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The Project Governance and Controls Annual Review (PGAR) showcases interesting and practical academic papers focused on enhancing the governance and practice of project, program and portfolio management in the Australasian region. Each annual update is published in the months following the Project Governance & Controls Symposium held each year in August, in Canberra; and includes papers received in the preceding year.

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PGCS PROJECT AND PROGRAM MANAGEMENT SYMPOSIUM
Better Management Better Projects

The Project Governance and Controls Symposium (PGCS) is designed to enhance the connections between project and program management, governance and controls. Project management cannot operate effectively without the support of senior management and the information from effective project controls. Frank and fearless reporting of status and issues cannot be assumed if the middle levels of management have the capability to restrict negative information. Conversely, executive management decisions depend on accurate and realistic assessments of risk, schedule and cost. Creating a culture where this type of information is not only available but accepted and used properly is the key governance issue within the project, program and portfolio domain.

For more information on this year's PGCS, see: https://www.pgcsymposium.org.au/

The Walt Lipke Awards

The Project Governance and Controls Symposium (PGCS) sponsors the annual Walt Lipke Award in honour of Mr Lipke's contribution to enhancing the governance and control of projects world-wide.

Walt Lipke (brown suit – shown here presenting the 2017 award at PGCS) is the creator of Earned Schedule, which extracts reliable schedule information from earned value data (resolving the long-standing error in the calculation of SPI and SV).

Mr. Lipke has published articles, and presented at conferences around the world, on the benefits of software process improvement and the application of earned value management, earned schedule, and statistical methods in the management of projects and programs. His contribution to project controls has been recognised by, among other, PMI, The College of Performance Management, and the EVM Europe Conference. Earned Schedule is freely available to the project community from: http://www.earnedschedule.com/

Walt Lipke Award Winners

2017 Mr. Peter Slay

2018 Dr. Raymond Young

2019 Professor Shankar Sankaran

2020 Mr. Munir Ahmad Saeed

2021 Ms. Roksana Jahan Tumpa

2022 Winner to be announced at PGCS 2022.

For more information on the **Walt Lipke Award** see: https://www.pgcs.org.au/academic-papers/#Walt

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Editorial

This 3rd edition of the Project Governance and Controls Annual Review (PGCAR) has again been published in extraordinary times. However, despite the COVID restrictions the PGCS 2021 Symposium was a great success with 450 people attending in-person and virtually, the Walt Lipke Award was keenly contested and the PGCS 2021 research grant has been awarded and the 2022 research grant announced[1].

The three academic papers included in this edition are the Walt Lipke Award finalists, and cover a diverse range of topics:

- Roksana Tumpa's paper (Walt Lipke Award winner) is part of an on-going effort to make project management courses at universities more relevant to industry, and graduates more employable.
- Li Guan's paper is a deep dive into the assessment of risk and probability. This paper complements a number of presentations at PGCS 2021 that considered the assessment of a realistic probability of completing projects successfully. The 2021 presentations can be downloaded from: https://www.pgcs.org.au/library/2021/
- Munir Saeed's paper highlights deficiencies in the management of the processes needed to realise benefits from projects.

The *Industry* paper by Walt Lipke introduces a process for assessing the probability of recovering lost time on a project using the TCPI ratios for both time and cost. The paper includes a link to a free spreadsheet for readers to test the concept on their projects.

Finally, Research Report by Dr. Yongjian Ke marks a major milestone in the growth of PGCS. This report concludes the first (2019) research grant awarded by PGCS. The core mission of PGCS is to advance and improve Australia's project delivery capabilities; supporting focused research is a key component of this mission, as is disseminating information to the industry.

[1] For details of the 2022 Research Grant see: https://www.pgcs.org.au/research/

Developing Employability Attributes of Higher Education Project Management Graduates: A Scoping Review

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Abstract

Projects play a pivotal role in modern enterprises. Functional structures of organisations are being replaced by project-based organisations. Along with the growth in project management, the need for skilled project professionals is mounting for the successful execution of the projects. This reflects the importance of preparing project management graduates for complex project environments. Higher education institutions (HEIs) are responsible for preparing work-ready project management graduates so are responding by continually reviewing and developing effective project management courses. This scoping review focuses on how HEIs are addressing the employers' demand by preparing project management graduates for the industry.

Recent research on the work-readiness of project management graduates adds valuable contribution to the literature, however, there is a lack of a rounded overview which focuses on HEIs contribute to the development of employability attributes of project management graduates. Accordingly, this scoping review paper aims to explore the status quo of research on the employability of graduates within the context of project management education. More specifically, the study will capture and investigate the different approaches adopted by HEIs in developing work-ready project management graduates. The paper contributes to the literature by providing insights into project management graduates' job readiness in order to inform higher education institutions, policymakers and future research.

Keywords: Employability, Work-readiness, Higher education, Project management

Introduction

Employability is one of the most highly prioritised agenda items of contemporary higher education all over the world as HEIs are often under pressure to produce employable graduates (Bridgstock, 2009; Mok et al., 2016). In Australia, employed graduates are expected to contribute to the sustainable economic growth of the country (Smith et al., 2014). Simultaneously, the reason students make investments in education is for achieving the marketable set of skills (Saunders & Zuzel, 2010). Hence, HEIs have a responsibility to help students develop the appropriate set of skills, thus increasing their productivity and their earnings (Suleman, 2017).

