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Empirical Research Paper

The main project complexity factors and their interdependencies in defence projects

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ABSTRACT

This research identifies 18 main project complexity factors affecting defence projects and four new factors to the literature. Many interdependencies among the factors were identified, suggesting they form a contextualised project complexity network capable of creating emerging behaviours that would not be observable if they were analysed in isolation. These interdependencies make the project adapt and self-organise, resulting in emergent behaviour and unintended consequences beyond the team's ability to cope with them. These characteristics challenge the classic view of project management based on objectivity, reductionism, control, and predictability in favour of new approaches based on subjectivity, systemic thinking, and adaptability. Moreover, the lower the team's delivery capacity, the greater the perception of the project complexity's effects, given that the project team will not have the capacity to manage and respond to these many interactions and elements. This systemic view contrast with the usual functionalist approach used on project complexity frameworks.

1. Introduction

Public and private major complex projects tend to fail on delivering benefits and being on budget and on time (Flyvbjerg, 2014; Denicol et al., 2020). On average, these projects tend to deliver half the promised benefits, cost 27.6% more than initially estimated, and are delayed 45% of the time (Flyvbjerg, 2014; Flyvbjerg et al., 2002).

Research on the complexity factors that lead projects to low performance is prominent in many industrial sectors such as transportation (Nguyen et al., 2019), public administration (Mishra et al., 2016), construction (Antoniadis et al., 2011), new product development (Kim and Wilemon, 2003), energy (Rad et al., 2017), among others. Defence projects, for instance, are one of these well-known cases of complexity, budget overruns, and delays. In 2014, 60% of the United States Department of Defence's major weapon programmes were, on average, 92% over the projected costs (Roberts et al., 2016). In 2016, the Australian National Audit Office reported an increase of 28% on the expected schedule of 25 major defence projects (ANAO, 2016).

Industries and sectors such as aerospace, construction, information technology, and electronic can all exhibit many complexity factors described in most project complexity frameworks existing in the literature. Defence projects, however, usually involve a higher level of complexity (Chang et al., 2013). While typical complex projects involve large number of activities and investment, defence projects tend to be highly uncertain given the secretive nature of the industry and the few people with knowledge and experience on developing complex defence systems. Defence projects tend to be time critical in order to develop strategic advantage over potential adversaries, usually involving the development of high technology, often new to the world. In addition, many issues addressed by defence projects are subject to strong internal and external political interference and interests.

More specifically for the defence sector, complexity is inherent to many projects, due to strategic issues, technological advancements, and large investments. The Manhattan project is usually attributed to originating the modern project management, although some authors, e.g. Lenfle et al. (2014), disagree. Nevertheless, the Manhattan project was the largest technical project during the World War II, and provides an example of the development of a scientific product that was subject to project management (Johnson, 2013).

Structured project management techniques were relevant to many defence projects such as the Manhattan Project, the Polaris missile system, and various US space initiatives (Cleland, 1964; Hällgren et al.,

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2012). As Johnson (2013) argues, complexity is a relevant feature of various military projects of the 1950s.

In fact, many advances in the analysis of complexity in project management have origins in the defence industry. For instance, in the space context, Sarsfield (1998) and Bearden (2003) propose standard mechanisms to define complexity scores of projects taking into account characteristics of different missions and spacecrafts. Therefore, defence projects are clearly complex endeavours that deserve a special analysis.

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 (organisations, governments, laws, among others) through feedback loops that create adaptation and non-linear emergent behaviours that can only be explained by principles and patterns (de Rezende and Blackwell, 2019). The idea of many interdependent elements of a system interacting with each other is a well-established concept in the literature (de Rezende et al., 2018a). However, most studies focus on single case studies (Lyneis and Cooper, 2001; Giezen, 2012; Davies et al., 2016; MacAskill and Guthrie, 2017; Gilbert and Yearworth, 2016; Mok et al., 2017) in specific industrial sectors, which limits our understanding given the structural conditions and contextual importance. If the project systems' elements are interdependent, as structural complexity explains (Baccarini, 1996; Williams, 1999), the project complexity factors that describe them are also interdependent given that they explain an interdependent phenomenon. Thus, it is important to identify and organise the project complexity factors in unique industries such as defence, and also to understand how one factor affects or is connected to others.

Therefore, moving the current project complexity discussion from single case studies to multiple case studies, and the analysis of project complexity factors from an independent to an integrated perspective is paramount. Moreover, the discussion on project complexity usually occurs from the perspective of developed countries and companies with much experience in developing complex projects. In contrast, developing countries are still developing mid-high-technological systems and have limited experience in the management and development of complex initiatives, which can result in different complexities and importance regarding different factors in these contexts. Despite defence projects being strategic, complex, and expensive, the literature on the management of such projects is very scarce. There are only a few articles contextualised on complex defence projects (Nidiffer and Dolan, 2005; Lawrence and Scanlan, 2007; Rezvani et al., 2016) and with limited focus on the specifics of project complexity. Thus, research on project complexity in the defence sector context might provide a different perspective to the current debate given the clear complexity that these projects pose, and the unique organisational environment shaped by hierarchy, discipline, power, and authority. In this context, we contribute to the project management field by exploring the research question on what are the major project complexity factors that affect defence projects, and the interdependencies among them are.

2. Theoretical framework

Project management long exists as practice (Morris, 1994), although it is a relatively recent research field as an academic discipline (Bredillet, 2010; Sydow and Braun, 2018). Throughout time, project management shifted from a "practitioner-driven domain to a proper academic discipline" in which the dominant technical perspective from the engineering and computing schools, shared space with the managerial perspective under the influence of research conducted by business schools (Bredillet, 2010). During this process, bodies of knowledge with "best practices" were created and several theoretical positions informed and influenced the way researchers debate project management, creating different schools of thought in the field (Söderlund, 2011).

Standards, professional certifications and "best practices" such as PRINCE2 (PRojects IN Controlled Environments) (Axelos, 2017) and the PMBoK Guide (PMI, 2017) are very influential in the field, retaining and reinforcing the classical view of project management (Svejvig and Andersen, 2015) in which a project is a "temporary endeavour undertaken to create a unique product, service or result" that can be properly managed by a series of 'best practices' tools and techniques. However, core characteristics of the classical view of project management such as objectivity, reductionism, control, and predictability are being challenged by approaches based on subjectivity, systemic thinking, adaptability, given the increased level of complexity of projects (de Rezende et al., 2018a; Pollack, 2007).

Battram (1999) explains that "complexity refers to the condition of the universe, which is integrated and yet too rich and varied for us to understand in simple common mechanistic or linear ways. We can understand many parts of the universe in these ways, but the larger and more intricately related phenomena can only be understood by principles and patterns - not in detail. Complexity deals with the nature of emergence, innovation, learning and adaptation".

