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Understanding the critical success factors for delivery of megaprojects in Colombia

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Abstract

By their very nature, megaprojects have significant short- and longer-term impacts on the socio-economic, technical, environmental and political landscape of the host country, but many are delivered with time and cost overruns and sometimes with quality discrepancies. This paper examines the critical success factors for megaprojects in Colombia – from the project definition stage to successful handover – from the perspective of professionals involved in the delivery of megaprojects in that country. It applies a mixed approach of quantitative and qualitative data collection and analysis to rank 34 factors identified in literature sources as being critical to the success of megaprojects. Analysis shows that inadequate information at the tender stage, design changes during the construction phase, and limited availability and supply of materials have had a major negative influence on the delivery of megaprojects in Colombia. In contrast, adverse weather conditions and lack of prior experience with similar projects have had the least impact. This paper recommends approaches to mitigate the risks associated with the factors investigated.

1. Introduction

In the 1990s, the US Federal Highway Administration defined megaprojects as large-scale projects with a budget over 1 billion US dollars (Richard, 2006). Since then, the term has been adopted for large infrastructure projects costing more than US\$1 billion. However, more recently, rather than using a monetary threshold only, many scholars have also used features to define megaprojects. In particular, Bruzelius et al. (2002) defined a megaproject to be any project that has a cost of delivery over US\$1 billion, a building time of more than five years, a life expectancy of over 50 years, high uncertainty over possible usage and cost estimations, and a large indirect and immeasurable benefit to a number of parties. Besides, many other scholars have used much broader descriptions; among these are Altshuler and Luberoff (2003) who characterised megaprojects as initiatives that are physical, costly and public in nature; Li and Guo (2011) who noted that they are challenging projects which involve a complex interplay of technology, millions of working hours, many stakeholders and high public attention; and Flyvbjerg (2014) who described them as unique, ambitious “trait making” infrastructures designed to change the structure of the society. Megaprojects occur in diverse sectors including scientific endeavours such as the Large Hadron Collider (the world’s largest and most powerful particle accelerator), large-scale transportation infrastructures and energy exploration in inhospitable seas. As observed by Mišić and Radujković (2015), it might be impossible to find two megaprojects that are identical.

There is sufficient evidence that megaprojects often experience considerable delivery delays and budget overruns, while at the same time failing to achieve their initial objectives

(see Aziz, 2013). Examples of notable megaprojects across the world that experienced these problems include:

- The Central Artery/Tunnel Project in Boston, USA, which was completed in 2007 at the cost of more than US\$14.6 billion against scheduled completion in 1998 at an estimated cost of US\$2.8 billion. This was in addition to technical shortcomings, design flaws and professional misconduct of project managers (see TRB, 2003)
- The Alberta Mega Oil Sands Projects in Canada, which ranged between 8 billion Canadian dollars (C\$) and C\$14 billion in terms of capital investment. These were reported by Jergeas (2008) to have mostly experienced cost overruns by up to 100% of the original cost estimates.
- The Channel Tunnel Rail Link in the UK, which experienced a four-year delay and a 57% budget overrun. It was completed in 2007 at a cost of 9.63 billion Great British pounds (£), as reported by Dimitriou et al. (2013).

Here, the focus is on Colombia, a country that has launched an ambitious infrastructural development plan during the last decade. The country's Intermodal Transportation Master Plan 2015–2030 has a US\$70 billion initial budget and an annual investment of US\$10.4 billion to 2035 to develop over 20,000km of roads, more than 1,600km of new railway, over 5,000km of waterways, as well as 31 airport expansions and port development projects (see The WorldFolio, 2016). In addition to this, the country has completed and ongoing megaprojects in many sectors of the economy, some of which are highlighted in Table 1.

Public records indicate that the three operational projects listed in Table 1 have experienced time and cost overruns. For example, the Reficar Modernization and Expansion Project experienced a delay of 21 months and a total cost of US\$8,016 billion – more than double of the original estimate of US\$3.78 billion (BNamericas, 2016). As reported by Semana (2016), the client, Ecopetrol – formerly known as Empresa Colombiana de Petróleos S.A. – blamed the delay on poor project planning by the main contractor and pressed for compensation of US\$2 billion, whereas the main contractor attributed the delay to changes in the scope of work which required design changes during the construction process, labour issues such as strikes and extreme weather conditions. However, the independent report of Colombia's Comptroller General ascribed both the delays and cost overrun to deficient control and supervision by the client and the project consultants at the initial stages, as well as the limited experience of the main contractor with respect to the design, procurement and construction of similar projects (see Pinzon et al. (2015 cited in Cepeda, 2016, p.35).

Many studies have been conducted to identify possible reasons for, and issues contributing to, time and cost overruns in projects generally and megaprojects in particular. Anderson et al. (2006) noted that the factors driving the escalation of a project cost may occur at any stage in the project cycle, but are more noticeable in the execution phase. This is especially due to public interest and spotlight on the project during this phase. Shehu et al. (2014) attributed key challenges in the execution phase to changes in the scope of work from the client, low speed in decision-making from management and inadequate site supervision. Merrow (2011) in his work on industrial megaprojects identified seven pitfalls, which we have

characterised as: i) inequitable distribution of project benefits; ii) unwarranted speed of delivery; iii) insufficient attention to detail at the initial stages; iv) inadequate attention to front-end activities; v) arbitrary cost-cutting; vi) dumping of project risk on the contractor; and vii) passing the buck. Nonetheless, a megaproject that presents delays and cost overrun may still generate positive outcomes for the stakeholders, and vice-versa. This suggests a clear distinction between the success of a project and that of project management, a view that has been advanced by many authors and is aptly reported by Yong and Mustaffa (2017). In the present article, the focus is on the success of project management.