The number of project-based operations has been increasing exponentially in recent years. It is anticipated that project-oriented organisations will require approximately 87.7 million project management professionals working in project management-oriented roles by 2027 (PMI, 2017). In addition, roughly 2.2 million project-oriented roles need to be filled by 2027 (PMI, 2017). With the increase in growth in project management jobs, most of the project practitioners are reaching retirement age. While this opens new avenues up for project professionals, the scarcity of qualified project practitioners might pose potential risks for projectised organization relying on those talents to implement strategic initiatives, drive change and deliver innovation. As a result, the potential talent gap may result in an approximate loss of around US$207.9 billion in GDP by 2027 in Canada, Australia, UAE, United States, China, Japan, India, United Kingdom, Brazil, Saudi Arabia and Germany (PMI, 2017). This reflects the importance of preparing project management graduates for the complexity of the project environment by HEIs (Borg & Scott-Young, 2020a).

The purpose of this scoping review paper is to examine HEIs' effort to prepare project management graduates for the world of project work. The rest of the paper is structured as follows: the theoretical underpinnings of the review, conceptual framework, definition of employability, graduate attributes of project management graduates, work-readiness of project management graduates, project managers' competencies and the role of universities in graduate work-readiness. Conclusion and future direction are discussed next.

Theoretical underpinnings

Students join HEIs not only to gain knowledge but to identify a career path and gain an understanding of professional culture and norms as part of their work readiness. HEIs are expected to develop graduates who possess the skills and attributes demanded by employers. As this review discusses the development of human capital, the paper is grounded on a combination of Becker's (1962) Human Capital theory and Gale and Shapley's (1962) Matching Theory.

Human Capital theory is a theory of earnings and was first developed by Becker and Mincer in 1962. According to Becker, the most crucial investment in human capital is education and training. Becker's (1975) Human Capital Theory proposes that the productivity of an individual is increased through the accumulation of knowledge during the education period which subsequently helps to improve their job performance (Becker, 1964). The core idea rests on the concept that individuals make investments in their education and training to achieve economic advantages. Becker perceives that academic attainment and economic gain share a proportional relationship. By participating in education and training, the graduates expect to open up better career development, broaden job opportunities and earn higher over time, thus contributing to the economic growth of the nation. Hence, HEIs should produce graduates who add value to the economy of the labour market. Therefore, this review focuses on understanding project management graduates' required competencies and how they can be better prepared by HEIs so that graduates can contribute to the sustainable economic growth of the nation.

Equally this review adopted the lens of Matching Theory. Matching Theory focuses on the matching of two sides (Abdulkadiroglu & Sönmez, 2013). As outlined above, there are two sides to the discussion of project management graduates: their work-ready attributes and employers' demanded skills. It is only when HEIs align the graduate attributes to those demanded by employers, can project management graduates make a successful transition into the labour market. Therefore, this review considered the literature about how HEIs contribute to the work readiness of project management graduates and what employers' expectation of the graduates.

Conceptual framework

A conceptual framework provides an extensive understanding of a phenomenon or phenomena as a network, or "a plane," of interlinked concepts. A conceptual framework aims to achieve two objectives (1) offering a theoretical clarification around the research being investigated (2) providing the reader with a clear outline of the research objectives and how that will be obtained (King et al., 1994). The lens of this review paper is how HEIs can contribute to the development of employability skills in project management graduates. Figure 1 demonstrates a proposed conceptual framework for this review. The independent variable considered was HEIs. On other hand, the work-readiness of project management graduates was considered as a dependent variable. In this review, the role of HEIs is examined to develop work-ready attributes in project management graduates.

HEIs can take a range of initiatives to help develop work-ready competencies such as soft and technical skills. The design of new project management degrees and the inclusion of a range of activities may contribute to the preparedness of project management graduates. As proposed in Figure 1, project management graduates are highly unlikely to develop the demanded competencies and make a successful transition from universities to the world of work unless they are taught the skills and attributes required for the workplace. The authors of this review are interested in exploring what HEIs can propose to produce work-ready graduates by setting and mapping critical graduate attributes to their curriculum.