In fact, "what has become known as complexity theory is actually a collection of a number of different theories" (Klijn, 2008), largely influencing the project management field. Klijn (2008, p. 301) explains that "what all these theories do share is the idea that the whole (the system) is more than the sum of the parts (the individual agents), while, at the same time, developments of the whole stem from the (interaction of the) parts. Complexity theories stress that systems tend to develop non-linearly and are subject to various feedback mechanisms. They are also dominated by self-organisation and usually co-evolve with other systems". The idea of complexity is strongly related to the definition of complex systems (Klijn, 2008; Frenken, 2006; Holland, 2014; Johnson, 2012; Miller, 2009; Stacey, 2002; Sturmberg, 2013). Thus, the use of systems theory in project management with its holistic and integrated focus challenges reductionist approaches such as decomposition which are inadequately dealing with systemic effects in projects (Pollack, 2007). Moreover, using complexity theory, co-evolutionary theory, and chaos theory to interpret projects as complex adaptive systems brings new set of ideas that challenge the classical project management paradigms. Therefore, aspects such as the dynamism of many interacting objects or agents, self-organisation, holism, openness, chaotic or emergent behaviour, feedback loops, learning, and adaptation (Klijn, 2008; Holland, 2014; Johnson, 2012; Miller, 2009; Battram, 1999; Domicini and Palumbo, 2013) are becoming more widely accepted in the project management field.

Under the new lens that complexity theory brings, traditional theories applied to project management such as contingency theory need to be revisited. For instance, contingency theory in project management views projects as temporary organisations and claims that an organisation's effectiveness is contingent upon the fit between structural and environmental factors (Shenhar et al., 2005; Zhu and Mostafavi, 2017; Müller et al., 2017; Shenhar, 2001). Contingency theory, interpreted under the lens of complexity theory, implies that contingent factors are interdependent and fluid, influencing each other, changing, and adapting as the project is conducted, forcing the organisation to adopt a responsive design based on flexibility rather than control and predictability to find its best fit. Thus, using complexity theory as a new lens to add to the theories commonly used in the project management field stresses the importance of project complexity frameworks that tries to explain the dynamic, interdependent and holistic nature of the complexity factors affecting projects.

The use of complexity theory as a new lens to reinterpret and add to the theories commonly used in the project management field created what is known as project complexity research field (de Rezende et al., 2018a). Within this field, project complexity is defined by many interdependent parts that can learn (people, stakeholders, among others) or not (product, documents, among others) over time and that interact internally or externally within their environment (organisations, governments, law offices, etc.) through feedback loops that create adaptation and non-linear emergent behaviours that can only be explained by principles and patterns (de Rezende and Blackwell, 2019).

The literature explained the complexity phenomena on project based on factors and dimensions (Geraldi et al., 2011). Factors are the attributes of complexity that can make a project more or less complex to manage. Dimensions, on the other hand, are the group of attributes organised around common characteristics.

Rezende and Blackwell (2019a) built upon Geraldi et al. (2011) project complexity systematic review and organised the project complexity factors around seven dimensions, namely: structural complexity, uncertainty, pace, dynamic complexity, novelty, socio-political complexity, and institutional complexity.

The project complexity literature evolved in three distinct waves: interpreting projects as technical systems (structural complexity and uncertainty); the subsequent incorporation of the dynamic nature of projects (pace, dynamic complexity and novelty); and the context in which projects are executed (socio-political and institutional complexity).

The discussion of project complexity as technical systems emerged from the use of systems theory in project management. The first project complexity dimension discussed was structural complexity, which focused on the underlining structure of a project (Williams, 1999), described in terms of the number or variety of elements (differentiation) and their interrelatedness (interdependence) (Baccarini, 1996). Uncertainty was discussed as a project complexity dimension by Shenhar and Dvir (1996) and its aligned to the classic definition proposed by Galbraith (1973, p. 36-37) who states that it is "the difference between the amount of information required to perform the task and the amount of information already possessed by the organisation". The distinction between ambiguity as a lack of clarity and its differences compared to uncertainty (Pich et al., 2002; Schrader et al., 1993) were considered in this research, though the terms are used interchangeably for sake of simplicity.

Since structural complexity and uncertainty focus on an almost static view of project complexity, authors used complexity theory and coevolutionary theory to discuss the dynamic nature of projects, proposing dimensions such as pace, dynamic complexity, and novelty. Shenhar et al. (2002) introduced pace as a complexity dimension involving a project's speed, timing, and criticality in projects. Dynamic complexity was introduced by Xia and Lee (2003) and explains how a project and its parts evolve over time, creating emergent behaviours and instability in the process. Novelty is a project complexity dimension introduced by Shenhar and Dvir (2004) to discuss how novel project's aspects are in terms of mission, product, processes, organisation, stakeholders, team, and market, among others.

An addition to the previous dimensions was the re-interpretation of project complexity under the lens of institutional theory, which led to the incorporation of social, political, and institutional aspects. Sociopolitical complexity was introduced by Geraldi et al. (2011) to explain how political and emotional aspects are involved in projects. Finally, institutional complexity was proposed by Rezende and Blackwell (2019) to organise normative and regulative aspects in the existing literature, focusing on informal and formal rules that govern the relationship between people and organisations.

3. Methods

The purpose of this article was to have an in deep understanding of project complexity in the defence industry. Interviews were considered the most appropriated method (Kumar, 2014; Saunders et al., 2016a) given their ability to capture subtle aspects in between the narratives of experienced managers, shining some light over the main projects complexity factors in the defence industry and how they affect each other. As a result, a semi-structured interview was designed following a seven-stage process described by Kvale (2008), namely thematising, protocol design, interviews, transcription, analysis, verification, and reporting.

The first stage of Kvale's (Kvale, 2008) process was thematising, which aims to define the focus of the interview. The focus of this research was to identify what are the major project complexity factors that affect defence projects and to understand the interdependencies among them.

The second stage of Kvale's (Kvale, 2008) process, protocol design, focus on developing the interview script and defining the sample. The interview protocol was designed following some steps to guarantee its reliability (Kvale, 2008). First, the interview's questions and its prompts were formulated based on the project complexity literature (de Rezende and Blackwell, 2019; de Rezende et al., 2018a). Also, two warm-up and three wrap-up questions were included in the script to make the interviewees more open to answer the questions. Before applying the interviews, research risks and ethics assessments were performed, and pre-piloting and piloting stages were performed to test the protocol (Gillham, 2005) and improve the interview script (supplementary material A). The interview script asked interviewees about their understanding of what project complexity is and what caused it, asking them to provide examples regarding how it happened in their project and how they managed it. The interview script also asked about their perception on the effects of project complexity on the success of their projects.

