

1 **RISK FACTORS AFFECTING THE ABILITY FOR EARNED VALUE**  
2 **MANAGEMENT TO ACCURATELY ASSESS THE PERFORMANCE OF**  
3 **INFRASTRUCTURE PROJECTS IN AUSTRALIA**

4 **Purpose** - The aim of this paper is to investigate a set of risk-related factors influencing the  
5 Earned Value Management (EVM) concept as an assessment technique in evaluating the  
6 progress of modern sustainable infrastructure construction projects.

7 **Design/methodology/approach** – A qualitative research approach has been adopted for  
8 identifying risk-related factors influencing EVM concept from a literature review and through  
9 interviewing industry personnel, followed by an inductive process to form sets of key factors  
10 and their measuring items.

11 **Findings** – Earned Value management is a common method for assessing project  
12 performance. A weakness of this approach is that EVM assessment in its current form does  
13 not measure the impact of a number of project performance factors that result from the  
14 complexity of modern infrastructure construction projects, and thus does not accurately assess  
15 their impact in this performance. This paper discusses and explains a range of potential risk  
16 factors to evaluating project performance such as sustainability, stakeholder requirements,  
17 communication, procurement strategy, weather, experience of staff, site condition, design  
18 issues, financial risk, subcontractor, government requirements and material. In addition, their  
19 measuring items were identified.

20 **Practical implications** –This research assists projects managers to improve the evaluation  
21 process of infrastructure construction performance by incorporating a range of factors likely  
22 to impact on that performance and which are not included in current EVM calculations.

23 **Originality/value** – This research addresses the need to include in the EVM calculation a  
24 range of risk factors affecting the performance of infrastructure projects in Australia and  
25 therefore makes this calculation a more reliable tool for assessing project performance.

26 **Keywords:** Earned value management, Infrastructure construction, Project management,  
27 Performance, Risk management.

28 **Article Type:** Research paper.  
29

30 **INTRODUCTION**

31 Infrastructure projects are significant contributors to the national economy and strengthen  
32 national and regional development. For example, the Western Australian Government's  
33 CEIID (2010) mentions that good management, good planning and a good investment for  
34 infrastructure projects play a vital and essential role in the economic growth of countries it  
35 supports. In addition, modern, effective infrastructure is an investment in our future and a key  
36 enabler of productivity growth which in turn drives improved living standards (Engineers  
37 Australia 2016). However, the infrastructure sector faces significant challenges due to high  
38 levels of required funding throughout the project life cycle (Goh & Yang 2013) and lack of  
39 effective monitoring and controlling of several factors which affect the overall performance  
40 of infrastructure projects (Goh et al. 2015). Titarenko et al. (2015) state that many researchers  
41 distinguish the importance of evaluating and measuring the performance of the projects and

1 the need for ways to assess project performance with a multi-dimensional and comprehensive  
2 approach. Langston (2012) identifies a critical issue in construction projects, which measure  
3 of the project's performance due to limited functionality as a result of working under  
4 uncertainty, and an inability to predict project performance accurately. Hence, there is a need  
5 for an accurate, useful approach that takes into account uncertainty.

6 Earned value management (EVM) is one of the most used concepts for evaluating the  
7 performance of projects. Najafi and Azimi (2016) mention that the EVM concept combines  
8 all of the scope, cost and the time for the project, and allows stakeholders to monitor the  
9 progress of the project during the project life cycle and furthermore, assists in correcting the  
10 deviations in a timely manner.

11 There are many external and internal critical success factors that impact directly and  
12 indirectly on earned value management. Reducing the negative impact of these factors,  
13 thereby increasing their positive impact is considered a key requirement for improving the  
14 efficiency of project management. A significant factor is risk management (RM) which plays  
15 an active and vital role in affecting the performance of project through the impact of risk-  
16 related factors such as sustainability, communication, stakeholder requirements and  
17 procurement strategies. Serpella et al. (2014) state that Risk Management in construction  
18 projects addresses the imbalance, flaws, shortcomings and disability, which affect the  
19 efficiency of the function of project management and project performance. Consequently, risk  
20 management is likely to have an impact on infrastructure project performance management.

21 During the past two decades, considerable research has been conducted on the application of  
22 EVM. Most of the literature focuses on cost and time only, without considering the various  
23 project risk-related factors in measuring and predicting the project performance, such as  
24 Estimated at Completion (EAC). It is important to consider risk and uncertainties in order to  
25 estimate better EAC and also to reduce inconsistency between EAC results obtained through  
26 standard formulae. Recently, Babar et al. (2016) and De Marco and Narbaev (2013) have  
27 identified a number of risk-related factors that affect the prediction of time and cost in EVM,  
28 but which do not include a number of major factors as discussed in the literature review. The  
29 scope of the study is to consider the risk-related factors as they have relevancy to the context  
30 of engineering infrastructure projects as well as to Australian context. Therefore, the primary  
31 objective of this research is to identify a set of the risk-related factors on the EVM technique  
32 for assessment of construction project performance such as sustainability, requirements of  
33 stakeholders, communication, procurement strategies and other factors. The secondary  
34 objective of the research is to identify the measurement items of these factors.

