An overview on megaproject management systems

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Abstract

Purpose – There is a large amount of published literature on project management. However, there exists a gap between the existing literature and current practices in the industry for the development and execution of megaprojects. Existing literature generally focuses on individual elements applicable to project management in general. This article aims to provide an overview of the project management system components used in industrial megaprojects and identify the gaps between theory and practice, which can be used as input for further research on the topic.

Design/methodology/approach – The topic of megaproject management is reviewed based on available literature sources on megaproject management systems to identify the main gaps in the literature between theory and practice. Based on the findings, an analysis is provided to discuss the improvements required in distinct project management areas and phases.

Findings – There are multiple gaps associated with issues, failures, successes and challenges in industrial megaprojects. Improvements are needed in distinct management areas and over the entire project lifetime. Further guidelines are required for achieving improved megaproject management systems. Such concepts could benefit researchers and practitioners in streamlining their research toward the most relevant and critical areas of improvement of megaproject management systems.

Originality/value – This study addresses the literature gaps between theory and practices on megaproject management systems with an overview that provides helpful guidance for industrial applications and future research. A holistic analysis identifies gaps and critical drives in the body of knowledge, revealing avenues for future research focused on quality as the central pillar that affects the entire megaproject management system.

Keywords Megaproject management, Challenges, Success, Improvements, Lessons learned, Quality

Paper type Literature review

1. Introduction

Megaprojects represent a complex, unstable, non-linear, irregular, uncertain, unpredictable and highly dynamic environment. They are often developed and executed over multiple years and encompass a multi-scope decision-making process. Hence, they are complicated to be efficiently implemented and control. Industrial megaprojects face numerous challenges in various areas and stages, which often lead to issues and failures in the economics, operations, social, environmental and political spheres. In this context, the effective use of a proper management system increases the success of megaprojects and has been the topic of multiple academic studies. The literature also reports various lessons learned from past and present megaprojects, which ideally should be incorporated for enhanced future megaprojects. Such management drivers for challenges, failures, successes and lessons learned are highly impactful in industrial megaprojects and need to be further addressed by the academic literature.

Most megaprojects face multiple challenges throughout all phases over their lifetime. The academic literature needs to address further and identify these challenges and develop

methodologies for properly handling them by building better management capabilities (Söderlund *et al.*, 2017). Megaproject management challenges are related to accomplishing the project objectives given multiple requirements and expectations within a highly complex and uncertain environment, in which various sources of risks often exist (Marrewijk, 2007). Planning and development often ignore risks and uncertainties, whereby megaprojects become inflexible and vulnerable to unexpected events (Giezen, 2012). Management systems often rely on experience and intuition rather than considering risks (Qazi *et al.*, 2016). Hence, long-term predictions are typically inaccurate or unreliable (Flyvbjerg *et al.*, 2007). That leads to significant exposure and the occurrence of risks. Despite the multiple risk management methodologies employed in the last decades, the increasing complexity of megaprojects imposes difficulties in achieving risk mitigation strategies. It often leads to significant issues and failures of megaprojects.

Megaproject outcomes are either very good or very bad, mainly because the project phases are interconnected (Hollmann, 2017). In general, poor management performance is expected. It includes budget, schedule and quality issues, which significantly impact the expected benefits and outcomes. Some of the main drivers for that are associated with project complexity, misinformation of data, underestimation of cost and schedule, overestimation of benefits, poor risk prediction, management and mitigation, long project's lifetime, lack of training and experience, inefficient organizational structure, poor stakeholder management, political influence and occurrence of major unexpected events (Marrewijk *et al.*, 2008; Flyvbjerg, 2017; Locatelli *et al.*, 2014).

Despite the importance of addressing issues and failures, there are also advantages in understanding the main factors that lead to successful megaprojects. This helps identify which changes are required and how they can be employed. Success factors in megaprojects are associated with well-defined project objectives, efficient management tools and strategies, accurate estimations and forecasts, stakeholder support and alignment, flexible and adaptive project management systems (PMS), reasonable organizational structure and project governance, proper planning, clear procurement procedures, management and execution strategies, good communication, trained, experienced and qualified teams, performance feedback, and monitoring, high-level technology, accurate analysis of geopolitical risks, good corporate reputation and social responsibilities (Bredillet and Dwivedula, 2008; Merrow, 2011; Crosby, 2012; Jetu and Riedl, 2012; Kwak *et al.*, 2014; He *et al.*, 2019).

It is fundamental to understand megaprojects' challenge, failure and success drivers. This work delivers well-structured insights by better understanding these factors that influence megaproject management systems. The discussion is extended to the main PMS categories in which gaps are identified, and improvements required are discussed. Quality-driven megaprojects are presented as a novel proposition highlighting the quality aspects of the megaproject ecosystem and its entire lifetime. The significance of incorporating lessons learned toward continuous improvement to achieve successful quality-driven megaprojects is also addressed. The outcomes of this research provide practitioners and researchers with a better understanding of the challenges, issues, failures, successes and lessons learned that are relevant for improved PMS, thereby highlighting the most impactful gaps and improvements required. This article contributes to the literature on megaproject management systems with an overview that provides helpful guidance for future research and industrial applications. A better understanding of the current gaps and how to achieve further improvements would enhance the megaproject management system with better and more efficient project outcomes. Such enhancements are helpful for both industry and academia through increasingly meaningful research and developments on the topic.