The present authors note that there was no agreement on the causes of the time and cost overruns in the three main reports that examined the Reficar Expansion Project, the largest megaproject so far in Colombia, and that despite the preponderance of literature, the factors that contribute to the success of a project may differ between countries – as observed by Yong and Mustaffa (2012). Yet, research specific to Colombia is sparse. Furthermore, a review of the literature indicates that many of the country-specific studies on time and cost overruns on projects in general and megaprojects in particular have applied flawed analytical approaches. In many respects, while the variables have been rightly measured using nominal and ordinal scales – which allow for qualitative classification of variables, but cannot quantify – they have been wrongly subjected to inferential statistics, which implies the adoption of materialistic or realist ontology and a positivist or empirical epistemology to qualitative data. For example, Ejaz et al. (2013) who studied megaprojects in Pakistan and Locatelli et.al (2014) who examined

megaprojects in the European Union (EU) wrongly applied the coefficient of determination and Fisher exact test respectively to nominal and ordinal data in their studies.

Therefore, the purpose of this research is twofold: first is to identify the factors that are critical to the success of megaprojects in Colombia; and second is to demonstrate an appropriate analytical approach to nominal and ordinal data – where numerical value is attached to world labels, but the scale cannot quantify.

In addition to this introduction (Section 1), the remainder of the paper comprises: Section 2, which outlines the methodological approach; Section 3, which discusses the results; Section 4 highlighting the implications for practice and potential applications; and Section 5 presenting the conclusions.

2. *Methods*

2.1 *Research design*

Following the aim of the study, the primary research question was: ‘Which factors have the most influence on the completion of megaprojects in Colombia?’ Both the research question and the aim fit into the hermeneutic understanding category of research purpose (see Willis, 2007) and lend themselves to the application of a qualitative enquiry approach with interpretive epistemology and necessitate the use of a descriptive conceptual framework that links to the research objectives.

The present study employed the theoretical underpinning of management of projects (MoP) advocated by Morris (1994), which places greater emphasis on the project definition phase. This is as opposed to the project management approach, widely attributed to Cleland

and King (1968), which rely on the tools and techniques approach to project management. The MoP Framework, developed from the work of Morris (2013) by Pinto and Winch (2015), indicates that successful delivery is dependent on critical organisational capabilities in the major functions – including strategy and finance, technology, commercial arrangements and the alignment of people and structures. It further shows that success in the project delivery (the execution) phase requires more than the management of *time, cost and quality* – the three traditional criteria for measuring the execution phase of a project; rather it also requires the management of *integration, human resources, communication and procurement*.

Considering the first objective of the study, the authors reviewed literature sources to identify a suitable definition for ‘critical success factors’ (CSFs). The review of literature indicated that while many definitions of the term are available, especially as it has found application in many disciplines, the definitions that relate to projects mostly conform to the project management approach. Nonetheless, the search indicated that the core of the definitions was consistent across disciplines. Examples of the definitions considered relevant to this study include Baccarini and Collins (2003), who described CSFs as a set of circumstances, facts or influences which contribute to the outcome of a project; Howsawi et al. (2014), who defined it as the factors that can contribute and influence the success of a project; and Alias et al. (2014), who defined it as the conditions or variables that can lead to the success of a project. However, considering the MoP theoretical underpinning of this study, the present authors define CSFs as *the factors that can significantly influence the success of the delivery of megaprojects in the entire project lifecycle, from project definition to successful handover*.

The descriptive conceptual framework comprised four elements, to: i) identify the factors contributing to time and cost overruns on megaprojects; ii) rank the identified factors from the perspective of stakeholders who have been involved in the delivery of megaprojects in Colombia; iii) confirm the ranking of the factors; and iv) provide recommendations for future experiences. Consistent with Denzin (1970), a mixed research method was deemed most appropriate and the explanatory method (see Creswell, 2003), which involved a sequential quantitative and qualitative data collection process, was applied.

The methodology adopted is presented retrospectively in Sections 2.2 to 2.6, below.

2.2 Identification of the factors investigated

Considering the availability of sufficient, credible and reliable information in the literature, the study identified the factors investigated from secondary sources – including academic literature, published reports, online sources and grey literature, which comprised government publications and reports, newsletters, working papers, technical reports and conference proceedings. From this process, 126 factors were identified; however, further analysis of the taxonomy showed some to be synonyms and interchangeable, while others were a mixture of features embedded within the functional and descriptive categories. For example, Anderson et al. (2006) listed *market conditions* and the *effect of inflation* as separate factors, while the present authors argue that the latter is a consequence of the former. Thus, the factors were reclassified using a four-stage linear process that involved identification, functional aggregation, labelling and domiciliation, where ‘domiciliation’ refers to the location of each factor in line with the observation of Sanvido et al. (1992) that success factors can be internal

or external. Consequently, the 126 factors were reclassified into 34 and grouped into nine categories based on the predominant themes through which they could be meaningfully organised, interpreted and presented. Although corruption was among the factors identified in the literature, the authors deliberately did not include it among the factors surveyed because it was perceived that questions on corruption might cause the respondents to be less responsive to the survey.

Table 2 presents the factors, their categories and locations where only the unique factors are numbered for ease of reference, but the order of appearance and numbering does not confer any level of influence at this time. An in-depth look at these factors suggested that they may apply to projects irrespective of size, scope, cost, duration of execution or any other project features. This potentially makes the findings of this study of more general application.

