulty (35) Risks (25) Technology (21) Large (20) Scope (18) Multidisciplinary (17) Long (13)	Deadline (32) Cost (20)
<b>Frequency equal or over 8 and under 11</b>	Expensive (9) Integration (9) Challenge (9) Interfaces (9) Complexity (8)	Management (10) Planning (10) Innovation (9) Changes (9) Resources (9)

Source: Adapted from EVOC software.

Central Nucleus are: **stakeholders, difficulty, risks, technology, large, scope, multidisciplinary and long.**

## 6 Discussion on the evoked words

The central nucleus is located to the left and above in the four quadrants of Vergès. The words of the central nucleus represent the most cited by the research subjects and, when quoted, they appear in the first positions. Therefore, this quadrant presents the words with high consensus, providing a cohesive, stable and less sensitive perspective to the immediate context (Reis & Sarubbi, 2013). In other words, the central nucleus, according to this author, provides organization and meaning to the social representation. In the case of this research, it is these words that represent the object “complex project” in the perception of the professionals of the area of engineering. For this reason, some considerations about the words of the central nucleus will be developed below, in descending order of importance.

According to the PMI (2013) and to 57% of respondents, multiple stakeholders is one of the characteristics that most define the complexity in projects. Therefore, the first explicit human aspect appears in the word most quoted by the respondents: **Stakeholders**. In this case, perceptions revolve around quantity and quality.

The concern with quantity is evident when it is pointed out that the environment of a complex project involves a large number of stakeholders. The concern with the quality of the stakeholders manifests itself in the sense of managing and engaging them the right way, since the understanding of their expectations increases the chances of success of the project (Jordão et al., 2015). When mixing these two elements - quantity and quality, one has the idea of a large number of positive and negative stakeholders to be managed in a complex project.

In addition, human behavior is a source of complexity that can arise from the interaction of behaviors, demeanors and attitudes of people (Yugue & Maximiano, 2013; PMI, 2014). Thus, the number of people is one of the ways to measure complexity (Baccarini, 1996; Tarride, 2013). In addition, human behavior has characteristics of non-linearity, which is characteristic of a complex adaptive system.

**Difficulty** was the second most cited word by respondents. This word corroborates the idea that the concepts of difficulty and complexity still get mixed up in common sense (Thomas & Mengel, 2008; Whitty & Maylor, 2009; Tarride, 2013). For example, project management practitioners often confuse complex projects with megaprojects (Whitty & Maylor, 2009). Thus, it is worth emphasizing that

complexity tends to decrease as knowledge, experience and understanding increase (Chapman, 2016), which leads one to believe that the same occurs with the difficulty of a project.

The presence of the word **Risks** in the central nucleus evidences the respondents’ perception that a complex project is, above all, uncertain and unpredictable. In addition, risk management is attested by Jordão et al. (2015) as a critical success factor for a project. These findings are in line with the explanation proposed by Vidal et al. (2011) about how complexity affects the behavior of projects, because even if there is information in quantity and quality, it becomes difficult to understand and predict the behavior of a project complex.

In addition, uncertainty is one of the main characteristics of a complex adaptive system (Thomé et al., 2016), since in this type of system external conditions and constant changes do not allow predictions based on history. From that it is possible to understand that complexity relates to the idea of fortuity, since it comprises uncertainties, indeterminations, and random phenomena (Tarride, 2013).

Next, the word **Technology** denotes a duality in relation to complex projects. On one hand, the positive association of respondents’ perception with the idea of innovation and the use of new technologies, and on the other hand, concerns about the high degree of knowledge needed to manage complex projects in a mutant technological environment. This approach is aligned with what Jordão et al. (2015, p. 292) when he mentions that

[...] agility, the power to innovate quickly and efficiently, the ability to adapt and the potential for continuous improvement with large resource constraints [...].

are some prominent requirements in a successful project. These visions also align with PMI (2013), which attest that technology is one of the characteristics that most define complexity in projects in two aspects: use of technology that is new to the organization (26%) and use of a Technology that is not fully developed (25%).