The sampling method choice considered characteristics of the defence sector. Some defence projects were not accessible to the researchers given national security issues, sensitive technologies, or confidentiality and non-disclosure agreements. Consequently, we discarded quota, volunteer, and haphazard sampling methods and considered it appropriate to use a critical case sampling technique aiming at providing an illustrative profile based on crucial and critical cases from the defence industry (Saunders et al., 2016a). The projects analysed in this study (supplementary material B) cover several sectors within the defence industry (aerospace, automotive, weapon systems, communication, information technology, research and development, construction, etc.), have high investments volume, totalling around 12 billion USD, and long durations, averaging 14 years and ranging from four to 30 years. Additionally, the projects are geographically distributed within Brazil, involve partnering institutions in several countries, and are considered strategic, not only from the Ministry of Defence's perspective but also from the presidential agenda.

The third stage focused on conducting the interviews. The interviewees were recruited from the Brazilian Army's Project Management Office, the main prime contractors, and the projects teams to analyse the issue from different perspectives. Thus, managers from these organisations were invited and received a participant information sheet (supplementary material C) and a consent form (supplementary material D) to understand the interview goal and protocol, deciding whether to participate or not in the research. The participant information sheet provided the potential interviewee with answers to frequently asked questions. The consent form presented to the participants the interview's procedures, the intended use of their responses and a quotation agreement. After the invitation, 22 people (supplementary material E) accepted to participate in the research. The interviewees were senior practitioners working on the most strategic projects in the Brazilian Army, usually occupying the role of project or programme directors, managers, and specialists and with the average working experience of 28 years. Thus, interviewees chose a date and place for the interview, which was recorded for later analysis. As a result, almost 17 h of interviews were recorded.

During the fourth stage, the recorded interviews were fully transcribed to retain the maximum information in its original form (Gillham, 2005). The transcriptions were synced with the audio files and sent to the interviewees, which approved both.

The approved transcriptions were then uploaded to NVivo for coding (Bazerley and Jackson, 2013). Then, during the fifth stage, interviews were analysed using structural, descriptive, conceptual, and provisional coding during the first coding cycle. Structural coding served as the foundation for the analysis, creating context-based or conceptual phrases to express the meaning of what the interviewees described. The descriptive coding was used simultaneously as a refinement of the structural codes, assigning basic labels, usually words, to express an idea. Conceptual coding enabled to express big picture ideas related to the interviews. Finally, provisional coding used a comprehensive list of project complexity factors identified by Rezende and Blackwell's (de Rezende and Blackwell, 2019) systematic review. After several coding iterations, a second coding cycle reorganised and reanalysed the codes. During this stage, pattern coding technique was used to develop categories from similar coded data. Finally, in vivo coding was used to highlight key interviewees' opinions (Salda ñ a, 2016).

The verification stage aimed to assess the collected data regarding its validity, reliability, saturation, and bias (Kvale, 2008). Data saturation was calculated based on the number of new codes found in each interview. Data saturation was found after 19 interviews (supplementary material F). No type of bias was found in the interviewees' responses. Moreover, the codes were considered unambiguous and coherent to interviewees responses.

Finally, the seventh stage focused on reporting the findings. Since this article seeks to establish the major project complexity factors, only factors that were mentioned by at least one-third of the respondents were discussed (law of the vital few). The project complexity factors were grouped using the same categories presented on the Project Complexity Framework (de Rezende and Blackwell, 2019), which was the foundation for provisional coding during the fifth stage. Additionally, when multiple complexity factors were coded from the same sentence of the interview transcription, they were considered correlated. The strength of the correlation was based on the number of interviewees mentioning the same pair of factors as sources of project complexity. Thus, the main project complexity factors in the defence context and its correlations were reported and discussed in the following section.

4. Results and discussion

Results from the interviews revealed the 18 most important project complexity factors, as depicted in Fig. 1 and clustered by complexity dimensions (de Rezende and Blackwell, 2019). The most mentioned project complexity factors are highlighted in blue and the less mentioned are plotted in red. The main complexity factors were found by counting the number of interviewees that mentioned that aspect as a source of complexity in their projects. These factors' frequency in the literature (de Rezende and Blackwell, 2019) is plotted in the grey area to allow comparison between the focus given in the literature and the focus according to practitioners in complex projects.. Finally, when