2.3 Study sample

As noted by Maylor and Blackmon (2005), population sampling for the purpose of qualitative research designs should be characterised and represented by concepts of gaining deeper knowledge and understanding of the study groups' perceptions of the subject of research. Hence, a non-probability (purposive) sampling method was considered most appropriate among the wide range of sampling techniques identified in the literature sources. In particular, the homogeneous sampling method was deemed most suitable and was selected as the study was not a test of a hypothetical generalisation and did not intend to seek relationships that may establish scientific laws. In addition, the research question was specific to the characteristics of the particular group of interest and the method achieves a sample whose units share the same

or close characteristics or traits: in this instance, construction professionals who have been involved in megaprojects. Hence, the homogeneous criterion used was involvement at a senior level in megaprojects in Colombia.

The participants were identified through a formal and an informal process. The formal process was the principal avenue for the identification of participants, as it generated nearly 90% of the study sample. It involved a request for participation to the 124 key personnel of the construction companies involved in megaprojects in the country. The informal process involved the use of social media platforms, mainly LinkedIn and Facebook, to identify professionals who might have had experiences with the delivery of megaprojects in the country; this process identified 13 professionals. Overall, these processes yielded 137 professionals, who constituted the study sample. The profiles of the eventual participants are presented and discussed in Section 3.

2.4 Questionnaire design

The design of the questionnaire involved conceptualisation, testing and revision. The conceptualisation was an iterative process that focused on clarity of the question, selection of appropriate scales of measurement and matching to analytical methods. Testing comprised an independent review of the questionnaire to assess the extent to which it was viewed as covering the concept it purported to measure ('face validity') and the degree to which it measured the variables intended ('construct validity'). Testing also included a pilot test which employed the test-retest reliability field-test method. The revision stage involved modification of both the form and content of questions based on the feedback received from the pilot sample.

BOS online survey tool was used to design the questionnaire, and this used a combination of categorical and rating questions. The categorical questions aided the identification of the respondents and were measured by nominal scales that enabled demographic analysis. The rating questions allowed participants to compare the variables based on a unipolar ordinal scale that measured the severity of the influence of the factors investigated.

Considering the second objective of the study, the authors observe that the distinction between ranking and rating questions is that rating allows for qualitative classification of variables but cannot quantify, while ranking measures and orders relative quality represented by the variables but does not necessarily represent equal intervals. Rating thus allows for comparison of a variable to itself on a scale, while ranking uses ipsative measures that force respondents to relatively order the variables under investigation.

It should be noted that this study did not employ ranking questions because of the large number of variables studied (34), but instead derived the ranking from the rating of the participants. Table 3 shows the composition, objective, type and measurement scale for each question.

2.5 Data collection

As stated in Section 2.1, data collection took place in two sequential stages. First, data was collected through questionnaires and second, data was collected using semi-structured interviews among the most experienced respondents.

The questionnaire was distributed to study participants electronically in English and Spanish, via email, LinkedIn and Facebook; this method lowered the cost of survey

administration and guaranteed prompt delivery and receipt. In addition, it eliminated geographical limitations at times when the researchers were not physically present in Colombia. The questionnaire included an information sheet on the study purpose and the contact details for any question or additional information the respondent might require. The respondents had four weeks to complete and return the survey.

The interview method was chosen for the second stage and was designed as a validation process for the findings of first stage. This is because the interview method offers confidentiality, which was considered crucial as it was anticipated that data might include information on potentially sensitive project-specific issues. The person-to-person semi-structured form of interview was used because of its flexibility and the opportunity it presents to the researcher to probe for more in-depth insights from the narratives of the respondent and to seek information that may not have been previously anticipated. The study addressed the main limitations of the method – which include the possibility of implicit and explicit bias, the potential inability of the interviewee to accurately recall specific details of events, and the possible imposition of preconceived ideas – through enquiries and the application of the principles of consistency (cross-checking each interviewee's testimony with other participants) and verifiability (cross-checking each interviewee's testimony with available public documents). Each interview lasted an average of one hour, and was tape recorded and subsequently transcribed. The interview plan included the ten secondary, broad, open-ended questions derived from the analysis of the questionnaires. Each interview was analysed before the subsequent one, and this allowed for the application of emerging insights

in subsequent interviews.

2.6 Data analysis

Analysis of the data generated through the survey employed the use of descriptive statistics, including a set of percentages and measures of central tendency, as the variables measured were nominal and ordinal data and did not support the use of parametric analysis as the measurement scales allow for qualitative classification of variables only (they cannot quantify). For ease of analysis, the world labels on the unipolar ordinal scale were assigned scores as follows Minimum Influence = 1, Medium Influence = 2, Strong Influence = 3, and Extreme Influence=4. The assigned numbers are ordinal and were used strictly for qualitative classification of variables only (they could not quantify). Nonetheless, this enabled the application of the ‘mean score’ – MS, which conveys no statistical meaning, as the measurement scale is ordinal – to rank the factors.

$$\text{Here, MS} = \frac{\sum (f \times S)}{N} \quad (1 \leq \text{MS} \leq 4)$$

where f, s and N represent the frequency of responses, respondents’ score for each factor and the total number of responses, respectively.