## 35 **LITERATURE REVIEW**

### 36 **Project performance**

37 In the last decade, the process of evaluating performance during the project life cycle has  
38 become one of the significant issues for the success of the project. Furthermore, it can impact  
39 on the success of companies due to excessive competition between companies, changes in the  
40 project environment and the complexity of infrastructure construction projects. According to  
41 Hughes and Thorpe (2014), the contribution of infrastructure construction projects in the

1 economic growth for Australia requires finding new concepts or the development of previous  
2 concepts for evaluating project performance in line with the changing environment of the  
3 project and keeping pace with the developments in the field of project management.

4 In the previous decades of the 1960s and 1970s, evaluating the performance of projects  
5 depended on traditional methods. Traditional methods rely on the three basic elements of  
6 project performance (e.g., cost, time, and quality) without taking into consideration the  
7 factors affecting these elements that change with the changing environment of the project.  
8 Thus, there is a need to identify the risk-related factors influencing the evaluation process of  
9 infrastructure projects performance, to make it more accurate, more realistic and more  
10 successful in measuring project performance. Trnka and Taspinar (1995) and Titarenko et al.  
11 (2015) explain that performance measurement is used to measure performance in construction  
12 projects to determine the proportion of the project's progress. It is also used to measure the  
13 success of the project in regard to the desired goals, such as completing the project within the  
14 specified period, within the allocated budget, within the required quality and customer  
15 satisfaction over the outcome of the project specifications.

16 **Project performance assessment techniques**

17 As discussed in the introduction, EVM is an effective instrument and effective system for  
18 project performance management (Chen et al. 2016). Most researchers in the field of  
19 performance of projects agree that EVM is a very good tool to assess and calculate the  
20 performance of the project (Corovic 2006; Fleming 2010; PMI 2013). Fleming (2010) and  
21 PMI (2013) define that EVM is predicated on three basic elements: Planned Value (PV) or  
22 budgeted cost of work scheduled (BCWS); Earned Value (EV) or the budgeted cost of the  
23 work performed (BCWP); and Actual Cost (AC) or the actual cost of work performed  
24 (ACWP). These items are linked with project performance. Many researchers have  
25 investigated the benefits of the use of EVM to evaluate the performance of the projects. Chin  
26 Keng and Shahdan (2015) summarise the benefits of the use of EVM to: provide a suitable  
27 environment for process planning through the promotion of understanding and  
28 communication between the various components of the project, and thus help those in charge  
29 of project management of appropriate planning for excessive work riskiness; take appropriate  
30 decisions in critical situations and achieve the project objectives; have a clear vision the scope  
31 of the project and the progress of work on the project; have an early warning of any potential  
32 defects; control costs and time, in order to predict the final cost and the final period of the  
33 project; and use information and historical data resulting from the use of the concept of  
34 earned value management in future projects.

35 Lipke (2004) discusses the shortcomings of the concept of EVM to predict the final duration  
36 of the project. (Lipke 2003, 2004, 2012) has developed the concept of EVM to solve the  
37 problem of prediction in the last stages of the project where it was proposed to use the earned  
38 schedule (ES), and also compared the use of earned schedule (ES) on different paths for the  
39 project to find the best use for the earned schedule (ES). The result was that the longest path  
40 (LP) gives the best and most accurate results. Naderpour and Mofid (2011) explore the  
41 dimensions of the concept of EVM and compare the use of the concept of EVM and the use  
42 of the traditional concept. Acebes et al. (2014) propose a new methodology for monitoring

1 and evaluating the performance of projects through a combination of EVM and risk  
2 management. Chin Keng and Shahdan (2015) note that when the level of awareness of those  
3 in charge of construction projects for the use and application of the concept of EVM is low, it  
4 is better to identify and understand the foundations and principles of the concept of EVM  
5 before expanding into new dimensions. Naeni et al. (2014) introduce a new fuzzy logic model  
6 under uncertainty with features of improved time and cost estimates at completion and which  
7 assesses progress in completing the project. The discussion in this paper builds on this by  
8 identifying the main risk factors in assessing EVM.

9 Based on the above, the shortcomings of EVM can be summarized. These are

- 10 a. the problem of prediction in the last stages of the project,
- 11 b. a low level of awareness of the use EVM concept by project management officials,
- 12 c. time and cost estimates at completion under uncertainty, and
- 13 d. lack of integration between EVM and risk management.

14 In addition, this paper has addressed the shortcomings of using a concept of EVM that  
15 focuses on the cost and time only, without considering other important factors such as  
16 sustainability, stakeholder requirements, communication, procurement strategies and other  
17 factors for measuring and predicting project performance.

