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REVISITING PROJECT COMPLEXITY:

a new dimension and framework

Abstract: Project complexity is defined by dimensions such as structural complexity, uncertainty, pace, dynamic complexity, novelty, social-political and institutional complexities. In this article, these dimensions were discussed and organized to form a comprehensive framework. The major contributions of this article were the introduction of institutional complexity and the development of a project complexity framework to allow researchers and practitioners to better understand projects and make more informed decisions. Similarly, industries may benefit from these findings and the framework, applying it in their projects, grasping complexity from them.

Keywords: project complexity; complexity; systematic review; institutional; framework

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1 Introduction

World Bank data shows that almost 24% of the world's gross domestic product (GDP), or US$19.062 trillion, is gross capital formation which is almost entirely from project-based investments (World Bank, 2015). Meanwhile, project management practices have been used in several industries and countries as a way to increase success rates in their efforts to develop products and services or improve results (PMI, 2017). Despite some improvements over the last few years, organizations are facing increasing levels of complexity in their projects, challenging their ability to deliver successful projects. Given the current importance of project complexity, the debate in academia has equally grown over time (Rezende et al., 2018). For instance, Baccarini (1996), Shenhar and Dvir (1996, 2007), Williams (1999) introduced the idea of structural complexity as an approach to analyzing projects. Shenhar and Dvir (1996) and Williams (1999) also discussed uncertainty as a dimension of project complexity that can affect project success. Shenhar et al. (2002) and later Shenhar and Dvir (2007) evolved their project complexity framework by introducing the idea of pace and novelty as new dimensions of project complexity. Xia and Lee (2003) later discussed dynamic complexity as an additional dimension that stresses the structural complexity of projects. Engwall (2003) discussed the role of norms that influence the interior process dynamic of projects while Remington and Pollack (2007), and Geraldi et al. (2011) explored social and political complexities as new ways to analyze project complexity. Alongside this, a number of project complexity frameworks have been developed, such as the ISDP (Information System Development Project) Complexity Framework (Xia and Lee, 2003), the Diamond Framework (Shenhar and Dvir, 2007), ALOE (Attributes, Links, Objects and Events) Framework (Vidal and Marle, 2008), MODeST (Mission, Organization, Delivery, Stakeholders and Team) Framework (Maylor et al., 2008), and the TOE (Technical, Organizational and Environmental) Framework (Bosch-Rekveldt et al., 2011).

Among the several debates within the project complexity research field, we highlight two important contributions upon which we build our work. On one hand, Shenhar and Dvir (2007) developed the Diamond Framework, a practical and extensively used tool to analyze project complexity, although it does not cover project complexity dimensions such as dynamic and social-political complexity. On the other hand, Geraldi et al. (2011) presented a systematic review to uncover the main dimensions and factors that create complexity in a project, although the number of publications on the field more than doubled since then, requiring us to revisit the field and incorporate a missing dimension. Therefore, our contribution is twofold. First, we expanded the work of Geraldi et al. (2011) defending novelty as a separated dimension, introducing institutional complexity as a new project complexity dimension and confirming previously discussed dimensions. After that, using Shenhar and Dvir (2007) framework as a starting point and the seven project complexity dimensions discussed in this article, we developed the foundation of the project complexity framework that covers all dimensions identified in the literature.

In the following sections, we discuss project complexity in detail, starting with the methods used to systematically review the literature and the main bibliometric data regarding the project complexity field. Then, the definition of project complexity and each dimension are presented and discussed. After that, a project complexity framework with all dimensions discussed is presented. Finally, some conclusions, implications, recommendations, limitations, and further research agendas are presented.

2. Methodology

The project complexity research field has been growing in importance over the last decades, especially in the last years, as suggested by the number of project complexity publications illustrated in Graph 1. Publications related to project complexity started in 1966, but only 24 articles had been published until 1989, what is considered the first wave of development of the research field. After the 1990s, the second wave of development started, and 172 articles were published until 2004. Finally, a third and actual wave started in 2005 and published 463 articles so far (Rezende et al., 2018). Given that 386 articles (**Graph 1**), almost half of all publications in the field so far were published between 2012 and 2018, after Geraldi et al. (2011) systematic review, the field needs to be revisited to incorporate the findings of the last years. Therefore, to conduct a comprehensive literature review, the Search, Appraisal, Synthesis and Analysis (SALSA) framework (Booth et al., 2013) was used as presented in **Figure 1**. The first two stages of the SALSA framework - search and appraisal - were divided into steps A to C and D to E, respectively. The remaining stages - synthesis and analysis - were composed of stages F and G, respectively. For the first stage, the search, Booth et al. (2013) argue that missing relevant sources is a risk for any search using specific parameters. In order to minimize this issue, the search stage was conducted using the broadest terms possible related to project and program complexity. The Web of Science Core Collection was the main database used to search for articles related to the topic.

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The keywords used to search titles, abstracts, and keywords were "project$ complexit*" OR "complex project$" OR "program$ complexit*" OR "programme$ complexit*" OR "complex program$" OR "complex programme$" in the topic field. The Science Citation Index Expanded (SCI-EXPANDED), the Social Sciences Citation Index (SSCI), and the Emerging Sources Citation Index (ESCI) were the indexes used.