This method has been used in similar studies, such as Chan and Kumaraswamy (1996), and is one of the most appropriate methods available for the analysis of ordinal data derived from rating questions. It is important to note that inferential statistical methods – such as the Chi square test for independence, the McNemar change test, the Wilcoxon matched-pairs signed-ranks test, the intra-class correlation coefficient, kappa statistics, Spearman’s rank-order

correlation coefficient, Kendall's W coefficient of concordance, t-statistics and F-tests – are not applicable to ordinal-scaled variables. It is also generally accepted that parametric statistics are applicable to interval and ratio data that conform to a normal distribution (see Riley et al., 2000). Hence, consensus measurement for rating questions fits to the use of qualitative analysis and descriptive statistics. Prominent statistical analyses for ranking questions are measures of central tendency, rank order correlation, frequency distributions and non-parametric analysis of variance (see Hill and Fowles, 1975; and Hasson et. al., 2000). There are three significance tests for cases involving more than two dependent samples, namely: the Friedman test (also known as the Friedman two-way analysis of variance), which is the significance test for more than two dependent samples and is used to test that there is no significant difference between the size of a dependent sample and the population from which it is drawn; Kendall's coefficient of concordance (W) test, which is a measure of the agreement among several judges who are assessing a given set of objects; and Cochran's Q test, which is used to test whether or not the part of a given variable is the same across multiple dependent samples.

This study did not employ ranking questions because of the large number of variables studied (34), but instead derived the ranking from the rating of the participants.

The analysis of the data collected using semi-structured interviews involved hermeneutics analysis premised on the theory of interpretation and achieving an understanding of texts and utterances, as described by Patterson and Williams (2002, pp.47–49). This method allows themes to emerge from data and promotes a holistic understanding. It also shows the inter-relationships among themes, while at the same time enabling individual themes to retain

rich characteristics. The data analyses were conducted at the individual level (idiographic) and across individuals (nomothetic).

3. Results and discussion

3.1 Quantitative survey

Fifty-three responses were received out of the 137 questionnaires distributed, but only 48 responses were valid. This represented an effective response rate of 35% and was within the anticipated range (see Callegaro et al., 2015). The distribution of the respondents, shown in Table 4, is expressed as percentages only to gain an understanding and not to make statistical inferences. As seen in the table, a majority (64%) of the respondents had over four years' experience with megaprojects, and this offers an advantage for the quality of data – especially as megaprojects are recent in Colombia and thus four years' experience is contextually significant. In addition, the nearly 20% of respondents that came from the planning, design and engineering professions was considered a great advantage, as megaprojects in Colombia have been awarded to international companies who have undertaken the early stages of the projects outside of Colombia. For example, the contractor for the Reficar Modernization and Expansion Project conducted detailed engineering and procurement out of Houston, USA. Furthermore, this explains why nearly 75% of respondents were site supervisors, control officers or allied professionals.

Although the distribution of the respondents was skewed to oil and gas, both the response rate and the distribution of respondents satisfied the goal of the study as the response rate was within the anticipated range and the participants broadly represented the purposive sample

given that two of the three operational megaprojects in the country are in the oil and gas sector. The likely impact of the respondents' profiles is discussed in Section 3.3, while the results are presented in a table format in Tables 5 to 8 and discussed in this section and Section 3.2.

As shown in Table 5, most of the respondents' opinions fall within two adjacent points, suggesting a convergence of views. This further indicates that the factors ranked as 1 in every category recorded a mean score greater than 3, indicating that each of the categories investigated has a 'Strong Influence' on the delivery of megaprojects. Table 5 indicates that *design changes* during the construction phase and the *availability of materials* jointly ranked as the most critical success factors, each with a mean score of 3.44 and with nearly all the respondents' opinions (92%) falling on the adjacent points of 'Strong Influence' and 'Extreme Influence' on the measurement scale.

As seen in Table 6, among the 34 factors investigated, 29 recorded a mean score greater than 3, suggesting that these factors have 'Strong Influence', while others recorded mean scores that were between 2.67 and 2.92, indicating 'Medium Influence'.

Whereas the top-five factors fall into only three categories, four of the bottom five are in the *project characteristics* category, which – as seen in Table 7 – is the only category with a mean score less than 3.

As seen in Table 8, there are six internal factors exclusive to the *planning* phase among which *adequacy of tender information* and *realistic cost estimates*, which both had overall ranks of 5 and 6 respectively, have the top-two ranks while *appropriate risk assessment* had the lowest rank. Nonetheless, all six factors have a mean score between 3.21 and 3.40, suggesting

that these factors have ‘Strong Influence’. All the factors exclusive to the *execution* phase comprising of nine internal and 3 external factors have ‘Strong Influence’ as they recorded a mean score range of 3.44 to 3.04, with *design changes* during construction, an internal factor jointly ranked as number 1 along with *availability of materials*, an external factor. Eight internal factors are common to both the *planning* and the *execution* phases and, among them, *management strategy*, with an overall rank of 3, has the top rank. This result suggests that the *management strategy* is critical in both phases of a megaproject and supports the MoP Framework developed by Pinto and Winch (2015).

Based on our reclassification, there is no strict external factor in the *planning* phase. However, there are three in the *execution* phase and eight that are common to both the *planning* and *execution* phases. The *availability of materials*, with a joint overall rank of 1, has the topmost rank – suggesting that both internal and external factors have a significant influence on project delivery. The two factors that are present both internally and externally are also common in both the *planning* and *execution* phases. These factors, *availability of skilled labour* and *transparency and trust*, both recorded a mean score greater than 3, which suggests that they both have a Strong Influence.