## 18 **Factors affecting project performance**

19 The documents that are admitted by organizations as a reliable exporter of information and  
20 data, called the academic literature (Evans 2011). Search and connect with previously  
21 published research in the initial stages of the research is obviously important (Gibson 2009).  
22 The literature review through research in libraries and internet is one of avenue for gathering  
23 initial data and is a significant step in the procedures of determining the research issue  
24 (Cavana 2001). In this article, three stages were followed in the literature review process. The  
25 first stage is determining the sources of research, the database of Scopus, ABI/Inform,  
26 EBSCO, Clarivate Analytics, Project Management Institute PMI, the USQ library and Google  
27 Scholar were used to review books, articles, Australia Government reports about the  
28 construction performance and risk management. This stage is essential for the credibility of  
29 all the articles used in the review of academic literature on the performance of infrastructure  
30 projects in terms of weaknesses in evaluation methods and factors affecting the performance  
31 of infrastructure projects were of great importance. The total number of articles reviewed is  
32 284, the themes ( keywords) used in the research are " Earned Value Management", "EVM",  
33 "construction performance", "Performance index", "performance assessment", " performance  
34 techniques", "performance assessment techniques", "construction industry", " construction  
35 environment", "construction sustainability", " sustainability", "critical success factors",  
36 "construction risk", "risk management", "risk-related factors", and "risk factors". Initial  
37 reviewing the literature assists promote and develop the researcher's knowledge and provide  
38 the researcher framework of research gap, research issue, research objectives and research  
39 questions (Collis 2009). The less recent articles, which were later developed by recent  
40 research and articles unrelated to the direction of this research, were excluded. Therefore,42  
41 articles were selected. The selected articles are closely related to the vocabulary of this  
42 research and have presented views on the weaknesses in the concept of Earned Value  
43 Management (EVM) and scientific solutions to address some of these points. In addition, it

1 reviewed risk factors such as sustainability, stakeholder requirements, communication and  
2 procurement strategy that affect the performance of construction projects in many  
3 countries. The second stage is to identify the key words (themes) which include Earned Value  
4 Management (EVM), infrastructure construction, project management, performance, and risk  
5 management. The third stage is to determine the time period for the search scope. Initially,  
6 the time period for the search scope was not specified, to take a comprehensive look at the  
7 principles of the concept of EVM and weaknesses in this concept. As a result of rapid  
8 developments in the implementation of infrastructure projects and developments and global  
9 economic trends towards a sustainable environment, the time period for research and  
10 academic publications was then determined for the period from 2004 to 2018.

11 A number of factors (for instance safety, environment, economic and political conditions)  
12 influence the measurement of project performance. These factors are called critical success  
13 factors (CSFs). In this process, to obtain the best measurement or evaluation for the project  
14 performance, the study of the impact of these factors on the components of performance  
15 (cost, time and scope) evaluation of projects is required. In addition, taking into consideration  
16 the impact of these factors during the process of assessing the project performance lead to  
17 making the measurement process more comprehensive and realistic.

18 There are many factors that affect the performance of infrastructure projects or impact on the  
19 success of projects. As discussed, risk management is one of the important factors affecting  
20 the performance of infrastructure. Standards Australia and Standards New Zealand (2009)  
21 mention that the ambiguity about the organizational activities affected by external and  
22 internal factors that create uncertainties about the extent and when to achieve their desired  
23 objectives is a "risk". Why focus on risk management? To answer this question, a number of  
24 literature sources, some of which have been discussed previously, suggest that risk is an  
25 important issue for infrastructure construction projects, particularly with respect to achieving  
26 the project objectives. Smith et al. (2014) point out that many projects do not meet deadlines  
27 and the budgeted cost, causing a bad reputation for construction projects manager in dealing  
28 with the negative consequences of scope changes. They also note that these changes cannot  
29 be eliminated but can be managed effectively by applying the principle of risk management.

30 One of the risk-related factors is sustainability in infrastructure projects, which is an emerging  
31 factor. Sustainability needs to be expanded and a comprehensive study needs to be  
32 undertaken because most of the world has identified sustainability as one of the important  
33 issues related to international expectations with respect to the economy, society, and  
34 environment. The relationship between these expectations and sustainability risk is through  
35 the risk of failure of the project to meet expectations in the areas of economy, society and  
36 environment. The Canadian Society for Civil Engineering (CSCE) refers to sustainability as  
37 an essential element for infrastructure projects (Upadhyaya et al. 2014). 'Establishment of  
38 sustainability requirements early in an infrastructure project are important in setting the  
39 expected standard of operation during the construction phase' (Engineers Australia 2017).  
40 Cheng et al. (2018) mention that the lack of a system for assessing the sustainability  
41 requirements in construction project lead to risks for the contractors to select the sustainable  
42 execution alternatives. Therefore, based on review of the literature, the emerging factor,

1 sustainability requires a comprehensive study to cover all aspects that affect the performance  
2 of projects under the influence of risk.

3 Most of the recent research focused on the relationship between risk and its impact on the  
4 sustainability of infrastructure projects during the operations phase only. For example,  
5 Padgett and Tapia (2013) argue that the impact of natural risks on infrastructure has a  
6 significant influence on infrastructure sustainability, which characterized through  
7 environmental, economic and social performance indicators. So, there is a lack of review that  
8 discussed or identified the relationship between risk and its impact on the sustainability of  
9 infrastructure projects during the construction phase. Based on this, we will use interviews to  
10 explore that. Therefore, based on review of the literature, a comprehensive study is required  
11 to cover the impact of sustainability as a risk-related factor on infrastructure projects during  
12 the construction phase.

13 Furthermore, stakeholder requirements and communication are factors that affect the goals or  
14 expectation of the project. Thekdi and Lambert (2013) explain the use of views, experiences  
15 and interests of stakeholders in the development of the priorities of infrastructure systems to  
16 address the risk of emergency conditions (emergent and future conditions). The number of  
17 variations and differences in the interests between stakeholders represents one of the risks that  
18 impact on infrastructure project performance (Li et al. 2013). Thus, good relationships among  
19 stakeholders and efficient communication between them positively affect the cost and  
20 duration of the project. It is worth mentioning that the management of stakeholders'  
21 requirements is therefore a significant risk issue.

