Investigating risk of bridge construction project: exploring Suramadu strait-crossing cable-stayed bridge in Indonesia

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Abstract

Purpose – The complexities in strait-crossing cable-stayed bridge project are increasing the risks. This study aims to identify and analyze the significant and worth-considered construction risks of the first, biggest and longest spanned strait-crossing bridge project in Indonesia.

Design/methodology/approach – As many as 32 risk events were identified and determined as the risks that exist and can be represented in the Suramadu bridge project context. Data was collected through a design-based questionnaire disseminated to experts involved in the project as well as semi-formal interviews. Several quantitative methods were applied to analyze the significant risks, such as relative importance index, Spearman's rank correlation test and Mann–Whitney U test.

Findings – The analyses reveal that "unexpected natural behavior" confirmed by both contractor and consultant parties is the most significant and crucial risk event. Another risk event found to be significant is the "delayed payment." On the other hand, it is also found that several risks within the legal category are found to be less significant compared to other major risk events.

Research limitations/implications – The results of the present research should be interpreted in the context of several limitations. Given these possible concerns regarding the generalizability of the findings, along with the relatively low rate of participants in the current research, additional studies are needed to provide a more complete picture of stakeholder perceptions who are involved directly in the construction environment as well as to identify more construction risks specifically in the large-scale bridge project.

Practical implications – This study has provided fundamental contributions to the body of knowledge and practical implication to promote and assist decision-makers toward developing a comprehensive risk assessment of a large-scale bridge project.

Originality/value – The analyses of outcomes and discussion, as well as the findings of this research, have shed light on the construction risks understanding, which contributes to delivering a theoretical framework for achieving large-scale bridge project success.

Keywords Project management, Infrastructure, Risk analysis, Megaproject, Construction project, Suramadu bridge

Paper type Case study

Introduction

Public infrastructure such as bridge plays a significant role as the backbone of society. A bridge refers to an engineering structure that is constructed to maintain the functions of

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railroads, roads and waterways. Not to mention, bridge structure also supports and provides modern society needs and services, respectively. In fact, a bridge is essential to enable, sustain and enhance community living conditions and economic stability. Accordingly, regardless of being funded by the public or private institution, the development of bridge in various sectors is rapid in every country.

To meet current modern and vast society demand, the longer span bridge projects are increasingly constructed worldwide. The construction of a long-span bridge is considered enormously complex, a daunting task and as a risky business. The complexity arises from its project scale, "technical structures" cost and the involvement of many contracting parties such as owners, designers, contractors, subcontractors and suppliers. Further, the complexity also emerges from the internal project team that is assembled from different countries, companies and cultures.

This leads to the understanding that the bridge project requires larger and long-term financing scheme with various stakeholders involved and influenced by various aspects. In this way, it is inarguable that the complexities increasing the risks affected the project, particularly within the construction phase. Project risk can be defined as an uncertain event or condition that – if it occurs – has a positive or negative effect on at least one project objective, such as time, cost, scope or quality.

In the view of construction context, construction risks are viewed as unexpected events, which result in a cost overrun or schedule delay (Wang and Chou, 2003). As such, inadequately dealt and mismanaged construction risks have been shown to cause inefficiencies in particular project and make contract relationships adversarial (Andi, 2006; Mousavi *et al.*, 2011). Moreover, the inherent risks exert significant disruption and have negative consequences on project success.

Therefore, achieving large-scale bridge project success is indeed a daunting task. In view of this, the proper strategy to reach bridge project success is to comprehensively identify the most critical risks and thus control them. On that account, this research aims to remedy this knowledge gaps by presenting a risk analysis of bridge project by using the case study of the first, largest and longest strait-crossing bridge project in Indonesia.

It is expected that this research will potentially benefit various stakeholders (e.g. the project owners, contractors, sub-contractors and other stakeholders) involved toward understanding the construction risk of the large-scale bridge project. By then, it is also expected that this research will contribute to the implication for delivering both theoretical framework and practical tools for decision-makers to measure significant construction risks specifically in the large-scale bridge project.

Literature review

According to the Oxford Handbook of megaproject management, megaprojects are large-scale, complex ventures that typically cost $1bn or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational and impact millions of people (Flyvbjerg, 2017). However, $1bn is not a constraint in defining megaprojects. As such, megaproject can also be referred to as the large-scale project which can be defined as a temporary endeavor characterized by large investment commitment, vast complexity and long-lasting impact on the economy, the environment and society (Brookes and Locatelli, 2015).

On the other hand, conventional large-scale delivery is highly problematic with a dismal performance record in terms of actual costs and benefits (Flyvbjerg, 2014). Large-scale projects are challenging, complex and risky, inherent with a large number of personnel, activities, interfaces and interdependencies (Jergeas and Ruwanpura, 2010). Owing to complexities of the construction environment, an increase of size, large resource requirements, long time horizons and exposure to interrelated and pervasive drivers of risk, large-scale projects by their nature are faced with unique risks and tend to stretch available resources to the limit and sometimes beyond during development.