To the best of our knowledge, the literature of megaproject management systems requires a recent review on the main drivers of challenges, failures, successes and lessons learned in

industrial megaprojects. Therefore, we propose the following research questions as main drivers toward a structured review to be presented and discussed herein:

RQ1. Which factors most affect megaproject management systems?

RQ2. Which are the main challenges faced in the execution of megaprojects?

RQ3. Which are the main issues and failures in megaproject management systems?

RQ4. Which are the main drivers of successful megaprojects?

RQ5. Which are the most important lessons to be learned in industrial megaprojects?

The outline of this paper is as follows. Section 2 presents an overview of megaproject management elements and discusses the main challenges, issues, success factors and lessons learned in industrial megaprojects. Section 3 discusses the most impactful gaps and improvements required in industrial megaprojects over nine distinct categories. Section 4 introduces the concept of quality-driven megaprojects with a novel perspective of how megaproject management systems should be addressed. Section 5 highlights the main conclusions of this work.

2. Overview on megaproject management elements
The literature review methodology employed in this paper retrieves relevant works from available online citation indexes published in peer-reviewed journals and other reliable sources. The framework for the literature search is illustrated in Figure 1 to provide easier visualization of the method.

In Step 1, keywords associated with megaproject management systems are selected to identify relevant articles to the topic correctly. The primary databases used for the search are Scopus and Web of Science, as shown in Step 2, leading search engines of peer-reviewed literature. Additional relevant papers from other reliable sources, such as Google Scholar, are also included. A first filtering procedure is performed in Step 3 by removing papers not relevant to the proposed review. Step 4 combines the selection of works from the databases and removes the duplicated papers (i.e. in case both databases provided the same article). The pool of papers selected undergoes a second filtering procedure performed in Step 5, consisting of an in-depth reading of the papers to ensure that all works to be reviewed are meaningful contributions to the topic of megaproject management and are closely related to the scope of this review paper. The final pool of papers selected comprises the data set of relevant literature on megaproject management to be reviewed and discussed herein. The data set contains relevant information on megaprojects' main challenges, failures, successes and lessons. The megaproject management topic is meaningful and essential to provide a solid structural foundation for the discussion proposed herein.

Most academic works on megaproject management focus independently on some aspects, concepts, ideas, strategies or methodologies related to a specific topic (e.g. risk analysis, stakeholder, and safety, health and environment (SHE), etc.), or project phase (e.g. planning, execution and closeout), or application (e.g. design, construction megaprojects). The literature on the topic requires covering the significant gaps and improvements needed in industrial megaprojects. Thus, it is fundamental to determine the critical drivers for challenges, issues, failures and successes typically existent over the project lifetime and to properly study, analyze, and capture the lessons learned throughout projects. This provides capabilities required for future guidance toward improved megaproject management systems. This work aims to explain the main gaps in megaproject management, which areas and topics should be further addressed in future research, and the requirements and improvements needed to accomplish such objectives.
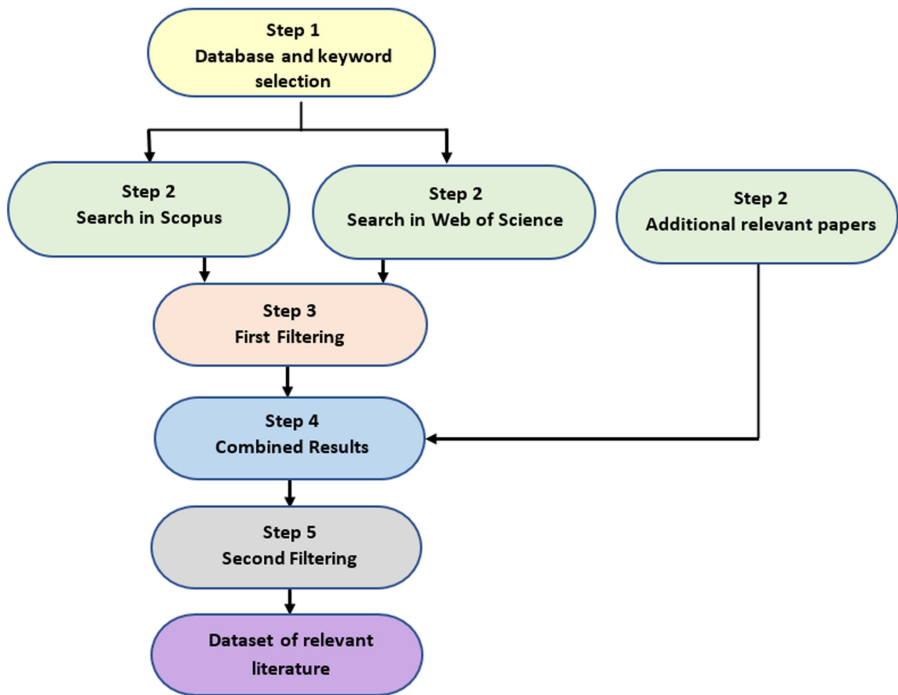
Figure 1.
Literature search
method

2.1 Challenges

Megaproject's face challenges in management and organization. They require a vast number of the skilled labor force to execute the work, whereby a shortage of skilled labor resources and organizational expertise is often present due to the high demand of megaproject labor requirements. Additional challenges for megaprojects are inadequate management skills, lack of experience and the duration it takes to complete the project, typically more than four to five years if the project stays on schedule. Those challenges lead to unstable management structures and poor monitoring and control as many team members leave the project before completion, taking the history and knowledge with them, which impacts the overall performance of the megaproject.