The results of the quantitative survey suggest that the *technical competence* and the *managerial ability* of the project leadership team, as well as the *organisation stability*, rather than the physical attributes and conditions of a megaproject, have a higher level of influence on successful delivery. These findings are supported by Lopez and Shane (2014), who identified early agreement with the community and local authorities, identification of the cultural and

socio-political circumstances and public outreach efforts as the key factors for the success of the Highway Durango-Mazatlan Projects (Mexico); and Hauswirth et al. (2004), who observed that earlier planning, procurement strategies, the involvement of the community and authorities in the feasibility phase, and a constant information update on the construction process were important factors in the delivery of the Transportation Expansion Project: T-REX (US) project, which took place two years earlier and within budget. The findings are further supported by the observation of Jergeas and Ruwanpura (2010) that the Alberta Mega Oil Sands Projects recorded both cost and time overruns due to an underestimation of the complexity, unrealistic schedules and budget, misaligned project management, misdirected execution, and weak interaction between the planning, budgeting and operations processes. Contrary to the observation by Haidar and Ellis (2010) that the long duration of megaprojects increases complexity and the possibility of variations in social, political, economic, technologic and environmental aspects surrounding the project, the *duration* of the project ranked last.

3.2 *Semi-structured interviews*

Three interviews that that formed the empirical text for analysis were conducted with senior professionals who were involved in the project control, construction management and project management of the Reficar Modernization and Expansion (oil and gas), Ituango Hydro (power generation) and Ruta del Sol Highway projects respectively. These interviews were designed to validate the findings of the survey, especially the relative importance of the success factors. As stated in Section 2.5, the interview plan included the ten secondary, broad, open-ended questions derived from the analysis of the questionnaires. These were: (1) Which three factors

were the most critical for delivering the megaproject you were involved with? (2) Are there factors that are not listed in the 34 investigated, but which you consider critical? (3) Does the result of the study reflect your opinion on the ranking of the CSFs? (4) Both design changes during construction and availability of materials jointly ranked first in the analysis; how do you rank these two? (5) Which party predominantly causes the design changes during the construction phase? (6) How can design changes be better controlled? (7) What are the specific concerns with transparency? (8) What are the project complexities in the context of projects in Columbia? (9) Were there any unintended consequences that occurred on the projects you were involved with? and (10) Were there any major external occurrences that interfered with the success of the project you were involved with?

Each interview was analysed before the subsequent interview in order to apply emerging insight, and to cross-check the interviewee's testimony with previous interviews and public documents for consistency and verifiability. Where necessary, follow-up interviews were conducted via telephone. The interviewers were presented with the survey results after answering the first question (1). This eliminated the possibility of bias and enabled confirmation of the results. For a proper contextual understanding of the narratives of the interviewees, the authors note that they were involved with projects that experienced both time and cost overruns. Analysis showed that the views expressed by the respondents were consistent with the results of the survey.

When asked which three factors were the most critical for delivering the megaproject they were involved with, the first respondent identified inadequate planning at the earlier

stages and incomplete information from the client; the second respondent identified lack of a good relationships between stakeholders and inadequate quality and experience on the part of both the project team and subcontractors; while the third respondent mentioned inadequate information at the tender stage and too many changes in the design and specifications. These findings align with Miller and Hobbs (2009), who noted that proper planning at the start of the project, which recognises and takes into consideration potential turbulence, could align projects with organisational strategy, especially when the project is being undertaken by a heterogeneous entity. On further enquiry, the first respondent confirmed that inadequate planning during the early stages reflected poor *management strategy* at the planning phase. Analysis revealed the factors stated by the interviewees to be in the top five of the ranks from the results of the quantitative survey. This outcome is supported by the World Bank (1996), which concluded that projects with adequate or better identification, preparation and appraisal had an 80% success rate, against 25% for projects that were deficient in all these aspects, and that thoroughness during the planning phase had a significantly higher influence on project success than key country macroeconomic variables, external factors or government considerations.

When presented with the outcome of the quantitative survey and asked if it reflected their views, the three respondents unanimously answered in the affirmative. They opined that a lack of information in the early stages of a project is linked to design changes during the construction phase. They expressed the view that changes in technology, unanticipated changes in regulation, stakeholder demands and considerations, difficulty in the actualisation of the

original design based on engineering complexities and/or cost considerations, and ‘scope creep’ were among the key factors that necessitated design changes, and that the availability of materials and their supply had an extreme influence on a project’s success. When asked specifically which of the factors investigated had the greatest impact on cost, each of the respondents identified the same three issues: clarity and completeness of the scope of work at the tender stage, a realistic budget and appropriate cost control.

Although the questionnaire deliberately excluded corruption, the interviewees identified this as an endemic and intractable hazard that cut across the fabric of the society and which may be difficult to eliminate. They thus recommended that appropriate government authorities must act to control corruption. In addition, the interviewees suggested the need for adequate control and early and timely supervision by relevant government agencies, including the use of auditable planning procedures as a tool to prevent unwarranted claims by the contractor at any time in the project life cycle, but particularly after project completion, and also to ensure early engagement and accuracy of the cost and schedule. They further expressed the view that risk analysis must start at the planning phase and project risks must be shared transparently and responsibly among key parties at every stage. They unanimously agreed that a multi-disciplinary project management team had a better chance of delivering a project successfully than one that solely comprised engineering experts.