Trying to eliminate all risks in the large-scale project is impractical. Accordingly, effective risk management is to recognize inherent risk events as organizing frames and the extent to which risk analysis provides a window on mitigating the inherent risk and minimizing its impact. For that reason, risk management in the project development process is required to reduce any possible optimism bias and strategic misrepresentation, as a curious paradox exists in which more megaprojects are being proposed despite their consistently poor performance against initial forecasts of budget, schedule and benefits (Flyvbjerg *et al.*, 2003).

Risk in cable-stayed bridge project

Unlike general construction project, large-scale cable-stayed bridge project possesses various risks beyond the normal project. This is because the construction of a large-scale cable-stayed bridge project is characterized by varying degrees of uniqueness and complexity, the active involvement of multiple stakeholders, capital intensiveness, dynamic environments, advance construction technology, uncertain political environment, long production durations and exposure to external environment and weather conditions (Taroun, 2014; Chan *et al.*, 2018; Charkhakan and Heravi, 2018).

In view of this, the bridge project is acknowledged as the most difficult business with high inherent risks and more uncertainties (El-Sayegh, 2008; Tian and Jinlin, 2010). While the construction project of cable-stayed bridge usually happens near or above the sea, constructing cable-stayed bridge in a marine construction environment poses high level of challenge and high risk (Gudmestad, 2013; Chan *et al.*, 2018). First, in marine construction, workers might be exposed to many safety hazards, such as offshore wind, storm, waves, polar low pressures, high temperature and sea-spray icing.

Additionally, in bridge project, marine construction typically involves tasks which are inherently risky, difficult, complex and prone to accidents such as dredging, drilling, pipe laying, buoy laying, dewatering, reclamation/filling, caisson construction and marine viaduct erection (Gudmestad, 2013). Furthermore, frequent thunderstorms, crisscross navigation, airport height restrictions and stringent environmental requirements and standards are examples of the critical challenges of the marine construction (Yeung, 2016).

The cable-stayed bridge structure represents state-of-the-art bridge technology, for which the advance level of engineering effort required to build a cable-stayed bridge versus the general engineering effort required to design the same structure is five-to-one ratio. Acknowledging large-scale cable-stayed bridge construction projects as unpredictable, large scale and complex systems, this research focuses on the analysis of risk events that are difficult to identify and assess prior to their occurrence particularly in the construction project of cable-stayed bridge.

Risk management role in built environment

A robust risk management plays a significant role in supporting and delivering the project success. An alternative approach to project success is to start from the basis of effective risk management. One of the keys to project success is to identify and assess the critical problem including the early identification and management of local and global issues, stewardship of mitigation plans and proper strategies for sharing risks (Jergeas and Ruwanpura, 2010). Hereby, it is undoubtedly clear that risk management is pivotal and plays an important role in the megaproject. Therefore, disregarding appropriate risk management in megaproject leads to the failure of project success delivery.

As such, risk management is a vital, an ongoing and iterative process used to identify possible risks sources during different phases of projects under development (Boateng *et al.*, 2017). It allows parties involved in the project development to recognize the existence and impact of uncertainties in the project and, hence, to consider an appropriate strategy to mitigate their effects in the project. Particularly, a large-scale bridge project demands the arrangement of enormous capital capacity, various natural resources, comprehensive information and technology diffusions, political stability and local community supports and limited project duration within the overall construction process.

There are a number of studies focused on the management of large-scale long-span bridge project during the construction phase. Schexnayder *et al.* (2011) investigated the bridge performance during the Chilean earthquake of 2010. Meanwhile, Lee and Yhim (2011) studied the dynamic behavior of long-span cable-stayed bridges under various wind effects. Kim *et al.* (2018) developed the cost estimation model, which uses case-based seasoning to build the database, which can reflect the character of the railway bridge project.

While there are many studies discussing both the conceptual and technical management as well as the evaluation of bridge performance, nonetheless little attention has been given in the research on construction risk of a large-scale bridge project, especially during the construction phase. For this reason, it is imperative to conduct research to identify, analyze and assess the construction risk of large-scale bridge project during the construction phase. The next subsection will give an overview of the case study used in this research.

Overview of Suramadu bridge project

The Suramadu bridge, also known as the Surabaya–Madura bridge is the first strait-crossing bridge project and has been recognized as the longest cable-stayed bridge in Southeast Asia (Harsaputra *et al.*, 2009). The bridge was built to cross Madura strait to link the Java island with Madura island. The total cost of the project, including connecting roads, has been estimated at Rp 4.5tn (US$445m). Once opened, the 5.4-km Suramadu bridge is considered as the longest strait-crossing cable-stayed bridge in Indonesia.