Due to the dynamic complexity and uncertainty of the connections between megaprojects and the stakeholder community, stakeholder satisfaction has been a concern. Megaprojects should create values for the stakeholder community compared to its value. Stakeholder alignment and engagement are challenging tasks given the intrinsic complexity of megaprojects. They can be achieved through proper communication and the development of healthy relationships. However, it is challenging to meet all stakeholder expectations due to resource constraints. To fulfill the gap in stakeholder engagement, the project team should respond to all stakeholders' expectations and prioritize their attention to their expectations. Bahadorestani *et al.* (2020) propose a framework to define priorities for stakeholder involvement relying on the balance mutual value creation between the stakeholder community and megaprojects by addressing the value creation theory. Their methodology can be applied through identifying, categorizing and managing stakeholder engagement in megaprojects to provide benefits toward improved megaproject management.

Megaprojects require careful management where client and contractor must be transparent and responsive to open record requests. Megaprojects typically present challenges because of their complexity, size, uniqueness and technological and innovation levels. It includes novelty features, a long time horizon, multiple sources of uncertainties and a high potential for corruption (Delatte, 2017). Delivering a worldwide megaproject to completion on schedule, according to planned budget and as per defined specifications is a tremendous undertaking requiring experience, teamwork and the appropriate tools to assist project teams (El-Sabek and McCabe, 2017). The problematic issues impacting the implementation of megaprojects globally include changes in schedule, budget, scope and quality specifications. Jobling *et al.* (2019) point out that standard PMS approaches cannot resolve complex challenges as megaprojects are generally riddled with pitfalls and problems.

According to Tshidavhu and Khatleli (2021), the significant barriers to effective execution are poor site management, inadequate worksite management, insufficient managerial capabilities, poor continuous monitoring, unbalanced roles and responsibilities, weak organizational structure and lack of expertise. Moreover, Flyvbjerg (2017) argues that megaprojects confront disproportionately huge scheduling and budget constraints compared to other project types. The causes include (1) increased hazards owing to complicated interfaces and extensive planning horizons; (2) planning processes involving many people with competing interests; (3) project scope that is subjected to considerable modification over time; (4) misrepresentation to the public regarding costs, benefits, and risks.

Artificial intelligence (AI) has been used to overcome multiple challenges and ensure success for megaprojects. Through an analysis of the project management literature, ethnographic studies and semi-structured interviews with project management professionals, Greiman (2020) explores the growing use of AI to manage megaprojects, including the obligations of private industry and the government as the guardian of the public interest, while at the same time exploring the technical, managerial and ethical considerations in the deployment of AI.

2.2 Failures and issues

Megaprojects tend to poor performance, with failure to deliver on-schedule, or within allocated budget, or with good quality, or by governing or environmental requirements that can have significant consequences on an organization's reputation and revenue performance (EY, 2014). Roughly two-thirds of all megaprojects fail, which means either going over budget, past deadlines or failing to meet the desired objectives. The root causes for project failure concern completing front-end loading, escalation, regulatory regimes, plant complexity, new technologies and complex ownership (Schoenhardt *et al.*, 2014). Dupont and Véronique (2013) argue that megaprojects commonly fail in addressing social concerns and social redistribution elements. According to Locatelli *et al.* (2014), technical, psychological and political are the three categories leading to poor performance. The main reasons include complexity, biased forecast, lack of information about cost and benefit and poor stakeholder management.

Schoenhardt *et al.* (2014) argue that multiple issues can affect the megaproject management system, increasing its complexity. It includes contemporary detailed design and construction, non-integrated project team, contractual risk misallocation, fast-tracking projects, lack of internal capacity, clearly defined process or industry complexity. Caldas and Gupta (2017) identify multiple factors that negatively impact the success of megaprojects and classify them into five categories, namely, location and technology, organization team and communication, planning and execution process, governance and governance stakeholders and delivery strategy.

Many works highlight the importance of SHE elements in megaprojects' execution (Flyvbjerg, 2017; HSE, 2021). To reduce or mitigate SHE and other quality issues, Delatte (2017) suggests that during the megaproject inception and planning and control phases, SHE and quality should be overseen by independent inspector agencies through a cold eye review process to handle quality and safety issues properly.

According to Söderlund *et al.* (2017), some of the essential and critical factors in megaproject management include managing megaproject investments with high benefit proportions that might significantly influence the government's corporate economic goals and boost people's trust in the nation's present and future.

As the majority of the megaprojects are funded by the governments and private capital investment banks, the decision-making process is slow, which impacts the progress of megaprojects and often leads to contractual claims, variation orders and delays in the project execution (Callegari *et al.*, 2018). Factors related to cost and schedule are the most common issues often faced in megaproject management (Tshidavhu and Khatleli, 2021). They are often associated with project management factors, stakeholder conflict, resource constraints, recurrent change orders, unrealistic time schedules imposed on contracts, regulatory and policy-related challenges, inadequate organizational structures and unfavorable external environment (Hudson *et al.*, 2016; Basak *et al.*, 2018). Jobling *et al.* (2019) discuss contractual issues and their impact on the execution of megaprojects, whereby risks are transferred to another party on the project, leading to additional costs.

Proper analyses, estimation and evaluation are essential at the early stages of megaprojects for minimizing disruptions and negative impacts due to unforeseen events and outcomes. Strategies and analysis methodologies should be periodically or continuously carried out to control the megaproject phases' activities, goals, accomplishments and deadline activities.

