



Review

What is wrong with the front-end of infrastructure megaprojects and how to fix it: A systematic literature review

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ABSTRACT

The Front-End process plays an essential role in deriving infrastructure megaprojects' performance. However, Front-End issues often negatively impact the process, hindering the value of infrastructure for society. This paper aims to systemise knowledge and understanding of the Front-End of infrastructure megaprojects, the main Front-End issues, and remedies for managing them. The paper leverages a Systematic Literature Review to address four research questions: What definition can appropriately describe the Front-End of infrastructure megaprojects? What are the issues at the Front-End of infrastructure megaprojects? What are the remedies for managing the issues at the Front-End of infrastructure megaprojects? What are the connections between Front-End issues and the remedies for managing them? Following thematic analysis, iterative coding and group discussions, the paper develops a definition for the Front-End of infrastructure megaprojects based on five characteristics, identifies 44 Front-End issues, and connects these issues to six remedies through 17 links.

1. Introduction

Megaprojects are “large-scale, complex ventures that typically cost a billion US\$ or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people” (Flyvbjerg, 2017, p3). Infrastructure is a general term for a basic set of fundamental facilities and systems (related to water, energy, transport etc.), that support the economic and social development of a certain territory (Smallwood, 2020; Bingham and Gibson, 2017; Williams et al., 2012; Klakegg, 2009). Not all megaprojects are infrastructure projects (e.g., developing a new vaccine), and, likewise, not all infrastructure projects are megaprojects (e.g., a small bridge). In this paper, we define an infrastructure megaproject as a ‘large-scale, complex, and one-off infrastructure project with a total capital cost beyond a billion US\$.’ According to *Global Infrastructure Outlook*, by 2040, the infrastructure sector will globally attract investments of 80 trillion dollars (*Global Infrastructure Outlook*). Significant investment in infrastructure megaprojects mandates high stakeholder engagement due to substantial socio-economic impact that lasts for an extended period (Sainati et al., 2017). This unprecedented effort is an essential part of government development plans, which will shape the future of societies for decades.

The Front-End has a significant role in shaping an infrastructure megaproject concept (Williams and Samset, 2010) and performance (Morris, 2013a). Poor front-end outcomes is one of the leading causes of inferior infrastructure megaprojects performance (Denicol et al., 2020). The reasons that contribute to generating poor front-end outcomes are widely discussed in the literature. In this study, front-end *issues* refer to those reasons, and *remedies* are the corrective actions for *managing* the front-end *issues*. By *managing*, we mean the ways that project managers can address, encounter, and hamper the issues. Also, front-end *outcomes* refer to the output of the managerial activities such as risk management, value management, and stakeholder management etc., within the front-end process.

Following a Systematic Literature Review (SLR), this paper aims to systemise knowledge and understanding of the front-end of infrastructure megaprojects, the main front-end issues, and remedies for managing them. The paper focuses on the front-end of infrastructure megaprojects since it is complicated (Williams and Samset, 2010), lengthy (Meier, 2008), involves many uncertainties and trade-offs (Gil et al., 2015; Giezen et al., 2015) and plays a significant role in projects performance (Klakegg, 2009). Furthermore, identifying front-end issues and using remedies for managing them creates the basis for preventing the issues in future projects and increases the potential to enhance

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infrastructure megaprojects performance (Sainati et al., 2017; Williams and Samset, 2010). Consequently, this generates massive rewards for project companies, governments and societies (Brookes and Locatelli, 2015; Williams et al., 2019).

Williams et al. (2019) provide a comprehensive SLR on the front-end. They investigate the front-end as a generic process for all project categories and discuss front-end importance, nature, its different elements, and roles and responsibilities during the front-end. They articulate front-end activities and explain how these activities function together. Building on Williams et al. (2019), our paper has two fundamental differences. First, our paper only focuses on the front-end of infrastructure megaprojects. Second, we investigate the issues at the front-end process and present the remedies for managing them. We consider both public and private infrastructure megaprojects. In particular, our paper addresses the following research questions:

- 1 What definition can appropriately describe the Front-End of infrastructure megaprojects?

The literature is ambiguous about front-end, especially when it comes to infrastructure megaprojects. Considering that front-end literature is dispersed across several domains (new product development, innovation management, IT, etc.), it is essential to precisely define what constitutes front-end in the infrastructure megaproject domain.

- 2 What are the issues at the Front-End of infrastructure megaprojects?

Precisely implemented front-end can enhance the infrastructure megaproject performance; however, front-end is often associated with issues (Williams and Samset, 2010). Literature about front-end issues is dispersed, and by this research question, we intend to collect all the front-end issues and deliver a comprehensive list of them.

- 3 What are the remedies for managing the issues at the Front-End of infrastructure megaprojects?

Academics and project managers developed remedies for managing front-end issues, such as using lessons learned (Miller and Hobbs, 2005) and involving external stakeholders' views in decision-making (Williams and Samset, 2010; Samset and Volden, 2016). This research question systematically collects these remedies and clarifies how they are linked to the issues in a broad perspective.

- 4 What are the connections between Front-End issues and remedies?

Following research questions 2 and 3, this research question demonstrates which specific remedies are more appropriate to manage a particular issue (or a group of issues). This research question also shows the key remedies for front-end issues and emphasises the gaps between issues and remedies requiring more attention.

Infrastructure megaprojects as the change agents (Miller and Hobbs, 2005) engage policymakers, project managers and society. Front-end has a pivotal role in linking the abovementioned stakeholders (Aaltonen et al., 2016). The front-end enables the stakeholders to work together at the infrastructure megaprojects initial stages when there is considerable space for changing the project concept, creating value, managing the risks and using the opportunities (Williams et al., 2019; Merrow, 2011; Fuentes et al., 2019). In this process, policymakers and project managers have the leadership role (Edkins et al., 2013), and society pays the costs and bears the consequences (DiMaddaloni and Davis, 2018). Therefore, this paper's contributions and recommendations go beyond the project management academics and include policymakers, project managers, and society, helping them get better results from infrastructure megaprojects.

The rest of the paper is structured as follows. Following the introduction, Section 2 explains the methodology of SLR. Section 3 describes

the SLR results associated with the research questions 1 to 3, respectively. Section 4 shows the connection between front-end issues (research question 2) and remedies for managing them (research question 3), section 5 presents the implications for society, policymakers and other relevant stakeholders. Finally, section 6 presents the key conclusions.

2. Method

We employed a Systematic Literature Review (SLR) consisting of three stages: planning, conducting the review, and reporting the findings (Tranfield et al., 2003; DiMaddaloni and Davis, 2017).

2.1. Planning stage

The planning stage's goal is to develop a protocol for searching relevant data along with inclusion and exclusion criteria (DiMaddaloni and Davis, 2017). Brainstorming sessions, review of the literature and group discussions led us to 'Front End,' 'Megaproject,' and 'Infrastructure' as three main keywords and developed the following list:

- Front End: "Front End," "Front-End Loading," "Front-End Engineering and Design," "Front-End Planning," "Pre-Project Planning," "Exploratory Phase," "Conceptual Phase," "Early Stage," "Appraisal Phase," "Project Governance," "Project Strategy," "Pre-Contract Phase," "Project Definition Phase," "Preliminary Stage," "Initiative Stage," "Seminal Stage," "Ex ante Appraisal," "Acquisition Stage," "Feasibility Study," "Planning."
- Megaproject: "Megaproject," "Major Project," "Capital Project," "Large Project," "Large Construction Project," "Project," "Large Engineering Projects," "Complex Project."
- Infrastructure: "Infrastructure," "Public Project."

2.2. Conducting the review process

We used "Scopus" as a searching database for its academic merits and the possibility to customise the search. Therefore, we combined the abovementioned keywords to make the following searching string:

"Front-End" or "Front-End Loading" or "Front-End Engineering and Design" or "Front-End Planning" or "Pre Project Planning" or "Exploratory Phase" or "Conceptual Phase" or "Early Stage" or "Appraisal Phase" or "Project Governance" or "Project Strategy" or "Pre Contract Phase" or "Project Definition Phase" or "Preliminary Stage" or "Initiative Stage" or "Seminal Stage" or Ex-ante Appraisal" or "Acquisition Stage" or "Feasibility Study" or "Planning" AND "Megaproject" or "Major Project" or "Capital Project" or "Large Project" or "Large Construction Project" or "Project" or "Complex Project" or "Large Engineering Projects" AND "Infrastructure" or "Public Project."

The result of this string was 4195 journal articles. We limited the results to English and journal articles and restricted the field of study to *Business, Management and Accounting, Engineering, Decision Science, Economics Econometrics and Finance, Energy, Social Sciences, Multidisciplinary and Undefined*. We only considered articles that were published after 2000. Following the limitations, we retrieved 1672 articles.

We evaluated the articles following this protocol:

1. Title, keywords and abstract. Consistent with (DiMaddaloni and Davis, 2017), in the first step we read the title, keywords, and abstract of each article. After this step, we excluded 962 articles, and 710 remained for analysis.
2. Introduction and conclusion. In this step, we reviewed the introduction and conclusion of the 710 remaining articles in detail and excluded 440 of them; consequently, 270 articles remained for the next step.

3. We read the remaining articles (by scanning the context, checking the tables, reading the headings and the first sentence of each paragraph, etc.), and 93 moved to the analysis step.
4. After initial analysis from 93 articles, only 64 were relevant to the research objectives, which we used to derive findings.
5. In addition to the articles, we used four essential references: three relevant books from leading authors in the field (references (Morris, 2013b), (Merrow, 2011) and (Miller and Lessard, 2001)) and a relevant government document (Treasury, 2018).

Findings are the output of iterative group discussions on the thematic analysis results. The leading author read all the articles (64 articles) and started a first thematic analysis following (Vaismoradi et al., 2013) using Nvivo to code the data as presented in (Saldana, 2013). We organised the themes in the group discussions with the co-authors and refined the codes. The lead author reviewed the articles again to avoid overlooking essential data and to check if the themes were inclusive enough to cover all the codes. We continued the iteration until marginal improvements were negligible and repeated a similar process to answer research questions one to three. We identified five critical characteristics for the front-end and proposed them in a new definition; we found 44 issues and clustered them into six themes, and we derived six remedies with 17 links to the issues. For the fourth research question we adopted the binary reductionist approach (i.e., yes/no) and connected issues to remedies through the abovementioned 17 links. Table 1 shows the result of thematic analysis and the themes related to them. We adopted this approach from the protocol presented in (Denicol et al., 2020).

3. Findings

In this section, we answer the first three research questions.

Table 1
The result of thematic analysis; themes and categories.