While Suramadu bridge was built with many purposes, the ultimate goal was to escalate the socioeconomic level of Madura society which was relatively left behind compared to other areas in East Java (Franck, 2005; Harsaputra *et al.*, 2009; Hidayat *et al.*, 2018). The bridge has three spans sections, which are causeway, approach-bridge and main bridge. The causeway bridge has 1,458 m and 1,818 m length for Surabaya and Madura side, respectively. The approach bridge has a length of 672 m both from Madura and Surabaya sides. The main bridge is a cable-stayed bridge with steel-concrete beam and twin cable planes, which are connected to twin tower pylons. The main bridge has three spans with lengths 192 m, 434 m and 192 m (as many as 818 m in total). Figure 1 depicts the Suramadu bridge specific profile.

The detailed design of the Suramadu bridge was created by the Consortium of China Contractor and most of the detail design was also carried out in China. Further, the works design check was conducted in Indonesia by Virama Karya Pty Ltd as a consultant, together with local partner Pattern General Consulting Pty Ltd and foreign partners COWI A/S in Denmark. Suramadu bridge project has been considered as a big milestone for the Indonesian construction industry, as it was the first national and mega construction project attempted by applying international joint venture agreement.

Acknowledging megaprojects as unpredictable, large-scale and complex systems, this research focuses on the analysis of risk events that are difficult to identify and assess prior

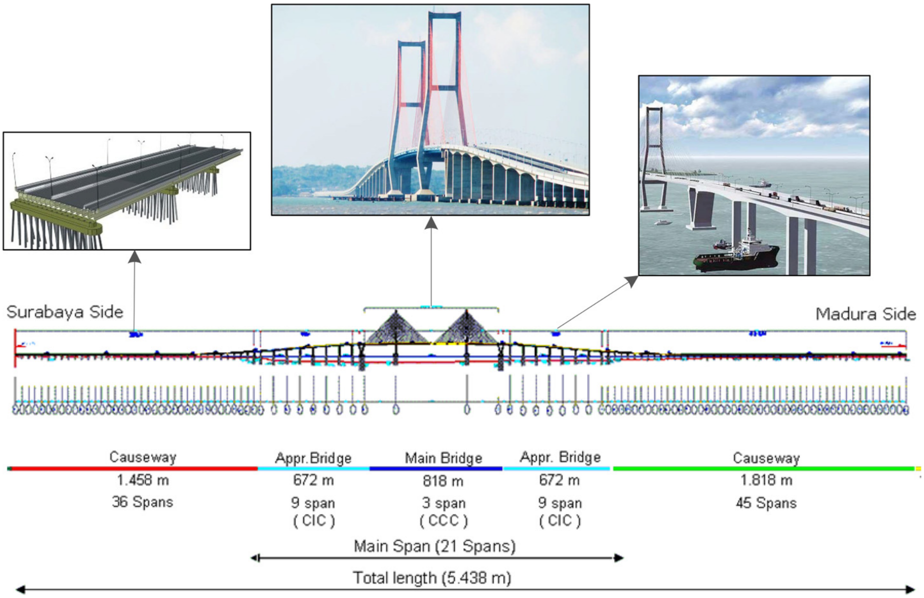


Figure 1.
Suramadu bridge specific profile

to their occurrence in Suramadu cable-stayed bridge project. The research methodology, data collection instrument, statistic techniques and quantitative risk analysis method are presented in the next section.

Research methodology

To achieve the research aim, this research develops a methodology framework, which is depicted in Figure 2 and discussed thoroughly in the next subsections.

Risk events identification

A total of 32 risk events were identified from the literature, which were considered significant in the Suramadu bridge project. To improve the risk identification process, risk can be categorized according to the source of risks (Ebrahimnejad *et al.*, 2010; Siraj and Fayek, 2019). Regardless of the categorization scheme adopted, in this research, various categories of risks are organized and presented using a risk breakdown structure (RBS). The RBS is developed to organize the different categories of risks. Figure 3 shows the RBS toward the risk groups, risk categories and risk events at the lowest level. According to whether the root of the risk is endogenous with the project, the risk factor can be divided into external risk factors and internal risk factors (El-Sayegh, 2008; Razzaq *et al.*, 2018). The external risk refers to the ectogenous risk, which occurs from the external surroundings; for instance, political, social, economic, natural and technical. On the other hand, internal risks are those that are project-related and usually fall under the control of the project management team, whereas external risks are those that are beyond the control of the project management team.

Following Figure 3, managerial risks are those risks which are related to the management skills and experience of the project team and project parties, the availability of project management professionals and the relationship and coordination among project