2.3 Success factors

Given the high rate of failure in megaprojects, it is also critical to investigate the factors that contribute to the success of megaprojects to overcome the complexity of managing megaprojects and increase the collaboration required among many parties (Kardes *et al.*, 2013). Instead of focusing on megaprojects failures, many works address and discuss the main essential factors required or helpful in providing success to megaprojects. The success of a megaproject is interpreted differently by different stakeholders. Large complex projects continue to underperform despite the increased availability of systemic and disciplined project management approaches. Tolerance in meeting project success criteria varies among distinct projects, and what may be acceptable in one project may be entirely unacceptable in another. As a result, each project's collection of performance indicators is distinct and cannot be compared across different projects.

Puerto and Shane (2013) address two major highways expansion megaprojects and identify the management practices that resulted in successful megaprojects. The main reason for the success of these two megaprojects relies on the commitment among the owners and the project delivery teams in identifying and resolving problems in an efficient and timely manner. Other success factors include (1) early agency agreements and commitments; (2) understanding the culture and socio-political circumstances surrounding the project; public outreach; and (3) recognizing circumstances that impact project delivery.

Crosby (2017) investigates success factors by identifying the key strategic area that exhibits robust correlation to project success, especially in the project definition phases starting from inception and planning and feasibility phase. The author emphasizes the importance of defining project goals and success definitions, efficient procurement, building project resilience, tackling complexity, early selecting optimism and mission assurance mindset and risk and preparedness analyses.

El-Sabek and McCabe (2017) highlight the importance of developing and employing new methods and tools to overcome shortcomings and provide efficient management capabilities. Eren (2018) provides insights on measures for achieving effective megaproject practices and discusses the proper strategies to address. Zhang *et al.* (2020) state that successful megaproject experiences are derived from different aspects, including governance system, method and objectives, organizational structure, resources protection, technical support and evaluation system.

Al-Hajj *et al.* (2018) examine when and how project management affects project success. The authors argue that such methodologies are not generic, and each project may have different success factors. Instead, they need to be adapted depending on the project objectives for achieving consistent management success. Further, the authors corroborate that PMS positively influences project success with a strong correlation between efficient project management and successful projects.

Performance measurement methods are different according to project. Regardless of the amount of work on the subject in literature, there is no commonly agreed framework of performance measurement on megaprojects (Yang *et al.*, 2019). Moreover, effective indicators for assessing megaproject success are not validated, which leads to an ineffective assessment of megaprojects (Wang *et al.*, 2020). Major project success factors include using tools of performance measurements and feedback, whereby key performance indicators (KPIs) can be employed to make decisions and reduce uncertainty in assessing megaprojects (Eshghi *et al.*, 2019). Toor and Ogunlana (2010) investigate the importance of KPIs from construction stakeholders' standpoint, including clients, consultants and contractors. Their primary outcomes imply that the traditional measures known as the iron triangle (time, cost and quality) are no longer valid for evaluating performance on sizeable public sector megaprojects development.

2.4 Lessons learned

Currently, leading companies have realized that their competitiveness depends on how fast knowledge flow through the organization. Learning has become a tactical resource of the organization as a viable advantage. Incorporating lessons learned into organizational processes can enhance their current and future project delivery. Therefore, the concept of lessons learned is fundamental for developing efficient PMS. It assists in reducing issues, risks, and failures and increases the success rate of projects. Due to the complex environment in which megaprojects are managed, the companies have many lessons and improvements. Project management for lessons learned involves aligning different aspects of a project to bring encouraging results for the overall industry (Amalraj *et al.*, 2007).

It is critical to learn from past lessons to find ways to aggregate acquired insights and transmit knowledge (Haynes, 2011; Lenfle and Loch, 2017). The lessons learned are gained from experience, success and failure to improve future performance and may be specific for distinct industries or projects (Aisheh, 2021). However, there are no guidelines on structured ways of analyzing projects and retaining lessons learned for future projects and few for building practical organizational capabilities and competencies. Project-based learning needs assurance, and continuous investment of time and resources are repeatedly neglected (Williams, 2008).

Khoo *et al.* (2009) point out many lessons learned and perspectives to be considered when developing megaprojects. This includes (1) novelty aspects are related to effort, diligence, discipline, and rigor required throughout all the phases of megaprojects; (2) many experiences, processes, tools and learnings can be applied in the future megaprojects even from different fields and in different places; (3) execution challenges are not necessarily simple extrapolations but may become orders of magnitude more complex; (4) although there

are many advantages for being a pioneer in novel and unforeseen megaprojects, a project team with knowledge and competency to anticipate and respond against disturbances and complications is crucial; (5) it is vital to have a large pool of technical personnel expertise from shareholder entities to rely on when significant challenges arise.

Learning lessons from past megaproject experiences assists companies in preventing the same mistakes and pursuing more successful projects in the future, enhancing their competitiveness (Arditi *et al.*, 2010). Paranagamage *et al.* (2012) state that the lesson learned should incorporate into the work process to (1) enhance future performance, (2) find the solution to the present problem or make a preventative action, (3) create the policy or obtain the guideline of the companies and (4) prevent the adverse situation. According to Puerto and Shane (2013), investigating successful megaprojects is an important lesson that enables practitioners to apply and refine successful practices to manage future projects. Ferrada *et al.* (2016) argue that lessons learned from megaprojects are typically not systematically incorporated into subsequent projects.