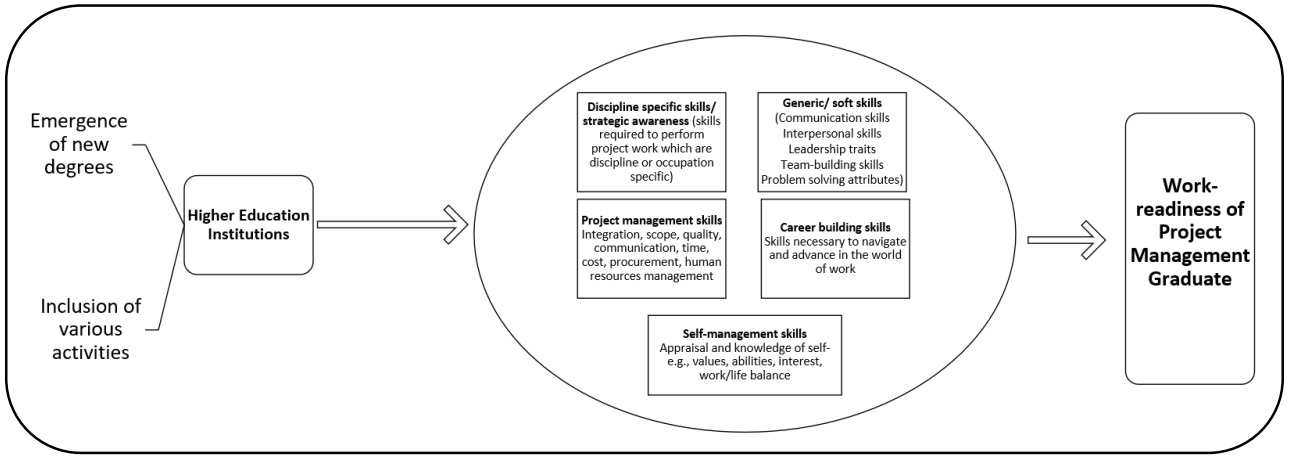

Figure 1: A proposed conceptual framework.

What is Employability?

Gazier first conceptualised employability in the early twentieth century. Henceforth, employability has been extensively discussed in the literature. A shift in the concept of employability was noticed from the 1940s to 1990s (Grazier, 1998). While higher education qualifications used to be considered a certain route to successful employment, the notion of graduate employability appears to change over time. In the contemporary world of work, graduates need to demonstrate their adaptability to changes and face countless challenges (Clarke, 2018; de Weert, 2007). Defining employability is complicated. Numerous scholars share the complexity involved in defining employability (Harvey, 2005; Holmes, 2006). Gazier (1998) described employability as a "fuzzy notion, often ill-defined and sometimes not defined at all" (p. 298) whereas employability is defined as a "confusing professional buzzword" by Thijssen et al. (2008).

The meaning of employability varies from one stage to another of a professional career. For higher education graduates, employability means finding a job or becoming employed whereas a person who is employed requires the capability of managing the ever-changing demands of the professional world and navigating successfully in the world of work to be sustainable in their employment (Nilsson, 2010). Although the meaning of employability is contextual, it can be approached through three perspectives in general (1) societal or national perspectives comprising of employment of society as a whole and economic health; (2) organisational perspectives referring to employees being capable of completing all tasks required (3) individualistic perspective comprising of an individual's ability to be sustainable in a job (Versloot et al., 1998).

On the other hand, employability can be defined as a collection of skills, attributes, and characteristics that an employee needs to demonstrate to a prospective employer (Lowden et al., 2011). Similarly, an individual's capacity to be able to maintain sustainable employment was defined as employability (Hillage & Pollard, 1998). In a similar vein, employability has been defined as "the ability to keep the job one has or to get the job one desires" by Rothwell and Arnold (2007, p.25). Additionally, Hogan et al. (2013) provided a similar definition of employability aimed at obtaining and keeping a job. A more precise definition was provided by Green et al. (2013) as "gaining, sustaining and progressing in employment" (p. 1). Similarly, Harvey (2005) disagreed that employability is limited to just getting a job. A range of literature mirrors Harvey's (2005) argument adding that employability is not only about acquiring cognitive skills (Yorke, 2006), but also a combination of obtaining qualifications, being work-ready, developing career and achieving critical and reflective skills (Harvey, 2005; Hillage & Pollard, 1998; Riebe et al., 2010). Along the same lines, York (2004) defined employability as a "set of achievements, skills, understandings and personal attributes – which makes graduates more likely to gain employment and be successful in their chosen occupations" (p. 410). A longer-term outlook of employability has shifted from an individual being able to secure a job to securing a range of attributes that make an individual attractive to multiple employers (Boden & Neveda, 2010). The recent emphasis has been driven by the change in employability policy, the increased emphasis given on lifetime job security, and skill-based and work-based solutions (Hillage & Pollard, 1998).

In Australia and the United Kingdom, the employment rate is dependent on the number of graduates who secure employment after six months of graduation (Department of Education, Science & Training, 2004). The government funding in the universities depends on the full-time employment of their graduates. However, the implementation of first-destination employment to assess the employability rate seems to be troublesome. The same notion was echoed by Dacre Pool and Sewell (2007). According to Dacre Pool and Sewell (2007), the concept of employability should not be assessed based on a graduate's ability to secure a position in the industry within a set time frame. Because some graduates may not have got engaged in graduate-level jobs under the pressure of financial burden. Therefore, measuring graduate employability depending on securing a position within six months of graduation provided an indistinct indication of students' employability (Dacre Pool & Sewell, 2007). Harvey et al. (2002) also criticised the concept of measuring employability based on obtaining full-time employment within six months upon graduation noting that employability covers much more than just gaining employment upon graduation as there may be some graduates who may have joined a lower-level job due to financial burden.

Employability is not just about vocational and academic skills. Individuals need relevant and usable labour market information to help them make informed decisions about the options available to them. They may also need support as to how to access such information successfully and to interpret that information and turn it into intelligence. Finally, people also need opportunities to do things differently and to access relevant training (Hillage & Pollard, 1998). According to Small et al. (2018),

the capacity to be self-reliant in navigating the labour market, utilising knowledge, individual skills and attributes, and adapting them to the employment context, showcasing them to employers, while taking into account external and other constraints are vitally important.