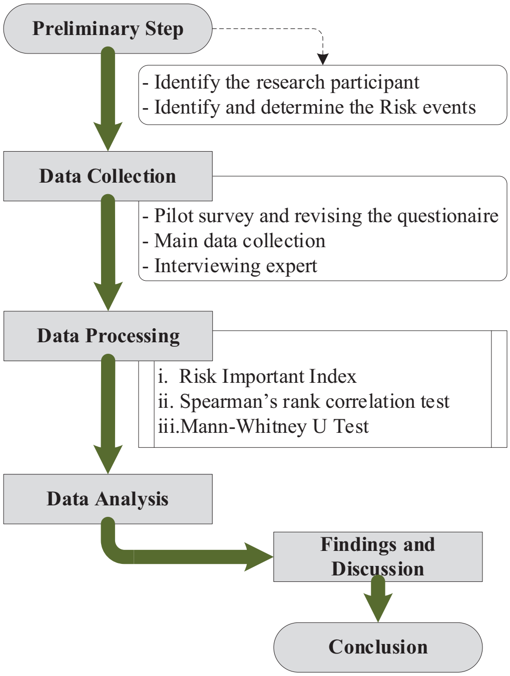


Figure 2.
Research methodology

parties (Ling and Hoi, 2006). Construction risks involve issues or concerns associated with construction methods, work tasks, delays and interruptions in construction, cost overruns and quality of construction (Shrestha *et al.*, 2017; Peng, 2019).

The environmental risk category includes risks created by nature, changes in environmental policies and regulations and impact on the environment caused by the project (El-Sayegh and Mansour, 2015; Shrestha *et al.*, 2017). Moreover, contractual and legal risks arise from inadequate claim administration, poorly tailored contracts, conflicts in contract documents, disputes and litigations, third-party liabilities, immature laws, inappropriate distribution of responsibilities and complexity in the legal environment (El-Sayegh and Mansour, 2015).

The economic and financial risk category includes risks related to inflation, fluctuations in exchange rates, changes in price, tax rates and economic policies and also risks arising from financing structures and the financial market as well as challenges in financing the project (Iyer and Sagheer, 2009; Zou *et al.*, 2016). Apart from the abovementioned risk aspects, large-scale construction project is also highly prone to the risks which are dependent on political and regulatory situations and the stability of the country where the project is taking place (El-Sayegh and Mansour, 2015).

Data collection processes

Prior to conducting the survey, the pilot survey was conducted on several experts in the project site toward forming the understanding for the respondents and to make sure that the determined construction risk events can be represented and applied to Suramadu bridge project. The purposive sampling, also known as judgmental or selective sampling