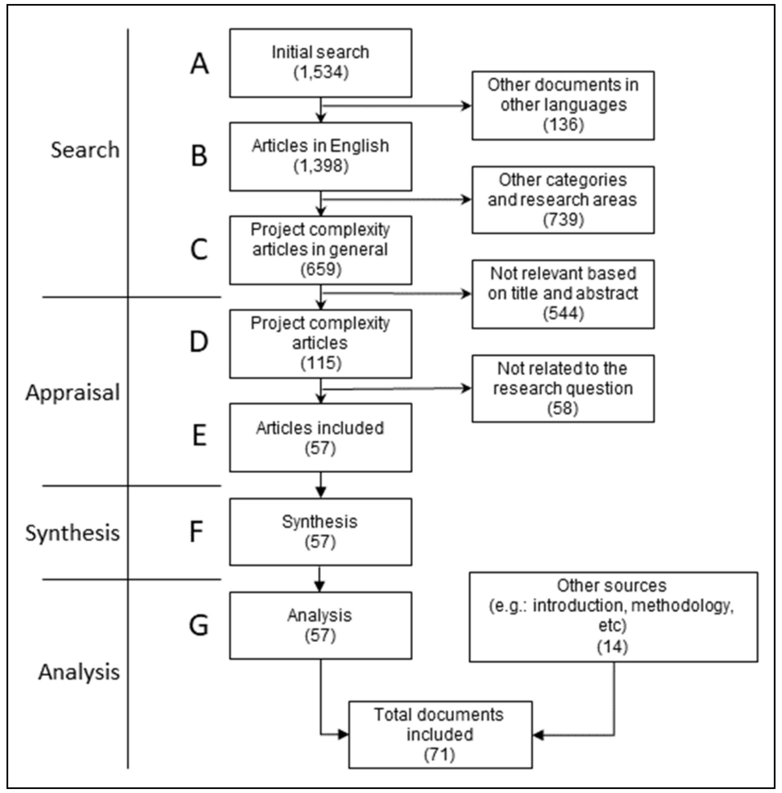
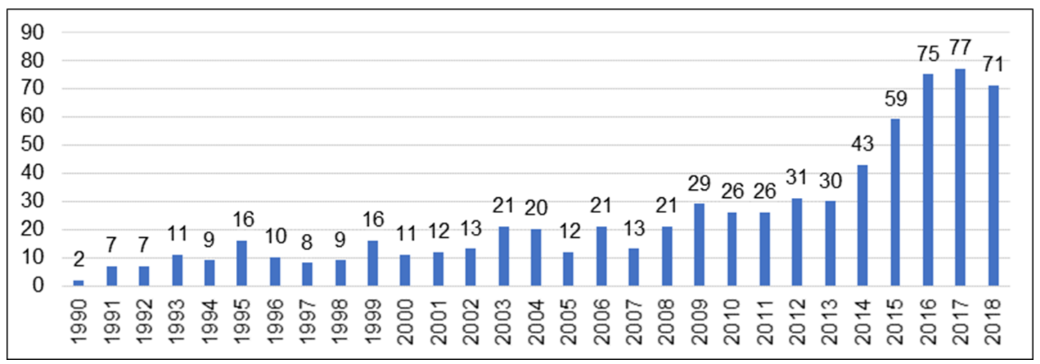


Figure 1: Literature review process



Graph 1: Project complexity publications by year
Source: Web of Science

Conference proceedings, book citations, and other kinds of sources were excluded from the search to avoid grey literature and focus on peer-reviewed documents (Step A). The search results were further refined to include articles in English (Step B). A final filter was applied to exclude research areas and Web of Science categories related to biology, medicine, and health sciences, among others, that use the terms 'complexity' and 'project' in situations unrelated to project management (Step C). After step C, a total of 659 articles related to project complexity were identified across 92 journals and 15 research areas. Given the diversity and amount of project complexity articles identified, during the appraisal stage, a quality assessment analyzed the title, abstract, and full-text to select articles specifically related to the research topic. Articles that used the keywords "programme" or "program" related to software, programming, or policy were excluded. The same was done with the keyword "complexity" when it was used to denote difficulty or was related to computational complexity (Step D). The articles not related to the research question under investigation were excluded (Step E), resulting in a final datasheet with 57 articles.
During the synthesis stage (Step F), the articles were coded (Saldaña, 2016) to develop a line of argument using the narrative synthesis approach, since this study combined documents with different objectives and methods to develop a robust literature review. The narrative was developed by organizing articles into different discussions and by how they evolved over time.
Finally, the analysis stage (Step G) was conducted to verify the consistency of the synthesis stage. During this process, a sensitivity analysis was done to ensure that the findings were sufficiently robust.

3. Project complexity

Baccarini (1996) presented one of the first project complexity definitions, stating that it consists of "varied interrelated parts and can be operationalized in terms of differentiation and interdependence." This definition emphasizes the growth of complexity based on the number and variety of elements and the interdependence between them (Vickery et al., 2016). The same idea of many elements interacting was discussed by Tatikonda and Rosenthal (2000), who defined project complexity as the "nature, quantify, and magnitude of organizational subtasks and subtasks interaction posed by the project."
Building upon the notion of uncertainty, Pich et al. (2002) explained that project complexity "means that many different actions and states of the world parameters interact, so the effect of actions is difficult to assess." This leads to two other important characteristics, namely the emergent behaviors observed and the dynamic nature of project complexity.
Regarding the idea of emergent behaviors and the dynamic nature of projects, Vidal et al. (2011) argued that project complexity "is the property of a project which makes it difficult to understand, foresee and keep control of its overall behavior, even when given reasonably complete information about the project system". Based on that, the ability to foresee such behaviors explains the main difference between something complicated or complex.
Bakhshi et al. (2016) discussed project complexity by exploring it through the lens of complexity theory, system thinking, and project management practices, explaining it in terms of project size, emergence, diversity, connectivity, project context, belonging, and autonomy. Chapman (2016) also identified several factors grouped into finance, context, management, site, task, and delivery. Mirza and Ehsan (2017), on the other hand, used factors such as schedule, scope, and cost/resources to describe project complexity. All these factors identified by the authors are key aspects that are organized into groups that help to outline project complexity characteristics.
As one may be noticed, the definitions of project complexity are usually related to complex systems characteristics. According to Skyttner (2001), a "system is a set of interacting units or elements that form an integrated whole intended to perform some function". Complex systems, on the other hand, are systems composed of several elements that are dispersed and free to interact locally. Their behavior is chaotic and disorganized, and thus highly unpredictable (Battram, 1999). This behavior is the result of the response to local conditions (rules, laws, forces, etc.) by the parts of the system, which leads to the emergence of a global pattern, even if there is no coordination or communication between parts (Klijn, 2008). Therefore, characteristics such as many interacting parts, self-organization, holism, openness, emergent behavior, sensitivity to initial conditions, nonlinearity, feedback loops, learning, and adaptation are important elements to define a complex system and, thus project complexity.
Given the lack of consensus among the research community, we define project complexity using all the characteristics of a

complex system. Therefore, project complexity is an aspect of projects created by many interdependent parts that can learn (people, stakeholders, among others) or not (product, documents, among others) over time and that interact with themselves and the environment (organizations, governments, laws, among others) through feedback loops that create adaptation and non-linear emergent behaviors that can only be explained by principles and patterns.