The extant literature has a number of employability frameworks such as The DOTS model (Decision learning, Opportunity awareness, Transition learning and Self-awareness), The USEM model (Understanding, Skills, Efficacy, Metacognition) and The CareerEDGE model (Career development learning, Experience, Degree subject knowledge, understanding and skills, Generic skills, Emotional intelligence). McQuaid and Lindsay (2005) also developed an employability framework that can be applied across various sectors. The framework was classified into individual factors, personal factors and external factors (McQuaid & Lindsay, 2005). Bennet et al. (1999) proposed a model consisting of five elements such as generic skills, disciplinary content knowledge, disciplinary skills, workplace awareness, and workplace experience. Another model was proposed by Bridgstock (2009) consisting of career management, employability skills, underpinning traits and dispositions, discipline-specific skills, generic skills, self-management skills and career-building skills. Bridgstock claimed Australian universities should recognise the significance of wider skill sets rather than narrow generic skills to effectively engage in graduate employability. Universities should not only map generic skills on the curriculum, but they should also involve the development and implementation of programs addressing career building and self-management skills, the partnership between faculties and career services. Clark (2018) demonstrated an integrated model of graduate employability comprised of human capital, social capital, individual behaviours and attributes that underpin an individual's perceived employability in a labour market context, and that, in combination, these influence employment outcomes. Hillage and Pollard (1998) proposed four main elements consisting of employability. Firstly, an individual's "employability assets" incorporates knowledge, skills and attitudes. Secondly, "deployment" involves career management skills. Thirdly, a person's "presentation" skills such as previous work experience, resume writing skills and techniques for handling interviews. The fourth, "personal circumstances" and "external constituents" include family accountability and available jobs in the industry respectively.

Although there are a wide range of frameworks present in the literature, the most comprehensive appears to be the CareerEDGE model. However, interpersonal attributes are absent in the CareerEDGE model and hence, should be added to the existing model. The model provides guidelines for HEIs regarding what should be included and considered in the curriculum. This model also allows all higher education stakeholders to explain each component of the model without clouding its significance. Through this model, key stakeholders, HEIs and employers can investigate their roles and contribution to graduate employability. Most importantly, this model is applicable for any stage of employability such as someone looking for a job, thinking to change in a mid-life career or dealing with redundancy (Dacre Pool & Peter Sewell, 2007).

Taken together, the reviewed literature suggests that understanding employability is important for graduates' employment, but employability is not well defined. The constitute of employability is discursively formulated starting from defining and measuring to developing and transferring (Cranmer, 2006). While a number of definitions were provided by various scholars, the literature lacks an agreed definition (Griffiths et al. 2018; Small et al., 2018; Suleman, 2017; Tymon, 2013; Williams et al., 2016). Without a proper understanding of the concept of employability and a collaborative discussion among academics, employers, students and professional staff, it is quite impractical to understand how graduates should be prepared for the world of work. While a conjoint narrative among all key stakeholders is rudimentary, the shared narrative seems to be highly disregarded in practice. This circumstance would be like "starting a journey without knowing your final destination,

or the route to get there". Williams et al. (2016) recognised the preponderance of a theoretical framework for employability. They conducted a systematic literature review on the concepts of employability. Their findings suggest that employability should be viewed through the lenses of identity, labour market demand, capital, career management, and signalling. Employability is therefore defined as a multi-faceted construct (Williams et al., 2016).

In view of the fact that there is a lack of harmony to define employability, Cole (2020) suggests that HEIs might not be able to address the employability agenda successfully. Cole and Hallett (2019) designed a taxonomy called 'Dimensions for Learning' to engage all stakeholders of HEIs. They argued that this taxonomy offers the potential to distort the narrow focus of employability and re-focus on a more holistic approach to employability.

While the notion of employability seems to be imprecise in the literature, it was apparent that HEIs are highly unlikely to confirm graduates' sustainable employability throughout their career as employability is not just about entering a job. The existing literature also questioned how employability is measured in countries such as Australia and the UK. In addition, without the collaboration of all stakeholders especially employers, it is arduous for universities to improve graduates' employability (Borg & Scott-Young, 2020; Cole, 2020). It appears that instead of focusing on enhancing employability, HEIs ought to focus on preparing graduates to be job-ready to help them enter into the industry. From the discussion above, it seems that graduates also have a part to play as Hillage and Pollard (1998) asserted stating it is an individual ability to maintain sustainable employment. To make graduates ready for the world of work, universities around the world should focus on a set of attributes namely 'Graduate Attributes'. As the scope of this review is to investigate HEIs' efforts regarding project management graduates' work-readiness, the graduate attributes of project management graduates are discussed in the following section.

Graduate attributes of project management graduates

Graduate attributes can be viewed as an array of skills and attributes that graduates are required to develop throughout their university life. These skills encompass both soft skills such as lifelong learning, generic, transferrable skills and disciplinary technical skills (Oliver, 2015). The Work-readiness of graduates is closely linked to the graduate attributes of a specific programme. The importance of graduate attributes in securing employment is paramount (Bennett et al. 2008). However, Hill et al. (2016) noted that graduate attributes can be viewed as more wide-ranging and encircled than employability as graduate attributes help develop not only academic attributes but also career competencies and citizenship.