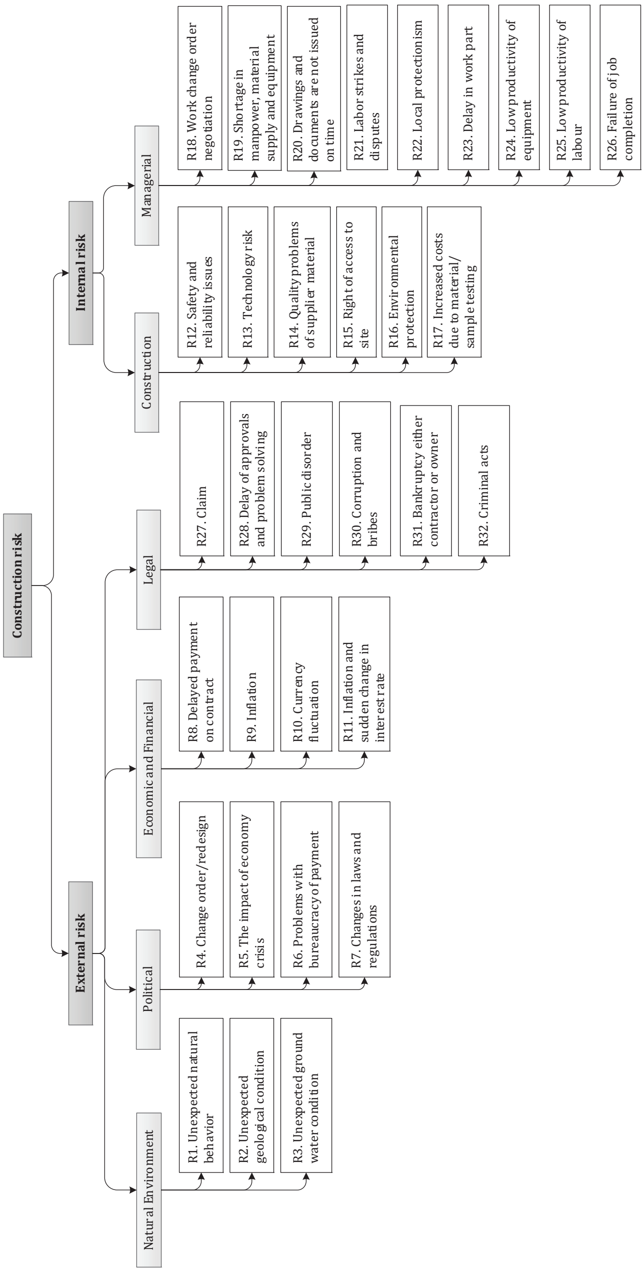

Construction risk
External risk
Internal risk
Natural Environment
Political
Economic and Financial
Legal
Construction
Managerial
R1. Unexpected natural behavior
R2. Unexpected geological condition
R3. Unexpected ground water condition
R4. Change order/redesign
R5. The impact of economy crisis
R6. Problems with bureaucracy of payment
R7. Changes in laws and regulations
R8. Delayed payment on contract
R9. Inflation
R10. Currency fluctuation
R11. Inflation and sudden change in interest rate
R27. Claim
R28. Delay of approvals and problem solving
R29. Public disorder
R30. Corruption and bribes
R31. Bankruptcy either contractor or owner
R32. Criminal acts
R12. Safety and reliability issues
R13. Technology risk
R14. Quality problems of supplier material
R15. Right of access to site
R16. Environmental protection
R17. Increased costs due to material/sample testing
R18. Work change order negotiation
R19. Shortage in manpower, material supply and equipment
R20. Drawings and documents are not issued on time
R21. Labor strikes and disputes
R22. Local protectionism
R23. Delay in work part
R24. Low productivity of equipment
R25. Low productivity of labour
R26. Failure of job completion

Figure 3.
RBS

(Palinkas *et al.*, 2015), is used in this research. Purposive sampling is defined as selecting a participant or a group of participants according to the specific inquiries or objectives of the study and in accordance with participants' profiles.

In this research, the respondents were selected based on their position, work experience, expertise and level of knowledge. Data were obtained through questionnaires and aided by face-to-face semi-structured interviews. The semi-structured interview was conducted to provide feedback and expert opinion pertaining to the identified and analyzed risk events. The interactions and discussions were voice recorded and converted to transcripts, along with the filled questionnaire during the sessions. The transcript is used to support the argument on the findings regarding the five most significant risk events generated from the quantitative analysis. Table 1 describes the participant data from both parties.

The questionnaire developed in this research adopts the "closed-response question" design. The questionnaire consists of three major parts. In the first part, the respondents were asked to provide general data needed, such as the demographical information. In the second part of the questionnaire, respondents were required to provide responses on a Likert scale of the frequency of the 32 risks affecting the Suramadu bridge construction project. The participants were required to provide numerical scores that expressed their opinions on the level of frequency of each factor.

Accordingly, respondents were asked to gauge each risk factor on a six-point Likert scale that applied 0 to 5 in this research (0 = never, 1 = very rarely, 2 = rarely, 3 = occasionally, 4 = frequently, 5 = very frequently). The next step is to process the collected data using three quantitative methods, which will be described, in the following sections. Out of 40 questionnaires disseminated, 34 usable questionnaires were gathered successfully, which represent qualified experts (i.e. contractor and consultant parties). The complete responses were collected personally in contractor and consultant offices located in the project site. Although the sample size was small, this does not invalidate the data processing and analysis.

This has been shown by previous studies on the analysis of risk in megaproject context which defined the sample of 30 is enough to validate the findings, considering there is no certain rule of thumb to determine the sample size (Charkhakan and Heravi, 2018;

Table 1.
Respondents' profile

Category	Respondents No.	(%)
Questionnaire set	34/40	85.00
Years of experience		
Another civil project	1.5–30 years	–
Suramadu bridge project	0.7–7 years	–
Role		
Contractor	10	29.41
Consultant	24	70.59
Position		
Engineers (e.g. structural engineer)	9	26.47
Management (e.g. project manager and cost manger)	5	14.71
Supervisor (e.g. site supervisor)	4	11.76
Construction foreman or similar role	8	23.53
Other (e.g. local authority)	8	23.53

Peng, 2019). The presentation of risk analysis results constitutes statistical descriptive analysis carried out using Excel spreadsheet and the Statistical Package for Social Science.

Quantitative data analysis

The quantitative methods used in this research to analyze and assess the risks in the Suramadu bridge project include relative importance index (RII), Spearman's rank correlation test and Mann–Whitney U test. The detailed discussion and calculation procedure for these three analysis methods are described in the next subsections.

Significant risk analysis and risk ranking. The significant risk assessment consists of two different parts. The first is a descriptive comparison portrayed as a risk-ranking outcome and the second is performed through statistical method. The participant perceptions regarding the frequency of particular risk occurred were then averaged following RII using equation (1) and thus, comparisons were presented. The RII outcome intended to discover the significant risk rank outcome for all parties which can be applied to prioritize risk for further quantitative assessment or response planning (El-Sayegh, 2008; Choudhry *et al.*, 2014; Muneeswaran *et al.*, 2018):

$$\text{RII}\,(R_i) = \frac{\sum_{i=0}^{5} W_i.X_i}{\sum_{i=0}^{5} X_i} \tag{1}$$

where W_i is weight assigned to the ith frequency of risk occurred (W_i = 0,1,2,. . ..,5) for never, very rarely, rarely, occasionally, frequently and very frequently; and X_i is the total number of respondents, who judge ith frequency for each risk as experts' preferences. Then, the ranking for each risk can be produced following its RII value. The higher the RII value, the more significant the risk would be.