While *transparency and trust* were seen to be a challenge from the accounts of the interviewees, corruption also emerged as a key contributory factor to the delay and cost overruns of megaprojects in the country. Nonetheless, the authors note that this might not be

peculiar to Colombia, as Ahmed and Othman (2013) observed that megaprojects tend to be associated with issues related to corruption because of their large scale, the number of stakeholders, different interests in the economic, political and social environments, and because of their duration. Furthermore, Kenny (2007) noted that the complexity of the construction industry, non-standard production processes and the close relationships between government and other stakeholders are some of the factors that contribute to corruption in construction.

Research participants in the present case identified key complexities specific to Colombia as being the protracted time for rights of way acquisition, delays in environmental licensing and difficulties in securing financing. While recent changes in legislation through the passage of Law No. 1,682 in 2013 were intended to facilitate and expedite the land acquisition process, the reallocation of utilities and speedy environmental licensing, difficulties in attracting financing remain as only 6 out of 30 concessions awarded by the Colombian government since 2013 have been able to secure financing and have advanced to the construction phase (See S&P Global, 2017). These findings and ongoing complexities bring to the fore the issue of the governance regime. Miller and Hobbs (2005) highlighted the design criteria that should be brought to bear when developing a governance regime for a megaproject and these are consistent with the outcomes of the studies on the Highway Durango–Mazatlan projects and T-REX (US) megaprojects.

Overall, the interviews fulfilled the intended objective as they enabled confirmation of the results of the quantitative survey.

3.3 Research limitations

Whereas the quality of responses – rather than the number of participants – is the true measure of the outcome of qualitative research, the dominance of the oil and gas sector in the demography of respondents was a limitation. Nonetheless, this situation did not have any adverse effects on either the quality of the data or the outcome of the analysis, which did not call for the expert panel to comprise representative samples for statistical purposes. However, it was possible that certain factors such as personal bias that could not be controlled for by the researchers influenced some of the views expressed. Moreover, unlike experimental studies or studies conducted with control groups in a laboratory, all the subjects who participated in this research were susceptible to external stimuli from diverse sources outside the control of the researchers.

4. Conclusion

While cost or time overruns or substandard quality outcomes are not desirable in a project, they become more troubling with megaprojects where delays and cost escalations may have far-reaching effects beyond the reputational risk for the companies involved, maybe threatening the socio-economic, technical, environmental and political systems of the contracting principal. This research aimed at understanding the challenges encountered in delivering megaprojects in Colombia – from the project definition stage to successful handover – with a view to providing industry practitioners in the country with the ability to be more effective and efficient in the management of future megaprojects.

While 29 of the factors investigated had a ‘Strong Influence’ on the success of megaprojects, the study found that an internal factor, *‘design changes during construction’*, and an external factor, *‘availability of materials’*, both recorded the same rank – suggesting that both internal and external factors have a significant influence on project delivery. Overall, the five most critical factors were found to be: *‘design changes during construction’*, *‘availability of materials’*, *‘appropriateness of management strategy’*, *‘competence and experience of the project management team’* and *‘adequacy of information in the tender stage’*. Among these, two pairs of factors relate to the scope of work and the project management categories, while one relates to procurement.

In contrast, the results indicated that factors related to project characteristics have less influence because they are part of the project and, subsequently, must be managed to minimise their impact from the early stages of projects. For that reason, factors such as *manager experience*, *management strategy* and *appropriate risk assessment* present a higher level of influence considering that they will have the responsibility to control and mitigate the influence of factors with less influence.

A transparent project definition stage – particularly the sharing of available information on project risk among all parties, provision of complete and clear information about the scope of work, proper coordination between the key stakeholders, and the institution of auditable planning procedures – will reduce project complexity and allow the development of realistic schedules and budgets. This in turn will potentially translate into better performance in project execution.

To have a better chance of successfully delivering a megaproject, the project management leadership team must be multi-disciplinary, with expertise in areas such as finance, stakeholder management, integration, human resources management, communication and procurement.

While the present study did not examine the impact of corruption comprehensively, it confirmed the results of previous research, which indicate the importance of addressing corruption. However, to avoid claims and counter claims in future projects, and as seen with the Reficar Modernization and Expansion Project, relevant government agencies must take adequate control and provide early and timely supervision to prevent unwarranted claims by either party at any time. In addition, risk analysis must start at the planning phase and project risks must be shared transparently and responsibly at every stage.

Although the research involved professionals working on megaprojects in Colombia, the variables investigated are of general application to other projects. Hence, the outcome may be of general application by project management professionals, especially where the country dynamics are similar.

Finally, the research demonstrated the application of an appropriate analytical approach to qualitative data as outlined in the aims, in part to highlight the misnomer in some earlier studies that examined critical success factors in specific countries where inferential statistics and non-parametric statistics were wrongly applied to nominal and ordinal data.

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Table 1. Key megaprojects in Colombia

Project Name	Sector	Initial cost estimate (million US\$)	Year of completion –Stage
El Dorado II International Airport	Airport	1,000	2021 – Early design
Magdalena River Navigation Project	Canal	2,500	TBD – Early design
Ituango Hydro	Electric power	5,500	2019 – Construction
Ruta del Sol Highway Sector 2	Highway	1,896	2017 – Construction
Meta Highway Network	Highway	1,355	2020 – Construction
Pacifico Highway 1	Highway	1,100	2020 – Construction
Canafisto Hydro Plant	Hydroelectric	5,000	2020 – EIA**
Porce III Hydro Plant	Hydroelectric	1,330*	2011 – Operational
El Quimbo Hydro	Hydroelectric	1,231	2015 – Post construction
Porce IV Hydro Plant	Hydroelectric	1,100	2015 – Construction
Bogota Metro Line No. 1	Metro	7,500	2022 – Early design
Reficar Modernization and Expansion Project	Oil & Gas	8,016*	2016 – Operational
Pacific Pipeline (OAP)	Oil & Gas	5,000	2018 – EIA**
Oluoducto Bicentenario Pipeline Phases 2 & 3	Oil & Gas	4,300	TBD – Early design
Barrancabermeja Refinery Modernization	Oil & Gas	3,390	2017 – Construction
Phase 1 Oleoducto Bicentenario Pipeline	Oil & Gas	1,600*	2013 – Operational
Carare Railway Network	Rail	1,536	TBD – Early design
Bogota Light Rail	Rail	1,145	2019 – Early design
Darien International Port	Sea Port	1,000	TBD – Early design