Small et al. (2018) stated that employability is one of the employers' most sought-after graduate outcomes. According to Mason et al. (2009), the work-readiness of graduates constitutes employability. However, there is a difference between work readiness and employability. Employability is more than just possessing a set of skills, knowledge and attributes as discussed in the previous section. Barrie (2004) established a research-based policy framework for graduate attributes. The framework entails information literacy, lifelong learning, scholarship, research and inquiry, ethical, social and professional understanding, personal and intellectual autonomy, global citizenship, and communication. Australia's Higher Education Standards Framework contends that "on completion of a course of study, students [must] have demonstrated the learning outcomes specified for the course of study, whether assessed at unit level, course level, or in combination. . . [and] the learning outcomes for a course (degree) must include generic skills important to employment and further

study, and independent and critical thinking skills suitable for life-long learning" (Commonwealth of Australia, 2015).

The graduate attributes outlined by The University of Sydney, are related not only to the technical skills of graduates, but also additional skills such as research and inquiry, information literacy, personal and intellectual autonomy, communication, and ethical social and professional understandings (Cairns & Malloch, 2017). Primarily, there is remarkable consistency across the attributes emphasised by Australian tertiary education providers. Alongside discipline-specific knowledge, the most common graduate attributes mentioned were Critical thinking, Global citizenship, Teamwork, Independence, Problem-solving, Communication, and Information literacy (Oliver & de St Jorre, 2018). Osmani et al. (2015) conducted a literature review on graduate attributes and identified 53 graduate attributes. Of the 53 graduate attributes, leadership skills, teamwork, self-management creativity, technological skills, communication, interpersonal skills, problem-solving, and flexibility/ adaptability were prevalent across the studies explored.

What can be found from reviewing the extant literature around graduate attributes is that graduate attributes are discussed in general in the literature across HEIs. However, the focus of this review was to identify the graduate attributes of project management graduates in particular, which seems to be a scantly researched area.

Work-readiness of project management graduates

While graduate attributes are generally explored in the literature, there is a dearth of research that adopted the concept of work readiness in the context of project management. Work-readiness can be viewed as graduate readiness to join the workforce (Jollands et al., 2012). They defined work readiness as graduates' generic attributes to apply the technical competencies. Work readiness has increasingly been critical to employers while recruiting graduates as it is considered as a construct of entry-level jobs and indicates graduate success at the workplace, their job performance and potential career progression (Caballero & Walker, 2010). Unfortunately, the research suggests that some graduates fall below the expectation of employers in entry-level jobs (Caballero & Walker, 2010). This review highlights the work-readiness of project management graduates. Recently work readiness of project management graduates has been on spotlight (Borg et al., 2017a, Borg et al., 2018; Borg & Scott-Young, 2020a; Borg & Scott-Young, 2020b).

Borg and Scott-Young (2020a) defined the work readiness of project management graduates as a combination of values, skills, behaviour and discipline-specific skills. They defined the work readiness of a project management graduate as being able to make a successful transition from their degree programmes to the world of work. Recently, Borg and Scott-Young (2020b) explored employers' perspectives of work readiness in the context of the construction industry and found that employers value passion, empathic communication and construction knowledge of project management graduates. However, the findings were based on the construction industry. The results might be different in another context which limits its generalisation.

To stress the importance of project management graduates' preparedness, it is timely to discuss the concept of "Accidental Profession" in project management which persists in the literature. While HEIs emphasise and focus on the work readiness of project management graduates, project management is often viewed as an 'accidental profession' because most project managers begin their career without an aim to become a project manager or completing formal training. Several people are

propelled into the profession and manage the projects by luck, persistence and dedication. The role of a project manager evolves over time and through the accumulation of experience (Richardson et al., 2015). While the accidental profession is very common in the public sector (Darrell et al., 2010), Borg and Scott-Young (2020a) argued that accidental profession is not necessarily true for project practitioners or young individuals in the project workforce.

Similarly, Australian Institute of Project Management (AIPM) and KPMG (2018, p. 16) claimed that "Accidental project managers are not the right solution for managing important investments". Borg and Scott-Young (2020a) argued project managers as being 'accidental' are not able to achieve the best career path into the project management profession. Hence, instead of relying on the concept of 'accidental profession', project practitioners should aim for project management preparation to make a successful step towards project management (Borg & Scott-Young, 2020a). To eliminate the word 'accidental' from the career pathway of project managers, tertiary undergraduate education has started to emerge for project practitioners (Ramazani & Jergeas, 2015). A 'chosen' career path in project management poses a unique challenge to higher education stakeholders – the work readiness of project management graduates (Borg & Scott-Young, 2020a). To get ready for the world of work, project management graduates should possess a set of skills including transferable attributes, behaviours, and skills required for the successful transition into the workforce (Verma et al., 2018). Hence, HEIs should focus on developing work ready attributes in project management graduates. Before examining HEIs' effort to make project management graduates job-ready, it is critical to have a rounded overview of the competencies of project managers required for the ever-challenging environment of project management.

Competencies of project managers

For the successful execution of projects, one of the critical factors is the competencies of project managers (Crawford, 2000). The competencies of project managers have been discussed extensively in the literature across disciplines (Ahsan et al., 2013; Alvarenga et al., 2018; Clarke, 2010; Dainty, de Araújo & Pedron, 2015; Dziekoński, 2017; Fisher, 2011; Keil et al., 2013; Liikamaa; 2015; Moradi et al., 2020; Müller & Turner, 2007; Müller & Turner, 2010; Napier et al., 2009; Nijhuis et al., 2018; Patanakul & Milosevic, 2008; Ramazani & Jergeas, 2015; Shah & Prakash, 2017; Shenhar, 2001; Skulmoski & Hartman, 2010; Stevenson & Starkweather, 2009; Sunindijo & Zou, 2011; Thomas & Mengel, 2008; Vaz-Serra & Mitcheltree, 2020).