Spearman's rank correlation test. To study the relationship strength between two sets of risk ranking, the Spearman rank correlation test was applied in this research (El-Sayegh, 2008; Chan *et al.*, 2011). The Spearman correlation equation is as follows:

$$r_s = 1 - \frac{6\sum d^2}{(N^3 - N)} \tag{2}$$

where r_s is Spearman rank correlation coefficient, d is ranking difference and N refers to the number of identified risks events. The coefficient r_s ranges between -1 and $+1$, where a positive value indicates a perfect positive correlation and a negative value indicates a perfect negative correlation. While there is no relationship between the two groups on the variable under study if r_s is approaching zero.

Mann–Whitney U test. Mann–Whitney U test was used to test the null hypothesis that there is no statistically significant difference between the two populations, thus they have the same median for the same risk factor and the median can be represented by mean ranks (Chan *et al.*, 2011). In this research, the level of significance for testing the hypothesis sets at 0.05. This means that there will be any statistically significant difference between two-sample medians when the significance value is less than 0.05 (sign $<$ 0.05).

Findings and discussion

In this research, only five and three risks, considered as the most and least significant, respectively, assessed by both parties will be discussed. Figure 4 depicts the overall risk significance analysis output. Following the Spearman correlation test analysis using equation (2), the r_s output is 0.9483. This indicates that there is a high relationship of significant risk perception between contractor and consultant parties toward the RII of 32 risk events. In other words, there is a strong and stable agreement between both parties on the importance of frequencies and the risks ranking.

According to RII and risk ranking, both parties agreed and confirmed that the “unexpected natural behavior” (R_1) is the most significant risk. It is confirmed by both parties that the aggregate, dimension and environment complexity, specifically for R_1, in Suramadu bridge project has created an extra burden on construction participants and resulted in lots of challenges. For instance, construction cannot commence in the case of a thunderstorm or if sea wind reached 60 km/h and the cable erection for main bridge section has to be postponed because of unsteady room temperature.

Importantly, this risk impact leads to project delay, rework and safety issues, which affect the project cost and schedule. While R_1 is recognized as the most significant risk by both parties, “claim” (R_{27}) is possessed as the second most significant risk which consultant party emphasized their agreement on these findings. On the other hand, the contractor party recognized “the problems with the bureaucracy of payments” (R_6) as a second significant risk. This dissimilarity appeared because of divergent roles, responsibility and expectation between two parties.

For example, consultant party associated with government bodies as a part of the project owner, while the contractor party mainly dealt with the construction works. To deal with R_6 issue and project complexity, it is found to be important that contractor proactively builds strategies to devise and arrange the project schedule following the cash availability. On the other hand, following both parties’ comments, R_{27} is considerably influenced by the design change and the unstable sociopolitical system and climate in Indonesia.

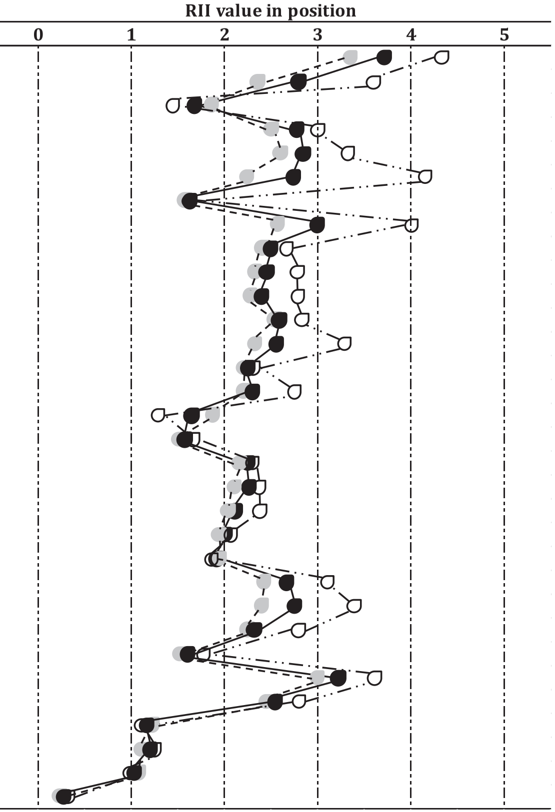
Response to this, the contractor party established the cost contingency plan to cover the monetary impacts of project uncertainties. In this case, the development of cost contingency plan is part of the risk mitigation responses. In here, contingency cost is an estimated amount added to a project base estimate to cover the inherent project risks. Particularly, these findings commented by El-Sayegh (2008), found that this practice leads to the contract price incremental.

The third global significant risk is “delayed payments on contract” (R_8), which correspond to contractors’ judgment. A majority of the bridge construction projects are owned by the public sector because of their complex nature and the involvement of large finances. In Suramadu bridge project, East Java State Government bailed out the development funds through East Java bank and loans from China Exim bank. Moreover, another source of the fund was from the central government and local government (Surabaya city and four Madura cities’ Government).