Category	Theme	Concept	Category	Theme	Concept
What are the front-end issues?	Front-end project managers	Skills and competencies	What are the remedies for managing the front-end issues?	Using more qualitative data and less detailed quantitative analysis for decision-making	Evaluating alternative concepts fast and flexible without the need for detailed information
		Staff working behaviour			Social value assessment and value creation in shaping the concept, all aspects of infrastructure benefits are not quantifiable
					Increasing half-life of the front-end outcomes
	Politicians and decision-makers	Political bias		Involving external stakeholders' views in decision-making	Discloses the core expectations of the external stakeholders
		Lack of evidence-based decision-making			Helps to align project goals and objectives with stakeholders' goals and objectives and prevents future conflicts
					Prepares appropriate ground for decision-making
	Front-end process and outcomes	Conducting the process		Generating reliable estimations and controlling the quality of the Results	Prevents high cost-overruns during and after front-end
		Generating the outcomes			Decrease the chance of manipulating project decisions
	Human factors	Cognitive biases		Applying lesson learned	Incentivise good and penalise the lousy practice
		Human restrictions			Use Lessons for training purposes to increase the effectiveness of the practices
Project context	Changes in the project context	Increasing the skills and competencies of the front-end actors	Creating a database for better estimations and evaluating alternative concepts		
			Increasing the managerial competency of project managers		
The early phase of projects	Characteristics of the projects' context	Promoting transparency, accountability	Increasing the individual competency of project managers		
	Nature of megaprojects		Promoting transparency		
			Promoting accountability		
			Defining procedures, roles, and responsibilities		
			Managing a project for its context		

3.1. What definition can appropriately describe the front-end of infrastructure megaprojects?

Front-end has various definitions; we deemed 12 relevant to the scope of the paper (Table 2). Although the definitions are well developed to serve the specific goals of their respective documents, no single definition combines key characteristics of infrastructure megaprojects' front-end.

A fundamental dilemma in defining front-end is considering front-end as a project phase or if a project starts when front-end finishes (Williams et al., 2019). The rationale behind considering the front-end as a project phase is that implementing the front-end requires a great deal of managerial knowledge, expertise, and effort (DiMaddaloni and Davis, 2018); therefore, the front-end is within the project management scope (Morris, 2016). Considering the front-end as a project phase is consistent with the UK Infrastructure and Projects Authority approach to the Five Case Model (Project Business Case) for infrastructure project initiation. In this approach, project managers should actively engage with front-end decision-making (Morris, 2016).

The other school of thought states that because the project only exists conceptually at the front-end stage (Samset and Volden, 2017), the front-end is not a project phase. Not considering the front-end as a project phase is consistent with the Norway Quality Assurance (QA) scheme (Morris, 2013a). The rationale for excluding the front-end from the project is that implementing the front-end does not guarantee project execution (Edkins et al., 2013). Excluding the front-end from the project defines but does not limit front-end project managers' positions at the project level in which project managers have an advisory role during front-end (Williams et al., 2019). Compared to the UK, in Norway, politicians have slightly less reliance on managerial advice in deciding to implement a project (Samset and Volden, 2017).

Front-end inclusion or exclusion from a project definition impacts

Table 2
Front-End definitions and highlighted Front-End characteristics in each definition.

Definition	Characteristics
“Project definition [phase] is regarded as the phase of project development where exploration of alternatives creates an innovative problem and solution definitions that allow maximum customer value generation to be developed.” (Whelton et al., 2002, p197)	Defines a project concept, develops alternatives, innovative, create value, exploratory process,
“Front-end planning is the essential process of developing sufficient strategic information with which the owners can address risks and make decisions to commit resources to maximise the potential for a successful project.” (Bingham and Gibson, 2017, p1)	An essential process for defining a project’s strategy, addresses risk, involve decision-making, ends up in final go or no-go decision for a project, uncertain, helps the project owner, maximise the chance of project success,
“The stage when value propositions are formulated is rich in interactions, especially for large complex megaprojects.” (Smyth et al., 2018, p174)	Defines the value for a project, has high stakeholder interaction
“The phase of planning, before the point when decision-makers finally commit to the financing of a project, is often referred to in the literature as the front-end phase of a project.” (Welde and Odeck, 2017, p615)	Plans a project, ends up in final go or no-go decision for a project, decision-makers play a crucial role, uncertain
“Activities and deliverables that occur prior the program entering the execution phase.” (Meier, 2008, p59)	Activity for planning a project, conduct before execution
“Where requirements are elicited and then accepted by the subsequent sanction stage.” (Morris, 2013b, p164)	Defines a project’s requirements
“Initial construction planning which takes place during the preconstruction phase of a project.” (Johansen and Wilson, 2006, p1305)	Focuses on the execution phase, plans a project’s construction
“The period prior to sanction of the project front-end loading.” (Merrow, 2011, p24)	It takes place before starting a project (execution)
“The period up until the permanent organisation tasks the person or organisation who is to be responsible for delivering the project.” (Williams et al., 2019, p73)	Done by a permanent organisation, ends up with go or no-go decision for a project, uncertain
“The early stages of development leading up to the appraisal of the project.” (Klakegg, 2009, p500)	Develops project appraisal, takes place early in the project
“The front-end phase is the stage when the project only exists conceptually before being operationalised.” (Samset and Volden, 2017, p93)	Defines a project’s concept, takes place before the execution, ambiguous
“Front-end is a general term used for the somewhat unstructured period between the proverbial a blank sheet of paper, up to the project proposal.” (Kock et al., 2016, p116)	Unstructured, Uncertain, defines a project concept

project managers’ roles and responsibilities, the accountability of the decisions (Morris, 2013a; Williams et al., 2019), and, consequently, the competencies required for the project managers’ role and responsibilities in the front-end process (Edkins et al., 2013). Both approaches agree that project managers require knowledge and expertise beyond the traditional project management framework to address front-end challenges adequately (Morris, 2013a, 2016; Williams et al., 2019).

For this study, consistent with the UK approach, we consider the front-end as a project phase. Also, our SLR focuses on the front-end’s institutional and strategic aspects. This approach is aligned with other researchers, more notably (Morris, 2013a, 2016). Table 2 shows the front-end definitions (associated with the aim of this paper) and the characteristics each definition uses to define the front-end of infrastructure megaprojects.

Five essential characteristics emerged from analysing front-end definitions: (1) Exploratory nature, (2) Generating managerial information, (3) Shaping a feasible concept, (4) Terminating with a decision, and (5) Uncertainty.

First, infrastructure megaprojects’ front-end is an exploratory process since it looks for different alternatives (Samset et al., 2013) to find the most feasible concept for the project (Samset et al., 2017). Exploring project alternatives is often disregarded from the infrastructure megaprojects front-end process (Williams and Samset, 2010; Williams et al., 2019), which is a critical reason for the failure in their performance (Meier, 2008).

Second, the front-end generates managerial information for decision-making and shaping an infrastructure megaproject concept (Edkins et al., 2013). This information results from several management activities, including cost estimation, risk identification, and value formulation (Elzomor et al., 2018). Front-end information comes from various sources and in different details (Morris and Gherardi, 2011) based on factors such as organisation maturity (Williams et al., 2019; Edkins et al., 2013), project type (Williams and Samset, 2010; Gil et al., 2015) and front-end procedures in a respective country (Samset and Volden, 2017).

Third, the front-end process shapes a feasible concept for an infrastructure megaproject based on its outcomes (Williams and Samset, 2010). The feasible concept should be shaped in an opportunity space (Samset et al., 2013), considering the different stakeholders’ needs, goals, and requirements (Samset et al., 2013, 2017). The feasible concept should balance society and stakeholders’ various and conflicting interests (Aaltonen et al., 2016) and be politically practicable (Samset et al., 2017).

Fourth, implementing the front-end does not guarantee project execution, and it is a challenging aspect of the front-end of infrastructure megaprojects (Treasury, 2018). Front-end outcomes should lead to the decision to continue (“Go”) or stop (“No Go”) a project. Due to an infrastructure megaprojects’ essential impact on society, this decision is usually affected by political interests, influential government groups and lobbyists (Klakegg, 2009; Mottee et al., 2020).

Lastly, the uncertainty inherent to an infrastructure megaproject’s early phase (Kloppenborg and Tesch, 2009) plays an essential role in front-end decisions and has positive (i.e., opportunity) and negative (i.e., risk) aspects. One goal of the front-end process is to reduce projects’ uncertainty (Elzomor et al., 2018) and improve the predictability of an infrastructure megaproject performance (Welde and Odeck, 2017). Often, front-end decision-makers focus on reducing risk without paying enough attention to take advantage of opportunities (Giezen et al., 2015).

According to the abovementioned characteristics, we define the front-end as:

‘An exploratory process for generating necessary information to shape a feasible concept for an infrastructure megaproject, assess the concepts’ uncertainties and make the final go/no-go decision’.

Although the definition specifies the front-end of infrastructure megaprojects, it also refers to general aspects of front-end due to the typical characteristics of a project’s early stages and the front-end process’s function in different project categories.

3.2. What are the issues at the front-end of infrastructure megaprojects?

We retrieved 44 front-end issues from 12 papers (Klakegg, 2009; Williams and Samset, 2010; Flyvbjerg, 2007, 2013; Volden, 2019a; Meier, 2008; Samset and Volden, 2016; Aaltonen et al., 2016; Welde and Odeck, 2017; Samset et al., 2013; Cantarelli et al., 2010; Andersen et al., 2016) and clustered them based on their context into six themes, namely: (1) Front-end project managers, (2) Politicians and decision-makers, (3) Front-end process and outcomes, (4) Human factors, (5) Project context, (6) The early phase of infrastructure

megaprojects. From theme one to five, we divided each theme's issues into two groups according to their impact area and similarities. Theme six remained in one group since issues have no distinct differences. Table 3 provides an overview, and then each theme is explained in the following paragraphs.

3.2.1. Front-end project managers

This theme refers to the issues caused by front-end staff and managers and consists of two groups: (1) Skills and competencies and (2) Staff working behaviour.

Table 3
A comprehensive list of Front-End Issues.