Complexity is a quantitative phenomenon due to the immense amount of interactions and interferences between a very large number of units (Tarride, 2013). Thus, the word **Large** reflects the respondents’ idea that complex projects are grandiose and involve a huge amount of elements. This view is traditional, to the point of being typified as structural complexity (Thomé et al., 2016). However, it should be remembered that complexity is not exactly synonymous with magnitude, as it is not proportional to the size of the project, since small projects can contain great complexity (PMI, 2014).



When mentioning **Scope**, the respondents are guided by perceptions of great scale or great specificity in relation to the work to be delivered by the project. In this sense, although a complex system does not necessarily have thousands of parts (Rensburg, 2012), Baccarini (1996) suggests that complexity in projects can be interpreted and measured in terms of differentiation (numerous parts), as well as Yugue & Maximiano (2013) warn that scope is one of the keys to dealing with complexity. In addition, multiplicity (quantity of potentially interacting elements) is one of the properties that determine the complexity of an environment (Sargut & McGrath, 2011; Tarride, 2013). Therefore, this finding is consistent with the researched literature.

The word **Multidisciplinary**, in the context put by the respondents, means different disciplines with different interfaces that must be harmonized. This is related with the idea of interrelationship, one of the characteristics of a complex adaptive system (Snowden & Boone, 2007; Aritua et al., 2009). To harmonize the interfaces, human and managerial aspects are relevant. For example, Jordão et al. (2015) mentions management planning, control, and support, as well as communication, customer engagement, and feedback as critical success factors for a project.

In this way, it is understood that the level of complexity can be dimensioned by the level of stability between interrelationships (Rensburg, 2012), with complexity increasing with the number of unplanned connections between the system components (PMI, 2014).

The last word, **Long**, maintains the tendency of respondents to associate superlative ideas with complex projects. In this case, they understand a complex project as one of extensive duration. It is worth noting that the word **Deadline**, if it were contained in the central nucleus of social representation, would assume the third place with 32 citations by the respondents (see Chart 4). This fact suggests that respondents associate complex projects with long-term projects.

In face of the above, as a result of the research and the analyzes carried out, it is possible to propose an alternative definition for complex project, based on the point of view of professionals in the engineering area: complex project is a long-lasting project with multiple connected and heterogeneous elements interacting unpredictably due to the quantity and diversity of stakeholders, new technologies, scope and interfaces of the project.

## 7 Conclusions and recommendations

In summary, a qualitative and descriptive research was carried out with the support of bibliographical research to capture the perception of 132 respondents

eligible as project management professionals in the engineering area.

The data collection was implemented by the word evocation technique based on primary data source and operationalized by questionnaire. The answers were treated and analyzed by the Vergès technique with the support of the EVOC software to create a diagram with four quadrants, operating the Social Representation Theory (SRT), giving particular attention to the central nucleus of the social representation, which contains the understanding of respondents on the “complex project” object.

The adopted approach allowed the fulfillment of the study’s objective, and that is to identify the factors that characterize the complexity in the vision of the engineering project management professionals and to propose a definition for complex project.

The factors that represent the perception of engineering project management professionals regarding the complex projects and that are present in the central nucleus of the social representation are, in descending order: stakeholders, difficulty, risks, technology, large, scope, multidisciplinary and long .

Therefore, in general, complex projects are seen as a superlative system in terms of quantity and quality of constituents, and stakeholder management gains prominence.

The following academic implications of this study are: (1) the association of techniques and theories, which together have been little used in the scientific literature, such as the use of Social Representation Theory to study complexity in projects; and (2) The alternative definition for complex project proposed in this work, since it is a demand of the scientific community.