Considering the fund source was from multi-nation, multi-level government with multi-actors involved, the fund disbursement process and bureaucracy were complicated and took great deal of time. Such as risk causality and loop impact, as a consequence, R_8 leads to delay in the project schedule. Furthermore, following the parties expression, both unstable political climate and lack of solid economic activity in Indonesia are found to be a substantial source of R_6 and R_8.

Nonetheless, R_8 is ranked 5.5th by consultant party, as this risk is found to be triggered and affected by both “claim” and “change order” (R_{27} and R_4) of the structural design, which

Risk ID	Contractor		Consultant		Global RII		Mann-Whitney U
	RII	Rank	RII	Rank	RII	Rank	Sign.
R1	4.300	1	3.478	1	3.727	1	0.107
R2	3.600	5	2.478	8	2.818	5	0.179
R3	1.222	29	1.864	24	1.677	25	0.068
R4	3.000	9	2.750	3	2.813	6	0.246
R5	3.333	7	2.636	4	2.839	4	0.038
R6	4.111	2	2.238	16	2.800	7	0.042
R7	1.667	25	1.600	26	1.621	26	0.801
R8	4.000	3	2.609	5.5	3.000	3	0.625
R9	2.667	17	2.421	11	2.500	13	0.546
R10	2.778	14	2.350	12	2.483	14	0.984
R11	2.778	14	2.286	14	2.433	15	0.166
R12	2.800	12	2.609	5.5	2.667	9.5	0.347
R13	3.300	8	2.348	13	2.636	11	0.339
R14	2.300	21	2.217	18	2.242	20	0.354
R15	2.700	16	2.217	18	2.364	17	0.604
R16	1.333	27	1.826	25	1.688	24	0.756
R17	1.625	26	1.524	17.5	1.563	28	0.620
R18	2.333	20	2.217	18	2.250	19	0.005
R19	2.444	18.5	2.182	20	2.258	18	0.139
R20	2.444	18.5	2.083	21	2.182	21	0.470
R21	2.100	22	1.958	22	2.000	22	0.288
R22	1.889	23	1.909	23	1.903	23	0.190
R23	3.100	10	2.478	8	2.667	9.5	0.000
R24	3.444	6	2.458	10	2.727	8	0.043
R25	2.778	14	2.250	15	2.394	16	0.432
R26	1.800	24	1.542	27.5	1.618	27	0.903
R27	3.667	4	3.000	2	3.214	2	0.779
R28	2.889	11	2.478	8	2.594	12	0.438
R29	1.111	30	1.217	29	1.188	30	0.836
R30	1.250	28	1.176	30	1.200	29	0.175
R31	1.000	31	1.091	31	1.065	31	0.892
R32	0.333	32	0.238	32	0.267	32	0.966



Notes: –●– Global RII point; –○– RII value point by contractor perception; –●– RII value point; ···– by consultant perception

Figure 4.
Overall risk significance analysis output

affects negatively on the construction cost and schedule. Considering the uniqueness of cable-stayed structure, the specifications should be custom made for these projects. Thus, changes are needed in the design and construction of cable-stayed bridges. Following contractor point of view, R_4 frequently occurred in any addition, deletion or revision to the structural design, which required big scale construction work to overhaul.

Furthermore, it is also acknowledged by both contractor and consultant party that R_4 was because of the designer error (particular design was out of date and inappropriate), the specific considerations of general specifications were not addressed properly, which led to disastrous performance impact on innovative design and the lack of coordination with other organizations involved.

This finding is supported by the previous study of Choudhry *et al.* (2014), where R_4 yields on the escalation of project cost and the delay on payment. In Suramadu bridge project, in the change order case, the constructor is obliged to incur the additional expense. In such cases, constructors have filed a constructability claim for additional damages incurred because of changes to original design and construction methods. With this in mind, contractor added the contingency cost within their working contract.

Moreover, as discussed by Reddy *et al.* (1999), the construction of cable-stayed bridges involves major changes in configuration of the structure with the addition and removal of structural components to the partially constructed structure. At every stage of construction, it is necessary to have sufficient information about the existing partial structure as built and to investigate the effects of possible modifications in the construction procedures. For instance, the completed structures are strongly dependent on the sequence of events during the construction and the erection procedure used.

As mentioned during the interview session, interestingly, it is also affirmed by the consultant party that R_{27} has a close relationship with R_4 which ranked third, which was found to be the most risk that occurred in the construction project of cable-stayed bridge. The aforementioned findings are supported by Jergeas and Ruwanpura (2010). It is confirmed that the common mistakes in megaproject to deliver the project are stakeholders generally underestimated the length and cost of delay.

Further, it is also revealed that change order reflects that there was a lack of understanding of the project scope definition. Importantly, as affirmed by Flyvbjerg *et al.* (2003), this issue is recognized as one of the main causes of the megaproject cost overrun. In this regard, additional engineering support responsibilities are required. For instance, development, coordination and documentation of the erection sequence with the construction engineer; preparation of all shop drawings, including post-tensioning requirements and stay-cable systems; and owner-required documentation of all the additional responsibilities.