The successful transfer of learning throughout projects has been a long-held demand by project professionals. The nature of projects as a team creates the complexities in achieving this activity is split from a permanent organization. This is valid for megaprojects, given that their complexity and size make it difficult to discern which elements of its myriad configurations mainly influence performance and how that happens (Brookes *et al.*, 2015).

Duryan and Smyth (2016) highlight the importance of understanding cultural barriers to incorporate lessons learned into organizational standards and processes disseminated among all stakeholders involved. The project challenges, risks, barriers, obstacles and complexities are intrinsic to the process, operation, field, place, among others and should be considered and analyzed when pursuing guidance toward megaproject learning. According to Poddar and Sue (2016), there is a significant increase in success when interface management is implemented as integrated megaproject steps, a valuable lesson for future works on the topic.

Upon the project completion, employees are often moved on to the next project before analyzing lessons or incorporating additional knowledge. That limits the flow of information and leads to the wastage of lessons. Delatte (2017) discusses the importance of having an effective communication strategy and carefully studying the lessons learned from previous projects to build effective management and troubleshooting strategies for future projects. Söderlund *et al.* (2017) address multiple critical issues in megaproject management for developing a preparedness assessment process with lessons learned from previous events. The assessment is expected to provide the project team with alignment on the criticality of the impact factor and effective mitigation strategies. Jo *et al.* (2018) argue that lessons and knowledge gathered from recently completed megaprojects assisted in understanding that a significant cause of delays is attributed to inefficient management of resources and unrealistic workloads.

Invernizzi *et al.* (2018) provide a novel benchmarking approach that incorporates qualitative and quantitative analysis to gather, identify and analyze successful and poor practices in a portfolio of megaprojects.

The complexities in achieving transfer of learning throughout projects are created by the nature of projects themselves, their split from a permanent organization and their uniqueness. Even with multiple attempts by companies to develop reliable systems to transfer learning across projects, most organizations still need to achieve more efficient ways of sharing learning among projects. This is especially valid for megaprojects, given that their complexity and size make it very difficult to discern which elements of its myriad configurations mainly influence performance and how that happens (Brookes *et al.*, 2015).

Liu *et al.* (2020) explore a mechanism for improving knowledge-sharing performance using the theory of planned behavior and conclude that four factors affect knowledge

sharing: benefit perception attitude, risk perception attitude, subjective norms and perceived behavioral control.

2.5 Summary of key elements
The most important drivers for each element previously discussed (challenges, risks, failures/issues, success and lessons learned) are summarized and illustrated in Table 1. This provides comprehensive, concise information concerning the literature reviewed in this work.

3. Discussion on PMS gaps and improvements
The literature on megaproject management systems is premature. It requires further research to understand better the main issues, failures, successes, and challenges and the improvements needed for future management of megaprojects. In this section, we discuss some of the most impactful gaps and enhancements required for enhanced megaproject management systems segregated into nine categories (project planning and control, conceptualization and execution strategies, organizational structure and project governance, safety, health and environment, cost and schedule, risks analysis and management, procurement process, stakeholder alignment, engagement and satisfaction, and project closeout).

3.1 Project planning and control
Effective project planning and management are fundamental for better success rates, given the complexity, risky, uncertain and unpredictable environment of megaprojects. At early stages, robust planning processes with appropriate tools should be employed to define project objectives, scope, responsibilities, complexities, uncertainties and resources needed for achieving the project objectives. Many gaps are often faced in the current project planning and control methodologies employed in megaprojects.

First, the traditional planning approach is centralized and focuses on taking control of actions only after problems. Second, the project planning and control policies simplify the methodologies and the project's overall scope. Third, evaluating risks, uncertainties and unforeseen events is often poorly designed or estimated. Fourth, the currently employed standard planning and control are often excessively restricted and limited, in which changes are not always suitable. That makes it difficult and inefficient to achieve reliable estimations, adapt to changes, cope with unexpected events, mitigate critical risks and address challenging elements. Therefore, better planning and control management tools and strategies need to be developed for improved megaproject management capabilities.

The main capabilities currently required include achieving realistic project planning and control with flexible responses and strategies, improved assessment and management of uncertainties and risks, further assist on the identification and communication of uncertainties, transparent and clear identification and communication of risks and ambiguities, and properly quantifying the importance of project flexibility from financial and management perspectives.

3.2 Conceptualization and execution strategies
Conceptualization and execution strategies are vital pillars for the success of megaprojects, mainly because they encompass most of the project lifetime. There are many management expectations to be consolidated during the conceptualization and execution phases, which are highly significant toward the project's success. It is the platform where the outcome expectations of the results are anticipated to be finalized through clear technical definitions. Most of them are vulnerable to difficulties and failures, especially given the complexity of