22 Another risk-related factor is procurement strategy. Risks can arise and spread in ways  
23 unpredictable, as a result of the complexity of the procurement strategy (Loosemore &  
24 Cheung 2015). Selection of appropriate contractual regulations are essential to achieve better  
25 performance of the project (Lu et al. 2015). Hwang et al. (2013) identify 23 procurement risk-  
26 related factors that have a significant influence on the public-private partnership (PPP)  
27 procurement strategies in Singapore. Hwang et al. (2015) identify the major risks facing the  
28 various parties involved in the international construction joint ventures (ICJVs) in Singapore.  
29 They also argue that “partners disagree over some conditions in contract” is a most important  
30 risk for the various parties involved in these ICJVs. Based on the literature, risk is therefore  
31 influenced by other variables such as sustainability, communication, stakeholder requirement  
32 and procurement strategies. Thus, selecting good procurement strategies positively affects the  
33 cost and duration of the project. Thus, procurement strategies are a significant project risk  
34 issue.

35 In summary, the traditional EVM method of measuring the performance of projects focuses  
36 on cost and time only without taking into account the impact of risk-related factors during the  
37 implementation phase. The effect of risk-related factors will use in future research to extract  
38 the risk performance index (RPI). The risk performance index (RPI) will incorporate into the  
39 Estimate at Completion (EAC) equation to modify the concept. The contribution of this  
40 research is to identify the significant risk-related factors influencing the process of assessing  
41 the progress of modern sustainable infrastructure construction projects, with an emphasis on  
42 the Australian context. Therefore, to achieve the primary aim of this research, which is

1 investigating a set of risk-related factors influencing the (EVM) concept as an assessment  
2 technique in evaluating the progress of modern infrastructure construction projects in  
3 Australia, the main research questions for this study are:

4 *Research Question 1.* What are the risk-related factors that impact infrastructure projects  
5 performance in Australia?

6 This question was used to investigate the influence of a set of risk-related factors like  
7 sustainability, requirements of stakeholders, communication, procurement strategies and other  
8 factors.

9 *Research Question 2.* What are the significant measuring items for these factors?

10 This question was used to identified measurement items for each risk-related factor because  
11 these factors are latent factors that cannot be measured directly.

## 12 **RESEARCH METHODOLOGY**

13 Based on the objectives and research questions of the research, the qualitative method of data  
14 collection and analysis is adopted to clarify and interpret data. The qualitative method is used  
15 to gather and analyse a majority of non-numerical data such as themes (Creswell 2014). The  
16 research method is described below.

### 17 **The first stage (Literature review)**

18 A literature review is used to explain the principle of earned value management (EVM)  
19 concept and to identify the benefits of using this concept. Moreover, it is used to identify the  
20 weaknesses and strengths of using this concept and to investigate the factors that affect the  
21 accuracy of EVM under the effect of risk management and its contributing factors. The  
22 preliminary results obtained from literature review showed four important risk-related factors  
23 are sustainability (SS), stakeholders' requirements (SH), communication (CM) and  
24 procurement strategy (PS). This stage of the methodology answers and achieves a part of  
25 RQ1.

### 26 **The second stage (Interviews)**

#### 27 • *Overview*

28 Interviews depend on individual experience and opinions to obtain perception about  
29 phenomenon or concept and the influence of different factors on them by answering semi-  
30 structured questions. According to Creswell (2009), the procedure of conducting semi-  
31 structured interviews, and their recording and transcription to text, is one of the approaches  
32 that used for gathering qualitative data. The purpose of the interview firstly, to ascertain the  
33 impact of the risk-related key factors obtained from the literature review on the performance  
34 of the infrastructure projects in Australia; secondly, to identify relevant risk-related sub-  
35 factors (measuring items) that influence key factors; thirdly, investigate new risk-related  
36 factors and their measuring items that impact the performance of infrastructure projects  
37 development in Australia. The structured interview questionnaire was divided into three  
38 sections as follows:

- 1 a. The first section is about participant demographics (four questions) such as years of  
2 experience, qualifications, roles in infrastructure projects and types of infrastructure  
3 construction projects
- 4 b. The second section was about factors obtained from the literature review ( 20  
5 questions) such as sustainability, procurement strategies, stakeholder's requirements  
6 and communication
- 7 c. The final section was about the exploration of new factors (three questions).

8

9 • *Sample*

10 For the objectives of this research, interview invitations were sent to more than 58 peoples  
11 and companies by email, mail and delivery by hand. The face-to-face interview was  
12 conducted with 15 people working on infrastructure projects in Australia. The response rate  
13 was 28.8%. More than 90% of interviewees had more than 10 years' experience in  
14 infrastructure projects. All interviewees had a bachelor's degree in civil engineering, 33.33%  
15 of the participants had a master's degree and 13% of the participants had a PhD degree. 73.3%  
16 of interviewees worked as construction engineers, and 60% of the participants worked as  
17 project managers. 93.3% and 73.3% of interviewees worked in roads and bridges respectively  
18 and out of 15 interviewees, some of them also worked in tunnel construction (26.7%), airport  
19 construction (33.3%), railway construction (53.3%), dam construction (26.7%), infrastructure  
20 maintenance (33.3%), and harbour construction (13.3%).