Themes	Groups	Issues
Front-end project managers	Skills and Competencies Staff working behaviour	<ol style="list-style-type: none"> 1. Lack of skills and competency in project managers for managing front-end (Williams and Samset, 2010; Meier, 2008) 2. Difficulty in acquiring the required skills and competencies (Meier, 2008) 3. Unclear roles and responsibilities in the front-end process (Meier, 2008; Welde and Odeck, 2017)
Politicians and decision makers	Political bias Lack of evidence-based decision making	<ol style="list-style-type: none"> 1. Reluctance to say no to the higher managers (Flyvbjerg, 2013) 2. Too much confidence in front-end outcomes (Klakegg, 2009) 3. No effort to find alternative concepts (Williams and Samset, 2010; Samset and Volden, 2016; Samset et al., 2013) 4. Perverse incentives (Flyvbjerg, 2013; Volden, 2019a)
Front-End process and outcomes	Conducting the Process Generating the Outcomes	<ol style="list-style-type: none"> 1. Principal agent issue at front-end (Volden, 2019a) 2. Putting political priorities first (Klakegg, 2009; Williams and Samset, 2010; Aaltonen et al., 2016; Volden, 2019a) 3. Putting too much pressure on a particular concept (Meier, 2008; Samset and Volden, 2016; Volden, 2019a) 4. Decision-making based on short term interests (Samset and Volden, 2016) 5. Politicians do not represent society's expectations (Williams and Samset, 2010)
Human factors	Cognitive biases Human restrictions	<ol style="list-style-type: none"> 1. Unclear decision-making process (Williams and Samset, 2010; Samset and Volden, 2016) 2. Lack of attention to the project context (Williams and Samset, 2010) 3. Lack of competency in using analytical information (Klakegg, 2009) 4. Reluctance to use the analysts' advice by politicians (Samset and Volden, 2016; Gibson et al., 2010) 5. Overcommitting a project concept (Samset and Volden, 2016; Aaltonen et al., 2016; Cantarelli et al., 2010) 6. Lock-in (Cantarelli et al., 2010) 7. Path dependency (Williams and Samset, 2010) 8. Not using the opportunity space for defining the project concept (Samset et al., 2013)
Project context	Changes in the project context Characteristics of the project's context	<ol style="list-style-type: none"> 1. Front-end sunk cost (Cantarelli et al., 2010; Flyvbjerg, 2007) • Long process (Welde and Odeck, 2017) • Costly process (Flyvbjerg, 2007) 2. High staff turnover (Meier, 2008) 3. The ambiguity of the process (Williams and Samset, 2010) 1. Generating unreliable estimations (Samset and Volden, 2016) 2. Inadequate external evaluation of estimations (Flyvbjerg, 2013) 3. Too much reliance on detailed quantitative data (Williams and Samset, 2010; Samset and Volden, 2016; Welde and Odeck, 2017) 4. Too little evaluation of the people's expectations (Klakegg, 2009)
The early phase of infrastructure megaprojects	Nature of Megaprojects	<ol style="list-style-type: none"> 1. Optimism bias and the planning fallacy • Underestimating technical issues related to the project implementation (Meier, 2008) • Underestimating costs, risks, etc. Overestimating the benefits (Williams and Samset, 2010; Flyvbjerg, 2013; Andersen et al., 2016) 2. Postponing solving conflicts (Klakegg, 2009) 3. Groupthink (Williams and Samset, 2010) 4. Bounded awareness/rationality (Williams and Samset, 2010; Cantarelli et al., 2010) 1. Inability to value realisation for assets' lifecycle at early stages (Samset and Volden, 2016) 2. Inability to find the early warning signs (Williams et al., 2012) 3. Inability to align the long term strategies with project objectives (Williams et al., 2012; Williams and Samset, 2010; Samset and Volden, 2016; Andersen et al., 2016)
		<ol style="list-style-type: none"> 1. Changes in the political group in power over time (Samset and Volden, 2016) 2. Changes in society's needs and priorities (Samset and Volden, 2016) 1. Corrupt environment (Flyvbjerg, 2013) • Misrepresentation of cost and revenue (Flyvbjerg, 2013) 2. Impact of the project environment on the decision-makers (Williams et al., 2012; Williams and Samset, 2010) • Organisational culture 1. Unclear project goals and objectives (Klakegg, 2009; Williams and Samset, 2010; Meier, 2008) 2. High level of complexity (Williams and Samset, 2010) 3. Stakeholder dynamics (Samset and Volden, 2016; Andersen et al., 2016) 4. Conflicting goals and objectives between stakeholders (Klakegg, 2009) 5. High level of uncertainty (Williams and Samset, 2010; Meier, 2008; Samset and Volden, 2016) 6. Lack of information for decision-making (Williams and Samset, 2010; Samset and Volden, 2016; Andersen et al., 2016)

Skills and competencies. The key issue in this group is the lack of skills and competencies of project managers managing the front-end (Klakegg, 2009; Miller and Lessard, 2001; Morris, 2016; Samset and Volden, 2017). Due to the front-end's strategic nature (Edkins et al., 2013), the traditional project management framework does not adequately cover all the required expertise for managing the front-end (Morris, 2013a, 2016; Edkins et al., 2013; Morris and Geraldi, 2011). Project managers with relevant skills and competencies are scarce (Meier, 2008; Edkins et al., 2013), and companies should compete over hiring them (Edkins et al., 2013). Moreover, many skilled staff are reluctant to join projects at the front-end since the execution is not guaranteed, and the competitive job market offers them better opportunities (Edkins et al., 2013).

Staff working behaviour. The key issue here is 'perverse incentives.' Cantarelli et al. (2010) highlight two approaches to the front-end, namely "formal" and "real." Formal front-end is when the decision-makers determine the project concept long before the front-end finishes, and front-end is only a formal process to justify a pre-determined concept. Meanwhile, a real front-end's goal is finding a feasible alternative among different possibilities (Cantarelli et al., 2010).

Perverse incentives (Volden, 2019a) is a consequence of a formal front-end (Samset and Volden, 2016, 2017) and refers to a situation in which the front-end team does not find incentives in providing evidence for stopping the project (Volden, 2019a). Reluctance to disagree with political decisions happens when there are no incentives in halting the project causes (Meier, 2008; Williams et al., 2019; Flyvbjerg, 2013; George et al., 2008). In this atmosphere, the front-end team becomes overconfident in the project concept (Samset et al., 2013) and loses motivation for finding better alternatives (Samset and Volden, 2016; Cantarelli et al., 2010).

3.2.2. Politicians and decision-makers

Issues in this theme refer to the role of decision-makers at government and institutional levels. The category consists of two groups: (1) Political biases and (2) Lack of evidence-based decision-making.

Political biases. Volden (2019a), Samset et al. (2013) and Samset and Christensen (2017) mention that, often, front-end decisions are political, and in many instances, politicians do not represent and sometimes ignore society's expectations (Klakegg, 2009; Edkins et al., 2013). Politicians tend to advocate an infrastructure megaproject concept that serves their parties' interests without considering the project's long term performance and social impacts (Klakegg, 2009; Volden, 2019a). This results in putting too much pressure on executing a particular concept through the formal front-end (Meier, 2008; Samset and Volden, 2016; Hetemi et al., 2020), and therefore the opportunity space is not capitalised on (Samset et al., 2013).

In some cases, the pressure on starting the project even before finishing the front-end leaves the choice of concept for negotiation and compromise between interest groups (Hetemi et al., 2020). Hetemi et al. (2020) mention that politicians mostly care about the publicity of cutting the red ribbons without considering how they are going to finish the project. Meier (2008) highlights that rushing into the execution for political reasons causes over-optimism and "bounded awareness," which "prevents [politicians] from seeing, seeking, using, or sharing highly relevant information during the decision-making process." (Meier, 2008, p61).

Lack of evidence-based decision-making. This group refers to the situation in which decision-makers are unable to use the analytical results regarding defining project goals and objectives due to a lack of analytical knowledge (Klakegg, 2009) or avoid considering them in decision-making (Hetemi et al., 2020) as a consequence of personal or political reasons (Klakegg, 2009). The key issue here is overcommitting a specific concept, which means the inability to withdraw from a project (Cantarelli et al., 2010) when no evidence shows the project will have satisfactory performance (Meier, 2008; Johansen and Wilson, 2006; Flyvbjerg, 2014). Cantarelli et al. (2010) mention that overcommitment

per se is not harmful in all situations, but when it leads decision-makers to lock-in, it causes ineffective decisions that lead to "escalating commitment of decision-makers to an ineffective course of action" (Cantarelli et al., 2010, p792). Hetemi et al. (2020) criticise the reductionist view in defining lock-in, which underestimates complex nature at the front-end of infrastructure megaprojects. Hetemi et al. (2020) mention that lock-in is a contextual phenomenon, and it happens due to long-term organisational mechanisms.

Another issue in front-end decision-making is path dependency (Samset et al., 2013; Cantarelli et al., 2010), which refers to decision-makers tendency to make decisions based on their previous experience without considering the new circumstances (Giezen et al., 2015; Samset et al., 2013). Decision-makers affected by path dependency follow what they have done in past projects, paying limited attention to the alternatives (Samset et al., 2013). Consequently, they cannot use the opportunity space to the optimum level (Samset et al., 2013, 2017) since they fail to find different alternatives, including the Zero option (Samset et al., 2013) (i.e., "business as usual") as the most profitable alternative (Samset and Christensen, 2017). Zero option refers, for instance, to upgrading an existing asset instead of executing a new one (Samset et al., 2013).

Unclear decision-making procedures is another issue in this theme. Williams and Samset (2010) note that front-end decision-makers, in many instances, do not follow the logical process, and Samset and Volden (2016) describe it as "unstructured and affected by chance." (p302). One explanation for this issue is decision-makers tendency to manipulate project decisions (Flyvbjerg, 2007) to support their favourite project concept (Welde and Odeck, 2017). Another reason is that decision-makers merely lack the skills and competencies to comprehend the analytical information (Klakegg, 2009).

3.2.3. Front-end process and outcomes

The theme refers to issues associated with implementing the front-end and consists of two groups: (1) Issues in conducting the front-end process and (2) Issues in generating front-end outcomes.

Issues in conducting the front-end process. This group's critical issue is high 'sunk cost' due to the time and cost associated with the long front-end process of infrastructure megaprojects (Welde and Odeck, 2017; Johansen and Wilson, 2006). Front-end cost for an infrastructure megaproject accounts for up to 35% of the project costs (Cantarelli et al., 2010; Hwang and Ho, 2012). After paying the front-end cost, decision-makers are reluctant to end up with no project (Miller and Lessard, 2001); consequently, they are unlikely to withdraw from the project.