The extant literature seems to focus on project managers' competencies in two distinct industries, Information Technology (IT) and Construction. In the following sections, IT and construction project managers' competencies are presented.

IT project managers' competencies

The information technology (IT) project managers' (PM) competencies were studied by Napier et al. (2009). The required skills involved leadership, communication, general management, planning and control, systems development, personal integrity, problem-solving, client management, personal integrity and team development (Napier et al., 2009). In a similar vein, Stevenson and Starkweather (2009) identified the top five IT/PM skills which were verbal communication skills, listening skills, leadership, scope management and project planning. A closer look at the skills identified by Stevenson and Starkweather (2009) reveals that all of the five skills are soft in nature. Similarly, the technical

skills were only considered "somewhat important" by the participants in the study of Stevenson and Starkweather (2009). The findings of Stevenson and Starkweather's (2009) study mirror those of Napier et al.'s (2007) study.

The competencies of IT project managers were also the focal point of Keli et al.'s (2013) research. While the findings of this study demonstrated a number of similarities to the results of Napier et al.'s (2009) and Stevenson and Starkweather's (2009) studies, some variances appeared. Keil, Lee, and Deng (2013) identified 19 critical attributes deemed essential for IT project managers. In line with what previously stated in the above-mentioned studies, along with communication, teambuilding, leadership, and quality, listening and scope management were highlighted as essential skills.

To identify the most relevant competencies in IT project managers required for IT project success, de Araújo and Pedron (2015) carried out a qualitative study through an exploratory approach. The most relevant competencies found were team management, business domain knowledge, communication, project management and people skills. The technical skills of project managers seem to be traditionally accepted for IT project success. However, the existing literature seems to include evidence of achieving project success through behavioural, business and managerial competencies which are aligned with the findings of Stevenson and Starkweather's (2009) study.

While Napier et al. (2009), Stevenson and Starkweather (2009) and de Araújo and Pedron (2015) examined IT project managers' competencies regardless of soft and technical skills, Skulmoski and Hartman (2010) analysed soft competencies of Information System (IS) project managers. Skulmoski and Hartman (2010) classified soft skills as per the project life cycle. In the initiation and planning phases, the most important competency was communication (questioning/generating feedback and listening skills). However, in the implementation phase, it was considered important for project managers to possess open communication skill as a critical competency followed by collaboration. Project managers should not only possess communication and collaboration competencies, but also own persuasiveness/marketing/selling, listening skills, vision-oriented/articulate the business problem, and consensus-building. The planning phase requires project managers to have skills and knowledge in consensus building and technical skills/theoretical knowledge. The ability to get along/team player, results-orientation, and truthful/honest were also identified as important. In the closing phase, the required competencies were writing skills, share information and credit, pride in workmanship/quality and truthful/honest (Skulmoski & Hartman, 2010).

This evidence indicates that IT project managers require a wide range of soft skills alongside their technical ones for the successful execution of IT projects. Employers expect graduates to be able to demonstrate soft skills at the workplace. The authors of this review are interested in investigating whether the value of soft skills is different in the construction industry. Hence, the following section discusses the required competencies of project managers in the construction industry.

Construction project managers' competencies

A plethora of research investigated the required competencies of construction project managers. Patanakul and Milosevic (2008) identified the competencies required for managing multiple projects. The competencies were multitasking, interdependency management, simultaneous team management, organisational experience and interproject process (Patanakul & Milosevic, 2008). A strong positive correlation between construction project managers' emotional intelligence (EI) and project performance was observed (Clarke, 2010; Zhang & Fan, 2013). The competency profile of

'superior' project managers in the construction industry was explored (Dainty et al., 2004). The superior construction managers exhibited a higher level of initiative, directiveness, achievement orientation; impact and influence; self-control; focus on clients' needs; information seeking; teamwork and cooperation; conceptual thinking; analytical thinking; team leadership; and flexibility than average managers (Dainty et al., 2004). The findings were in alignment with the findings of Zhang et al.'s (2013) study. The study examined construction project managers' social competencies required for Chinese construction projects. They attempted to construct a social competency model for project managers working within the construction industry in China. The model consists of four dimensions such as working with others, stakeholder management, leading others and social awareness. Working with others includes teamwork, conflict management and cooperation; stakeholder management includes impact and influence and change management; leading others involves interpersonal leadership and inspirational understanding; social awareness encompasses personal relationship and organisational awareness (Zhang et al., 2012).

In a similar vein, the ten core competencies of project managers require for their superior performance comprised of relationship building, group capabilities, leveraging diversity, achievement orientation, maintaining order, stress tolerance (management), leadership, language proficiency, flexibility and understanding others (Moradi et al., 2020). This is consistent with conclusions by Fisher (2011) and Dziekoński (2017). To be an effective project manager, one should have attributes such as understanding of behavioural characteristics, leading others, influencing others, authentizotic behaviour, conflict management and cultural awareness (Fisher, 2011). Emotional intelligence, basic managerial skills, formal skills and interpersonal abilities supporting managerial skills were identified as four factors affecting the construction project managers' competency (Dziekoński, 2017). Alvarenga et al. (2018) revealed the most important competencies to project success. They were communication, commitment and leadership appeared as the top three aspects. However, the study did not mention the industry of surveyed project managers.