It is visualized as managerial implications of this study: (1) an alert for the managers in order to differentiate the concept of complex project from the other types of project. In this way, complex projects could gain differentiated approaches to increase their likelihood of success; (2) highlighting the importance of stakeholder management for the successful conduct of complex projects, followed by risk management, scope management and time management, and (3) support for project manager recruitment areas to optimize the selection of managers for projects considered as complex.

It is natural for the studies to present some degree of limitation, since the sample collected by the snowball method is non-probabilistic and its external validity cannot be guaranteed. Therefore, since non-probabilistic samples do not allow generalizations, the first limitation of this study is the impossibility of generalizing the conclusions.

Another limitation is the degree of subjectivity involved in the process of categorizing words evoked by the word evocation technique. This process is not standardized and depends on the level of knowledge of the researcher. Therefore, to minimize this subjectivity, in this study we adopted the standardization criteria suggested by Kalache et al. (1987) as a guide for categorization.

An additional limitation arises from the difficulty of understanding the real meaning of the evoked words from the point of view of the respondents, since those are isolated words. In this article, we tried to deal with this problem with the addition of a question in the questionnaire that captures the words, asking the respondent about his understanding about the concept of complex project. This open question served to better understand the evoked words when there was doubt from the part of the researchers.

One more limitation is due to the fact that the research focuses on project management professionals in the engineering area in Brazil. Therefore, professionals from other areas or residents of other countries may have a different perception of complexity in projects.

As a result of this research, other studies are suggested. First, we analyze the change in the perception of engineering project management professionals over time in a longitudinal study compared to the cross-sectional analysis developed in this research. With this, one can verify if there is maintenance of the current perception, mainly, in the Brazilian context.

Additionally, it is recommended to capture the perception of engineering project management professionals from other countries or even professionals in other areas of engineering. This would increase the consistency of the understanding on the constructo complexity in projects.

Another possibility correlated to this research is to study the skills of a project manager to manage complex projects. In this sense, studies of the application of complexity in the field of program management would also be valid; as well as studies on management tools, techniques and practices that can assist in the management of complex projects. In addition, it is recommended to study what traditional project management practices could also be applied to the management of complex projects.

Finally, it is expected that this research has contributed to the understanding and discussion of the constructo complex project, by exposing the vision of project management professionals in the engineering area.

## References

- Albrecht, J. C., & Spang, K. (2014). Linking the benefits of project management maturity to project complexity. *International Journal of Managing Projects in Business*, 7(2), 285-301. <http://dx.doi.org/10.1108/IJMPB-08-2013-0040>.
- Alves-Mazzotti, A. J. (2008). Representações sociais: aspectos teóricos e aplicações à educação. *Revista Múltiplas Leituras*, 1(1), 18-43. <http://dx.doi.org/10.15603/1982-8993/ml.v1n1p18-43>.
- Aritua, B., Smith, N. J., & Bower, D. (2009). Construction client multi-projects: a complex adaptive systems perspective. *International Journal of Project Management*, 27(1), 72-79. <http://dx.doi.org/10.1016/j.ijproman.2008.02.005>.
- Baccarini, D. (1996). The concept of project complexity - a review. *International Journal of Project Management*, 14(4), 201-204. [http://dx.doi.org/10.1016/0263-7863\(95\)00093-3](http://dx.doi.org/10.1016/0263-7863(95)00093-3).
- Biernacki, P., & Waldorf, D. (1981). Snowball sampling: problems and techniques of chain referral sampling. *Sociological Methods & Research*, 32(1), 148-170.
- Cervo, A. L., & Bervian, P. A. (2002). *Metodologia científica* (5 ed.). São Paulo: Pearson Prentice Hall.
- Chapman, R. J. (2016). A framework for examining the dimensions and characteristics of complexity inherent within rail megaprojects. *International Journal of Project Management*, 34(6), 937-956. <http://dx.doi.org/10.1016/j.ijproman.2016.05.001>.
- Cooke-Davies, T., Cicmil, S. J. K., Crawford, L. H., & Richadson, K. (2007). We're not in Kansas anymore, Toto: mapping the strange landscape of complexity theory. *Project Management Journal*, 38(2), 50-61.
- Farr, R. M. (2002). Representações sociais: a teoria e sua história. In Guareschi, P., & Jovchelovitch, S. (Orgs.), *Textos em representações sociais* (7 ed.). Petrópolis: Vozes.
- Geraldi, J., Maylor, H., & Williams, T. (2011). Now, let's make it really complex (complicated): a systematic review of the complexities of projects. *International Journal of Operations & Production Management*, 31(9), 966-990. <http://dx.doi.org/10.1108/01443571111165848>.
- Jodelet, D. (Org.). (2001). *As representações sociais*. Rio de Janeiro: Ed. UERJ.
- Jordão, R. V. D., Pelegrini, F. G., Jordão, A. C. T., & Jeunon, E. E. (2015). Fatores críticos de sucesso na gestão de projetos: um estudo de caso numa grande empresa latino-americana de classe mundial. *Gestão & Produção*, 22(2), 280-294. <http://dx.doi.org/10.1590/0104-530X1091-13>.
- Kalache, A., Veras, R. P., & Ramos, L. R. (1987). O envelhecimento da população mundial: um desafio novo. *Revista de Saude Publica*, 21(3), 200-210.