Challenge drivers	- Efficient project management system
	- Many uncertainties, disruptions and unforeseen events
	- Specific, complex and often unique processes, technology and requirements
	- Constant changes in the project scope
	- Perform accurate and detailed estimations over a long horizon
	- Long planning horizon and detailed scheduling operations
	- Budget and schedule constraints
	- Stakeholder alignment and engagement
Failure/Issue drivers	- Project complexity
	- Poor estimations or biased forecasts
	- Lack of information or misinformation
	- Poor stakeholder management and conflicts among stakeholders
	- Inadequate structure and governance
	- Lack of teamwork and communication
	- Safety, health, environmental and quality concerns
	- Political and social conflicts and issues
Success drivers	- Properly addressing the known or expected challenges and issues
	- Efficient project management capabilities
	- Development, acquisition and employment of novel and efficient technology, strategies and methodologies
	- Incorporation of previous lessons learned
	- Stakeholders' commitment and alignment
	- Continuous updating of planning/scheduling over the project lifetime
	- Performance measurement tools and continuous feedback
	- Use of KPIs
	- Focus on project quality and safety
Lessons learned drivers	- Identifying main factors and elements associated with risks, issues, failures and successes
	- Execution challenges may scale exponentially with project complexity
	- Technical and operational expert teams are vital to mitigate risks and handle uncertainties
	- Enhanced PMS is required for megaprojects
	- Organizational behavior, structure and governance
	- Risk management and mitigation strategies can be of great assistance
	- Experiences, processes, tools and learnings can significantly enhance the development, management, and execution of future projects
	- Although megaprojects are typically unique, lessons learned are often adaptable and implementable to future projects, even from different fields and in other regions

Table 1.
Challenges, failures/
issues, success, and
lessons learned

megaproject environments. Many times, alignment of the stakeholders and shareholders are either missed out or misinterpreted during the early stage of the project because of a lack of joint opportunity framing workshops which leaves an unclear definition, incomplete project development, and faulty execution strategies. This severely impacts the budget and schedule overruns during the execution of the project due to frequent scope changes, repetition of works, and added expectations leading to unforeseen issues and risks, which makes the project vulnerable to missing its objectives. This also brings a big challenge in framing the execution strategies regarding contracting and procurement strategies, organizational structures, key issues and significant cost optimization opportunities.

The development and application of effective strategies for the conceptualization and execution phases are fundamental for avoiding issues and failures, mitigating risks and handling unforeseen events. Therefore, there is a need to establish separate but interdependent processes through the development of deliverables starting from the planning phase until the defined phase of the project. This also requires adequate flexibility to adapt against changes, unforeseen events, company commitment and periodic improvements.

3.3 Organizational structure and project governance
The organizational structure represents a critical part of megaproject management over the entire project lifetime, in which well-defined corporate planning in every stage is fundamental for enhancing the project's success and mitigating issues and failures. Effective organizational structure can adequately reduce the megaproject complexity without compromising quality. Moreover, it provides the capabilities required to survive megaprojects by mitigating risks, issues and the impact of uncertainties, increasing the project performance, strengthening the inter-organizational compatibility and communication and enhancing cooperation and coordination aspects within megaprojects. A proper governance system and organizational structure have been vital for the excellent performance of multiple recent complex megaprojects. It is worth highlighting the importance of identifying and exploring resources for creating and capturing value for organizations.

Due to challenging aspects, many organizational structures and project governance factors may compromise the megaprojects' key elements (e.g. budget, schedule, scope). The literature highlights major requirements toward transparent and robust processes, ethical considerations, enhanced knowledge management, better communication strategies, proper team management and inter-organization relationships. Such elements are fundamental to tackling the main gaps in megaproject management, avoiding project delays, cost overruns, safety, health and environment hazards, and general quality issues.

3.4 Safety, health and environment
Most works on megaprojects have generally focused on cost and schedule, although recent global trends have highlighted the importance of the safety, health and environmental elements. The traditional cost-schedule-quality basic megaproject management concepts have been adapted according to the current social and ecological needs. This includes concerns with the health and safety of people, project security, sustainability and value creation, and multiple climates and environmental concerns.

Improvements are required to provide safer, healthier and environment-friendly megaprojects. The industry needs to clearly define safety and health concepts and how they should be considered during the execution of megaprojects. More attention is required to mitigate accidents at the project sites through well-defined safety guidelines, periodic and rigorous on-site safety inspection procedures (e.g. by employing third-party safety inspection to achieve safer conditions and provide guidelines for improved megaproject safety

management), implementation of preventive measures and robust safety policies to avoid the occurrence of accidents, enhanced communication and feedback on safety practices, the commitment of the management team and site supervisors, training and education to the employees to provide adequate safety knowledge. One of the main objectives in megaprojects is to ensure all people involved in the project goes home safely to their family at the end of the project as all safety incidents are preventable. It is also essential to improve the hierarchy of control for health risks, provide access to health services, improve health data management, reduce risks and exposures, adequately address health risks and behavioral safety measures and awareness and further emphasize the importance of occupational health risks health management.

3.5 Cost and schedule

Cost and schedule are the most critical features considered within project management, the former because the economic aspect is crucial for implementing megaprojects. The latter is for financial, strategic and operational aspects. Cost overflow and schedule slippage are the most common challenges in megaproject management. They often involve recurrent change orders by the contractor due to unrealistic time schedules imposed on contracts and inadequate organizational structures. The leading causes include project management factors, stakeholder conflict, resource constraints, regulatory and policy-related challenges and an unfavorable external environment.

Novel methodologies must be developed to manage better and execute megaprojects to handle cost and schedule elements. Future research should focus on adequately analyzing and estimating risks for the better contingency of cost and time over the megaproject lifecycle, designing improved estimation tools for accurately determining budget and schedule information, and developing systematic cost and schedule methodologies using proven tools from the planning phase of projects. The cost and schedule estimates are predictions based on given data and conditions, which should include realistic levels of contingency and accuracy depending on the pre-defined estimations, and which must be updated accordingly throughout the project lifecycle.

3.6 Risk analysis and management

The literature on quantitative risk analysis for megaproject management is still premature due to the lack of studies that quantitatively measure and evaluate the impact of risks on the execution of megaprojects.