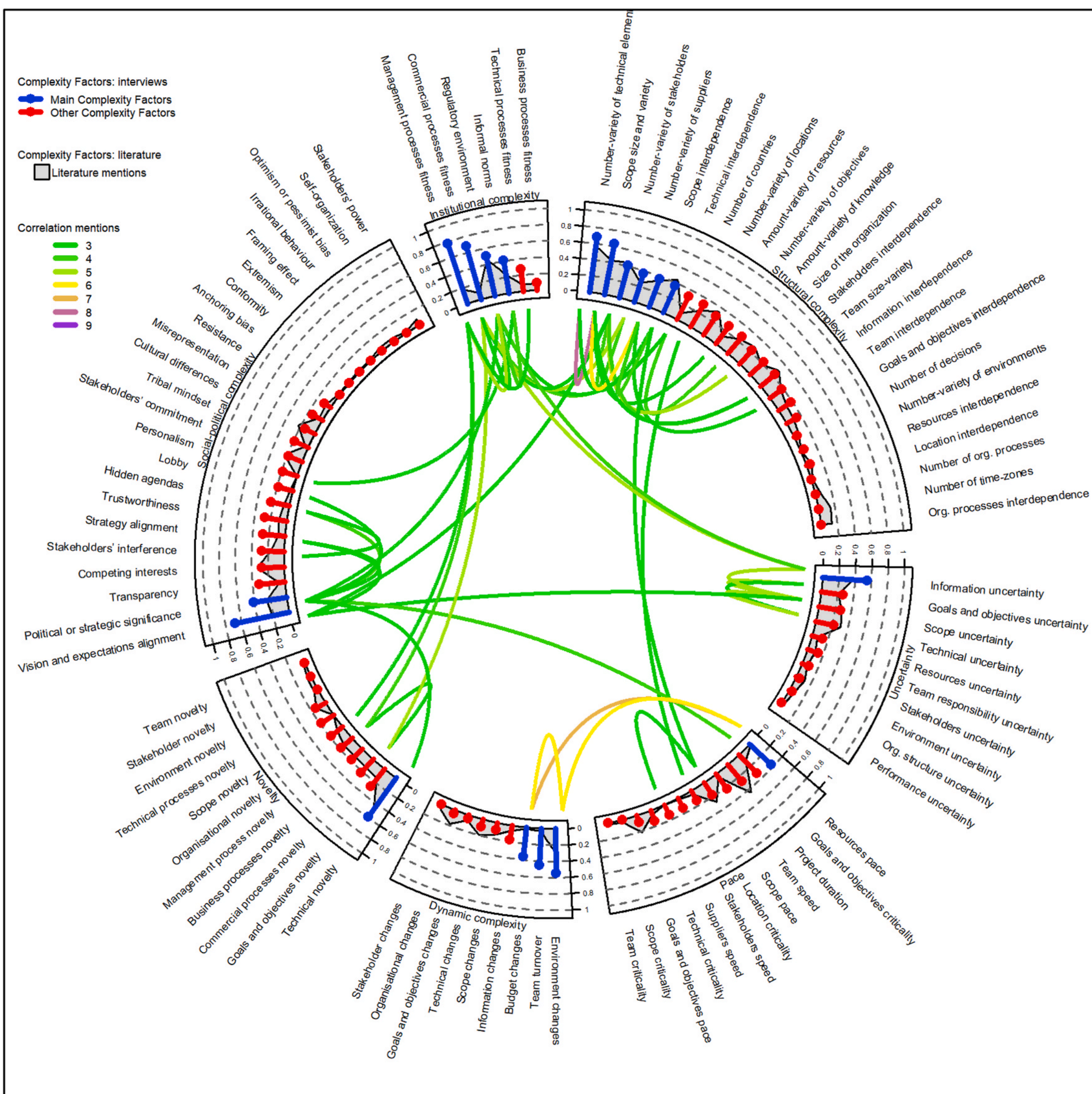

Fig. 1. Project complexity factors in the Brazilian Army projects (animated version on supplementary material G).

interviewees mentioned multiple complexity factors in the same statement, the factors were considered interdependent and were plotted in the inner circle. The links between project complexity factors were coloured based on the strength of the correlation, which was found based on the number of interviewees mentioning the pair of factors as sources of complexity in their projects.

The findings uncovered 18 main project complexity factors affecting projects in the Brazilian defence industry. Among the most mentioned factors by interviewees were six structural-complexity factors: the number/variety of technical elements, scope size/variety, number/variety of stakeholders, scope interdependence, technical interdependence, and number/variety of contractors and suppliers. The second most mentioned dimension was institutional complexity, with four factors, specifically, management process fitness, commercial process fitness, regulatory environment fitness, and informal norms and organisational culture. Dynamic complexity had three factors: environment and market changes, team turnover, and budget changes. Socio-political complexity had two major factors: vision and expectations alignment as well as political or strategic significance. The uncertainty, pace, and novelty dimensions had one major factor each, namely information and knowledge uncertainty, resource pace, and technical novelty, respectively. Moreover, four new factors were identified, namely the number or variety of environments, personalism, contractor and supplier speed, and scope novelty. The links in Fig. 1 demonstrate how one factor affects the others, causing a ripple effect that further stresses the system and causes even more project complexity. The main and new project complexity factors identified highlight the importance of the context in assessing project complexity. In the following sections, the factors presented in Fig. 1 are discussed.

4.1. Structural complexity

Structural complexity was the most mentioned dimension by the interviewees. It was found six main factors (Fig. 1) in the structural complexity dimension, namely: the number of technical elements (68.18%–15 sources), technical interdependence (36.36%–8 sources), scope size and variety (63.64%–14 sources), scope interdependence (36.36%–8 sources), number and variety of stakeholders (40.91%–9 sources) and the number and variety of suppliers (36.36%–8 sources). A new factor, number or variety of environments, was identified in this context and describes the diversity of environments for which a defence product or system has been developed. Interviewee S illustrated this factor, arguing that a defence system must cope with a variety of environments because "in modern warfare, during full-spectrum military operations, a system may be involved in an offensive operation, following that a peace-keeping operation, or a defensive operation, or even a humanitarian mission". Therefore, since the range of scenarios is diverse, a defence system must be developed to operate sufficiently in these many situations. In turn, project complexity is increased, for instance, by the need of additional product components and activities to develop a flexible yet robust defence system.

The number of technical elements and the technical interdependence factors describes the number, variety, and interdependency of a project's technical elements such as products, components, systems, technologies, and requirements. Interviewee V exemplified the number of technical elements involved in a defence system, arguing, "It is not just a vehicle; it is the vehicle, the weapon system, the command-and-control systems, and many other systems, accessories, and components". Regarding the technical interdependence factor, interviewee U, similarly to Antoniadis et al. (2011), argued that complexity in his project did not involve the number of technical elements but the interdependence among them. Thus, the choices regarding more or less complex technical characteristics can make a project more difficult to manage (Giezen, 2012). In the Brazilian Army case, the strategy used to cope with these issues was to develop the ability to integrate components and use a system thinking approach to manage the project. In the literature, such strategy is described in many cases by using system engineering (Eppinger et al., 2014; Sheng, 2019), Design Structure Matrices (DSM) (Browning, 2001; Shokri et al., 2016; Nightingale, 2000; Hsu et al., 2016; Yang et al., 2014, 2015) and project management canvas (Elia et al., 2020).

The scope size and variety and the scope-interdependence factors describe the number, variety, and interdependency of tasks necessary to deliver the project's product. Interviewee I exemplified some of these tasks, showing that defence projects go beyond the defence system itself, including also "supply acquisition, training people, integrated logistics, which included warranty assurance, infrastructure building, writing manuals, cataloguing components, environmental management, so it is a project that involves several areas". As a result, these various aspects demanded managers to have abilities related to system thinking, collaboration, and communication. Interviewee N illustrated how approaching the project with a system-thinking view helped him: "I cannot monitor only my project; I have to check the progress of other projects because they will impact me ahead. We have many aspects involved and everything affects the deadlines". In contrast, interviewee B argued that, in addition to perceiving these interrelations, managers must create an environment with increased collaboration and communication. Similar to technical factors, scope size and interdependence were discussed in the literature using team and activity-based DSMs (Browning, 2001), the benefits of team collaboration were explored by authors such as Walker et al. (2017), and the effects of task complexity on the project's performance was discussed by An et al. (2018), showing an alignment between practice and theory.

Another project complexity factor was the number and variety of stakeholders involved in a defence project. The factors discussed illustrate how defence projects require the collaboration of multiple departments within one or more organisations, which implicates the involvement of many stakeholders in the process. Interviewee I contextualised this by stating, "this project involves military organisations, internal and external stakeholders such as the Treasury, the Army's general staff, the main contractor, and its subcontracted companies. Moreover, it involved the Congress because some bilateral agreements with other countries must be signed, so the project naturally becomes complex". Similarly, interviewee M also described several stakeholders involved in his project and added that interoperability was an important issue because agencies, such as the Federal Police, Motorway Police, State Police, Customs, Environment Agency, and others, must work together to achieve security and defence goals. Interviewees' narratives indicated that organisational cooperation was relevant to create alignment between stakeholders and facilitate project execution.