The front-end process for infrastructure megaprojects often goes beyond one parliamentary period (four to five years) (Samset and Volden, 2017); this inevitably entails changes in the project context and the political party in power (Welde and Odeck, 2017; Cantarelli et al., 2010). Changes in project context may change society's needs and problems (Welde and Odeck, 2017). When it adds to political changes, they may shift the strategic priorities and question the demand for the project (Mottee et al., 2020). Political changes also have severe consequences for getting required permissions later in execution (such as making an access road to the site) (Merrow, 2011). Furthermore, the long front-end is associated with staff turnover, which causes a lack of expertise, inconsistency in management and accountability problems (Meier, 2008). Staff turnover creates a negative loop since the new manager needs to review the documents again (Meier, 2008).

Issues in generating front-end outcomes. The key issue in this group is over-reliance on detailed quantitative information (Williams and Samset, 2010; Welde and Odeck, 2017; Andersen et al., 2016). Front-end decisions for infrastructure megaprojects are conventionally based on detailed quantitative information (Samset and Volden, 2016). However, detailed quantitative information at the front-end is often unreliable (Williams and Samset, 2010; Samset and Volden, 2016; Welde and Odeck, 2017; Samset and Christensen, 2017) and expires quickly due to

changes in the project context and the project concept (Williams and Samset, 2010; Samset and Christensen, 2017). Therefore, the information requires frequent adjustments during the front-end period to comply with the changes (Williams and Samset, 2010; Welde and Odeck, 2017). Adjusting the information frequently is impractical because it is costly, time-consuming (Samset et al., 2013) and vulnerable to new changes (Welde and Odeck, 2017). Often lobbyists use this unreliable information to justify their front-end decisions and obtain approval for their pet project (Samset and Volden, 2016; Welde and Odeck, 2017). Welde and Odeck (2017) highlight how relying on detailed quantitative cost and value estimations results in higher cost overrun at the front-end of infrastructure megaprojects compared to execution.

Inadequate evaluation of the external stakeholders' expectations (Klakegg, 2009) is a consequence of the formal front-end process (Samset and Volden, 2017; Cantarelli et al., 2010) and causes decision-making with the absence of diverse views (Smyth et al., 2018; Suprayoga et al., 2020). This leads the front-end team to shape a concept that does not meet the stakeholders' expectations (Klakegg, 2009) and causes future conflict (Aaltonen et al., 2016; Cuppen et al., 2016).

3.2.4. Human factors

This theme refers to issues associated with human capabilities. Two groups of human factors are involved in front-end issues: (1) Cognitive Biases and (2) Human restrictions.

Cognitive Biases. Optimism bias is the well-recognised cognitive bias described in infrastructure megaproject front-end literature (Williams and Samset, 2010; Flyvbjerg, 2013). Optimism bias causes overestimations of benefits and value and underestimations of costs (Flyvbjerg, 2013). The planning fallacy results from the optimism bias, which impacts the front-end of infrastructure megaproject decisions (Cantarelli et al., 2010).

The second cognitive bias is 'conflict avoidance,' which refers to postponing the conflicts instead of solving them (Klakegg, 2009). Klakegg (2009) mentions that unsolved problems tend to become more severe in later phases; in contrast, Giezen et al. (2015) consider unsolved conflicts as opportunities to increase the flexibility of the decisions facing future changes. "Groupthink" refers to "where the individuals within a group conform in their thinking with, what they think, is the group consensus" (Williams and Samset, 2010, p41). It is another cognitive bias at front-end decision-making resulting from ineffective communication amongst stakeholders (Williams and Samset, 2010).

Human restrictions. Issues in this group are associated with the front-end team's limited ability in predicting an infrastructure megaproject's future values, risks, etc., at the early stages of its lifecycle (Williams and Samset, 2010; Samset and Volden, 2016). An infrastructure megaproject's lifecycle spans decades, if not centuries, during which many changes occur in technological and socio-economic aspects of a society (Samset and Volden, 2016), and it is impossible to forecast them. Therefore, infrastructure megaprojects require more flexibility to accommodate the changes; but this is challenging, costly and involves trade-offs (Gil et al., 2015). Usually, the front-end team sticks to the firm options to avoid the consequent costs; this makes the project concept vulnerable to the changes (Gil et al., 2015).

3.2.5. Project context

Issues in this category are rooted in the project context and environment, divided into two groups: (1) Change in the project context and (2) Characteristics of the project context.

Change in the project context. An infrastructure megaproject's principal goal is to meet society's everchanging needs and problems (Williams and Samset, 2010; Samset and Volden, 2016; Samset et al., 2013). Political changes, along with social changes (Samset and Volden, 2017), cause difficulty in defining project goals and objectives and aligning them with society's needs and problems (Samset and Volden, 2016); this creates challenges for the front-end team to define an appropriate concept for the infrastructure megaprojects (Williams et al., 2012;

Williams and Samset, 2010; Edkins et al., 2013).

Characteristics of the project context. Corruption is the key issue in this theme (Locatelli et al., 2017). Locatelli et al. (2017) indicate that megaprojects are fertile grounds for developing corruption due to characteristics such as colossal investment, high complexity, and engaging with various stakeholders. Corruption is also discussed as a systematic misrepresentation of infrastructure megaproject value and benefits, affecting front-end decisions (Welde and Odeck, 2017; Flyvbjerg, 2013).

The key internal stakeholders' organisational culture is a vital element of the robust front-end process (Williams et al., 2012; Edkins et al., 2013; Shiferaw and Klakegg, 2012), since it shapes decision-makers mindsets and structures their practices (Williams et al., 2012; Edkins et al., 2013). Despite the benefits of a robust front-end process for generating appropriate outcomes (in mature organisations), it can be counterproductive and lead to path dependency (Samset et al., 2017).

3.2.6. The early phase of infrastructure megaprojects

This category includes issues associated with the nature of the early stage of shaping infrastructure megaprojects. Fundamental issues here are high uncertainty and complexity (Giezen et al., 2015; Aaltonen et al., 2016; Edkins et al., 2013). The front-end has the highest potential for reducing uncertainty and complexity by shrinking the number of alternatives (Samset and Volden, 2016; Samset et al., 2013, 2017), but often the focus is on deriving detailed information (Samset and Volden, 2016). Detailed information under uncertainty has little value for decision-making (Johansen and Wilson, 2006).

Uncertainty and complexity also cause difficulty shaping value at the front-end (Martinsuo et al., 2018) due to scarce relevant information. In this regard, a front-end team should only consider high-quality information (Samset and Volden, 2016). A common notion for reducing uncertainty at the front-end is defining clear goals and objectives for projects (Samset and Volden, 2016; Edkins et al., 2013). However, Giezen et al. (2015) mention that, to some extent, ambiguity in goals and objectives opens space for applying different views to decisions according to future changes.

Stakeholder dynamics at an infrastructure megaproject early phase cause changes in stakeholder expectations (Cuppen et al., 2016) and sometimes creates conflicts amongst interest groups (Aaltonen et al., 2016). Different stakeholders have various and sometimes conflicting perceptions about the value (Smyth et al., 2018); changing the stakeholder changes the perceived value and restricts the front-end staff in defining project goals and objectives (Martinsuo et al., 2018).

3.3. What are the remedies for managing the issues at the front-end of infrastructure megaprojects?

With a broad view towards front-end issues, we derive six remedies for managing the front-end issues, namely: (1) using more qualitative data and less detailed quantitative analysis for decision-making, (2) Involving external stakeholders' views in decision-making, (3) Generating reliable estimations and controlling the quality of the results, (4) Applying lessons learned, (5) Increasing the skills and competencies of front-end actors, and (6) Promoting transparency, accountability and defining clear roles and responsibilities in project governance.

3.3.1. Using more qualitative data and less detailed quantitative analysis for decision making

Using more qualitative data and less detailed quantitative analysis for decision-making at the front-end of infrastructure megaprojects enhances the accuracy of evaluating alternative concepts (Samset and Volden, 2016; Samset et al., 2013) and assessing social values (Williams and Samset, 2010; Samset and Volden, 2016; Mottee et al., 2020; Volden, 2018). As the result it facilitates front-end value creation (Mottee et al., 2020; Smyth et al., 2018; Volden, 2019b) and enhances the

front-end outcomes' half-life (Samset and Volden, 2016; Samset and Christensen, 2017; Volden, 2018).

Conventionally, front-end decisions are based on detailed quantitative information (Samset and Volden, 2016), for which deriving them requires time and cost. Decreasing the level of detail in quantitative analysis and using more qualitative data for decision-making at the front-end of infrastructure megaprojects allows for flexible (Williams and Samset, 2010; Volden, 2018) and fast (Samset and Volden, 2016; Volden, 2018) decision-making. Samset et al. (2013) mention that the front-end team's first objective should be shrinking project alternatives to more feasible concepts by eliminating unfeasible concepts based on simple analysis. For instance, a broad understanding of future uncertainties can lead to eliminating unfeasible concepts (Cascetta et al., 2015). The rapid assessment also prevents analysis paralysis (Williams and Samset, 2010) by increasing the front-end team's capability in dealing with an overwhelming amount of information.

Decision-making at the front-end of infrastructure megaprojects is often based on detailed quantitative information because it is easy to justify and compare (Welde and Odeck, 2017). Measuring infrastructure megaprojects' value with quantitative information causes incomplete value realisation (Volden, 2019b), whereas using qualitative data for assessing values (Volden, 2019b) and social values (Mottee et al., 2020) at the front-end enhances the potential for value creation (Volden, 2019b).

Using more qualitative data and less detailed quantitative analysis for front-end decision-making increases the half-life of the front-end outcomes (Mottee et al., 2020; Samset and Christensen, 2017). Moreover, qualitative data is valid for longer and is more reliable for forecasting future demand (Welde and Odeck, 2017). For instance, while estimating the precise amount of increase or decrease in the future need for a service might not be possible, establishing an upward or downward trend will be feasible and reliable (Samset and Volden, 2016).

Using more qualitative data and less detailed quantitative analysis for decision-making at the front-end of infrastructure megaprojects does not mean there is no need for detailed quantitative information. The obstacles in using more qualitative data and less detailed quantitative analysis are finding the appropriate level of analysis, aligning quantitative and qualitative data and finding a reasonable balance between the qualitative and quantitative data (Williams et al., 2012; Samset and Volden, 2016). The latter is highly relevant to engaging external stakeholders' views in decision-making, which is explained in the next section. For deriving adequate qualitative data, the front-end team should find appropriate and reliable data sources (Nik-Bakht and El-Diraby, 2020), and decision-makers should be able to use and comprehend them (Klakegg, 2009).

3.3.2. Involving external stakeholders' views in decision-making

Involving external stakeholders refers to using infrastructure megaprojects' external stakeholders' views and meeting their concerns in front-end decisions (Aaltonen et al., 2016). External stakeholders range from "local citizens, community groups, and environmentalists to those stakeholder groups who typically oppose the project and that need to be convinced of the project's worth" (Aaltonen et al., 2016, p17).