21

22

23 • *Qualitative data analysis*

24 The procedure adopted at this stage is recording the interviews, transcription of the record  
25 interviews to text, analysing qualitative data by using thematic analysis, and using the  
26 computer software programs (NVivo) to confirm the process of qualitative analysis.

27 Based on interviews, the first author developed a number of themes that related to risk  
28 factors. Then, the NVivo program was used to confirm the manual analytical procedure and  
29 undertake further analysis. This software is used to validate the researcher's decision making  
30 procedure and to assist the researcher with the ability to process data and identify notes  
31 (Cavana 2001). Use coding technology allows to clarify and concentrate on a set of features  
32 and helps the analyst to summarize (Richards 2007). The coding technique used consists of  
33 three parts: word Interviewee; hash key (#), and number indicating the sequence of the  
34 interview procedure. For example, (Interviewee #3) referring to a third interview conducted.  
35 After the recording transcription to text, the manual qualitative analysis starts to investigate  
36 the themes in the text. The manual qualitative analysis was conducted at intervals during  
37 interviews. The manual qualitative analysis of the first three interviews was conducted to  
38 ensure that the interview questions were consistent with the research objectives. The manual  
39 qualitative analysis was then carried out after the eighth interview to obtain a clear view of  
40 the interview track. After the interview no.15, the manual qualitative analysis was conducted.  
41 The saturation state was reached at interview no.12. While nothing new was added during the  
42 last three interviews, they confirmed of what was mentioned in the previous 12 interviews.



1 Saturation deduces when no extra data will be added from the obtained information (Mills et  
2 al. 2009).

3

#### 4 **FINDINGS**

5 Most of the participants confirmed the risk-related factors obtained from the literature review  
6 (sustainability (SS), stakeholders' requirements (SH), communication (CM) and procurement  
7 strategy (PS)). In addition, they referred to new risk-related factors. The researcher  
8 summarized the interviews data and categorized the results. For example, the rain was  
9 reported in interviews which are part of the weather factor and in another interview were  
10 reported storms which are also part of the weather factor and so on. The factors were arranged  
11 sequentially according to the percentages of the number of times these factors were  
12 mentioned in the interviews. Table 1 shows all the factors mentioned by interviewees.

13 **Table 1 Risk-related factors**

14

##### 15 *Sustainability (SS)*

16 All the participants confirmed sustainability as an important risk-related factor affecting  
17 the performance of infrastructure projects. As shown in Table 1, the reference to  
18 sustainability was repeated in all 15 interviews. Furthermore, the interviewees  
19 explained the measuring items of sustainability. The following are the observations of  
20 some of the interviewees, which illustrate the importance of sustainability and its  
21 measuring items.

22 Design incorporating sustainability requirements is mentioned in this comment:

23 'I will go back to the risk associated with the design and sustainability. This design  
24 should be long enough. Let's suppose if you have a project which you have to  
25 maintain for next 50 years, ...' (Interviewee #6)

26 Current market price which is reinforced in this comment:

27 'In our field, complying with all the requirements is so essential to proceed with the  
28 project and one of the requirements is the sustainability. Bearing in mind the current  
29 market prices, it is very difficult to implement the 100% sustainability requirements  
30 which will dramatically increase the project cost and then reflect badly on the  
31 decision to proceed with the entire development plan.' (Interviewee #1)

32 Materials supply and resources are highlighted in this comment:

33 'With sustainability obviously, your materials supply. For sustainability things like  
34 asphalt, if you're using recycled asphalt things like that. ...As for risks of that, it's a  
35 hard one. Affect the sustainability. There's the procurement material and if you can  
36 incorporate those things into a design. It's designed as well.' (Interviewee #9)

37 Government legislation is confirmed in this comment:

38 '.... A large one is possibly government legislation. We define sustainability as,  
39 typically, defined long-term through government legislation, and then obviously,

1 there's a lot of more short-term items such as predominantly environmental  
2 sustainability and also sustainability in terms of impact to the end users.'  
3 (Interviewee #15)

4 Understanding the principle of sustainability, this issue was confirmed by (Interviewee  
5 #10) in this note:

6 'Risks are so a person's understanding of the principle of sustainability. If they know  
7 what they are looking at and what they need to be looking for, they'll make better  
8 decisions in regarding of wasted material ...'

### 9 *Stakeholders' requirements (SH)*

10 The other risk-related factors influencing the performance of infrastructure projects is  
11 stakeholder requirements that confirmed by 93.3 % of interviewees. As shown in Table  
12 1, the stakeholders' requirements was referenced in 14 of interviews. Furthermore, the  
13 interviewees explained the measuring items of stakeholders' requirements. Here are  
14 some comments from interviewees, which clarify the importance of stakeholders'  
15 requirements (SH) and it's measuring items.

16 Government requirements, (Interviewee #7) declared that:

17 'In terms of stakeholders, you'd have things like the approving authorities. To an  
18 extent, they could probably fall under that client category as well. It's the person  
19 who's paying for the project but you've also got to meet the requirements of local  
20 authorities or state authorities ...'

21 The risk of diverse requirements are mentioned in this comment:

22 'The risk of the stakeholders when they're looking at their requirements, they're  
23 really looking at the final job, the final outcome and getting it on time, getting it on  
24 cost, meeting the expectations and perceptions, those sorts of things.' (Interviewee  
25 #2)

26 Type of contract, this issue was stated in this comment: 'Risk of choosing the  
27 appropriate contract type, for example, clients want a project that is fit for purpose,  
28 whatever that purpose is defined as.' (Interviewee #4)

### 29 *Communication (CM)*

30 Communication is a significant risk factor in the performance of infrastructure project  
31 in Australia. As shown in Table 1, communication was confirmed by 93.3% of  
32 participants and it was duplicated in 14 interviews. The following are the remarks of  
33 some of the interviewees, which depict and explain the measuring items of  
34 communication.