Finally, many interviewees mentioned the number and variety of suppliers as additional sources of project complexity. A defence project may involve many individual suppliers or a prime contractor responsible for integrating the project's supply chain. Both strategies were used in the Brazilian Army case, although interviewees highlighted that the choice over a prime contractor contributed to decreasing the level of project complexity, given the transfer of activities and responsibilities. Moreover, interviewee J added that the transfer of activities and responsibilities facilitated communication, arguing that the "prime contractor A contracted around 100 companies to supply the components needed in this project, although I deal just with one company". Interviewee N argued that the suppliers' diversity and characteristics also play an important role in creating project complexity in defence projects, since "there are suppliers that have a way of working totally different from others. For some companies, this project is just a small part of their business, but for others, it is crucial or strategic to be part of it, so they react to problems in different ways". The variety and number of technical components involved in a defence project lead to creating a long and diversified supply chain. The decision for integrating a single or a few prime contractors may reduce the level of complexity in a project, allowing the management team to focus on other project aspects. Nevertheless, it is important to learn lessons from other defence projects and consider aspects such as "oversight, the quality of the acquisition workforce, the defence contractors' cost inefficiency, ethical lapses, or weak corporate governance, or combinations of these factors" (Euske et al., 2012).

Different from most project complexity frameworks that organise factors independent from each other (Xia and Lee, 2003; Shenhar and Dvir, 2007; Vidal and Marle, 2008; Maylor et al., 2008; Bosch-Rekveldt et al., 2011), we argue that an important aspect to consider is how the main structural complexity factors identified have interdependent links between them and other factors, which creates a ripple effect that further stresses the project. Most main structural complexity factors identified are connected among them, with other structural complexity factors and with factors from other dimensions such as pace, social-political complexity, and institutional complexity. For instance, the increased number of stakeholders tends to create many requirements, which leads to an increased and interdependent number of technical elements. Consequently, an increased and interdependent number of activities is needed to build such systems. This complex scope requires an increased and specialised number of suppliers (structural complexity), which can influence the commercial process fitness factor (institutional complexity). Moreover, these many requirements, activities, and suppliers make it difficult to align visions and expectations (social-political complexity) and, in many cases, forces the project team to increase pace to deliver the many expectations within the project deadline.

In summary, as the project's elements (people, technical elements, organisations) increase in number, variety, and interdependency, they inevitably interact more, creating feedback loops that make the system adapt and self-organise (people and organisations), resulting in emergent behaviour and unintended consequences beyond the team's ability to cope with them. These dynamics challenge the classic theories and view of project management based on objectivity, reductionism, control, and predictability in favour of new theories based on subjectivity, systemic thinking, and adaptability. Moreover, the lower the team's delivery capacity, the greater the perception of the project complexity's effects, given that the project team will not have the capacity to manage and respond to these many interactions and elements.

4.2. Institutional complexity

Institutional complexity was the second most mentioned dimension. A total of four of its six factors (Fig. 1) were considered main factors according to interviewees, namely management process fitness (77.27%–17 sources), commercial processes fitness (68.18%–15 sources), regulatory environment fitness (50%–11 sources), and informal norms and organisational culture (40.91%–9 sources).

The most mentioned institutional complexity factor was management process fitness, which explains the appropriateness of project management and support processes used. In the case of the Brazilian Army, this factor was related to the existence of immature processes, as interviewee M pointed out: "the Army's project management office was created right after the beginning of the project, so the project management norms were created along the way". More recent projects were able to use such norms. Interviewee C argued that it was an important aspect contributing to better project performance, explaining, "the existence of a method adapted to our reality was a critical success factor. Without it, we would face many problems, having a higher probability of being unsuccessful and it would be much more difficult to manage it". These situations highlight the importance of project-based processes tailored to the project's organisational and industrial context (Dasí et al., 2020) and the choice regarding project management methods (Butler et al., 2020).

"Commercial processes fitness" is a factor related to the use and existence of processes that properly support the procurement and contracting of management activities. The low level of organisational maturity regarding commercial processes impacts the projects in many ways. Interviewee E exemplified that "the Army has laws, rules, and norms to donate properties [land], but we do not have norms to buy, receive or seize property from others, this is usually done by federal laws when necessary". The inexistence and immaturity of these commercial processes put their project on hold for a while because they could not easily install equipment in some regions, creating uncertainty around the project. In a project P1, for instance, the low level of organisational maturity was balanced out by very specialised people who supported and even developed some of the commercial processes, gradually leading the organisation to a higher maturity level. Interviewee K explained how "a lot of what we achieved was because of the commercial knowledge; the counterpart brought specialised lawyers, but they could not understand the contract as a whole as we could". Beyond the role of specialised people, "contractual coordination can deal with risks induced by technical, organisational, and environmental complexity, whereas the adaptation function can address environmental complexity-related risk. However, contractual control is ineffective when either technical or environmental complexity is high" (Gao et al., 2018).

Half of the interviewees mentioned "regulatory environment fitness". This factor describes the complexity of the regulatory environment in which the projects are conducted. Defence projects are executed in very specialised and often very restrictive regulatory environments, not only because of the technological nature and purpose of the products and systems in question but also because they involve specific regulations such as offset contracts to transfer technology from one country to the other, intellectual property and commercial rights issues, and legal limitations regarding the use and transfer of defence systems. Though a project's regulatory environment is bounded by the country's legal framework, issues may occur and affect the project because of the perspective of people from different countries and industries. Naturally, these nuances and understanding of the regulatory framework involving defence projects usually cause some conflicts, which, in the case of the Brazilian Army, were managed by involving specialised lawyers who worked alongside project managers as part of the project team.

The institutional aspects discussed so far are related to formal regulations (laws, standards, and processes), although an important institutional aspect is informal norms and organisational culture. This factor is associated with informal normative aspects that govern the relationship between agents and the resulting culture they create (Haji-Kazemi et al., 2015; Williams, 2005; Turner, 2009; Shenhar and Dvir, 2004; Hanisch and Wald, 2011). The development of defence projects involves the work of several organisations that sometimes have completely different cultures. Interviewee N described a case involving "many organisations with different objectives, organisational structures, and cultures working together to make it happen. One organisation is young and small and was created by a large organisation to integrate defence systems without carrying the problems of the mother organisation, and to develop agile and cost-effective processes. The other is a typical technology development company, almost like a university laboratory, so the understanding of deadlines is different, and there are many organisational culture differences." The interviewees constantly mentioned understanding organisational culture differences, which usually was overcome by managers' awareness and competence to navigate the project's organisational environment. Despite being able to navigate such issues, managers recognised that the actual organisational culture should evolve towards a project-driven culture. In this context, aspects such as legality, transparency, accountability, and less personalistic decision-making are core organisational values that are promoted and respected by the organisations and their members.