3.1. *Structural complexity*

Baccarini (1996) introduced the idea of structural complexity arguing that it can be explained in terms of differentiation and interdependence, that is, the number of elements in the project and the interrelatedness between them. Baccarini (1996) applied it to the organizational and technological aspects of a project. Vertical organizational differentiation is related to the depth of the organizational hierarchical structure, while horizontal differentiation is related to its variety and size. This definition is directly associated with the level of the organization's specialization and can be analyzed from the perspective of organizational units or personal specialization. On the other hand, organizational interdependence explains the relationship between the organizational units, teams, specialists, and workers in general. Technological complexity uses differentiation to express the variety and number of elements, such as inputs, outputs, outcomes, actions, tasks, technologies, time, territories, and many other aspects of the project. Technology interdependence involves the connections between technical elements of the project, for example, "between tasks, within a network of tasks, between teams, between different technologies, and between inputs" (Baccarini, 1996).

Based on Baccarini's (1996) work, Williams (1999) suggested that the project complexity concerning to the underlying structure of the project should be named 'structural complexity'. Since then, the majority of the articles about project complexity define structural complexity based on size (or number), variety and interdependence between elements within the project, supporting the idea of differentiation and interdependence proposed by Baccarini (1996).

At the same time that Baccarini (1996) developed his research, Shenhar and Dvir (1996) explored a similar idea by developing a framework to categorize projects based on its uncertainty and scope. The scope dimension was intended to classify projects based on the hierarchies of its products, arranging them along an axis composed of components/materials, assemblies, systems and arrays (system of systems) (Shenhar, 2001; Shenhar et al., 2016), and that represents the number and variety of elements being developed by the project. Williams (1999) argued that the scope dimension corresponds to the differentiation sub-dimension, but it can be argued that it is also composed of interdependence because Shenhar and Dvir (1996) integrated both sub-dimensions (differentiation and interdependence) into one higher dimension (scope).

Despite the importance of differentiation, the level of interdependence within a project plays a more crucial role. Williams (2005) argues that reciprocal interdependencies have an important impact on increasing project complexity and states that "where there are reciprocal dependencies allowing feedback effects to develop, the project will behave in a way difficult to predict intuitively and certainly at variance to how conventional techniques would indicate." Antoniadis et al. (2011) also argued that complexity is more related to the interconnection between the elements than the role of a single element. Interdependencies between elements of the project, especially reciprocal interdependence, is also discussed by Xia and Lee (2003) as an important characteristic that makes project's processes and outcomes more difficult to predict. As a consequence of the importance of interdependencies, Nassar and Hegab (2006) developed a complexity measure for project schedules in order to better express a project complexity based on the number of tasks (differentiation) and the number of connections between them (interdependence). Moreover, the importance of interdependencies also leads to the development of interface-management practices to deal with this kind of project complexity (Ahn et al., 2017).

The differentiation and interdependence were researched in different industries, such as construction (Antoniadis et al., 2011; Baccarini, 1996; Nassar and Hegab, 2006), Complex Products and Systems (CoPS) (Hobday, 1998), new product development (Kim and Wilemon, 2003), information technology (Xia and Lee, 2004, 2003), entertainment (Vidal et al., 2011), and large engineering projects (Bosch-Rekveldt et al., 2011). Moreover, they were also consistent throughout the literature, even when authors used different names to refer to the same idea.

3.2. *Uncertainty*

Shenhar and Dvir (1996) introduced the notion of technology uncertainty discussing it in terms of the amount of information available about the system and how people understand it. In this sense, Geraldi et al. (2011) argued that "uncertainty relates to both the current and future states of each of the elements that make up the system being managed and also how they interact and what the impact of those states and interactions will be." There are different definitions of uncertainty depending on the area of knowledge studied. For instance, in general management, uncertainty is usually explained in terms of variety (the probability of change of an event), lack of information, lack of agreement over the current and future situation, or ambiguity. In project management, uncertainty is usually expressed more specifically as the uncertainty of goals and methods, the level of unpredictability (variation, foreseen uncertainty, unforeseen uncertainty, and chaos), the ambiguity of goals, and novelty (technology or uncommon contractual frameworks).

Uncertainty explained in terms of variety, as argued by Geraldi et al. (2011), is related to situations where managers have information about possible outcomes, but they do not have any information or confidence about the probability of occurrence of the identified outcome. This is comparable to what Padalkar and Gopinath (2016) called structural uncertainty, when the elements are known but their values are not. Similarly, Zheng and Carvalho (2016) argued that there is an uncertainty degree that varies from "variability or statistical uncertainty, predictable uncertainty or scenarios, unpredictable or recognized uncertainty, and chaos or total ignorance". Likewise, Schrader et al. (1993) argued that uncertainty is related to "situations where the set of possible future outcomes is identified, but where the related probability distributions are unknown, or at best known subjectively." The classic definition of uncertainty presented by Galbraith (1973) is more straightforward, stating that it is "the difference between the amount of information required to perform the task and the amount of information already possessed by the organization." Based on Galbraith (1973), it is possible to argue that uncertainty in terms of variety is caused by a lack of information, so it is more reasonable to define uncertainty in terms of information (cause) rather than variety (effect).