Involving external stakeholders' views in the front-end decisions allows for understanding their core expectations (Morris, 2016; Samset et al., 2017) and aligning the infrastructure megaprojects concept with their objectives to create social values. Appropriate external stakeholders involvement develops the sense of ownership and commitment amongst them (Aaltonen et al., 2016), and prevents future conflicts and leads to smooth project delivery (DiMaddaloni and Davis, 2018; Doloi, 2018). In this regard, the stakeholder management strategy at the front-end of infrastructure megaprojects should be open and flexible enough to engage external stakeholders' views in front-end decisions (Aaltonen et al., 2016; Doloi, 2018; Enserink, 2000; Hwang and Yang, 2014). To this end, project managers' experience and capability in identifying the stakeholders and creating a positive relationship with

them are essential (Yang, 2014).

Conventional methods for deriving external stakeholders' views include; "surveys, community meetings, and having active involvement from key stakeholders" (George et al., 2008, p73). Also, studies show the positive impact of online platforms in engaging external stakeholders' views in infrastructure megaprojects decisions and collaboration (Nik-Bakht and El-Diraby, 2020; Lorenz, 2011). However, a drawback of using these platforms is the complexity of analysing considerable data generated from the engagement (Nik-Bakht and El-Diraby, 2020; Lorenz, 2011).

There are obstacles in involving external stakeholders' views at the front-end of infrastructure megaprojects. For instance, Aaltonen et al. (2016) mention that external stakeholders might not be able to express their views to the required standard, and there is a need to interpret them when necessary. Additionally, DiMaddaloni and Davis (2018) state that external stakeholder engagement is usually a formal process and cannot appropriately contribute to the front-end decisions. To this end, organisational culture and the project context should be flexible enough to accept diversity in decision-making (Aaltonen et al., 2016).

3.3.3. Generating reliable estimations and controlling the quality of the results

Reliable estimations are those with minimum variation from the actual performance (Welde and Odeck, 2017). The front-end of infrastructure megaprojects includes several estimations such as cost, time, lifecycle, and benefits (Williams et al., 2019); these are the key decision-making elements (Edkins et al., 2013). Reliable estimations prepare a realistic ground for decision-making, and quality control detects errors and compensates for procedures shortcomings (to an acceptable extent) (Williams and Samset, 2010; Flyvbjerg, 2013). This decreases the chance of manipulating and prevents high cost-overruns during and after the front-end process (Andersen et al., 2016).

Cost-Benefit Analysis (CBA) results are essential for defining the infrastructure megaproject concept at the front-end (Volden, 2019b). Still, CBA is criticised for its vulnerability to biases, especially optimism bias (Volden, 2019b), weakness in defining non-monetised benefits (Williams and Samset, 2010), and the possibility of manipulating the results by beneficiary parties (Volden, 2019b). Moreover, CBA or other cost-based analyses do not reflect all aspects of an infrastructure megaproject's impact. Therefore, Samset and Volden (2016) mention that CBA should be used with a complementary non-monetised analysis such as cost-effectiveness analysis, social impact analysis, multi-criteria analysis, and multiple multi-criteria analysis (Kariyawasam et al., 2019) to improve estimation accuracy.

The outside view has an essential role in generating robust estimations, minimising the planning fallacy and decreasing the chance of a cost overrun (Flyvbjerg, 2007, 2013). Early estimations are often unreliable due to enormous changes to the infrastructure megaproject concept during the front-end (Welde and Odeck, 2017). Therefore applying cost control by an external party (Flyvbjerg, 2007, 2013) is essential for generating realistic estimations and addressing cost deviation associated with the concept changes before committing the project (e.g., benchmarking) (Welde and Odeck, 2017; Cantarelli et al., 2010; Andersen et al., 2016).

A key obstacle in generating reliable estimations is perverse incentives (Flyvbjerg, 2013); to manage perverse incentives, an assessment framework for the estimating process, including incentives, rewards, and penalties, is helpful (Meier, 2008; Flyvbjerg, 2013). The other obstacle here is showing the monetary value of qualitative estimations. Since the non-monetary analysis is easy to manipulate and interpret regarding a particular party's interests (Volden, 2019b), the quality control's role in generating reliable estimations is prominent. Regular reviews are the typical quality control measures, and in applying them, it is crucial to consider the extent that procedures are followed (George et al., 2008), and reviewers find the errors (Williams et al., 2012). Volden (2018) highlights the impact of the maturity of an

organisation in conducting robust reviews. In this regard, the organisational culture and the leadership style are crucial elements for motivating the front-end team to find and communicate errors (Williams et al., 2012).

3.3.4. Applying lessons learned

Applying lessons learned refers to deriving and systemising the knowledge achieved during the planning and delivering an infrastructure megaproject (Gemünden et al., 2018). Applying lessons learned seems neglected from the front-end research agendas (Williams et al., 2019). Learning and development are bonded together (Morris, 2013a). Implementing the front-end without applying lessons learned does not improve an infrastructure megaproject's performance (Fuentes et al., 2019) since the organisations repeatedly make the same mistakes.

In front-end literature, lessons learned are discussed for training purposes (Williams et al., 2012; Miller and Hobbs, 2005; Burger et al., 2019; Winch and Leiringer, 2016), creating a database for deriving and validating estimations (which also facilitates conducting reliable estimations) (Flyvbjerg, 2013; Volden, 2018) and evaluating alternative concepts (Samset and Christensen, 2017). The results of scientific studies (Morris, 2016) and ex-post analysis (Volden, 2018) are common sources for capturing and systemising lessons learned. The lessons are formally conveyed through organisations by robust training procedures (Williams et al., 2012; Miller and Hobbs, 2005) and informally by senior managers such as the project sponsor through coaching (Morris, 2013a; Kloppenborg and Tesch, 2009) and mentoring (Williams et al., 2012; Edkins et al., 2013; Kloppenborg and Tesch, 2009). Organisational culture significantly impacts capturing and systemising lessons learned (Williams et al., 2012, 2019) in both formal and informal approaches.

In the formal approach, organisational culture impacts the procedures for training the employees (Williams et al., 2012) and deriving "ex-post analysis" (Miller and Hobbs, 2005; Volden, 2018). In this regard, mature organisations have robust procedures for capturing and applying lessons learned (Williams et al., 2019; Miller and Hobbs, 2005; Volden, 2018).

In the informal approach, organisational culture impacts applying lessons learned by impacting project management structure (Williams et al., 2012; Edkins et al., 2013) and leadership style (Morris, 2013a). To this end, the sponsor should perform a mentor's role to share tacit knowledge (Kloppenborg and Tesch, 2009); they should also increase learning effectiveness through group activities (Morris, 2013a; Edkins et al., 2013).

To create an appropriate database, adequate experience in managing a spectrum of infrastructure megaprojects is essential for organisations, but many organisations do not have that background (Miller and Hobbs, 2005). Organisations also tend to focus on future projects instead of learning from past projects (Samset and Volden, 2016). Volden (2018) mentions organisations are under time pressure to start the next project thus they do not capture lessons learned. Also, organisations are reluctant to disclose their mistakes in public (Williams et al., 2012), and project managers do not see any benefit in learning from past experience and applying to future projects because they believe each project is a unique endeavour (Williams and Samset, 2010). In this regard, Miller and Hobbs (2005) emphasise the government's role in capturing lessons from governmental projects.

3.3.5. Increasing the skills and competencies of the front-end actors

The skills and competencies of front-end actors are significant factors in generating front-end outcomes (Morris, 2013a, 2016; Morris and Gherardi, 2011). Front-end has three levels, namely institutional, strategic and project (Morris and Gherardi, 2011). By front-end actors, we mean the groups of people who implement front-end and make the decisions. There are four key actors in the front-end, namely:

- (1) *Politicians/Policy-makers*: responsible for front-end decision-making in the government (Klakegg, 2009; Samset et al., 2013).

- (2) *Owner*: individual or organisation that is the most influential actor at the institutional level for defining project goals and long-term strategies (Edkins et al., 2013; Morris, 2016).
- (3) *Sponsor*: responsible for conveying the strategy from the institutional level to the project level, assuring the strategic alignment between different levels (Morris and Gherardi, 2011), and facilitating the delivery of the strategies by structuring the project management practice (Edkins et al., 2013).
- (4) *Project manager*: responsible for implementing projects and strategies (Williams and Samset, 2010) under the sponsor's supervision.

The significance of front-end actors' skills and competencies, especially strategic competencies, are frequently cited in the literature (Williams and Samset, 2010; Morris, 2013a; Edkins et al., 2013). In front-end literature, skills and competencies are discussed in managerial skills and competencies (Klakegg, 2009; Morris, 2013a, 2016; Edkins et al., 2013) and individual competencies (Williams and Samset, 2010; Edkins et al., 2013).

Managerial skills and competencies. Due to the nature of the work at the front-end of infrastructure megaprojects (Edkins et al., 2013), strategic competencies are essential for the front-end team (Morris and Gherardi, 2011). Morris (2016) highlights the professional institutions' role in promoting the required skills and competencies regarding the strategic aspects of managing the front-end process.

The owner and sponsor should have enough competencies to structure and define governance, strategy and commercial aspects at the front-end of infrastructure megaprojects (Kloppenborg and Tesch, 2009; Winch and Leiringer, 2016). Kloppenborg and Tesch (2009, p154) mention three competencies for sponsors to manage the front-end: "defining performance/success, mentoring the project manager, and prioritising projects." The latter refers to the sponsor's role to choose and prioritise projects that align with the organisation's strategic objectives.

Adequate leadership has an essential role in improving front-end outcomes by involving individual senior managers or a "constituted board" (Edkins et al., 2013, p76). Leadership is a necessary skill for project managers at all levels of the organisation (i.e., institutional, strategic and projects), and it has different implications and functions at each level. For instance, at the institutional level, leadership capabilities enable managing the front-end of infrastructure megaprojects in terms of "establishing strategy, forming teams, making decisions and so on" (Morris and Gherardi, 2011, p27).

Edkins et al. (2013) propose a list of six competencies for managing front-end with a strong emphasis on leadership: "(1) Leadership and decision-making, (2) Selecting individuals and forming teams, (3) Technical and technology assessment, (4) Project scoping, (5) Risk and value assessment, and (6) Establishing and instilling an appropriate oversight and governance system" (p77).