Institutional complexity factors have been previously discussed (de Rezende and Blackwell, 2019), although there is a clear difference between the focus given in the literature and the factors raised by the interviewees. For instance, in the literature, external factors such as regulatory environment fitness are the most discussed topics in terms of institutional complexity (Fig. 1). However, in the case of the Brazilian

Army, internal organisational processes were the main institutional complexity factors raised by the interviewees. The reason is unclear and may be related to contextual aspects such as low organisational maturity of companies in developing countries that are still developing mid-high-technological systems and have limited experience in the management and development of complex initiatives. Nevertheless, it is worth highlighting this difference and arguing that each factor or dimension's importance may vary by industry, country, or organisation (Bosch-Rekveldt et al., 2018).

Analysing institutional complexity factors from an integrated point of view based on the links between the factors demonstrates that most institutional complexity factors are clearly interdependent, not only among themselves but also with other project complexity dimensions such as structural complexity, uncertainty, novelty, and socio-political complexity. For instance, the political and strategic significance (socio-political complexity) of the defence industry base influences the regulatory environment (institutional complexity), which shapes the commercial, managerial, and informal processes and norms (institutional complexity). Moreover, many stakeholders and suppliers (structural complexity) are interested in shaping the commercial process to their will, making it difficult for a project team to find good commercial process fitness. This leads to information uncertainty and to new processes and means of organizing (novelty dimension).

4.3. Dynamic complexity

Dynamic complexity had 3 of its 8 factors (Fig. 1) listed among the main complexity sources in defence projects, namely environment and market changes (54.55%–12 sources), team turnover (45.45%–10 sources), and "budget changes" (36.36%−8 sources).

Interviewees mentioned the environment and market changes factor to describe changes and instability in the project's environment. Narratives discussed the effects of a period of deep political instability in Brazil after the 2014 presidential elections. Interviewee V described a meeting on a project in which "the prime contractor presented [changes in] currency exchange rates, commodities prices variations, the price of steel, and importing costs, and the Brazilian economy was starting to decelerate, so the government removed some incentives regarding importation, some taxes rose, so all that impacted the project". Most interviewees indicated that the Brazilian crisis affected their projects because, on one hand, the economy had deteriorated, affecting public expenditure on defence projects. On the other hand, the political instability was at extremes with several competing agendas, so defence projects were not perceived as a priority in the public agenda. Environment and market changes or instability are well-established project complexity factors in the literature (Bosch-Rekveldt et al., 2011; Bakhshi et al., 2016; Saunders et al., 2016b; Mirza and Ehsan, 2017). The case of the Brazilian Army clearly illustrates how defence projects are affected by environmental factors in diverse areas, especially politics, market fluctuations, and economics.

Team turnover was the second most mentioned dynamic complexity factor, which describes how often people involved in the project are replaced. The turnover in the Brazilian Army is high, given its policy of staff relocation across the country. Interviewee A, exemplified that "during the last two years, we had four different programme managers," influencing their ability to make decisions with an understanding of the project's history and context (Engwall, 2003). The main consequence of high team turnover was the constant need to transfer knowledge. To cope with this scenario, the interviewees invested into knowledge-management techniques and had contracted civilians who stay in projects for longer periods, acting as knowledge guardians and facilitators. These strategies are similar to Ahern et al. (2014) discussion regarding leadership and knowledge creation, coordination, and transfer in complex project management and Bjorvatn and Wald (2018) findings regarding absorptive capacity, project complexity and performance. Moreover, Hartono et al. (2019) found a positive association between knowledge management maturity and performance in projects with higher structural complexity, showcasing the importance of knowledge management in complex projects.

Budget changes was the third most mentioned dynamic complexity factor, which describes changes in defence expenditures caused by internal or external aspects. In the case of the Brazilian Army's defence projects, budget changes were strongly related to the aforementioned political and economic crises. The budget changes affected projects' scope and duration. One project, for instance, had maintained scope regarding of what was being produced (variety) but with a reduced number of brigades receiving the defence systems (size). In most projects, however, the impact was on the duration of the projects, which maintained their scope but spread it across more years of development and production. The mentioned causes of the budget changes were all external to the project and beyond any possible action to revert them. Thus, two strategies were used to respond to these changes. The first one was to focus the budget on technological development, by producing fewer systems but keeping the same features. The assumption was that the project could recover its scale and initial objectives during the mass-production phase, when it could be accelerated. The second strategy was to take a calculated and even counterintuitive risk of producing extra defence systems and having them on the shelf for the opportunity to sell them promptly during the end of fiscal year, when the government usually reallocates unused budgets between ministries. Therefore, choices over strategies depended upon aspects such as the prime contractor's risk appetite and the project's lifecycle stage.

In the dynamic complexity dimension, the budget change and environmental change factors are strongly connected, not only between them but also with the resource pace in the pace dimension. Based on the interviewees' narratives, the environment instabilities clearly resulted in changes to the budgets' size (dynamic complexity) and timing (resource pace). Budget changes and the resource pace naturally impact the scope size (structural complexity), the stakeholders' expectations (socio-political complexity), and the level of uncertainty for the project, leading to increased project complexity.

External and internal changes in a project environment affect the project's stability. The number, variety, and interdependency (structural complexity) of project elements are stressed further by the constant flux of change, reinforcing the transformation process through further feedback loops, adaptation, and self-organisation. This scenario creates emerging and chaotic behaviour beyond the team's ability to manage it, given that the team members need time to adapt themselves, make well-thought decisions, and develop other members of the team. Dynamic complexity forces the organisation and the project team to adopt a design based on flexibility rather than on control and predictability (the classic project management view) in order to find its best fit (contingency theory), although the level of change may force organisations and their members into a constant state of adaption, in which good fit is never reached.

4.4. Socio-political complexity

Interviewees mentioned two main socio-political complexity factors, namely vision and expectations alignment (68.18%–15 sources) and political or strategic significance (40.91%−9 sources). Additionally, they mentioned a new project complexity factor named personalism (18.18% – four sources), describing a characteristic of certain managers making their personal preferences prevail over formal or informal norms that rule people's interactions. Interviewee A, for instance, described that they "observe some practices that are not written, so people act accordantly with their will at that moment". Narratives suggested that this characteristic is a consequence of working environments with low institutional maturity that are strongly shaped by hierarchy, discipline, power, and authority, in which managers can enforce their will using their military rank ("it is an order!").