Risks should be identified as early as possible, whereby risk assessments should be continuously performed with recommended risk mitigation tools, measures and action plans. Risk management can assist in anticipating future consequences and timely support the mitigation or avoidance of risks before their occurrence. Given the complexity of megaprojects, the identification, assessment and mitigation of risks are critical. Their success depends on how well complexity and risk are addressed over the entire megaproject decision-making process. Hence, exploring how complexity can be incorporated into risk management is critical for formulating appropriate strategies.

Most project risks are driven by front-end loading, ownership structure, new technologies, plant complexity, regulatory regimes, failure to forecast escalation, materials, resources, equipment issues and unforeseen or unpredictable conditions. One of the primary sources of risks is derived from cost-cutting attempts at different project stages, which leads to risky decisions and unexpected consequences. Transferring risks from owners to contractors is another critical issue, as it is typically ineffective, compromises the project's success and jeopardizes openness and collaboration among the stakeholders involved. Better strategies

should jointly manage risks between stakeholders. All these elements are related to risk-related factors, including organizational, environmental and technical.

To correctly manage risks over the execution of megaprojects, it is fundamental to employ quantitative risk analyses to anticipate issues in the presence of uncertainty. Novel approaches are required for risk management. Efficient risk management is challenging for the success of megaprojects. It helps minimize delays and cost overruns, improve project quality, improve decision-making processes and enhance execution performance. This represents a crucial topic on megaproject management, whereby further research with improved tools, strategies and approaches is imperative.

3.7 Procurement process
Procurement processes are essential for the overall megaproject performance. They account for reasonable costs and provide multiple resources required for the project execution. It is highly recommended to have a well-defined procurement management plan for the project and how the procurement documentation should be developed and managed through the contract closeout. Many project failures can happen due to poor procurement processes. Therefore, better procurement management plans are required for megaproject management systems. A systematic framework supported by an effective procurement plan should be implemented in early megaproject phases. Significantly, it should be updated accordingly over the project's lifetime to account for relevant acquisition and market changes. Better approaches are required to enhance the decision-making selection for the procurement process according to the type, area, scope, and size of the megaproject, aiming to avoid a shortage of materials and resources, delays and cost overruns. This represents great potential for improvements that affect the overall scope of megaprojects.

3.8 Stakeholder alignment, engagement and satisfaction
Stakeholders are essential for megaprojects' planning, management, and execution stages and contribute to the decision-making process over the project lifetime. Therefore, good alignment and engagement of the stakeholder objectives and good cooperation among them are essential for successful megaprojects because of the dynamism, complexity and uncertainty of the several relationships between the projects and stakeholders' community. This includes understanding the needs, requirements and objectives of all stakeholders involved in the project, adopting structured mechanisms for better stakeholder engagement and providing a proper environment with collaborations and synergies among the stakeholders for contributing to a common goal.

Significant issues in megaproject management arise due to poor stakeholder alignment. The approval of final investment decisions is difficult as they require alignment from all stakeholders and huge funds with substantial backing from the government and international banks. Exist overlapping interests should be handled by balancing the stakeholders' interests through management and analysis methods, engagement initiatives and external influence. Many stakeholders may lead to high political and social interest, whereby the project leadership is unclear or not identified, which often jeopardizes the communication and synchronization of people and resources.

The development of stakeholder management strategies, in which the stakeholders affect the decision-making processes, is essential. Stakeholder engagement is critical for success in megaprojects. Important factors include forming community advisory groups, effective management of stakeholders' objectives and requirements, collaboration and mutual trust, transparency and a well-defined scope of works with a clear definition of responsibilities at early stages. This enhances the stakeholder relationship, reduces disputes, eliminates conflict of interest, allows knowledge exchange, provides a collaborative environment and healthy

interactions between stakeholders, and improves problem-solving techniques by including external stakeholders in the organization's decision-making process.

3.9 Project closeout

The closeout phase begins once the project has already been completed, and it might last or extend for long after the work has been constructed on-site. It represents a crucial phase that is under-evaluated in importance and challenging aspects and frequently not well-planned. This leads to many obstacles, including lack of funding and resources, time overrun, conflicts and litigation. Hence, the closeout is a challenging phase that must be carefully considered.

Long-term impacts are not well analyzed and evaluated. The megaproject success should include the project's long-term benefits, which may be measured and achieved years after the project's completion and delivery according to the stakeholders' expectations and objectives. Many megaprojects face relevant changes after years of completion, whereby significant issues arise, leading to the total failure of expected successful megaprojects.

Inefficient megaproject closeout processes are driven by several factors, such as poor planning, punch-list delays, external barriers, project delayed, misplaced, missing or insufficient documentation, owner postponement decision-making, unresolved change orders, the financial struggle of the owners, government intervention, miscommunication, sluggish contractor's response to requests, limited contractor staff, owners' inattention and change of contractor key individuals at critical times are the significant challenges and pitfalls that arise within project closeout phase. Notably, the project closeout should be planned and prepared by all stakeholders. Inefficient project closeout often leads to significant delays, cost overruns, compromise completion, quality and success.

In addition, many megaproject closeouts do not adequately address, emphasize, save and transfer the knowledge and learning obtained or do not provide effective methodologies to capture that value to be used in future megaprojects. This is important for coping with similar issues to achieve enhanced success in future projects.