On a similar line, Edum-Fotwe and McCaffer (2000) acknowledged that a project manager's role is not limited to the conventional project constraints such as time, cost and scope. While this study focused on the construction industry only, the results might be different in other industries. To provide a comprehensive overview of project managers' competencies, Moradi et al. (2020) conducted a rounded literature review on project managers' competencies published between 1959 and 2018. It was apparent that the focus of existing literature was largely on construction, IT and engineering industries. Moradi et al. (2020) found that communication, leadership, teamwork and cooperation, flexibility, problem-solving, goal orientation, developing others, impact and influence, stakeholder management, cost management and resource management are project managers' eleven key competencies. These competencies contributed significantly to the project success than any other competencies (Moradi et al., 2020). However, project managers' competencies are not identical in an array of project types (Müller & Turner, 2010; Shenhar, 2001).

Inspired by Shenhar's (2001) and Müller and Turner's (2007, 2010) studies, Moradi et al. (2019) investigated project managers' competencies of varying projects and sizes. The analysis showed that construction project managers require the largest number of competencies than those of engineering projects, IT projects, organisational change projects, metallurgical projects, international NGO projects and public service projects.

Project managers' competencies as per job advertisements

The literature brings insights into the competencies of project managers presented in job advertisements. Do Vale et al. (2018) conducted a systematic literature review on job advertisements based on project managers' competencies. They categorised the competencies into four categories including behavioral, technical or specific, management and contextual. One of the limitations of the study was that the research was constrained to information extracted from only five job sites in Brazil. Ahsan et al. (2013) and Chipulu et al. (2013) also investigated the competencies of project manager published in job advertisements. Chipulu et al. (2013) investigated 2,306 project management job advertisements in Asian countries, the United Kingdom and the United States of America. Ahsan et al. (2013) investigated 762 job adverts in the Australian and New Zealand market. The results of both studies demonstrated that employers put more emphasis on soft skills (61.68% of advertisement) and disciplinary technical skills than project management expertise. The findings were in contrast with the results of a study by do Vale et al. (2018). In the study of do Vale et al. (2018), behavioural competencies were discussed in 27% of the job advertisements, whereas technical or specific competencies were highlighted in 35% of the job advertisements. The difference in the findings may be attributed to the geographical locations of the studies.

The importance of industry-specific skills was dominated by soft skills in the study of Chipulu et al. (2013). Soft skills were more important than project management hard skills in the financial, business, engineering, construction, manufacturing and the information and communications technology (ICT) sector than in other industries such as media and education (Chipulu et al., 2013). The engineering, construction and ICT industries stressed disciplinary technical skills and soft skills over project management hard skills (Chipulu et al., 2013), whereas disciplinary technical skills and soft skills along with project management hard skills were considered important in the construction, engineering and health care sector (Ahsan et al., 2013).

It is apparent from the discussion that soft skills, disciplinary technical skills and project management hard skills are paramount to different extents across industries. Therefore, it shows that despite a difference in how important soft skills, disciplinary technical skills and project management hard skills are, they are important to some degree across all industries. Although a wide range of research has been conducted on the competencies of project managers and employers' expectations of project managers competencies, the findings of these studies were not discussed in the light of the work-readiness of young project professionals.

To be prepared for the complexity of the project environment, technical knowledge is not enough for labelling a graduate work ready. As established previously, project management graduates also need to develop soft skills in their skillset. In the following section, the university's contribution to the development of work-ready attributes of project management graduates is discussed.

University's responsibility of graduates' work-readiness

As previously established, HEIs are under scrutiny to develop work-ready attributes in project management graduates. Employers hold HEIs responsible for the under-preparedness of the project management graduates as project management graduates lack employers' demanded skills. Although graduates are well trained in technical knowledge, they lack soft and interpersonal skills (Cavanagh et al., 2015). Project management involves numerous roles and responsibilities (Pant & Baroudi, 2008). HEIs must have curriculum content and activities pertaining to these roles and responsibilities

reflected in educational programs (Pant & Baroudi, 2008). Work-ready attributes as discussed above are not only technical skills but also transferrable competencies (Borg & Scott-Young, 2020a).

Thomas and Mengel (2008) argued that current project management education is not suited at all to prepare project managers for managing projects (Córdoba & Piki, 2012). The focus of project management education seems to be on the technical aspects of project management (Atkinson, 1997; Pant & Baroudi, 2008; Thomas & Mengel, 2008). Whitty (2005) stresses that 'projects are simply a synthesis of human sensations and expectations about how multiple resources are to be used' (p. 577). Universities should design curriculum in a manner that project management graduates are equipped with the work-readiness attributes (Cavanagh et al., 2015).

According to the Project Management Institute Global Accreditation Center (GAC) (2016), universities should provide academic curricula that integrate practice and theory at different degree levels. Programs should be innovative and forward-thinking which will prepare students to be more effective and professionals. Universities should focus on three core areas of technical expertise, professional behaviour, strategic awareness. Technical expertise comprises managing projects within constraints regarding professional standards and guides. Stakeholder engagement, leadership, communication and teamwork are part of professional behaviour. Strategic awareness incorporates contextual awareness and knowledge of strategic and operational drivers (Handbook of Accreditation for Academic Degrees and Awards, 2016).