Information uncertainty was also discussed as knowledge uncertainty or incomplete pre-given knowledge and, based on Luft and Ingham (1955), Ahern et al. (2014) classified it as 'known knowns' (knowledge), 'known unknowns' (risks), 'unknown knowns' (untapped knowledge) and 'unknown unknowns' (uncertainty). The two last categories are related to project complexity and are characterized by high or extreme knowledge change (Ahern et al., 2014). Williams (1999) exemplifies the relationship between uncertainty and knowledge, arguing that the difference between the knowledge required and existing was correlated with complexity, explaining that "a project where a body of knowledge exists (e.g. building an airliner) is less complex than a state-of-art project where there is no experience (e.g. building an HOTOL craft to go to the atmosphere edge)." Tatikonda and Rosenthal (2000) share a similar view, arguing that "the more uncertain the task, the greater the quantity and quality of information processing required during the task activity to generate necessary knowledge to complete the task." Therefore, uncertainty as a project complexity dimension is based on a lack of information.

Uncertainty (lato sensu) as a project complexity dimension is composed of the uncertainty of information (stricto sensu) and ambiguity, so it is important to differentiate these. Pich et al. (2002) explained that ambiguity "refers to the lack of awareness of the project team about certain states of the world or causal relationships." Similarly, Schrader et al. (1993) argued that ambiguity is defined as the "lack of clarity regarding the relevant variables and their functional relationship" or just the "lack of clarity in a problem situation." The notion of ambiguity most associated with situational uncertainty is when "a 'messy' situation is difficult to identify and evaluate" or when "people think that they are facing a known known (personal communication or process interpretation) when in fact they are facing a mis-known known" (Walker et al., 2017). Xia and Lee (2003) applied the ideas of uncertainty and ambiguity to characterize system complexity in information systems development projects. Though they did not explicitly differentiate one definition from the other, it is possible to infer that their understanding of ambiguity is similar to Pich et al. (2002) and Schrader et al. (1993) because they argue that as "changes occur [in the project environment], the cause-and-effect relationship becomes ambiguous and non-linear" as a reference to the lack of clarity when changes occur in projects. Despite the differences between uncertainty and ambiguity, they are not differentiated in some cases. This issue is more evident when uncertainty regarding goals and methods are being discussed, as noted by Williams (2005) and Geraldi et al. (2011). Turner and Cochrane

(1993) specifically debate this topic and argued that "projects can be judged against two parameters: how well defined the goals are, and how well defined the methods of achieving them are." Although they do not differentiate between the ambiguity and uncertainty of the goals and methods, an analysis of their research suggests that uncertainty is treated generally to include the possibilities of ambiguity and uncertainty in regard to goals and methods. Williams (1999) argued that software development projects are typical endeavors "whose methods are known but whose goals are uncertain, since users' requirements are difficult to specify, and are often changed when initial prototypes are seen," and this kind of uncertainty creates cross-impacts, re-work, and feedback-loops that lead to the increase of structural complexity. In summary, an information may be available, leading to a low level of uncertainty of information, although its lack of clarity may contribute to increasing the level of ambiguity, which leads to the use of different approaches to coping with it.

It is important to differentiate uncertainty from risks as well, given that an "important task of risk management is to transform uncertainty into risk as far as possible in order to make it plannable and controllable" (Böhle et al., 2016). In this regard, tools such as the Uncertainty Kaleidoscope (Saunders et al., 2016) help managers to grasp uncertainty and ambiguity using factors from categories such as environmental, individual, complexity, information, temporal aspects, and capability. Therefore, risk management focuses on the known/knowns and known/unknowns, while uncertainty and ambiguity management deals with unknown/knowns or unknown/unknowns. This means different approaches need to be applied to cope with any nondeterministic aspects (risks, uncertainty and ambiguity) surrounding a project.

The various views about uncertainty and ambiguity support the idea that those characteristics are clearly related to the main aspects of complex systems and project complexity, such as emergence (uncertainty of state), nonlinearity (uncertainty of interactions), and positive feedback. In summary, uncertainty as a project complexity dimension can be explained in terms of a lack of information.

3.3. *Pace*

The pace is a project complexity dimension introduced by Shenhar et al. (2002) to assess projects based on their speed and criticality. The subject was discussed earlier by Williams (1999), although without proposing any framework to incorporate such aspects; rather, he only argued that "projects have tended to become more time-constrained, and the ability to deliver a project quickly is becoming an increasingly important element to winning a bid" and that "as a project becomes shorter in duration, this enforces parallelism and concurrency, which by definition increases project complexity further." Shenhar et al. (2002), on the other hand, evolved their previous framework based on technology uncertainty and complexity (Shenhar, 2001; Shenhar and Dvir, 1996) to an extended version of it that incorporated a pace dimension into their Uncertainty, Complexity and Pace (UCP) model. They explained that pace dimension involves an assessment of the speed and criticality of time goals and that, although all projects have time limitations, the degree of urgency is an important factor to distinguish among projects, because the same goals may require different approaches according to the timeframes imposed. The pace dimension of the UCP model was developed based on "how much time is available and what happens if the time goals are not met" (Shenhar et al., 2002). The authors initially identified three types of projects: regular projects, fast or competitive projects, and critical or blitz projects.

Regular projects are those that missed the deadline for completion are tolerated because time was not a critical success factor to the organization responsible for it. Projects such as public buildings, organizational improvement efforts, non-competitive or non-profit projects, and long-term technology building efforts are examples of regular projects. The authors explained that this kind of project has less pressure to be completed on a specific dates, and so it can be easily de-prioritized to accommodate new demands or it can suffer from a 'no ending syndrome' that halts the project and consumes valuable resources (Shenhar et al., 2002; Shenhar and Dvir, 2004).

Fast or competitive projects are more commonly found in the private sector, where the "time to market is directly associated with competitiveness, and although missing the deadline may not be fatal, it could hurt profits and competitive positioning" (Shenhar et al., 2002). The authors argued that managing the time frame in this type of project should be one of the main concerns of the project manager and that the project's sponsor needs to support the endeavor and closely monitor the main control milestones in order to act to correct or prevent any deviation from the schedule. In this kind of project, the pace starts to increase the complexity of projects (Shenhar et al., 2002; Shenhar and Dvir, 2004).