Besides, late to consider the cumulative impact of R_4 is also one of the misaligned strategies within megaproject, which results in the additional cost overruns. Despite there being a dissimilar result toward risk significant and risk ranking, global RII and risk ranking showed that "unexpected natural behavior" (R_1), "claim" (R_{27}) and "delay payment on contract" (R_8) are the three most significant risks in Suramadu bridge project which are ranked first, second and third, respectively.

Globally, the fourth significant risk is the "impact of economic crisis" (R_5). This result has been agreed by consultant party while the contractor party ranked it at seventh. Though there is a slight difference in ranking order, however, both parties agreed that Indonesian economic crisis had a substantial impact on the project progress. As a matter of fact, the Suramadu bridge project had been temporarily suspended due to national economic crisis.

Because of the national monetary crisis, several big infrastructure projects (Presidential decree No. 39/1997) including the Suramadu bridge had been stopped.

Providentially, in 2002 the project was unearthed again with a Presidential Decree (No.15/2002, dated March 22, 2002) (Franck, 2005). The bridge construction began in August 2003. Unfortunately, work on the bridge was halted at the end of 2004 owing to lack of funds. After gaining solutions by both local and international stakeholders toward the fund, the project was restarted in November 2005.

The fifth significant risk is "unexpected geological condition" (R^2). While contractor party ranked R^2 as a fifth most significant risk, interestingly consultant party ranked R^2 as eighth. Similar to the previous discussion, it is found that this dissimilarity result took place because of different tasks, responsibilities and expectations between both parties. Following a contractor standpoint, unless understanding comprehensively the offshore geotechnical, both engineers and technicians may generate a less reliable analysis.

In the Suramadu bridge project, it was found that both seabed and soil condition were complicated and difficult to assess, respectively, owing to the nature of Madura strait condition. Apart from the Madura strait geological condition that created hindrance for the contractor to manage construction work, it is found that there were numerous sea mines in Madura strait, particularly around the tract area of Suramadu bridge project. It was known that 90% of those mines were not working; however, the explosive used within the mine is both environment and life threating.

Admitting that RII graphs from both contractor and consultant parties have similar trends, nonetheless, figure 4 also highlights five different risks which are statistically different at the 95% level of confidence generated by using the Mann–Whitney U test method. These five risks are "the impact of economic crisis" (R_5), "problem with the bureaucracy of payment" (R_6), "work change order negotiation" (R_{18}), "delay in work part" (R_{23}) and "low productivity of equipment" (R_{24}). This difference appears because of dissimilar task and responsibility, different culture and diverging visions of the way that contractor and consultant parties structured and managed.

The remaining 27 risk events were somewhat similarly determined by both parties with respect to their significance. Thus, it can be concluded that both parties considered a majority of significant risks as similar. Besides, this research also revealed that the contractor party tends to rank significant risks related to the construction phase higher than consultant party. For instances, "technology risk" (R_{13}), "delay in work part" (R_{23}), "poor construction equipment productivity" (R_{24}) and "claim" (R_{27}) which significantly affected the project progress.

Conclusion

Adding to the existing body of knowledge, this research explores the construction risk of megaproject to fill the knowledge gaps by identifying, analyzing and assessing Suramadu bridge project as well as discussing the correlation (and difference) of the output obtained between contractor and consultant parties. The key findings indicate that the significant risks mostly occurred in the technical, physical and financial categories and were a major factors that affected cost, schedule and safety objectives.

Following global RII analysis, the highest ranked risk factor identified was "unexpected nature behavior." The result indicates that construction project located above or near the sea poses a high risk and has a direct impact on the project schedule, cost and overall performance. From the analysis, it is also revealed that the contractor party pointed significant risk within the technical category, as they are associated with project performance-technical activity and physical progress.

Compared to general construction project, on the other hand, it is found that the lack of experienced personnel working for the constructor's organization was one of the most frequent problems in the construction of cable-stayed bridges project. As discussed by Chan *et al.* (2018), not like other general projects, cable-stayed bridges represent innovative construction. Thus, project personnel must have engineering-oriented attributes and the ability to work with sophisticated bridge technology.

As of this research limitation, the results of the present research should be interpreted in the context of several limitations. Given these possible concerns regarding the generalizability of the findings, along with the relatively low rate of participants in the current research, additional studies are needed to provide a more complete picture of stakeholder perceptions who are involved directly in the construction environment as well as to identify more construction risks specifically in the large-scale bridge project. Moreover, further study is needed to develop a model, or a framework that could support the expert adopting and addressing the risk, and reduce its impact within the large-scale bridge construction project.

This research contributes to the construction safety body of knowledge by presenting one of the first studies analyzing risk in large-scale cable-stayed bridge projects, which can help stakeholders for improving the development of plan and strategy, both in initial and during construction stages, to reduce the probability and impact of a threat, increase the probability and impact of an opportunity and prevent the recurrence of fatalities that may pose potential threats to project performance in terms of cost, quality, safety and time

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