- PMid:3445102. <http://dx.doi.org/10.1590/S0034-89101987000300005>.
- Larson, E. W., & Gobeli, D. H. (1989). Significance of project management structure on development success. *IEEE Transactions on Engineering Management*, 36(2), 119-125. <http://dx.doi.org/10.1109/17.18828>.
- Major Projects Authority – MPA. (2013). *The Major Projects Authority Annual Report 2013*. London: MPA.
- Maylor, H., Vidgen, R., & Carver, S. (2008). Managerial complexity in project-based operations: a grounded model and its implications for practice. *Project Management Journal*, 39(S1), 15-26. <http://dx.doi.org/10.1002/pmj.20057>.
- Moller, R. C. (1996). A representação social do fenômeno participativo em organizações públicas do Rio de Janeiro. *Política e Administração*, 3(1), 43-51.
- Morel, B., & Ramanujam, R. (1999). Through the looking glass of complexity: the dynamics of organizations as adaptive and evolving systems. *Organization Science*, 10(3), 278-293. <http://dx.doi.org/10.1287/orsc.10.3.278>.
- Patton, M. Q. (1999). Enhancing the quality and credibility of qualitative analysis. *Health Services Research*, 34(5), 1189-1208. PMID:10591279.
- Pinto, J. S., Novaski, O., Anholon, R., & Besteiro, E. N. C. (2014). Proposta de método de mensuração da complexidade em projetos. *Revista Gestão e Projetos*, 5(3), 14-29. <http://dx.doi.org/10.5585/gep.v5i3.280>.
- Ponchiroli, O. (2007). Teoria da complexidade e as organizações. *Diálogo Educ*, 7(22), 81-100.
- Project Management Institute – PMI. (2009). *Exploring the complexity of projects: implications of complexity theory for project management practice* (92 p.). Newtown Square: PMI.
- Project Management Institute – PMI. (2013). *PMI's Pulse of the Profession In-Depth Report: navigating complexity* (28 p.). Newtown Square: PMI.
- Project Management Institute – PMI. (2014). *Navigating complexity: a practice guide* (113 p.). Newtown Square: PMI.
- Reis, A. O. A., & Sarubbi, V., Jr. (2013). *Tecnologias computacionais para o auxílio em pesquisa qualitativa – Software EVOC*. São Paulo: Schoba.
- Rensburg, A. C. J. V. (2012). Can complexity analysis support business performance insight? *South African Journal of Industrial Engineering*, 23, 16-28.
- Sá, C. P. (2002). *Núcleo central das representações sociais* (2 ed.). Petrópolis: Vozes.
- Sargut, G., & McGrath, R. G. (2011). Learning to live with complexity. *Harvard Business Review*, 89(9), 68-76. PMID:21939129.
- Serva, M., Dias, T., & Alpersted, G. D. (2010). Paradigma da complexidade e teoria das organizações: uma reflexão epistemológica. *Revista de Administração de Empresas*, 50(3), 276-287. <http://dx.doi.org/10.1590/S0034-75902010000300004>.
- Snowden, D. J., & Boone, M. E. (2007). A leader's framework for decision making. *Harvard Business Review*, 85(11), 68-76. PMID:18159787.
