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

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INVESTIGATING RISK OF BRIDGE CONSTRUCTION PROJECT: EXPLORING SURAMADU STRAIT-CROSSING CABLE-STAYED BRIDGE IN INDONESIA

PURPOSE. The complexities in strait-crossing cable-stayed bridge project increasing the risks. This research focuses on identifying and analyzing the significant and worth-considered construction risks of the first, biggest and longest-span of the 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 the Mann-Whitney U test.

FINDINGS. The analyses reveal that ‘Unexpected natural behavior’ confirmed by both contractor and consultant parties as 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 LIMITATION. The results of the present research should be interpreted in the context of several limitations. Given these possible concerns regarding the generalisability of the findings, along with the relativity low rate of a participant in the current research, additional studies are needed to provide a more complete picture of stakeholder perceptions who involve directly in the construction environment as well as to identify more construction risks specifically in the large-scale bridge project.

PRACTICAL IMPLICATION. This research has provided fundamental contributions to the body of knowledge and practical implication to promote and assists decision-makers towards developing a comprehensive risk assessment of large-scale bridge project.

ORIGINALITY/VALUE. The analysis outcomes and discussion, as well as the findings of this research, have shedded lights on the construction risks understanding which contributes to delivering a theoretical framework for achieving large-scale bridge project success.

KEYWORDS: Infrastructure, construction project, risk analysis, Suramadu bridge, megaproject.
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 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 as well as economic stability. Accordingly, regardless funded by the public or private institution, the development of bridge in various sectors is developed rapidly 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; (i) project scale, (ii) technical structures’ cost, and (iii) 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 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 inarguably 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, Tavakkoli-Moghaddam et al. 2011). Moreover, the inherent risks exert significant disruption and have negative consequences on project success.
Therefore, achieving large-scale bridge project successes 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 towards 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 the 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 $1 billion or more, take many years to develop and build, involving multiple public and private stakeholders, are transformational, and impact millions of people (Flyvbjerg 2017). However, $1 billion are 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 endeavours 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). Due 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 project 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, Bruzelius et al. 2003).

**RISK IN CABLE-STAYED BRIDGE PROJECT**

Unlike general construction project, large-scale cable-stayed bridge project possess various risks beyond the normal project. This because the construction of large-scale cable-stayed bridge project is characterized by their 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, Yang et al. 2018, Charkhakan and Heravi 2018).

In view of this, the bridge project 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, Yang 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 accident such as dredging, drilling, pipe laying, buoy laying, dewatering, reclamation/filling, caisson construction and, marine viaduct erection (Gudmestad 2013). Furthermore, frequent thunderstorm, crisscross navigation, airport height restrictions, and stringent
environmental requirements and standards are examples of the critical challenges of the marine
construction (Yeung 2016).

Furthermore, cable-stayed bridge structure represents state-of-the-art bridge technology 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 project 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 include 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 that risk management is pivotal and play
an important role in the megaproject. Therefore, disregards 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, Chen 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 processes.

There are a number of studies focused on the management of large-scale long-span bridge project
during the construction phase. Schexnayder, Alarcón 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, Lee 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 discussed 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 the 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 employed 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, Jayakarna et al. 2009). The bridge was built to cross Madura strait in order to link the Java island with Madura island. The total cost of the project, including connecting roads, has been estimated at 4.5 trillion rupiahs (US$445 million). 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 is to escalate the socio-economic level of Madura society which relatively left behind compared to other areas in East Java (Franck 2005, Harsaputra, Jayakarna et al. 2009, Hidayat, Mulyadi et al. 2018). The bridge has three spans sections, which is; causeway, approach-bridge, and main bridge. The causeway bridge has the 1458m and 1818m length for Surabaya and Madura side respectively. The approach bridge has a length of 672m both from Madura and Surabaya side. The main bridge is a cable-stayed bridge with steel-concrete beam and twin cable planes which connected to twin tower pylons. The main bridge has three
spans with lengths 192 m, 434 m and 192 m (as many as 818m in total). Figure 1 depicts the Suramadu bridge specific profile.

<<< Figure 1 >>>

The detailed design of the Suramadu bridge was created by the Consortium of China Contractor (CCC) where 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, as well as foreign partners COWI A/S in Denmark. Suramadu bridge project has been considered as a big milestone for the Indonesia construction industry as it was the first national and mega construction project attempted by applying international Joint Venture (JV) 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 to their occurrence in Suramadu cable-stayed bridge project. The research methodology, data collection instrument, statistical 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 respectively.