35 Communication strategy. Interviewee #1 states that:

36 'The communication strategy and the responsible parties should be identified from  
37 the beginning of the project. In addition to that, using the advanced communication  
38 programs will improve the communication between all the parties. ...'

1 Stakeholders' experiences are mentioned in this comment: 'The people on the project  
2 and their experience that affects the communication of the project and it's a big risk'  
3 (Interviewee #2)

4 The relationship between stakeholders is emphasized in this comment:

5 'Communication between stakeholders is very important. I guess the main risk in  
6 terms of communication between stakeholders is all about the relationship. It's very  
7 important to have a long-term relationship for the better of the project...'  
8 (Interviewee #14)

9 *Procurement strategy (PS)*

10 As shown in Table 1, 14 participants (93.3%) agreed on that procurement strategy as  
11 related risk factor affecting infrastructure performance. Here are some of the  
12 perceptions of some of the interviewees, which depict the importance of procurement  
13 strategy and its measuring items.

14 Design meets the contracting requirement is strengthened in this note:

15 'Depending on contracting requirements, if you don't define the performance of the  
16 design, with a performance-based specification adequately, you can get poorer  
17 quality and design outcomes. I've seen that happening ...' (Interviewee #5).

18 Type of procurement strategies is confirmed in this comment:

19 'Each contract type is going to have its own type of risk ..... So choose the  
20 appropriate type of contract is a big issue have a risk in infrastructure projects'  
21 (Interviewee #10)

22 Size of the project, the interviewer #8 answered the question about the types of risks  
23 affecting the procurement strategy with the following comment:

24 'What kind of risk affects the procurement strategy? It comes down to size.  
25 Nowadays, it comes down to two or three things. One is it is very much about the  
26 size of the project and who are the owners of those projects'

27 *Weather (WE)*

28 Weather is a new factor was derived from interviews. The recurrence of weather during  
29 the interviews was referenced by 12 out of 15 participants (80%) as shown in Table 1.  
30 The following are the comments of some of the interviewees, which clarify the  
31 importance of weather and its measuring items.

32 Extreme weather such as heavy raining and flood, accordant to (Interviewee #15):

33 'Weather is always an issue. .... I have been involved in projects where you shut the  
34 project for three months because you expect the rainy season. Typically, you have to  
35 manage the weather.'

36 Extreme weather such as low and high temperature, Interviewee#2 stated that:

37 'Even things like fog, cold temperatures, and hot temperatures. When you're further  
38 out west, sometimes it gets too hot and the men actually struggled to work, and then  
39 some of them would get sick through heat stroke, and things like that. Conversely,

1 cold temperatures, sometimes they can't hold the tools. They had tires overworking  
2 and sleeping, and things like that because of the weather.'

3 Extreme weather such as storms and cyclones, (Interviewee #7) argued that:

4  
5 'Again, the weather.... It's just the very similar type of things really. If you get  
6 delays due to weather, that might mean that you have to go back and you don't think  
7 a major-- a storm event or something like that, causing a lot of damage, it's going to  
8 cost you a lot of money, particularly depending on the insurance coverage that  
9 you've got. You might recover them insurance-wise but some would go down the  
10 drain. That can have a major effect.'

### 11 *Experience of staff (SE)*

12 Another theme is the experience of staff. As shown in Table 1, the frequency of  
13 indication of the experience of staff during interviews was (60%) and it was referenced  
14 by 9 participants. Here are some the views of some of the interviewees, which  
15 emphasize the importance of the experience of staff and its measuring items.

16 Staff commitment level is mentioned in this comment:

17 'On the performance, you've got to look sometimes are the team all here for the  
18 right reason. Are they all working together? Do they get along? Sometimes they  
19 don't get along... Definitely, things like the experience of the team, whether they are  
20 committed to your project, what are they there for and what are their motives? It's a  
21 big, big thing.' (Interviewee #2)

22 Staff Skills level is mentioned in this comment. Interviewee #12 supposed that: 'Kind  
23 of risks made a few notes. I supposed the skilled workforce'

24 Staff Management is mentioned in this comment, Interviewee # 15 found out that:

25 'Getting sufficient resources. So, people are a huge issue. Also, this includes  
26 management. Staff management is a big issue. Having good project management.  
27 Team culture. Overall project delivery.'

28

### 29 *Site condition (SC)*

30 Site condition theme was found through qualitative analysis. Where site condition was  
31 mentioned by nine interviewees (60%) during interviews as shown in Table 1. The  
32 following are the perceptions of some of the interviewees, which emphasize the  
33 importance of site condition and its measuring items.

34 Geotechnical investigation, Interviewee # 11 explained that: 'So just particularly for my  
35 job, I guess some of the risks can be like soft soils or not enough geotechnical  
36 information during design.'

37 Earth works, Interviewee # 9 mention that: 'the earthwork is a quite a big risk in the  
38 performance of infrastructure projects.'