Individual competencies. Individual competencies apply to all project actors. Gut feeling (Klakegg et al., 2016) and intuitive decision-making capabilities (Williams and Samset, 2010) are two essential complementary judgmental competencies for formal front-end decision-making. These are examples of decision-making capabilities based on simple analysis and qualitative approaches that using them requires management integrity (Morris and Gherardi, 2011), creative thinking and seniority in the front-end team (Williams et al., 2012).

The front-end team's seniority and experience are essential elements for decision-making at the front-end of infrastructure megaprojects. However, over-reliance on past experience limits creativity in making front-end decisions (Williams et al., 2012; Edkins et al., 2013); this calls for diversity in the front-end team.

3.3.6. Promoting transparency and accountability and defining clear roles and responsibilities in project governance

Transparency and accountability are essential elements of project governance (Samset and Volden, 2017). Promoting transparency and accountability and defining clear roles and responsibilities of each project party in project governance allows for managing projects for their context and increases the potential to manage front-end issues (Samset and Volden, 2017). Klakegg (2009) emphasises project governance's role in defining clear roles and responsibilities at the front-end of infrastructure megaprojects to manage front-end issues.

Klakegg (2009) and Samset and Volden (2016) state that transparency is crucial for implementing any remedies for managing front-end issues. An organisation can increase transparency by establishing a transparent "decision-making process, [and saving] the documents used as a basis for decisions, in reviews and monitoring" (Klakegg, 2009, p513). Transparent decision-making facilitates external stakeholders' participation in decision-making (Samset and Volden, 2017), increases the CBA effectiveness (Volden, 2019b) and reduces corruption in the project context (Locatelli et al., 2017). It is noteworthy to remind that transparency is not disclosing analytical data to the public (Lorenz, 2011) but is an element of organisational culture, procedures, and project context (Locatelli et al., 2017). Transparency is also a precondition for accountability (Samset and Volden, 2017) since, with a lack of transparency, the roles and responsibilities and procedures followed for making front-end decisions are unclear.

Accountability and transparency are correlated, which means that enhancing transparency in decision-making (Shiferaw and Klakegg, 2012; Shiferaw et al., 2012) and generating front-end outcomes (Flyvbjerg, 2007) increases accountability. For instance, increasing transparency in documenting the decision-making process and giving voice to the external stakeholders increases accountability (Samset and Volden, 2017). Also, exercising transparent cost estimations (Andersen et al., 2016) controlling measures at the front-end (Winch and Leiringer, 2016) and ex-post evaluations (Volden, 2018) play a significant role in increasing accountability at the front-end of infrastructure megaprojects. All in all, increasing accountability reduces the potential for misrepresenting the estimations' results, which is a precondition for improving estimations' accuracy (Flyvbjerg, 2007).

4. What are the connections between front-end issues and remedies for managing them?

Appendix 1 (Table 5) comprehensively shows the connection between issues and remedies for managing them. To create Appendix 1, we divided each remedy into the links that connect it to the issues (Table 3 represents the issues). Of course, there are elements of arbitrary judgment in identifying these links and using the binary reductionist approach (i.e., yes/no) to link the issues and remedies. However, we see the table as a broad image for identifying the issues and finding the relevant remedies for managing them. For policymakers and project managers, this could be a blueprint for managing the front-end issues. For academics investigating front-end (and projects in general), it could be a useful starting point.

The links explained in Section 3.3 refer to how a remedy manages the issue(s), and the dots in Appendix 1 represent these connections between issues and their respective remedies. We created Appendix 1 through group discussions and brainstorming sessions.

Table 4 is a brief version of Appendix 1, in which each value represents the number of connections between front-end issues and remedies. The table's last row represents the total number of connections that each remedy has to the themes, and the last column represents the total number of connections that each theme has to the remedies.

Regarding issues, the table shows that front-end issues are interrelated and exist in different levels of an organisation. There is no single remedy that can manage all the issues, but a series of them must be in place. Among the six themes, Politicians and Decision-Makers have

more connections to the remedies, which indicates this theme includes essential issues and attracts researchers' attention. The theme Project Context has the lowest number of connections to the remedies, leaving the front-end team with limited possibilities to manage the issues, even though the importance of managing a project for its context is emphasised in the literature (Merrow, 2011; Morris and Galdi, 2011).

According to those mentioned above, it is noteworthy to emphasise that some issues have more connections to the remedies because more research is available for managing them; it does not indicate that they are more important or complicated than the issues with fewer connections. For instance, optimism bias receives more attention than corruption, though corruption can play an equally (if not more) important role in deviating front-end outcomes.

In terms of remedies, Appendix 1 shows that the remedies are interrelated and should be employed simultaneously to have more effectiveness. Project governance is the key remedy for managing infrastructure megaproject front-end issues since it offers more connections to the issues and covers more issues than other remedies. This emphasises the significance of project governance in empowering other remedies (Burger et al., 2019) and facilitating managing a project for its context (Edkins et al., 2013). The most important takeaway is that the project governance that promotes transparency and accountability and defines clear roles and responsibilities in the project is the most effective remedy to reduce the front-end issues and improve front-end outcomes.

Applying lessons learned is the remedy that offers the least connections to the issues. However, it is not a good indicator of the importance of applying lessons learned, considering that applying lessons learned is a precondition for creating a sound database for generating reliable estimations and controlling the quality of the results.

Therefore, applying lessons learned requires more attention from researchers, a finding that is consistent with Williams et al. (2019). As is noted, remedies not only manage the issues but also empower one another, and, often, more than one remedy is required for managing one issue.

5. Toward a better front-end of infrastructure megaprojects

The findings show that front-end issues are interrelated and exist in different levels of an organisation which managing them requires using remedies simultaneously. Therefore policymakers, project managers and society should work together to be able to apply the remedies and increase the infrastructure megaprojects' social and financial values. In this respect, the organisational culture of key internal stakeholders and the front-end procedure they follow are catalysts for using remedies effectively (Williams et al., 2012; Edkins et al., 2013) and preparing the ground for cooperation among policymakers, project managers and society. This section summarises the key implications of our research for policymakers, project managers, and society.

5.1. Implications for policymakers

Policymakers are critical stakeholders in megaprojects. They often promote megaprojects and shape them based on their visions or agendas, if not interests (Samset and Volden, 2016). The literature discusses how different megaproject temporalities and political mandates could foster opportunistic behaviours (Flyvbjerg, 2014; Locatelli et al., 2017). Still, our research shows how policymakers can be fundamental actors in the infrastructure front-end to foster the value delivered by a megaproject to society. Our research implications for policymakers include the following.

Applying lessons learned, and generating reliable estimations and controlling the quality of the results, requires a database consisting of the data collected from a spectrum of projects beyond a single company's database (Miller and Hobbs, 2005). Therefore, policymakers should support the creation and development of such a database using organisations such as Nationally Significant Infrastructure Projects

Table 4
Summary of Appendix 1; the number of the connection between front-end issues and remedies.

	Remedies	Using more qualitative data and less detailed quantitative analysis for decision-making	Involving external stakeholders' views in decision-making	Generating reliable estimations and controlling the quality of the results	Applying lessons learned	Increasing the skills and competencies of the front-end actors	Promoting transparency and accountability and defining clear roles and responsibilities in project governance	
Themes	Groups							Themes total connections
Project managers	Skills and Competencies	0	0	0	1	4	1	11
	Staff working behaviour	0	0	4	0	0	1	
Politicians and decision-makers	Political bias	0	1	1	0	0	6	22
	Lack of evidence-based decision-making	1	0	7	0	1	5	
Front-end process and outcomes	Conducting the Process	2	0	0	1	0	1	11
	Generating the Outcomes	1	1	2	1	2	0	
Human factors	Cognitive biases	1	0	2	1	0	2	13
	Restrictions	4	0	0	1	2	0	
Project context	Changes in the project context	1	0	0	0	0	2	7
	Characteristics of the projects' context	0	0	1	0	0	3	
The early phase of infrastructure megaprojects	Nature of Megaprojects	4	5	0	2	2	3	16
Remedies total connections		14	7	17	7	11	24	

(NSIPS), National Audit Office (NAO) and Infrastructure Projects Authority (IPA). These organisations are significant agents in collecting lessons learned and creating a database consisting of a spectrum of projects for all parties involved in the front-end of infrastructure megaprojects (Miller and Hobbs, 2005; Flyvbjerg, 2013; Volden, 2018).

Policymakers need to develop frameworks and procedures that foster transparency at front-end processes (Samset and Volden, 2017; Klakegg et al., 2016). The IPA in the UK or similar organisations in other countries are essential to promote transparency and accountability to the decision-making process, prioritising alternatives or zero option studies, assuring effective involvement of external stakeholders in the decision-making process, and so on.

5.2. Implications for project managers

Appendix 1 demonstrates the primary contribution of our study for project managers, which can be used as a checklist or a compact “guide for actions”. Appendix 1 summarises the main front-end issues, remedies and connections between them. The links between issues and remedies explained in previous sections represent a “gateway” for project managers to learn more about managing front-end issues.

Table 3 suggests several front-end issues such as reluctance to say no to the higher managers (Flyvbjerg, 2007), too much confidence in front-end outcomes (Samset and Volden, 2017) and no effort to find alternative concepts (Klakegg, 2009; Meier, 2008; Welde and Odeck, 2017), are rooted in the project managers' working behaviour. Therefore, an appropriate framework with adequate incentives and penalties should be in place to assess project managers performance (Flyvbjerg, 2007, 2013).

Project managers also need to consider using more qualitative decision-making approaches and avoid generating detailed analysis, especially at front-end early stages (Samset et al., 2013). For instance, design thinking offers a new and innovative approach to managing front-end complexities (Ben Mahmoud-Jouini et al., 2016).

Findings show that external stakeholders' views are not well

considered at the front-end of infrastructure megaprojects (Aaltonen et al., 2016). Project managers need to employ open and flexible stakeholder management approaches that give voice to diverse views in project decisions (Aaltonen et al., 2016; Doloi, 2018; Enserink, 2000; Hwang and Yang, 2014). This prepares the ground for using qualitative methods to create value for projects (Volden, 2018) and manage projects for their contexts (Morris and Gerdali, 2011).

The literature shows the gap in project management skills associated with what is needed for managing the front-end of infrastructure megaprojects, as opposed to a traditional project (Morris, 2013a, 2016; Edkins et al., 2013; Morris and Gerdali, 2011). To fill this gap, the institutions that prepare professional knowledge and those that educate project managers must equip project managers with the required skills and competencies for managing front-end of infrastructure megaprojects (Williams et al., 2019; Tranfield et al., 2003).