<<< Figure 2 >>>

RISK EVENTS IDENTIFICATION

Thirty-two risk events were identified from the literature which considered significant in the Suramadu bridge project. To improve the risk identification process, risk can be categorized according to the source of risks (Ebrahimnejad, Mousavi et al. 2010, Siraj and Fayek 2019). Regardless of the categorization scheme adopted, in this research the various categories of risks are organized and presented using a risk breakdown structure (RBS). The RBS is then developed to organize the different categories of risks. Figure 3 shows the RBS towards 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, Thaheem 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, while external risks are those that are beyond the control of the project management team.

<<< Figure 3 >>>

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 relationships and coordination among project 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, Chan 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, Chan 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, Kiviniemi et al. 2016). Apart from above-mentioned risk aspects, large-scale construction project is also highly prone to the risks which are dependent on political and regulatory situations as well as 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 to several experts in the project site towards 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 (Palinkas, Horwitz 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 respondent was 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 participant required to provide numerical scores that expressed their opinions on the level of frequency of each factor.

Accordingly, respondent were asked to gauge each risk factor on a six-point Likert scale, that is 0 to 5 is applied 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 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, but 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, Peng 2019). The presentation of risk analysis results constitutes statistical descriptive analysis carried out using Excel spreadsheet and the Statistical Package for Social Science (SPSS).

QUANTITATIVE DATA ANALYSIS

The quantitative methods employed 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) below 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, Choudhray, Aslam et al. 2014, Muneeswaran, Manoharan et al. 2018).

\[
RII (R_i) = \frac{\sum_{i=0}^{s} W_i \cdot X_i}{\sum_{i=0}^{s} X_i}
\]
where, $W_i$ is weight assigned to the $i$th frequency of risk occurred ($W_i = 0, 1, 2, ..., 5$) for: never, very rarely, rarely, occasionally, frequently, and very frequently; $X_i$ is a total number of the respondent which judge $i$th 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 applied in this research (El-Sayegh 2008, Chan, Chan et al. 2011). The Spearman correlation equation can be seen below.

\[
    r_s = 1 - \frac{6 \sum d^2}{N^3 - N}
\]

where $r_s$ is Spearman rank correlation coefficient, $d$ is ranking difference and $N$ refer 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**

The Mann-Whitney U Test was employed 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, 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, significance difference between two-sample medians when the significance value less than 0.05 (sign<0.05).
FINDINGS AND DISCUSSION

In this research, only five and three risks which considered as the most and less significant respectively assessed by both parties will be discussed. Table 2 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 towards 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.

Table 2 depicts the overall risk significance analysis output.

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; (i) construction cannot commence in the case of a thunderstorm or sea wind reached 60km/h, (ii) the cable erection for main bridge section has to be postponed due to unsteady room temperature.

Importantly, this risk impact leads to project delay, rework and safety issues which affect the project cost and schedule. While $R_1$ recognized as the most significant risk by both parties, ‘claim’ ($R_2$) 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 due to 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 build strategies to devise and arrange the project schedule following the cash availability. On the other hand, following both parties comment,
considerably influenced by the design changed and the unstable socio-political system and climate in Indonesia.

Respond to this, contractor party regularly applied the cost contingency which is allocated and accepted for identified risks, as well as for which mitigation responses are developed.” 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) which 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 fund 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 $5.5^{th}$ by consultant party as this risk found to be triggered and affected by both ‘claim’ and ‘change order’ ($R_{27}$ and $R_d$) of the structural design which 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, $R_d$ frequently occurred in any addition, deletion, or revision to the structural design which require big scale construction work to overhaul.
Furthermore, it is also acknowledged by both contractor and consultant party that $R_4$ was due to:

(i) the designer error (particular design was out of date and inappropriate), (ii) the specific consideration of general specifications have not addressed properly which lead to disastrous performance impact on innovative design and, (iii) the lack of coordination with other organizations involved.