39 Ground condition (old building foundations, an archaeological find, and water table  
40 level) is mentioned in this comment:

1           ‘If you're working through a site and you find something that's been buried that  
2           might be contamination that needs to be remediated or you might find some  
3           archaeological find that could stop your project and slow things down while that  
4           gets dealt with. That can have an effect on your cost as well.’ (Interviewee # 7)

5           Site access on time (possession in time), Interviewee # 3 specified that, ‘site possession  
6           in time is one of risk affecting infrastructure performance.’

7

### 8           *Design issues (DI)*

9           Eight interviewees (53.3%) pointed to that design issues one of an important related risk  
10          factor in Infrastructure projects in Australia as shown in Table 1. Here are some the  
11          opinions of some of the interviewees, which highlight the importance of design issues  
12          and its measuring items.

13          Poor and inefficient design (mistakes in design) is cited in this comment: ‘Mistakes in  
14          design, they cost lots when you come to implementation to be fixed.’ (Interviewee # 2)

15          Inadequate and Insufficient design (lack of details, information and specifications) is  
16          quoted in this comment:

17                   ‘During implementation, I guess probably poor design, or inadequate design or  
18                   insufficient design information have a big impact on the program. Getting designs  
19                   checked and inquiries closed there.’ (Interviewee #11)

20          Major design changes are mentioned in this comment:

21                   ‘There is a risk of a design change as well, which I have faced a lot in my career  
22                   during the execution process once the design changes... These are the biggest risks,  
23                   in my opinion, during the execution process.’ (Interviewee # 6)

24

### 25          *Financial Risk (FR)*

26          As shown in Table 1, eight participants (53.3%) underwrote that financial risk as risk-  
27          related factor affecting infrastructure performance. The following are the notes of some  
28          of the interviewees, which expose the importance of financial risk and its measuring  
29          items.

30          Fluctuation of an inflation rate, it was reported in this comment:

31                   ‘Australia is a distorted economy. Depending on the phase and the economic cycle.  
32                   Right now in WA, you can get things probably half the price and you can get them  
33                   immediately because they are in a low economic activity period. That's a big one,  
34                   and you can't predict it.’ (Interviewee # 4)

35          Fluctuation of an exchange rate is mentioned in this comment. ‘Kind of risks made a  
36          few notes. I supposed the price of the Australian Dollar would affect that.’ (Interviewee  
37          # 12)

38          Fluctuation of an interest rate, it was mentioned in this comment.

1 'The global financial situation is beyond our control. The ability to borrow money at  
2 what cost? During the global financial crisis, nobody would lend you money. If they  
3 did it, it was at a very high rate.' (Interviewee # 4)

#### 4 5 *Subcontractor (CO)*

6 Another risk-related factors influencing the performance of infrastructure projects is  
7 subcontractor performance. It was derived from interviews. As shown in Table 1,  
8 subcontractor confirmed by 46.7% of interviewees. Where it was mentioned by seven  
9 interviewees. Here are some notes from interviewees which illustrate the importance of  
10 subcontractor and its measuring items.

11 Subcontractors' performance is presented in this note:

12 'Subcontractors. There's always a risk on subcontractors. Whether you've  
13 adequately assessed their capability, they might say they can do all sorts of thing,  
14 but when you get them out on site, they can't perform or function as well as they  
15 said they could.'(Interviewee # 2)

16 Subcontractors' availability is indicated in this comment:

17 'The volume of work at that time. If there is a lot of jobs, a lot of contracts  
18 happening, that will impact the project as well. If there are not many project  
19 happenings, all the good contractor would come and work for you...' (Interviewee #  
20 6)

#### 21 22 *Government requirements (GR)*

23 Government requirements theme was constructed through qualitative analysis. Where  
24 government requirements authority was specified by six interviewees (40%) during  
25 interviews as shown in Table 1. The following are the reports of some of the  
26 interviewees, which detect the importance of government requirements authority and its  
27 measuring items.

28  
29 Change in government policy is accredited in this comment:

30 'Changes in government policy can affect. That's a big one. Can you identify risks  
31 affecting project time? Over in WA, the government is saying they want to have a  
32 special tax regime for the mining companies... Mining companies could not predict  
33 that, so change in government policy and objectives.' (Interviewee # 4)

34 Sovereign government intervention is referred to this comment:

35  
36 'I would say out of that you already mentioned a couple of issues there. I think in  
37 Australia sovereign risk as increased. What I mean by sovereign government  
38 intervention... That kind of sovereign risk it's becoming really important to consider  
39 in Australia.'(Interviewee # 8)

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*Materials (MR)*

As shown in Table 1, six interviewees (40%) pointed to that materials was crucial risk-related factor in Infrastructure projects in Australia. The following are the opinions of some of the interviewees, which discover the importance of materials and its measuring items.

Material procurement is highlighted in this note:

‘In terms of construction risks or any? First off, procurement risks around larger items among late time items. Now, I went to order them in time, something that could be six months late time. You've got to order really early otherwise you'll have problems with program.’ (Interviewee #13)

Availability of material is quoted in this comment:

‘Sometimes you just can't get the supplies. Like at this multiple contracts going all at one time, and there's only one gravel supplier in the area, if you don't get your order in, you might not be able to get gravel from that person, or it could just be the distance from the delivery.’(Interviewee #2)

Consequently, the interviewees focused on the more than 12 themes which indicate of types of risk during performed infrastructure in Australia. The discussions with the interviewees suggested sustainability, stakeholders’ requirements, communication, procurement strategy, weather, experience of staff, site condition, design issues, financial risk, subcontractor, government requirements authority and materials. These factors have gained consensus by participants more than 40%. As shown in table 1, the rest of the factors were neglected that obtained consensus less than 40%.