Critical or blitz projects are the most complex in the pace dimension since they are the most time-critical. These projects exist in both the private and public sectors and are usually initiated during crisis situations or as a result of an unexpected event, such as an aggressive move to surprise the competition, military and security projects to respond to an unanticipated threat, or even problems that were anticipated but became more critical as the deadline approached, such as projects that have fixed date for delivery or execution. This kind of project demands a different approach tailored to non-stop interaction and a continuous decision-making process with a high degree of autonomy assigned to the project manager. In this type of project, the level of detailed documentation and written reports are small, being replaced by more communication among the project team and direct and oral reporting between the project manager and sponsors (Shenhar et al., 2002; Shenhar and Dvir, 2004).

In a NASA case study, Shenhar et al. (2005) divided the last level of the pace dimension into critical and blitz projects. The authors described the time-critical level as "crucial for success-windows of opportunity" and the blitz level as "crisis-project – immediate solution is necessary." They used the Orbiter Boom Sensor System (OBSS) as an example of a blitz project with the scope to develop a self-inspection system for the Orbiter while in orbit, as a response to the Columbia Accident Investigation Board, in order to allow NASA to return the shuttle to flight (Shenhar et al., 2005). Breaking down the classification dimension allowed NASA to differentiate extreme pace projects, such as response to crises, and critical pace projects related to date-driven events.

Williams (2005), Shenhar et al. (2002, 2005) and Shenhar and Dvir (2004, 2007) argued that structural complexity, uncertainty and tight time-constraint are the main factors that cause overruns. The authors argued that when the project is heavily time-constrained, the project manager is forced to take acceleration actions that can produce problems and cause project overruns. The authors explain that, unlike simple projects that can be replanned to adapt to changes in the environment, complex projects can become unstable when perturbed and difficult to manage over high pace circumstances, given a large number of decisions to be made rapidly. The mentioned effects are caused by feedback loops and are sensible to initial conditions - both characteristics common in a complex system.

Finally, Geraldi et al. (2011) argued that it is difficult to operationalize measures to pace and that it is usually summarized as the "speed of", which refers to a "rate at which projects should be delivered relative to some reasonable or optimal measure", however, it can be operationalized as in the Diamond framework. Therefore, pace as a project complexity dimension assesses projects based on two different aspects: speed and criticality.

3.4. *Dynamic complexity*

Dynamic complexity describes change, adaptation, and evolution, by expressing the non-predictable and nonlinear nature of project complexity (Zhu and Mostafavi, 2017). "Research in the dynamic stream addresses temporal emergence, particularly processes that bring about sudden, radical and unpredictable change in systems" (Floricel et al., 2016). Therefore, dynamics as a dimension of project complexity attempts to explain how a project and its parts evolve over time.

Dynamic complexity was approached by researchers from several perspectives. Xia and Lee (2003), the first authors to incorporate it into a framework, explored dynamic complexity in the context of task complexity arguing that "dynamic complexity is caused by changes in the states of the task environment" from organizational and technological perspectives. From the organizational perspective, they explained that dynamic organizational complexity is the "rate and pattern of changes in the ISDP [information system development project] organizational environments, including changes in user information needs, business processes, and organizational structures." In technological perspective, dynamic information technology complexity was defined as "the rate and pattern of changes in the IT [information technology] environment of the ISDP, including changes in IT infrastructure, architecture and software development tools." Similarly, Maylor et al. (2008) argued that "for every structural element, there is a corresponding dynamic element," as a way to explain how project elements evolve during its life cycle. Moreover, they stated that the scale and the frequency of change are important factors that make a project difficult to manage and that those aspects are traditionally managed by processes such as risk management, configuration management, and change control, although in some cases the response triggered by those processes can exacerbate issues in the form of a positive feedback loop. Ahern et al. (2014) considered the environment as the main cause of change in a project, exploring dynamic complexity through the lens of knowledge

change, introducing the idea of dynamic knowledge (know-how) and static knowledge (plans).
Geraldi et al. (2011) argued that "changes may lead the project to a high level of disorder, rework, or inefficiency when changes are not well communicated or assimilated by the team and others involved. In the dynamic context, it is also relevant to make sure that the goals of the projects continue to be aligned with those of the key stakeholders, and new developments in competition (e.g. in NPD). Projects not only change 'outside-in' but also 'inside-out', team motivation levels may change, internal politics may emerge."
Dynamism in a project can emerge from several aspects such as a change in stakeholder attributes, positions, relationships among them, new emerging stakeholders or relationships, and changes in ways or strategies to engage stakeholders (Aaltonen and Kujala, 2016). Because of the dynamic aspect of projects, understanding the pattern of change can help to avoid chaos, for example, by systemizing change processes. Despite the differences, similarities, and focus given by authors to dynamic complexity, they all try to explain how the project and its parts evolve over time. Therefore, dynamism is a project complexity dimension that expresses changes and evolution.