4. Quality-driven megaproject management systems

Based on the review and discussion provided in this work, we stimulate the perspective of highlighting the importance of quality for megaproject management systems. Quality is the vital pillar that affects the entire system. Any category or element within the megaproject context is related to quality. The decision-making process is the main foundation of the megaproject should focus primarily on achieving high quality. Quality is essential to achieve expected results assured by quality assurance, control and management system. Quality assurance is the planned and systematic actions necessary to ensure that a product or service satisfies requirements.

In contrast, quality control is required to verify that a product or service meets the requirement. A further quality-driven management system is necessary to provide enhanced industrial capabilities. The academic literature indicates many complications in which the decision-making has difficulties beyond the project management's schedule–cost–quality scope criteria. All aspects of megaprojects' efficiency and performance are a consequence of quality. Recently, companies have started to focus on quality by creating quality management systems, assurance and control. The current focus of the industrial PMS is on quality drivers because they affect every stage and feature of the project. Significantly, quality is associated not only with equipment or tools. Instead, it is embedded in all areas and phases of megaprojects and involves the people, resources, assets, software and management strategies. Figure 2 proposes a quality-driven improved megaproject iron triangle, whereby

quality is a central key aspect related to all other main drivers of megaproject management: schedule, cost and scope (Dhillon, 2018).

In our perspective, quality is the central pillar that affects the entire PMS applied to every megaproject product, service, task, action or decision. Any aspect, category or element within the megaproject context is related to quality. The entire decision-making process should focus primarily on achieving high quality. It may directly or indirectly handle challenges, mitigate issues and failures, leverage success factors and adequately incorporate lessons learned into developing and implementing enhanced megaproject management systems. Therefore, increasing focus on quality PMS aspects is a key recommendation of this paper.

5. Conclusions

The findings from this article contribute to the literature on megaproject management systems with a comprehensive overview that provides helpful guidance for industrial applications and future research. Based on the conducted analysis, the literature on megaproject management requires further research to understand better the gaps, factors of failure and success, challenges and risks associated with the project performance, and which affect the industrial practices over the entire project lifecycle.

The main challenges faced by industrial megaprojects are the process complexities, dynamic environment and management of people and resources. They include the need for more efficient management capabilities, strategies to handle uncertainty, and reliable methodologies and tools. Such challenges lead to multiple issues and failures in industrial megaprojects, often derived from poor estimations, biased forecasts, lack of information, poor stakeholder management, inadequate structure and governance, lack of teamwork and communication, safety, health, environmental concerns and political and social conflicts. Conversely, effective use of a proper management system leads to successful megaprojects. The most critical success drivers are associated with using efficient project management capabilities, understanding and considering known or expected challenges and issues, employment of novel and efficient technologies, strategies and methodologies, incorporation of previous lessons learned, stakeholder commitment and alignment, continuous updating of planning/scheduling over the project lifetime, performance measurement tools and constant feedback, use of KPIs, and intense focus on project quality and safety. Megaprojects are rich
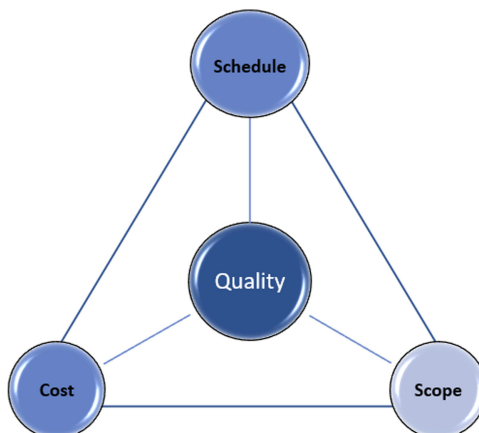
Source(s): Adapted from Dhillon (2018)

environments full of knowledge. The literature reports multiple lessons learned to identify the primary factors and elements associated with risks, challenges, issues, failures and successes, the importance of qualified personnel, organizational behavior, structure, governance, risk management and mitigation strategies.

The challenges, issues, successes and lessons learned are closely related to the overall quality of the megaproject management system. Quality is the degree to which a set of inherent characteristics fulfills the specified requirement for a product fit for purpose. Implementing quality criteria in megaprojects is essential to (1) improve employee safety and environmental protection; (2) deliver and sustain premier performance; (3) assure business continuity in the face of adverse situations (accident/downtime or service disruptions); (4) reduce product waste and inefficient use of the supply chain; (5) support business excellence and continuous improvement; (6) attain consistent processes and results; (7) prevent and manage operational risks; (8) satisfy customers and stakeholders. In addition, it is essential to emphasize the topic of lessons learned toward an improved, safer, efficient and higher-quality megaproject environment by continuously enhancing the current organizational and personal capabilities. Industrial management practices often do not incorporate lessons learned into their systems. Lessons learned are fundamental for people's development and involve all quality aspects, including cost, schedule and SHE.

This paper combines the various components of PMS available in the literature as it is used in managing megaprojects in industrial settings. It also provides a discussion on the most impactful gaps (between literature and industry) and improvements required in future megaprojects over several categories that are greatly important in megaproject management systems, namely, project planning and control, conceptualization and execution strategies, organizational structure and project governance, safety, health and environment, cost and schedule, risks analysis and management, procurement process, stakeholder alignment, engagement and satisfaction, and project closeout.

Project management is a vast subject, and this paper focuses on addressing multiple project management elements currently used in ongoing industrial megaprojects. We believe this study contributes to the literature on megaproject management systems in providing helpful guidance for future industrial megaprojects. Current industrial gaps and improvements required are highlighted in several management areas that can enormously benefit from future research on the topic.

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