The most mentioned socio-political complexity factor was vision and expectations alignment, which describes the need to align the team and the stakeholders involved in the project. The high levels of turnover and personalism among team members may cause issues to arise about a project's continuity and priorities. Shenhar and Holzmann (2018) discussed the importance of creating a shared vision for projects and added that not only is a clear strategic vision needed, but also total alignment between stakeholders and the ability to adapt to cope with complexity are critical success factors. van der Hoorn and Whitty (2017) described practices and tools used to address that and create alignment such as "creating a vision, storytelling, seeding ideas, identifying and using personal drivers, and appealing to stakeholders and team members' sense of a 'higher good'".

The project's political or strategic significance was the second most mentioned socio-political factor and describes how important a project is for the stakeholders involved in it. This factor was approached in many ways by interviewees, highlighting the diversity of stakeholders and agendas involved in a defence project. Interviewee I described that for some politicians, their interest in defence projects usually translates into votes, explaining that "some resources come from politicians' personal budget allocations, so logically, some companies and interest groups want that capital invested in their city. Therefore, there is a political aspect in which the politicians have to 'sell' a security and development agenda and deliver some products to create the perception that he or she brought jobs or security to the city or region". Interviewee I added that a defence project's political or strategic significance of can go even beyond local aspects, affecting foreign political actors. Interviewee V explained that political significance is fluid and may change based on political circumstances, or given the long duration of defence projects, they may be affected by political alternations with different ideologies, interests, and priorities. Many authors (Engwall, 2003; Chapman, 2016; Gransberg et al., 2013; Revellino and Mouritsen, 2017) recognise the political nature of major projects and their significance or importance to public and private agendas. There is no "one size fits all" strategy for managing political and strategic significance. The narratives suggest the allocation of experienced managers with good political awareness and personal networks within the Brazilian Army and the federal government, highlighting the importance of social and political skills on complex projects (Zaman et al., 2019).

The socio-political complexity factors relate to other factors in different ways. On one hand, vision and expectations alignment is connected to the number and variety of stakeholders, scope uncertainty, and strategic alignment, demonstrating the challenge of aligning a project to an organisation's strategy and the many stakeholders' expectations as well as its effects on the scope uncertainty. On the other hand, the political or strategic significance is related to factors such as strategy alignment, the regulatory environment, lobbying, and technical novelty, suggesting that highly technological systems with political and strategic significance are influenced by lobbying to shape the regulatory environment and the military organisation's strategy in favour of some stakeholders' interests. These factors illustrate how project complexity begins at the political and strategic level of decision-making in defence projects, a characteristic known in complexity science as sensitivity to the initial conditions.

In summary, because people involved in projects have conflicting, hidden, or misaligned interests, views, or priorities, the level of uncertainty increases regarding the real nature of the project elements, leading people to act or make decisions based on wrong assumptions and thus creating a series of unintended consequences (emergent behaviour) that moves the project far from equilibrium.

4.5. Uncertainty

Uncertainty had only one factor (Fig. 1) mentioned by more than one-third of the interviewees. Information uncertainty (54.55%–12 sources) describes a lack of information or clarity necessary to make decisions regarding a project. However, the causes and consequences of information uncertainty vary by project. For instance, interviewee G stated that information sometimes is known but, for security reasons, is not available to certain management levels. Interviewee E described a similar situation that affected his project because the information had to be kept secret given the system's nature, mentioning, "the equipment that will be designed needs to be built based on the satellite's technical specifications, which were not released by the Ministry of Defence. We will know them only after its launch. It will enter in orbit, and then we will know the upload and download specifications, for example, which will determine the terminal's antenna size, and its power, band, and modulation". The literature provides some tools for coping with uncertainty in complex projects (Walker et al., 2017; Saunders et al., 2016b; Schrader et al., 1993; Pich et al., 2002; Sommer and Loch, 2004; Turner and Cochrane, 1993), although the strategy used by the Brazilian Army managers was to allocate people with knowledge and experience to key project areas. This people-centric approach was highlighted by interviewee P, a civilian, who added that on top of knowledge and experience, military managers are trained to deal with uncertain combat scenarios, so they respond well to uncertainty in defence projects, which helps projects to progress despite adversities.

Information uncertainty is mainly related to scope uncertainty, commercial process fitness, and regulatory environment factors. As discussed previously, institutional complexity factors create information uncertainty, which, makes the project's scope less certain. Uncertainty and ambiguity create project complexity because they produce an incomplete perception regarding what the objective and perceived realities are. The difference between these two states (objective versus perceived) demonstrates that reaching a good fit, as described in contingency theory, may not be straightforward in complex scenarios, given that agents and organisations may adapt to an incorrect configuration based on the perceived reality. Moreover, "project complexity is not only in the eyes of the beholder but also in the eyes as influenced by the role of the beholder" (Mikkelsen, 2020).

4.6. Pace

The pace dimension had one main project complexity factor (Fig. 1) namely the resources pace (36.36%–8 sources). Additionally, interviewees mentioned contractor and supplier speed (13.64%–3 sources) as a new complexity factor. The contractor and supplier speed factor describes a company's ability to cope with a project's schedule and explores aspects such as suppliers' lead time and their ability to integrate them into an assembly line without disturbing or interrupting its flow.

The resource pace (36.36%–8 sources) describes the resource flow in a project. This factor differs from and complements the aforementioned budget changes factor (dynamic complexity) because the focus shifts from the amount of budget received to its timing. Interviewee M argued that the problem is not only receiving fewer financial resources than the initial estimate but also receiving it out of pace, meaning the prime contractor and suppliers had to dismiss people to cut costs, making the project lose key expertise, which is usually difficult to recruit later. The resource pace, especially funding and payment delays, is a well-documented topic (Trammell et al., 2016; Amoatey and Ankrah, 2017; Adam et al., 2017; Rostami and Oduoza, 2017) that can affect different projects. Trammell et al. (2016) exemplified that in software development projects, "an organisation that stops and starts jobs or cuts and restores staff will inevitably suffer from morale loss, which will likely affect productivity and recruitment as well as turnover". In the case of the Brazilian Army, on top of the issues mentioned by Trammell et al. (2016), the biggest consequence of resource pace was the risk of losing key expertise, given that knowledge of and experience with some defence technologies are not easily available in the market.

The resource-pace factor has one of the strongest links within the project complexity factor network. As analysed in the dynamic complexity section, environmental changes in these projects tend to affect the pace of the receiving resources, especially for the financial resources (budget). In summary, the pace can create complexity by increasing the speed of change (dynamic complexity) and the interaction among project elements (structural complexity), leading to increased uncertainty and ambiguity. On one hand, the pace forces the project team to make decisions based on distant situations (the project duration factor, for instance), inevitably subjecting the project to a change process over the lifecycle and to more ambiguity regarding it. On the other hand, it also imposes a speed that may not allow proper information gathering creating poor decision-making. Therefore, the pace tends to increase the project complexity beyond the team's capacity to keep up with it. The misfit between pace and capacity may imply poor decision-making, thus leading to unintended consequences (emergent behaviour).