3.5. *Novelty*

Novelty has been discussed for a long time by new product development researchers (Clift and Vandenbosch, 1999; Griffin, 1993; LaBahn et al., 1996; Tatikonda and Rosenthal, 2000) and project complexity researchers (Ahern et al., 2014; Bosch-Rekveldt et al., 2011; Dvir et al., 2006; Hobday, 1998; Kim and Wilemon, 2003; Maylor et al., 2008; Shenhar et al., 2005, 2002; Shenhar and Dvir, 2004), although it was included as a dimension to classify projects only by Shenhar and Dvir (2004).
In the new product development research field, Griffin (1993) was one of the first to research the topic and defined it as "percent change across product generations." In a later research, Griffin (1997) named novelty as newness and explained it as "a matter of how much of the product must be redesigned, independent of the complexity of the product for making that change." She goes on to explain that most researchers concentrated their efforts on analyzing "new to the firm" products, which are projects developed from scratch, rather than product improvements that are an important aspect of developed projects. This reveals that novelty can be understood as an incremental change in the project and also as a radical change, such as the new-to-the-firm projects. Clift and Vandenbosch (1999) also used the idea of the degree of modification within a product to classify it as simple or complex, arguing that "re-engineering projects and minor modifications to existing projects were classified as simple projects, whereas major modifications and projects leading to new-to-the-world products were classified as complex projects." Thus, the level of complexity of a project is related to its level of novelty. Similarly, LaBahn et al. (1996) used the idea of product innovation to express ideas related to novelty and used three variables: innovativeness of the product to the market, novel features, and new technology for consumers. The definition presented by LaBahn et al. (1996) allows novelty to be interpreted as a relative definition that varies according to the opinion of the observer, given that different customers and markets have different perceptions about the level of novelty or innovation of a product.
Tatikonda and Rosenthal (2000) researched novelty from a technological perspective, defining technology novelty as "the newness, to the development organization, of the technologies employed in the product development effort" and they operationalized it using two sub-dimensions: product technology novelty and process technology novelty. Product technology novelty is related to "new product architectures in addition to new product parts and modules", while process technology novelty is related to "new manufacturing flows and layouts in addition to specific new manufacturing tools and process stages." The idea of product technology novelty proposed by Tatikonda and Rosenthal (2000) is related with the definition of novelty proposed by Griffin (1997), while the idea of process technology novelty opens a new perspective that focuses not only on the product but also on the process and the managerial implication of that to the project. The idea of process novelty was also explored by Ahern et al. (2014), who argued that the causes of novelty can come from different aspects, such as "combining existing ideas and techniques in a new way." Hobday (1998) also used the idea of product technology novelty as an important indicator of complexity in CoPS projects, while Kim and Wilemon (2003) focused on technological newness in new product development projects.
In the project complexity research field, novelty was initially discussed as market uncertainty and described as "how new the product is to the market, and how well customers or users know about it" (Shenhar et al., 2002). Later, Shenhar and Dvir (2004) and Dvir et al. (2006) discussed it in terms of "how new the product is to its potential users" and "the extent to which customers are familiar with this kind of product, the way they will use it, and its benefits." This last definition is based on a user's perspective, similar to LaBahn et al. (1996). However, similar to Griffin (1993, 1997) and Tatikonda and Rosenthal (2000), Shenhar and Dvir (2004) and Shenhar et al. (2016) categorized projects according to its novelty level using a progressive scale starting as derivative, platform, new to the market, and ending as new to the world products. Novelty can influence different aspects of a project and not only its product or its technology. For instance, Shenhar et al. (2005) argued that "projects often build on technology that may have come from previous projects; thus, technology is not the main challenge, but the mission is." Actually, several aspects such as management and commercial process novelty (Bakhshi et al., 2016; Tatikonda and Rosenthal, 2000), market newness (Bosch-Rekveldt et al., 2011; Kim and Wilemon, 2003; Maylor et al., 2008), objectives novelty (Bakhshi et al., 2016; Kim and Wilemon, 2003; Maylor et al., 2008; Shenhar et al., 2005; Tatikonda and Rosenthal, 2000), organizational novelty (Bakhshi et al., 2016; Geraldi et al., 2011), stakeholder, and team novelty (Aaltonen and Kujala, 2016; Ahn et al., 2017; Bakhshi et al., 2016) are examples of the kinds of novelty that can affect a project.
Novelty is closely related to uncertainty (Shenhar et al., 2002; Tatikonda and Rosenthal, 2000), although they are different dimensions used to classify projects. A project may have new parts or agents that are known and unambiguous to the team managing it, although the feedback loops introduced by the new parts or agents may cause the project system to adapt itself, creating new emergent behaviors in the project. Therefore, novelty as a dimension of project complexity is defined by how new the project's aspects are in terms of mission, product, processes, organization, stakeholders, team, market, among others.

3.6. *Social-political complexity*

The human aspects of project complexity form an important dimension to analyze and better understand projects, namely the social-political complexity.
Geraldi et al. (2011) argued that "projects are carried out by human actors, with potentially conflicting interests and difficult personalities" and that "this type of complexity emerges as a combination of political aspects and emotional aspects involved in projects". Similarly, Azim (2011) argued that people deliver projects and they exhibit characteristics of a complex adaptive system such as adaptiveness, emergence, nonlinearity and sensitivity to initial conditions, based on their actions, reactions and interactions during the project, and so the human aspect is a complexity dimension. Therefore, social and political complexity emerge from the diversity of aspirations, mental models, decision makers' values, transparency, empathy, variety of languages, cultures, disciplines, interests, agendas, opinions, among others (Geraldi et al., 2011; He et al., 2015; Lu et al., 2015). However, despite the similarities between social and political complexity, it is important to highlight the main aspects of each sub-dimension.
Social complexity is related to the emergent behaviors revealed during the interactions among people and organizations collaborating in the project. Megaprojects are examples of projects that clearly suffer from these complexities due to the immense effort required to coordinate a large number of contractors and employees, resulting in interpersonal and intra-organizational social complexities (Kardes et al., 2013). For instance, the NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) project presented similar issues related to social complexities given that "cultural differences created communication difficulties and integration problems, where partner roles needed better definition and more seamless coordination" (Shenhar et al., 2005). Kim and Wilemon (2003) also presented several factors that create such complexities, such as the "'Not Invented Here' syndrome, interdependence problems, the 'capacity gaps' between organizations, conflicts, communication problems, and the degree of formality/informality needed, [...] difficulty in communicating and maintaining relationships, managing relationships, appraising a partner's contributions, and sharing performance equitably contribute to intra-organizational complexity." Therefore, social complexities are created by people and organizations collaborating on projects.
Political complexity is related to the emergent behaviors created by people and organizations supporting the project. Bosch-Rekveldt et al. (2011) explained that organizational complexity, among other things, is related to "actors involved, their interests, and the risks and consequences of the project in relation to its environment" and that factors such as trust, political influence, level of competition, strategic pressure, and required local content play a role in creating such complexities. Stakeholders are an important aspect of political complexity and their influence may vary according to several factors, such as "stakeholders' local embeddedness, [...] the types of stakeholder behaviors and influence strategies viewed as acceptable, the multiplicity of institutional environments, and the complexity of the interpretation process" (Aaltonen and Kujala, 2016). Lack of