Data source: BNamericas (2016), available at: <<https://www.bnamericas.com/en/project-profile>>

* Final cost estimate, but not including financing cost

** EIA – Environmental Impact Assessment

Table 2. Critical success factors investigated

Category	Location	Factors in the planning phase (project definition)	Factors in the execution phase (project delivery)
1. Project characteristics	External	1. Adverse weather conditions 2. Project location 3. Project type 4. Nature of stakeholders 5. Duration	Appropriate weather conditions Project location Project type Nature of stakeholders Duration
2. Scope of work	Internal	6. Clear scope of work 7. Adequacy of tender information	23. Design changes during construction
3. Planning and scheduling	Internal	8. Realistic work schedule 9. Appropriate risk assessment	24. Periodic update of work schedule
4. Cost management	Internal	10. Realistic cost estimates	25. Regular budget update 26. Cost control
5. Stakeholder relationship and communication	Internal and external	11. Transparency and trust 12. Collaboration	Transparency and trust collaboration
	Internal	13. Timely and adequate communication	Timely and adequate communication
	External		27. Ability of client to manage the main contractor
6. Procurement	Internal	14. Proper procurement scheduling	
	External		28. Availability of materials 29. Reliability of supplier

7. Project management	Internal	15. Management strategy	Management strategy
		16. Competence and experience	Competence and experience
		17. Support of top management	Support of top management
		18. Clear organisation structure	Clear organisation structure
8. Construction process	Internal	30. Sub-construction and supplier management	Sub-construction and supplier management
		31. Site management and supervision	Site management and supervision
		32. Control of site resources	Control of site resources
		33. Coordination and communication	Coordination and communication
9. Labour	Internal	34. Method of construction	Method of construction
		19. Labour productivity	Labour productivity
		20. Availability of skilled labour	Availability of skilled labour
	External	21. Relevance of prior experience	Relevance of prior experience
		22. Availability of skilled labour	Availability of skilled labour

Table 3. Characteristics of the questions in the survey

Round 1	Objective	Type	Scale
Q1. Please select the total cost range of the largest megaproject in which you have participated?	Identification	Categorical	Nominal list of cost ranging from US\$1 billion to US\$8 billion and above
Q2. In which sector was the project?	Identification	Categorical	Nominal list of the sectors including industrial processes, transportation, building, oil and gas, and the environment
Q3. How many years of experience do you have in megaprojects?	Identification	Rating	Ordinal scale of years in bands comprising 1–4 years, 5–10 years, 11–20 years and more than 20 years
Q4. What was your role on the project?	Identification	Categorical	Nominal list of functions
Q5. Please indicate your opinion about the level of influence of the 34 factors listed in the nine categories below based on your perception of how they might be critical to the success of megaprojects.	Validation	Rating	Ordinal unipolar comprising four labels as follows: ‘Minimum Influence’, ‘Medium Influence’, ‘Strong Influence’ and ‘Extreme Influence’

Table 4. Distribution of respondents by years of experience, project cost, field of expertise and industry

Description	Number or respondents	Proportion to total number of respondents
1–4 years' experience with megaprojects	22	46%
4–10 years' experience with megaprojects	21	44%
10–20 years' experience with megaprojects	4	8%
> 20 years' experience with megaprojects	1	2%
	48	100%
Cost of project less than US\$4 billion	5	13%
Cost of project between US\$4 and 6 billion	11	23%
Cost of project between US\$6 and 8 billion	12	25%
Cost of project more than US\$8 billion	20	40%
	48	100%
Site supervision professionals	12	25%
Other professionals	11	23%
Project control professionals	11	23%
Planning professionals	5	11%
Design and engineering professionals	4	8%
Safety professionals	3	6%
Project management professionals	2	4%
	48	100%
Megaproject experience in oil and gas industry	43	89.6%
Megaproject experience in transportation	3	6.3%
Megaproject experience in industrial processes	2	4.2%
	48	100%