This findings is supported by the previous study of (Choudhry, Aslam 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, Ghaboussi 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 structure 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 3rd which 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, Bruzelius et al. (2003), this issue is recognized as one of the main causes of the megaproject cost overrun. In this regards, 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 \( R_d \) also one of the misaligned strategies within megaproject which result on the additional cost overruns. Despite there is a dissimilar result towards risk significant and risk ranking, however, global RII and risk ranking showed that; ‘unexpected natural behavior’ (\( R_f \)), ‘claim’ (\( R_{c} \)), ‘delay payment on contract’ (\( R_8 \)) are the three most significant risks in Suramadu bridge project which is ranked 1\(^{st}\), 2\(^{nd}\) and 3\(^{rd}\) 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 7\(^{th}\). Though there is a slight difference in ranking order, however, both parties agreed that Indonesia economic crisis had a substantial impact on the project progress. As a matter of fact, the Suramadu bridge project ever terminated due to the national economic crisis. Due to 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, date 22 March 2002) (Franck 2005). The bridge construction began in August 2003. Unfortunately, work on the bridge was halted at the end of 2004 due to lack of funds. After gained solutions by both local and international stakeholders towards 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 5\(^{th}\) most significant risk, interestingly consultant party ranked \( R_2 \) as 8\(^{th}\). Similar to the previous discussion, it is found that this dissimilarity result took place due to different tasks, responsibility and expectation between both parties hold. 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 was complicated and difficult to assess respectively due to the nature of Madura strait condition. Apart from the Madura strait geological condition that hindrance 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 not working however, the explosive used within the mine is both environment and life-threatening.

Admitting that RII graphs from both contractor and consultant parties have similar trends, nonetheless, Table 2 also highlights five different risks which have 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 due to 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 the majority of significant risks are 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$_{27}$) arises because of the late to 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 factor 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 have 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 associated with project performance-technical activity and physical progress.

Compare 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, Yang 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 generalisability of the findings, along with the relativity low rate of a participant in the current research, additional studies are needed to provide a more complete picture of stakeholder perceptions who involve 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.
REFERENCES


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Table 2. Overall risk significance analysis output.
Table 1. Respondents' profile

<table>
<thead>
<tr>
<th>Category</th>
<th>Respondents</th>
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<td></td>
<td>Number</td>
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<td>Consultant</td>
<td>24</td>
</tr>
<tr>
<td><strong>Position</strong></td>
<td></td>
</tr>
<tr>
<td>Engineers (e.g., structural engineer)</td>
<td>9</td>
</tr>
<tr>
<td>Management (e.g., project manager and cost manger)</td>
<td>5</td>
</tr>
<tr>
<td>Supervisor (e.g., site supervisor)</td>
<td>4</td>
</tr>
<tr>
<td>Construction foreman or similar role</td>
<td>8</td>
</tr>
<tr>
<td>Other (e.g., local authority)</td>
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</tbody>
</table>
Table 2. Overall risk significance analysis output.

<table>
<thead>
<tr>
<th>Risk ID</th>
<th>Contractor</th>
<th>Consultant</th>
<th>Global RII</th>
<th>Mann-Whitney U</th>
<th>RII value in position</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>RII Rank</td>
<td>RII Rank</td>
<td>RII Rank</td>
<td></td>
<td></td>
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<tr>
<td>R1</td>
<td>4.300</td>
<td>3.478</td>
<td>3.727</td>
<td>0.107</td>
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</tr>
<tr>
<td>R2</td>
<td>3.600</td>
<td>2.478</td>
<td>2.818</td>
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</tr>
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<td>R3</td>
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</tr>
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<td>R4</td>
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<td>2.750</td>
<td>2.813</td>
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</tr>
<tr>
<td>R5</td>
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<td>2.636</td>
<td>2.839</td>
<td>0.038</td>
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</tr>
<tr>
<td>R6</td>
<td>4.111</td>
<td>2.238</td>
<td>2.800</td>
<td>0.042</td>
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</tr>
<tr>
<td>R7</td>
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<td>1.600</td>
<td>1.621</td>
<td>0.801</td>
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</tr>
<tr>
<td>R8</td>
<td>4.000</td>
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<td>3.000</td>
<td>0.625</td>
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<td>R9</td>
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<td>2.483</td>
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</tr>
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<td>R12</td>
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<td>0.238</td>
<td>0.267</td>
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<td>31</td>
</tr>
</tbody>
</table>

Note: ● Global RII point, ↔ RII value point by contractor perception, ◀ RII value point by consultant perception
List of Figure Captions

Figure 1. Suramadu bridge specific profile.

Figure 2. Research methodology.

Figure 3. Risk breakdown structure.
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