commitment and problematic relationships among stakeholders can also create political complexity in a project (Maylor et al., 2008). Megaprojects are, again, examples of projects that experience high levels of political interest given their substantial cost and direct and indirect impacts on communities, the environment, and budgets (Gann and Salter, 2000; Kardes et al., 2013). The political influence over megaprojects goes beyond mere interest, given that "in order to sell projects that have an economic gain or political leverage, project sponsors can exaggerate the benefits while underestimating costs" and that the "decision maker, knowingly or unintentionally, optimistically misinterprets projects facts and figures." This ultimately leads to failure in terms of cost overruns, benefits shortfalls, and deception by players with conflicting interests (Kardes et al., 2013). This phenomenon has been previously identified by Williams (2005) as well, who argued that political factors influence the approval of non-sustainable projects, leading to future problems regarding its objectives. In order to deal with such political factors, companies, organizations, and individuals lobby against or in favor of regulations or gaining political and market power to set their own rules. In so doing, they are reducing the impact of political complexity factors on their interests in the project. Despite the various views about what authors called cultural, social, environmental, organizational, or political complexity, it is the people and organizations involved in projects that contribute to the rise of emergent behaviors, which is a characteristic proper of complex adaptive systems. Therefore, in this article, the interpretation of social-political complexity is aligned with Geraldi et al. (2011), for whom "this type of complexity emerges as a combination of political aspects and emotional aspects involved in projects."

3.7. *Institutional complexity*

Project complexity dimensions mentioned previously usually increase the interaction between projects' elements. Conversely, institutional complexity constrains or forces the interactions in the system, which creates conflicts and the emergence of unforeseen behaviors. The idea that policies, regulations, laws, or standards impact a project had been researched for a long time, usually related to the organizational, environmental, or market context of the project (Gransberg et al., 2013; Rad et al., 2017; Schrader et al., 1993).
Institutional complexities can emerge in a project because of changes in policies, regulations (He et al., 2015), laws (Qureshi and Kang, 2015), or industry standards (Bosch-Rekveldt et al., 2011; Kim and Wilemon, 2003). Even when those elements are not changing, they are able to create conflict in a project, such as the case of organizations and project teams that have to adapt themselves to local laws (Qureshi and Kang, 2015), when the project is the first to implement or execute a norm (Floricel et al., 2016), when there are no laws, when conflict emerges from immature laws and regulations, or when there are inconsistencies between regulations and the project's reality (Li et al., 2015).
The consequences of institutional complexity for projects vary from case to case, but heavy regulation and control are usually involved in a complex project (Hobday, 1998). For example, Gransberg et al. (2013) stated that a "transportation project is typically a public work, constrained by the regulations applied to public funding and as a result, susceptible to influence by public opinion, political motivations, and a variety of other external factors that are outside the direct control of the PM [project manager]." The effects of these factors also shape the organizational structure of projects (Kardes et al., 2013), given that "the multiplicity of procedures force all processes to strictly obey related regulations," making the highest level of the hierarchy "responsible for issuances of outline documents for the entire construction project, framing all project-related rules and regulations, guiding management manuals and executive standards of each subsystem" (Fang et al., 2010). Most projects focus on compliance with these norms (Kardes et al., 2013), although in some industries, such as aerospace, nuclear or civil engineering, for example, the implications of regulations go beyond the current rules, norms, standards or laws, as "these organizations all need to be able to track configuration items to be able to revisit designs and comply with future regulation on safety-critical facilities" (Whyte et al., 2016).
Despite the negative emergent behaviors that regulations create in projects, the existence of common norms can also help managers to coordinate, reduce uncertainty, and avoid chaos, given the shared understanding of procedures and routines (Oedewald and Gotcheva, 2015). Liu et al. (2014) argued that this is possible because people know how to behave based on common norms. This dual effect caused by regulative issues was also discussed by Engwall (2003) for whom it is necessary to create an alignment between the project and its surrounding environment. Aaltonen and Kujala (2016) also highlighted that a lack of structure and governance models or multiple processes can make a project more complex in the context of stakeholder management.

In summary, regulations have the potential to increase the complexity of a project, unless there is a proper fit between what the project needs and what the institutional environment allows it to be. This contrasts the social-political complexity dimension that deals with informal relationships between people and organizations, while institutional complexity deals with the formal aspects of these relationships. Therefore, institutional complexity dimension refers to all the factors related to policies, regulations, laws, or standards and compliance elements that constrain a project.

4. Project complexity framework

Several frameworks were developed to help researchers and practitioners to analyze project complexity. Among them, the Diamond framework has been proved as a tool able to help to inform decisions and analyze case studies (Shenhar et al., 2016, 2005).

The Diamond framework is composed of four dimensions with four levels each, most of them focusing on aspects related to the product of the project (e.g.: complexity, technology and novelty). Therefore, it is necessary to incorporate the other project complexity dimensions discussed in this article.
The Diamond Framework uses structural complexity to classify the project as components, assemblies, systems and arrays. Uncertainty is expressed by the technology axis under the argument that the major source of internal or task uncertainty is technology uncertainty (Shenhar et al., 2002; Shenhar and Dvir, 2004). However, as the discussion regarding the project complexity dimensions revealed, these and the other dimensions can influence projects from different perspectives and in different ways. Therefore, we propose a general project complexity framework based on the Diamond Framework, but that includes all dimensions uncovered so far. Some project complexity dimensions describe aspects that are subjective in its nature and dependent on the context and from the observer, so a system can be "assessed as having different complexity in each of those contexts" and "each context may have different stakeholders who may well have different perspectives" (Efatmaneshnik and Ryan, 2016). It means that "complexity is necessary in the eye of the beholder" (Efatmaneshnik and Ryan, 2016; Standish, 2001). As such, our framework (**Figure 2**) does not intend to measure complexity, but help practitioners and researchers to discuss and analyze the types and levels of complexities in their projects, and doing so, make better-informed decisions.