Table 5. Respondents views and relative ranking of critical success factors

Category	Factor	Score				Mean score	Relative rank
		1	2	3	4		
Project characteristics	Number of stakeholders involved	1	8	25	14	3.08	1
	Type of project	6	8	19	15	2.90	2
	Adverse weather conditions	1	16	21	10	2.83	3
	Location of the project	4	15	20	9	2.71	4
	Duration of the project	9	11	15	13	2.67	5
Scope of work	Design changes during construction	0	4	19	25	3.44	1
	Lack of information at the tender stage	2	4	15	27	3.40	2
	Clear scope of work	1	9	16	22	3.23	3
Planning and scheduling	Realistic work schedule	0	8	20	20	3.25	1
	Appropriate risk assessment	1	6	23	18	3.21	2
	Periodic schedule update	1	7	23	17	3.17	3
Cost management	Realistic estimates	1	2	23	22	3.38	1
	Regular budget update	2	3	22	21	3.29	2
	Cost control	1	4	24	19	3.27	3
Stakeholder relationship and communication	Competence to manage contractor	2	6	15	25	3.31	1
	Communication between parties	1	8	19	20	3.21	2
	Collaboration	0	9	20	19	3.21	3
	Transparency and trust	2	8	19	19	3.15	4
Procurement	Availability of materials	0	5	17	26	3.44	1
	Proper procurement scheduling	0	7	19	22	3.31	2
	Reliability of supplier	0	11	20	17	3.13	3
Project management	Management strategy	0	3	22	23	3.42	1
	Competence and experience	0	5	18	25	3.42	2
	Subcontractors and supplier management	0	5	24	19	3.29	3
	Support of top management	0	10	20	18	3.17	4
	Clear organisation structure	0	9	23	16	3.15	5
Construction process	Site management and supervision	2	4	18	24	3.33	1
	Coordination and communication	0	7	21	20	3.27	2
	Control of site resources	1	5	24	18	3.23	3
	Method of construction	1	8	27	12	3.04	4
Labour	Labour productivity	0	6	19	23	3.35	1
	Availability of skilled labour	0	6	27	15	3.19	2
	Motivation	0	11	26	11	3.00	3
	Experience	1	11	23	12	2.92	4

Table 6. Rank order of the critical success factors

Factor	Category	Mean Score	Relative rank
1. Design changes during construction	Scope of work	3.44	1
2. Availability of materials	Procurement	3.44	1
3. Management strategy	Project management	3.42	3
4. Competence and experience	Project management	3.42	3
5. Adequacy of tender information	Scope of work	3.40	5
6. Realistic estimates	Cost management	3.38	6
7. Labour productivity	Labour	3.35	7
8. Site management and supervision	Construction process	3.33	8
9. Competence to manage contractor	Stakeholder relationship management	3.31	9
10. Proper procurement scheduling	Procurement	3.31	9
11. Regular budget update	Cost management	3.29	11
12. Subcontractors and supplier management	Project management	3.29	11
13. Cost control	Cost management	3.27	13
14. Coordination and communication	Construction process	3.27	13
15. Realistic work schedule	Planning and scheduling	3.25	15
16. Clear scope of work	Scope of work	3.23	16
17. Control of site resources	Construction process	3.23	16
18. Appropriate risk assessment	Planning and scheduling	3.21	18
19. Timely and adequate communication	Stakeholder relationship management	3.21	18
20. Collaboration	Stakeholder relationship management	3.21	18
21. Availability of skilled labour	Labour	3.19	21
22. Periodic schedule update	Planning and scheduling	3.17	22
23. Support of top management	Project management	3.17	22
24. Transparency and trust	Stakeholder relationship management	3.15	24
25. Clear organisation structure	Project management	3.15	24
26. Reliability of supplier	Procurement	3.13	26
27. Nature of stakeholders involved	Project characteristics	3.08	27
28. Method of construction	Construction process	3.04	28
29. Motivation	Labour	3.00	29
30. Experience	Labour	2.92	30
31. Type of project	Project characteristics	2.90	31
32. Adverse weather conditions	Project characteristics	2.83	32
33. Location of the project	Project characteristics	2.71	33
34. Duration of the project	Project characteristics	2.67	34

Table 7. Ranking of the nine categories of factors investigated

Category of critical success factors (CSFs)	Mean score	Rank
Scope of work	3.36	1
Cost Management	3.31	2
Procurement	3.29	3
Project management	3.29	4
Stakeholder relationship and communication	3.22	5
Construction process	3.22	6
Planning and scheduling	3.21	7
Labour	3.12	8
Project characteristics	2.84	9

Table 8. Results of CSF ranking along the dimensions of location, category and life cycle

Location	Categorisation of factor	Factors in the planning phase only	Mean score	Rank	Factors in the execution phase only	Mean score	Rank	Factors common to planning and delivery phases	Mean score	Rank
Internal only	Scope of work	Clear scope of work	3.23	16	Design changes during construction	3.44	1			
		Adequacy of tender information	3.40	5						
	Planning and scheduling	Realistic work schedule	3.25	15	Periodic update of work schedule	3.17	22			
		Appropriate risk assessment	3.21	18						
	Cost management	Realistic cost estimates	3.38	6	Regular budget update	3.29	11			
					Cost control	3.27	13			
	Stakeholder relationship and communication							Timely and adequate communication	3.21	18
	Procurement	Proper procurement scheduling	3.31	9						
	Project management				Sub-construction and supplier management	3.29	11	Management strategy	3.42	3
								Competence and	3.42	3

		experience			
		Support of top management	3.17	22	
		Clear organisation structure	3.15	24	
Construction process	Site management and supervision	3.33	8		
	Control of site resources	3.23	16		
	Coordination and communication	3.27	13		
	Method of construction	3.04	28		
Labour	Labour productivity	3.35	7		
	Relevance of prior experience	2.92	30		
	Motivation	3.00	29		
External only	Project characteristics	Adverse weather conditions	2.83	32	
		Project location	2.71	33	
		Project type	2.90	31	
		Nature of stakeholders	3.08	27	
		Project duration	2.67	34	
Procurement	Availability of materials	3.44	1		
	Reliability of supplier	3.13	26		
Stakeholder relationship and communication	Ability of client to manage main contractor	3.31	9		
	Collaboration	3.21	18		

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Internal and external	Labour	Availability of skilled labour	3.19	21
	Stakeholder relationship and communication	Transparency and trust	3.15	24