4.7. Novelty

The novelty dimension had only technical novelty (59.09%–13 sources) mentioned as a main project complexity factor (Fig. 1). However, interviewees also indicated a new factor named scope novelty (18.18%–4 sources), describing how new some tasks were to them. Developing countries building mid-to high-technology systems and with limited experience in managing and developing complex initiatives may experience different project complexity factors.

Technical novelty describes the level of novelty technical aspects like technology, components, products, and requirements. Defence projects usually involve research and development of highly technological areas such as aircraft, missiles, satellites, armoured vehicles, rocket launchers, telecommunications, electronic warfare equipment, submarines, ships, cyber technology, bio-warfare technology, and radars. Interviewee E added that to reduce the technological gap in a project, the development of some technologies was postponed to other stages of the project, adopting a keep it simple complexity-reduction strategy discussed by Giezen (2012). Defence projects in the Brazilian Army involve different kinds of technical novelty, ranging from crossover innovation (joint development) to component or modular innovation (the development of new component technology) (Cheung, 2016). The main strategy for coping with technical novelty was to involve people and companies with knowledge and experience in similar areas, allowing them to absorb foreign technology acquired through offset contracts and to use this new knowledge for performing incremental and architectural innovations. In addition, these projects have involved research and development initiatives to develop indigenous technology (de Rezende et al., 2018b).

Technical novelty is very much influenced by the political and strategic significance of defence projects. Government and military officials, and politicians influence the decision-making towards highly technological defence products, putting further stress on the project's technical aspects and making the project more complex.

In summary, novelty creates complexity because it increases and modifies the nature of project elements and their interdependencies (structural complexity), while promoting change (dynamic complexity) and uncertainty along the way. Contingency theory explains that managers and organisations adapt to environmental factors such as novelty factors within a system. However, project complexity is felt when the level of novelty exceeds the team's capacity to manage and adapt to the environment. In such scenarios, the project may pursue the good fit sought by contingency theory; however, it may never be reached if it exceeds the team's capacity to adapt as quickly as necessary.

5. Conclusion

Defence projects are well-known by their complexity, budget overruns, and delays, posing significant challenges for project managers and teams, but also making it a great opportunity for learning from such extreme cases. This research identifies the main project complexity factors that affect defence projects and charts how they are interdependent. In order to address this question, we conducted 22 interviews with senior practitioners working on the most strategic projects in the Brazilian Army.

Based on the findings of the study, one can conclude that the project context can shape which project complexity factors are more predominant. The defence case demonstrates that some industries may have specific characteristics that creates different project complexity factors, which are not often discussed in detail by the literature. Thus, a contextualised assessment is necessary when dealing with project complexity. Additionally, project complexity factors are not isolated aspects that can be assessed individually. Most complexity factors in major projects have interfaces with other factors, demonstrating that the decisions regarding one issue in the project can lead to unintended consequences on other areas of the project. Therefore, project complexity is not explained by a universal list of factors, but a contextualised network of factors that constantly interact with each other, creating the emerging behaviour perceived as complexity.

Previous literature explored complexity in several industrial sectors (Antoniadis et al., 2011; Kim and Wilemon, 2003; Mishra et al., 2016; Nguyen et al., 2019; Rad et al., 2017), however project complexity affects defence projects in many ways and requires different strategies and competencies to manage it. Experienced and knowledgeable managers play a crucial role in navigating complexity within defence projects. Individual and social competencies such as systematic thinking, collaboration, communication, networking, prioritisation, and socio-political awareness are key. The project's organisational environment is equally important (Denicol et al., 2021), so knowledge management, organisational cooperation, and an integrated supply chain managed by one or a few prime contractors are important aspects to be considered when managing complex defence projects. Moreover, cultural aspects that favour principles such as legality, transparency, accountability, and less personalist decision-making can make a difference in managing complex defence projects. These findings highlight that managers do not necessarily need to use sophisticated tools or techniques to manage complex defence projects, but it is fundamental to focus on skilled people.

This article has implications for theory and practice. Academics might use the identified project complexity factors to elaborate data-collection instruments or to outline the aspects to be analysed in a case study involving the defence industry. Moreover, the findings show how some classic theories such as contingency theory are pushed to their boundaries under complex scenarios. For instance, according to contingency theory, an organisation's effectiveness is contingent upon the fit between structural and environmental factors. However, this fit may not be achieved in complex projects. On one hand, project complexity factors may lead to adaptation towards an incorrect configuration based on the perceived reality rather than on the objective reality. On the other hand, project complexity factors may create a large, interdependent, and chaotic project, leading the organisation and project team towards a constant state of adaptation in which good fit is pursued but never reached. In both cases, the level of project complexity was beyond the team's and organisation's ability to adapt promptly towards a good fit. Therefore, project complexity challenges not only classic theories but also the classical view of project management based on objectivity, reductionism, control, and predictability in favour of approaches based on subjectivity, systemic thinking, and adaptability. Practitioners, on the other hand, might incorporate the project's complexity factors into their decision-making process and discuss those aspects to have a better understanding of the projects in which they are involved. On top of knowing the main project complexity factors and the competencies needed to manage them, it is important to highlight that these factors are interdependent and connected, so an integrated and systemic analysis of the project's complexity would be beneficial.

Therefore, we contributed to the literature on project complexity by providing a different discussion that approaches the subject from an integrated perspective, contrasting the usual discussion based on project complexity frameworks with independent factors. An integrated perspective presents information that can explain the relationship between complexity factors, providing the reader with a systemic view, and helping to understand the systemic effects and unintended consequences when dealing with complex systems such as defence projects. Moreover, we contributed to the literature by adding a discussion from the perspective of developing countries. These countries are usually developing mid-high-technological systems and have limited experience in the management and development of complex initiatives, which can result in different complexities and importance regarding different factors in these contexts.

Further research is necessary to identify the weight or priority (Kim et al., 2020) of each project complexity factor. Our paper focused on identifying project complexity factors, by interconnecting results from the interviews and the theoretical framework. A subsequent study could investigate the interactions between factors and implications, aiming at understanding how complexity factors can be influenced, and handled in a project management context. Moreover, a more systemic analysis informed by the priorities of factors would advance our ability to assess the level of project complexity. In addition, it is worth further investigating the roles of competencies and capabilities in delivering complex defence projects, exploring the interplay between multiple levels of analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.plas.2022.100050.

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