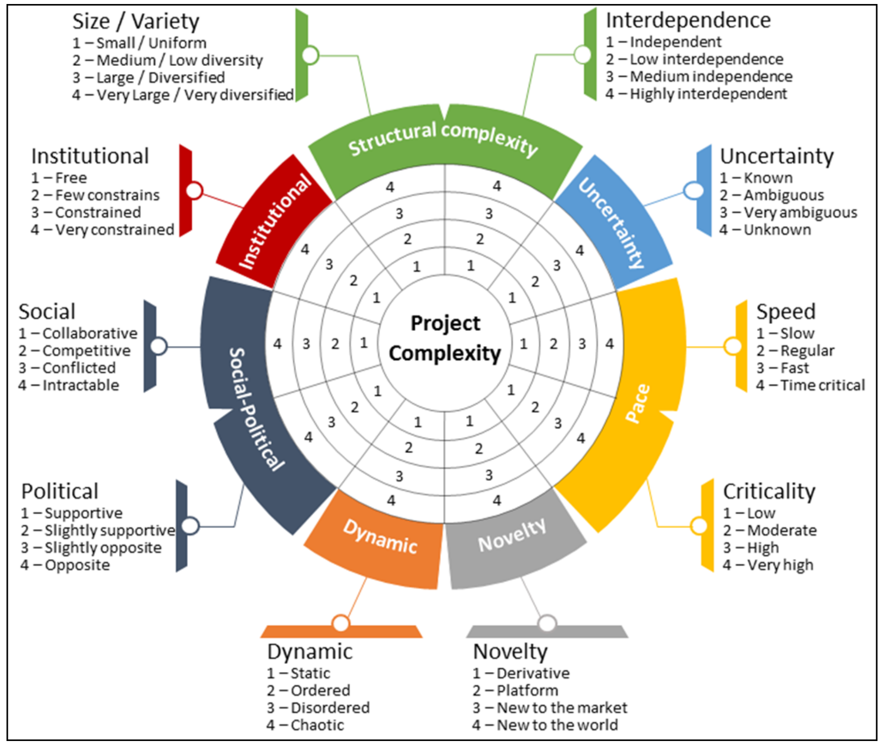


Figure 2: Project complexity dimensions

The "levels of complexity" of each dimension were expressed as a semantical differential scale with opposite adjectives at each end of the axis. Some dimensions such as novelty and pace used the same scales described in the Diamond framework. As discussed previously, this framework does not intend to measure with numbers the level of complexity of a project, because the boundaries between the "levels of complexity" are blurred, dependent from the context and from the observer perspectives. However, the discussion of the project complexity factors may help practitioners and researchers to grasp complexity from their projects. We suggest that practitioners and researchers select themes (e.g.: product, schedule, goals, methods, organization, stakeholders, environment, budget, among others) regarding their projects, use the project complexity factors as examples, and discuss and analyze them based on the dimensions and levels presented in the project complexity framework.

5. Conclusions

This article had the purpose of reviewing the project complexity literature to summarize the main project complexity dimensions in the literature, introducing institutional complexity as a new dimension and proposing an updated project complexity framework based on the Diamond Framework.

In order to answer the research questions, a systematic review was done using the SALSA Framework (Booth et al., 2013). The search terms used were aimed at project complexity in general, incorporating results from projects, programs, and other specific areas. A quality assessment of these results was conducted during the whole process. The results were then analyzed, and a synthesis was done to address the research gap.

The findings suggest that project complexity is an aspect of projects created by many interdependent parts that can learn (people, stakeholders, among others) or not (product, documents, among others) over time and that interact with themselves and the environment (organizations, governments, laws, among others) through feedback loops that create adaptation and non-linear emergent behaviors that can only be explained by principles and patterns. The complexity factors that create such behaviors in projects are organized into dimensions as groups of similar factors applied transversally to the whole project, expressing different perspectives of project complexity.

The project complexity dimensions identified in the literature are structural, uncertainty, pace, dynamic, novelty, social-political, and institutional complexities. The structural complexity is related to the number, variety, and interdependencies between the project parts. The uncertainty dimension incorporates the idea of uncertainty as lack of information, and ambiguity, as the clarity of information. The pace dimension can be summarized as the speed and criticality of the project. Dynamic complexity is related to how the project and its parts evolve over time. The novelty dimension is related to how new project's aspects are in terms of mission, product, processes, organization, stakeholders, team, market, among others. The social-political dimension highlights the complexities created by the human aspect of projects, exploring issues such as culture, languages, politics, power, conflicts, commitment, and agendas created by people and organizations collaborating and supporting the project. Finally, institutional complexity deals with policies, regulations, laws, or standards and compliance elements that constrain a project.

In this article we build upon the influential work of Geraldi et al. (2011), validating their findings and incorporating the results of other articles published during the last years. Geraldi et al. (2011) argued that project complexity was described in terms of five dimensions, namely structural complexity, uncertainty, dynamic, pace and social-political complexity. We argue that novelty and institutional complexity are also project complexity dimensions that should be considered by practitioners and researchers, recognizing complex system characteristics such as emergence (novelty) and openness (institutional complexity). Analyzing a project from the seven dimensions proposed may lead to a better understanding of the complexity of a project or program.

The Diamond Framework was used as a starting point and reference to incorporate the project complexity dimensions uncovered by this article. We proposed that instead of using four dimensions mainly focused on the technical aspects of projects, we should analyze its complexity based on all seven project complexity dimensions. In doing so, practitioners and researchers may grasp complexity from technical, social and institutional perspectives, including the dynamic nature of complex systems. Analyzing and discussing project complexity from a holist perspective can significantly help practitioners and researchers to better understand the challenge in front of them.

Moreover, researchers can use the complexity dimensions to develop their data collection instruments, analyze case studies, and develop further research. Practitioners can use these factors and dimensions to analyze their projects and promote discussions around these topics in order to obtain a better understanding of their project and, in doing so, make more informed decisions.

Naturally, the findings and conclusions of this article are limited by the number of articles reviewed, the methods used to analyze them, and the specific objectives addressed. For that reason, it is important to pursue further research to identify the weight of each dimension, the limitation of the proposed framework, among others. Additionally, a future research agenda can also focus on how the importance of each dimensions change over the lifecycle of a project or program. Moreover, it is also important to discuss which competencies and capabilities people and organizations need to develop to cope with each project complexity dimension.

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