- Svevig, P., & Andersen, P. (2015). Rethinking project management: a structured literature review with a critical look at the brave new world. *International Journal of Project Management*, 33(2), 278-290. <http://dx.doi.org/10.1016/j.ijproman.2014.06.004>.
- Tarride, M. I. (2013). The complexity of measuring complexity. *Keybernetes*, 42(2), 174-184. <http://dx.doi.org/10.1108/03684921311310558>.
- Thomas, J., & Mengel, T. (2008). Preparing managers to deal with complexity - advanced project management education. *International Journal of Project Management*, 26(3), 304-315. <http://dx.doi.org/10.1016/j.ijproman.2008.01.001>.
- Thomé, A. M. T., Scavarda, L. F., Scavarda, A., & Thomé, F. E. S. S. (2016). Similarities and contrasts of complexity, uncertainty, risks, and resilience in supply chains and temporary multi-organization projects. *International Journal of Project Management*, 34(7), 1328-1346. <http://dx.doi.org/10.1016/j.ijproman.2015.10.012>.
- Vergara, S. C. (2012). *Métodos de pesquisa em administração* (5 ed.). São Paulo: Atlas.
- Vidal, L. A., & Marle, F. (2008). Understanding project complexity: implications on project management. *Kybernetes*, 37(8), 1094-1110. <http://dx.doi.org/10.1108/03684920810884928>.
- Vidal, L. A., Marle, F., & Bocquet, J. C. (2011). Measuring project complexity using the Analytic Hierarchy Process. *International Journal of Project Management*, 29(6), 718-727. <http://dx.doi.org/10.1016/j.ijproman.2010.07.005>.
- Vieira, S. (2009). *Como elaborar questionários*. São Paulo: Atlas.
- Wachelke, J. (2012). Social representations: a review of theory and research from the structural approach. *Universitas Psychologica*, 11, 729-741.
- Wachelke, J., & Wolter, R. (2011). Critérios de construção e relato da análise prototípica para representações sociais. *Psicologia: Teoria e Pesquisa*, 6, 27-521.
- Wagner, W. (1999). *Theory and method of social representations*. London: LSE Research Online. Recuperado em 12 de fevereiro de 2016, de <http://eprints.lse.ac.uk/2640>

- Whitty, S. J., & Maylor, H. (2009). And then came Complex Project Management (revised). *International Journal of Project Management*, 27(3), 304-310. <http://dx.doi.org/10.1016/j.ijproman.2008.03.004>.
- Williams, T. (1999). The need for new paradigms for complex projects. *International Journal of Project Management*, 17(5), 269-273. [http://dx.doi.org/10.1016/S0263-7863\(98\)00047-7](http://dx.doi.org/10.1016/S0263-7863(98)00047-7).
- Xia, W., & Lee, G. (2004). Grasping the complexity of IS development projects. *Communications of the ACM*, 47(5), 69-74. <http://dx.doi.org/10.1145/986213.986215>.
- Yin, R. K. (2001). *Estudo de caso: planejamento e métodos* (2 ed.). Porto Alegre: Bookman.
- Yugue, R. T., & Maximiano, A. C. A. (2013). Understanding and managing project complexity. *Revista Gestão e Projetos*, 4(1), 1-22. <http://dx.doi.org/10.5585/gep.v4i1.109>.