Based on the above, table 2 explains the risk related factors and their measuring items.

Table 2 Risk related factors and measuring items

## 1 **VALIDATION OF THEMATIC ANALYSIS**

2 The researchers originally determined the main distinguishing by inspection different themes  
3 that related to risk factors. At this stage of research, the NVivo program (reference?) was used  
4 to confirm the initial analytical procedure. NVivo software is used to buttress the researcher's  
5 decision making procedure and to grant the researcher the ability to process data and identify  
6 notes (Cavana 2001).

7 NVivo confirmed the risk-related factors affecting the infrastructure construction  
8 performance. The outcomes of NVivo confirmed the results of the qualitative analysis. Table  
9 3 shows all factors and their sources (frequency).

10

11 **Table 3 Summary - Confirmation of qualitative analysis**

12

### 13 **Discussion**

14 The results of qualitative data collection and analysis identified several of risk-related factors  
15 likely affect the performance of infrastructure projects during the implementation phase.  
16 Table 3 summarizes the results of the qualitative stage. The results were categorized  
17 according to the comments of the interview participants, as shown in the findings section. The  
18 first four factors were derived from the literature review (SS, SH, CM and PS), which was  
19 confirmed during the interviews. The selecting of these factors was for several reasons first,  
20 emerging factors such as sustainability (SS) that need to be studied more deeply and  
21 extensively. Second, factors have been studied in different parts of the world and on  
22 construction projects in general such as stakeholders' requirements (SH), communication  
23 (CM) and procurement strategy (PS). Therefore, there is a need to study more deeply and  
24 extensively for their impact on infrastructure projects and in Australia specifically. As can be  
25 seen in Table 3, which reflects the results of interviews, the main factors' proportion (SS, SH,  
26 CM and PS) has been high, which underlines the significance of these factors on  
27 infrastructure projects performance. At the same time, the risk-related factors were emerged  
28 from interviews including (WE, SE, SC, DI, FR, CO, GR and MR) have received a good  
29 percentage, which confirms the need to be included in the research. The percentages obtained  
30 were between 40% - 80%. The factors have been neglected that reported less than 40%. For  
31 the purpose of collecting qualitative data in the least number of themes, the researcher fixes  
32 up, modernizes and reassembles the data (Creswell 2013). Accordingly, some of these factors  
33 will be included in the accepted factors indirectly, through the measuring items of the  
34 accepted factors. For example, despite the fact that the quality control factor reached 13.3%,  
35 the quality factor will be addressed indirectly when measuring items of design issues are  
36 mentioned. As well as with resources (20%) that will be referred to within the availability of  
37 materials. The impact of these factors on the performance of infrastructure projects is  
38 through their impact negatively or positively on the main elements of performance (duration –  
39 cost). This impact will be evaluated and calculated in future research to improve the  
40 performance assessment of infrastructure projects in Australia.



## 1 **Conclusion**

2 The focal point of this study is to increase the trust and credibility of the EVM concept by  
3 developing this concept to be more comprehensive and inclusive of several factors that can be  
4 classified as risk-related factors rather than just concentrate on the key elements of  
5 performance measurement (time, cost, scope). This is done by combining the impact of these  
6 factors as the Risk Performance Index (RPI) in the equation of Estimate at Completion  
7 (EAC), as is the case for both the Cost performance index (CPI) and the Schedule  
8 performance index (SPI). This process led to match increasing between the predicted values  
9 with the real values and makes the variation between them less than possible. The findings of  
10 this paper are investigating and identifying a set of risk-related factors during the  
11 implementation phases of infrastructure projects in Australia. This was obtained through a  
12 qualitative study (literature review and interviews). The results are confirmed by data analysis  
13 using NVivo. This study highlights 12 factors (Sustainability (SS), Stakeholders'  
14 requirements (SH), Communication (CM), Procurement strategy (PS), Weather (WE),  
15 Experience of staff (SE), Site condition (SC), Design issues (DI), Financial risk (FR),  
16 Subcontractor (CO), Government requirements (GR) and Material (MR)) as risk- related  
17 factors. These factors were propped by literature review or participants' comments. Factors  
18 that were not mentioned at high rates during interviews were neglected. Some of these  
19 neglected factors are included as measuring items of accepted factors.

20 The research reported in this paper has the potential to not only aid in the assessment of risk  
21 factors in the Earned Value project control process, but also in areas like the impact of project  
22 risks in the design and construction phases of the project. For example, an understanding of  
23 the project delivery risks identified in this paper is able to assist planners to optimise project  
24 selection, designers to improve their estimation and contract design processes, and  
25 constructors in identifying, managing and controlling the major cost and other risks in project  
26 delivery.

27 The calculation and assessment of the impact of risk- related factors on the performance of  
28 infrastructure projects in Australia will be studied in depth in future research. This approach  
29 will further help those managing infrastructure projects improve the performance  
30 measurement of infrastructure construction projects in Australia, by warning them of these  
31 factors and taking them into account in the processes of designing, estimating and  
32 constructing the project.

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