5.3. Implications for society

Infrastructure megaprojects must meet social needs and expectations (Samset et al., 2013). People within the affected society – i.e., local communities (DiMaddaloni and Davis, 2017), end-users (Fuentes et al., 2019) etc.– should be at the centre of decision-making. The front-end is the best opportunity to engage the abovementioned groups as external stakeholders and give voice to their views in decision-making (Aaltonen et al., 2016). This requires the society to engage with the front-end proactively and leads to developing an infrastructure megaproject concept aligned with society's expectations and the United Nation's Sustainable Development Goals. The remedies presented in this paper should be demanded by societies and their representatives when discussing the front-end of new infrastructure. Also, the issue presented in Table 3 can be operationalised as a checklist for identifying red flags. With this paper being open access, we believe that stakeholders such as NGOs and journalists could be more knowledgeable when discussing (or scrutinising) the front-end of infrastructure.

5.4. Limitations to the study

There are two sets of limitations worth discussing: research limitations and literature limitations. From these limitations, we will elaborate on future research for the front-end of infrastructure megaprojects.

In our research, we focused on the scientific literature, i.e., peer-reviewed papers. Indeed, several stakeholders such as the World Bank, the OECD and even consultancy companies have investigated the front-end. It would therefore be useful to assess the differences between these bodies of literature. In this research, we considered the front-end as a single process. In practice, the front-end consists of a series of different yet interrelated sub-processes, such as cost estimation or risk analysis etc. Future research should focus on these sub-processes and their operational capabilities. Regarding the limitations of the literature, it is clear how infrastructure megaprojects in the global south are far less investigated than those in developed countries. Indeed, authors from the global south are far less represented; therefore, little is known about the front-end of infrastructure megaprojects in those countries and the implications for those societies.

5.5. Future research

The paper paves the way to further studies about the front-end of infrastructure megaprojects. In particular, there are several possible research avenues for future studies to improve front-end outcomes.

Findings of the SLR show that, although managing a project for its context is recommended as one of the critical elements of improving front-end outcomes (Samset et al., 2013), not much attention have been given to manage the issues associated with this theme.

There is a consensus among project management scholars about the different nature of front-end tasks compared to conventional project management (Morris, 2013a, 2016; Edkins et al., 2013). However, except for Edkins et al. (2013) and some dispersed literature about the required competencies for front-end project managers, no research investigates the necessary skills and competencies explicitly for front-end.

Another aspect of front-end research is the difference between front-end processes in different infrastructure projects. One example of this comparison is Elzomor et al. (2018), which compared front-end requirements between small and large infrastructure. There is a need for more research to show the differences between the front-end of different infrastructure megaproject categories. For instance, the difference between the front-end of a nuclear power plant and a railroad or the front-end for building a new power plant and decommissioning an old power plant can be some topics for more investigations.

There is also a lack of research considering the zero option. Future research on this topic can answer questions such as ‘To what extent a front-end team considers the zero option as a significant alternative to a project concept?’, ‘What characteristics of an old infrastructure make it viable as a zero option?’ and ‘What are the barriers against defining zero option as the project concept?’ Based on BenMahmoud-Jouini et al. (BenMahmoud-Jouini et al., 2016), design thinking can be used at the front-end. For instance, design thinking application at the front-end of infrastructures in defining a feasible concept regarding zero option, value creation, qualitative approaches etc.

6. Conclusions

The front-end is a key driver for the success of infrastructure. Still, it remains poorly executed, with several issues undermining the value of infrastructure megaprojects to society and the environment. This paper aims to systemise knowledge and understanding of the front-end of infrastructure megaprojects, the main front-end issues, and the remedies for managing them.

To answer the research question ‘What definition can appropriately describe front-end of infrastructure megaprojects?’, we derived five critical characteristics of front-end of infrastructure megaprojects from

12 definitions; these characteristics include: (1) Exploratory nature, (2) Generating managerial information, (3) Shaping a feasible concept, (4) Front-end terminates with a decision, and (5) Uncertainty. Thus, we defined the front-end of infrastructure megaprojects as:

‘An exploratory process for generating necessary information to shape a feasible concept for an infrastructure megaproject, assess the concepts’ uncertainties and make the final go/no-go decision.’

In answering the question ‘What are the issues at front-end of infrastructure megaprojects?’, we gathered 44 issues and clustered them into six themes according to their context: (1) Front-end process, (2) Front-end project managers, (3) Politicians and Decision-makers, (4) Project context, (5) Human factors, and (6) The early phase of infrastructure megaprojects. Then we explained the interrelations between the issues and exhibited them in Table 2. The findings show that front-end issues are interrelated and exist in different levels off an organisation.

To answer ‘What are the remedies for managing the issues at front-end of infrastructure megaprojects?’, we derived six remedies for managing the front-end issues, namely: (1) Using more qualitative data and less detailed quantitative analysis for decision-making, (2) Involving external stakeholders’ views in decision-making, (3) Generating reliable estimations and controlling the quality of the results, (4) Applying lessons learned, (5) Increasing the skills and competencies of the front-end actors, and (6) Promoting transparency and accountability and defining clear roles and responsibilities in project governance. We explained the remedies by explaining each remedy’s meaning, the area of its impact, how the remedies manage the issue (the link to the issue), and the obstacles against implementing each remedy.

Lastly, to sufficiently answer ‘What is the connection between front-end issues and remedies?’, we created a table that uses the results of research questions two (front-end issues – columns) and three (front-end remedies – rows) to show the connection between front-end issues and remedies (see Table 5). The findings show that remedies for managing the front-end issues should be used simultaneously to effectively manage the issues, and organisational culture and the front-end procedures play a significant role in preparing the ground for applying the remedies. Project governance that promotes transparency and accountability and defines clear roles and responsibilities is the most important remedy for managing the front-end issues and facilitating the application of other remedies.

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.2021.100032>.

References

- Aaltonen, K., Kujala, J., Havela, L., Savage, G., 2016. Stakeholder dynamics during the project front-end: the case of nuclear waste repository projects. *Int. J. Proj. Manag.* 46, 15–41.
- Andersen, B., Samset, K., Welde, M., 2016. Low estimates – high stakes: underestimation of costs at the front-end of projects. *Int. J. Manag. Proj. Bus.* 9 (1), 171–193.
- Ben Mahmoud-Jouini, S., Midler, C., Silberzahn, P., 2016. Contributions of design thinking to project management in an innovation context. *Proj. Manag. J.* 47 (2), 144–156.
- BenMahmoud-Jouini, S., Midler, C., Silberzahn, P., 2016. Contributions of design thinking to project management in an innovation context. *Proj. Manag. J.* 47 (2), 144–156.
- Bingham, E., Gibson, G.E., 2017. Infrastructure project scope definition using project definition rating index. *J. Manag. Eng.* 33 (2), 1–8.

- Brookes, N.J., Locatelli, G., 2015. Power plants as megaprojects: using empirics to shape policy, planning, and construction management. *Util. Pol.* 36, 57–66. <https://doi.org/10.1016/j.jup.2015.09.005>.
- Burger, K., White, L., Yearworth, M., 2019. Understanding front-end project workshops with social practice theory. *Int. J. Proj. Manag.* 37 (1), 161–175. <https://doi.org/10.1016/j.ijproman.2018.11.003>.
- Cantarelli, C.C., Flyvbjerg, B., van Wee, B., Molin, E.J.E., 2010. Lock-in and its influence on the project performance of large-scale transportation infrastructure projects: investigating the way in which lock-in can emerge and affect cost overruns. *Environ. Plann. Plann. Des.* 37 (5), 792–807.
- Cascetta, E., Carteni, A., Pagliara, F., Montanino, M., 2015. A new look at planning and designing transportation systems: a decision-making model based on cognitive rationality, stakeholder engagement and quantitative methods. *Transport Pol.* 38, 27–39. <https://doi.org/10.1016/j.tranpol.2014.11.005>.
- Cuppen, E., Bosch-Rekvelde, M.G.C., Pikaar, E., Mehos, D.C., 2016. Stakeholder engagement in large-scale energy infrastructure projects: revealing perspectives using Q methodology. *Int. J. Proj. Manag.* 34 (7), 1347–1359. <https://doi.org/10.1016/j.ijproman.2016.01.003>.
- Denicol, J., Davies, A., Krystallis, I., 2020. What are the causes and cures of poor megaproject performance? A systematic literature review and research agenda. *Proj. Manag. J.* 1–18. <https://doi.org/10.1177/8756972819896113>.
- DiMaddaloni, F., Davis, K., 2017. The influence of local community stakeholders in megaprojects: rethinking their inclusiveness to improve project performance. *Int. J. Proj. Manag.* 35 (8), 1537–1556. <https://doi.org/10.1016/j.ijproman.2017.08.011>.
- DiMaddaloni, F., Davis, K., 2018. Project manager's perception of the local communities' stakeholder in megaprojects. An empirical investigation in the UK. *Int. J. Proj. Manag.* 36 (3), 542–565. <https://doi.org/10.1016/j.ijproman.2017.11.003>.
- Doloi, H., 2018. Community-Centric model for evaluating social value in projects. *J. Construct. Eng. Manag.* 144 (5), 04018019.
- Edkins, A., Gherardi, J., Morris, P., Smith, A., 2013. Exploring the front-end of project management: Exploring the front-end of project management. *Eng. Proj. Organ. J.* 3 (2), 71–85.
- Elzomor, M., Burke, R., Parrish, K., Gibson, E., 2018. Front-end planning for large and small infrastructure projects: comparison of project definition rating index tools. *J. Manag. Eng.* 34 (4), 1–12.
- Enserink, B., 2000. A quick scan for infrastructure planning: screening alternatives through interactive stakeholder analysis. *Impact Assess. Proj. Apprais.* 18 (1), 15–22.
- Flyvbjerg, B., 2007. Policy and planning for large-infrastructure projects: problems, causes, cures. *Environ. Plann. Plann. Des.* 34 (4), 578–597.
- Flyvbjerg, B., 2013. Quality control and due diligence in project management : getting decisions right by taking the outside view ✕. *Int. J. Proj. Manag.* 31 (5), 760–774. <https://doi.org/10.1016/j.ijproman.2012.10.007>.
- Flyvbjerg, B., 2014. What you should know about megaprojects and why : an Overview. *Proj. Manag. J.* 45 (2), 6–19.
- Flyvbjerg, B., 2017. Introduction: the iron law of megaproject management. *Oxford Handbook of Megaprojects*. Oxford University Press, UK, pp. 1–18.
- Fuentes, M., Smyth, H., Davies, A., 2019. Co-creation of value outcomes: a client perspective on service provision in projects. *Int. J. Proj. Manag.* 37 (5), 696–715. <https://doi.org/10.1016/j.ijproman.2019.01.003>.
- Gemünden, H.G., Lehner, P., Kock, A., 2018. The project-oriented organization and its contribution to innovation. *Int. J. Proj. Manag.* 36 (1), 147–160. <https://doi.org/10.1016/j.ijproman.2017.07.009>.
- George, R., Bell, L.C., Edward Back, W., 2008. Critical activities in the front-end planning process. *J. Manag. Eng.* 24 (2), 66–74.
- Gibson, G.E., Bingham, E., Stogner, C.R., 2010. Front end planning for infrastructure projects. *Constr Res Congr 2010 Innov Reshaping Constr Pract - Proc 2010 Constr Res Congr* 1125–1135.
- Giezen, M., Salet, W., Bertolini, L., 2015. Adding value to the decision-making process of mega projects: fostering strategic ambiguity, redundancy, and resilience. *Transport Pol.* 44, 169–178.
- Gil, N.A., Biesek, G., Freeman, J., 2015. Interorganizational development of flexible capital designs: the case of future-proofing infrastructure. *IEEE Trans. Eng. Manag.* 62 (3), 335–350.
- Global Infrastructure Outlook - A G20 initiative. <https://outlook.gihub.org/>.
- Hetemi, E., Jerbrant, A., Mere, J.O., 2020. Exploring the emergence of lock-in in large-scale projects: a process view. *Int. J. Proj. Manag.* 38 (1), 47–63. <https://doi.org/10.1016/j.ijproman.2019.10.001>.
- Hwang, B.G., Ho, J.W., 2012. Front-end planning implementation in Singapore: status, importance, and impact. *J. Construct. Eng. Manag.* 138 (4), 567–573.
- Hwang, B.-G., Yang, S., 2014. Rework and schedule performance. *Eng. Construct. Architect. Manag.* 21 (2), 190–205.
- Johansen, E., Wilson, B., 2006. Investigating first planning in construction. *Construct. Manag. Econ.* 24 (12), 1305–1314.
- Kariyawasam, S., McGovern, M., Wilson, C., 2019. Partial information and complex development decisions: illustrations from infrastructure projects. *Environ. Impact Assess. Rev.* 78 (May), 106281. <https://doi.org/10.1016/j.eiar.2019.106281>.
- Klakegg, J.O., 2009. Pursuing relevance and sustainability: improvement strategies for major public projects. *Int. J. Manag. Proj. Bus.* 2 (4), 499–518.
- Klakegg, O.J., Williams, T., Shiferaw, A.T., 2016. Taming the "trolls": major public projects in the making. *Int. J. Proj. Manag.* 34 (2), 282–296. <https://doi.org/10.1016/j.ijproman.2015.03.008>.
- Kloppenborg, T.J., Tesch, D., 2009. Successful project sponsor behaviors during project initiation : an empirical investigation, 21 (1), 140–159. <https://www.jstor.org/stable/40604638>.
- Kock, A., Heising, W., Gemünden, H.G., 2016. A contingency approach on the impact of front-end success on project portfolio success. *Proj. Manag. J.* 47 (2), 115–129.
- Locatelli, G., Mariani, G., Sainati, T., Greco, M., 2017. Corruption in public projects and megaprojects: there is an elephant in the room! *Int. J. Proj. Manag.* 35 (3), 252–268. <https://doi.org/10.1016/j.ijproman.2016.09.010>.
- Lorenz, J., 2011. Building support for new transportation funding and financing program: linking investments to stakeholder priorities through collaboration and economic impact analysis. *Transport. Res. Rec.* 2245, 8–16.
- Martinsuo, M.M., Vuorinen, L., Killen, C., 2018. Lifecycle-oriented framing of value at the front end of infrastructure projects. *Int. J. Manag. Proj. Bus.*
- Meier, S.R., 2008. Best project management and intelligence and defense agencies preacquisition phase for federal systems engineering practices in the. *Proj. Manag. J.* 39 (1), 59–71.
- Morrow, E.W., 2011. *Industrial Megaprojects*. John Wiley & Sons, Inc, Hoboken, New Jersey.
- Miller, R., Hobbs, B., 2005. Governance regimes for large complex projects. *Proj. Manag. J.* 36 (3), 42–51.
- Miller, R., Lessard, D.R., 2001. *The Strategic Management of Large Engineering Projects*. Massachusetts Institute of Technology. Massachusetts Institute of Technology.
- Morris, P., 2013a. Reconstructing project management reprised: a knowledge perspective. *Proj. Manag. J.* 44 (5), 6–23.
- Morris, P., 2013b. *Reconstruction Project Management*. John Wiley & Sons, Ltd, London.
- Morris, P.W.G., 2016. Reflections. *Int. J. Proj. Manag.* 34, 365–370.
- Morris, P.W.G., Gherardi, J., 2011. Managing the institutional context for projects. *Proj. Manag. J.* 42 (6), 20–32.
- Mottee, L.K., Arts, J., Vanclay, F., Howitt, R., Miller, F., 2020. Limitations of technical approaches to transport planning practice in two cases: social issues as a critical component of urban projects. *Plann. Theor. Pract.* 21 (1), 39–57. <https://doi.org/10.1080/14649357.2019.1696980>.
- Nik-Bakht, M., El-Diraby, T.E., 2020. Beyond chatter: profiling community discussion networks in urban infrastructure projects. *J. Infrastruct. Syst.* 26 (3), 05020006.
- Sainati, T., Brookes, N., Locatelli, G., 2017. Special purpose entities in Megaprojects : empty boxes or. *Proj Manag Inst* 48 (2), 55–73.
- Saldana, J., 2013. *The Coding Manual for Qualitative Researchers*, second ed. SAGE Publications, Thousand Oaks, California.
- Samset, K., Christensen, T., 2017. Ex ante project evaluation and the complexity of early. *Publ. Organ. Rev.* 17 (1), 1–17.
- Samset, K., Volden, G.H., 2016. Front-end definition of projects: ten paradoxes and some reflections regarding project management and project governance. *Int. J. Proj. Manag.* 34 (2) <https://doi.org/10.1016/j.ijproman.2015.01.014>, 297–313.
- Samset, K., Volden, G.H., 2017. Governance of major public investment Projects : principles and practices in six countries. *Int. J. Proj. Manag.* 48 (3), 90–108.
- Samset, K., Andersen, B., Austeng, K., 2013. To which extent do projects explore the opportunity space ? *Int. J. Manag. Proj. Bus.* 7 (3), 473–492.
- Samset, K., Sankaran, S., B Henning, P., Ferries, T., Edson, M.C., 2017. Systems engineering in front-end governance of. *Systems* 5, 13.
- Shiferaw, A.T., Klakegg, O.J., 2012. Linking policies to projects: the key to identifying the right public investment projects. *Proj. Manag. J.* 43 (4), 14–26.
- Shiferaw, A.T., Klakegg, O.J., Haavaldsen, T., 2012. Governance of public investment projects in Ethiopia. *Proj. Manag. J.* 43 (4), 52–69.
- Smallwood, N., 2020. Setting up for Success: the Importance of Front-End Loading - Infrastructure and Projects Authority. <https://ipa.blog.gov.uk/2020/09/09/setting-up-for-success-the-importance-of-front-end-loading/>.
- Smyth, H., Lecoeuvre, L., Vaesken, P., 2018. Co-creation of value and the project context: towards application on the case of Hinkley Point C Nuclear Power Station. *Int. J. Proj. Manag.* 36 (1), 170–183. <https://doi.org/10.1016/j.ijproman.2017.04.013>.
- Suprayoga, G.B., Witte, P., Spitt, T., 2020. Coping with strategic ambiguity in planning sustainable road development: balancing economic and environmental interests in two highway projects in Indonesia. *Impact Assess. Proj. Apprais.* 38 (3), 233–244.
- Tranfield, D., Denyer, D., Smart, P., Goodhue, D.L., Thompson, R.L., 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *Br. J. Manag.* 14 (2), 207–222. <https://www.jstor.org/stable/249689?origin=crossref>.
- Treasury, H.M., 2018. Guide to developing the project business case. *Infrastructure and projects authority*. www.gov.uk/government/publications.
- Vaismoradi, M., Turunen, H., Bondas, T., 2013. Content analysis and thematic analysis: implications for conducting a qualitative descriptive study. *Nurs. Health Sci.* 15 (3), 398–405.
- Volden, G.H., 2018. Public project success as seen in a broad perspective.: lessons from a meta-evaluation of 20 infrastructure projects in Norway. *Eval. Progr. Plann.* 69 (September 2017), 109–117. <https://doi.org/10.1016/j.evalprogplan.2018.04.008>.

- Volden, G.H., 2019a. Public funding, perverse incentives, and counterproductive outcomes. *Int. J. Manag. Proj. Bus.* 12 (2), 466–486.
- Volden, G.H., 2019b. Assessing public projects' value for money: an empirical study of the usefulness of cost–benefit analyses in decision-making. *Int. J. Proj. Manag.* 37 (4), 549–564. <https://doi.org/10.1016/j.ijproman.2019.02.007>.
- Welde, M., Odeck, J., 2017. Cost escalations in the front-end of projects—empirical evidence from Norwegian road projects. *Transport Rev.* 37 (5), 612–630.
- Whelton M, Ballard G, Adjunct Professor A. A Knowledge Management Framework for Project Definition URL: <https://www.itcon.org/2002/13>. *ITCon.* 2002;vol. 7 (August):197–212. <http://www.ce.berkeley.edu/~whelton>.
- Williams, T., Samset, K., 2010. Issues in front-end decision making. *Proj. Manag. J.* 41 (2), 38–49.
- Williams, T., Jonny Klakegg, O., Walker, D.H.T., Andersen, B., Morten Magnussen, O., 2012. Identifying and acting on early warning signs in complex projects. *Proj. Manag. J.* 43 (2), 37–53.
- Williams, T., Vo, H., Samset, K., Edkins, A., 2019. The front-end of projects: a systematic literature review and structuring. *Prod. Plann. Control* 7287.
- Winch, G., Leiringer, R., 2016. Owner project capabilities for infrastructure development: a review and development of the "strong owner" concept. *Int. J. Proj. Manag.* 34 (2), 271–281. <https://doi.org/10.1016/j.ijproman.2015.02.002>.
- Yang, R.J., 2014. An investigation of stakeholder analysis in urban development projects: empirical or rationalistic perspectives. *Int. J. Proj. Manag.* 32 (5), 838–849. <https://doi.org/10.1016/j.ijproman.2013.10.011>.