In order to respond to employers' demands, universities have adopted many approaches to developing graduate employability by teaching and developing soft skills (Mason et al., 2009). The literature includes descriptions of the teaching of group activities (Shah, 2013); Project Management Professional Development Programme (PMPDP) (Alam et al., 2010); Outdoor Adventure Education (OAE) (Cooley et al., 2015); group assessments (Ballantine & McCourt Larres, 2007; Huff, 2014; Zou & Darvish, 2011); Project-Based Learning (PBL) (Ballantine & McCourt Larres, 2007; Córdoba & Piki, 2012); curriculum design (Ritter et al., 2017; Sin & Amaral, 2016); and finally an attention to transferrable skills, and work internships.

In an attempt to respond to whether project management programs are preparing project management graduates for the labour market, Thomas and Mengel (2008) investigated the curriculum of 15 universities and colleges that offered project management programs. Of the 15 programs, ten were offered at the master's level (MBA, MA, MSc, etc.) whilst the other five were offered at certificate level or doctoral programs. Eight programs had detailed discussion about PMBOK knowledge areas and included PMP certification preparation (Thomas & Mengel, 2008). Some providers offered advanced training even at the graduate level which focused on a PMBOK Guide based education and professional certification. Of the 15 studied curriculums, only two providers explicitly went beyond the PMBOK Guide. There is a clear gap between what universities are offering and what graduates are required to possess to tackle the uncertainty of the project environment (Thomas & Mengel, 2008).

The development of the Bachelor of Project Management degree is a new development in undergraduate tertiary education (Borg & Scott-Young, 2020a; Nijhuis et al., 2018). All over the world, 291 education providers offer bachelor's degree in project management (Study Portal, 2020). With an aim to identify whether the learning outcomes of bachelor project management degrees are in line with the employers' demanded soft skills, Borg and Scott-Young (2020a) investigated the work-ready attributes of 12 Australian bachelor's degree programs. The most frequently mentioned learning outcomes were knowledge acquisition, respect, and work ethic (values); being globally aware, collaborative, and self-aware (behaviours); and being critical, literate, and good at problem-solving (skills). The three highest-ranking 'values' were knowledge acquisition, respect, and work ethic. The

top three 'behaviours' were globally aware, collaborative, and self-aware, while the top three work-ready 'skills' were critical analysis, literacy, and problem-solving (Borg & Scott-Young, 2020a). The findings suggest that graduate attributes are being included in university curricula. However, there is a further need to investigate the effectiveness of the Bachelor of Project Management degrees with regard to the development of the work-ready attributes in young project practitioners. In addition, the findings are geographically limited to Australia and cannot be generalised to all Project Management degrees. Further studies are required to see how well these project management graduates completing bachelor's in project management meet the expectations of employers.

While universities are slowly responding to the identified needs of employers to prepare graduates for the labour market, it is critical to know how employers regard the efforts higher education is making towards ensuring project management graduates' work readiness. Construction employers acknowledged that graduates completing the Bachelor of Construction Project Management possess strong work-ready attributes both in technical and soft or interpersonal skills (Borg & Scott-Young, 2020b). Employers believed that these graduates are better prepared for verbal communication skills, professional presentation and technological use. However, graduates were found to be less confident in seeking help, acting to confrontational situations, professional writing ability and applying basic construction knowledge (Borg & Scott-Young, 2020b). It is encouraging to see that employers understand their involvement as an important component in graduates' work preparedness. Employers can provide newly recruited project practitioners with mentoring and training programmes (Borg & Scott-Young, 2020). While employers can contribute to graduates' work readiness, universities should focus more on industry engagement, embedded practice, literacy lessons and career coaching (Borg & Scott-Young, 2020b, p. 1372). There was also discord found between employers' expectations and university preparation. While employers stressed work experience when it comes to hiring project management graduates, Bachelor of Project Management programmes focused less on graduates' work experience and internship programs (Borg and Scott-Young, 2020b).

The employers in the study of Borg and Scott-Young (2020b) also highlighted the importance of collaboration between employers and universities. It is therefore essential that creating "shared value" is established among stakeholders. Borg et al., (2019) emphasised a close collaboration among all stakeholders and asserted that it "involves a major (but necessary) departure from the traditional educator-only approach to curricula design" (p. 59). An open discussion between universities and employers is encouraged to better prepare project practitioners. While the findings cannot be generalised in another industry and to other employers, the results can be considered as a starting point for further investigation to apply to another industry.

Discussion

It was proposed in the conceptual framework (Figure 1) that HEIs can contribute to the work-readiness of project management graduates through developing project management degrees specific to project management (such as Bachelor of Project Management) and designing a range of group work and project-based learning in the curriculum. Project management graduates' work-readiness is not a mere accumulation of technical and subject-specific skills but a balanced mixture of soft and technical skills.

The reviewed literature also indicates that it is impractical for HEIs to confirm graduates work-readiness by themselves. Employers may play a part to develop a shared responsibility for better prepared project management graduates. Both universities and employers can work together to

develop required competencies in graduates. Once graduates enter the job industry, employers can provide mentoring and training programs for professional and continuous development. Only when all key stakeholders hold accountability for developing demanded competencies in project management graduates, will project management graduates be appropriately prepared for the labour market. Hence, the modified conceptual framework is presented in Figure 2.

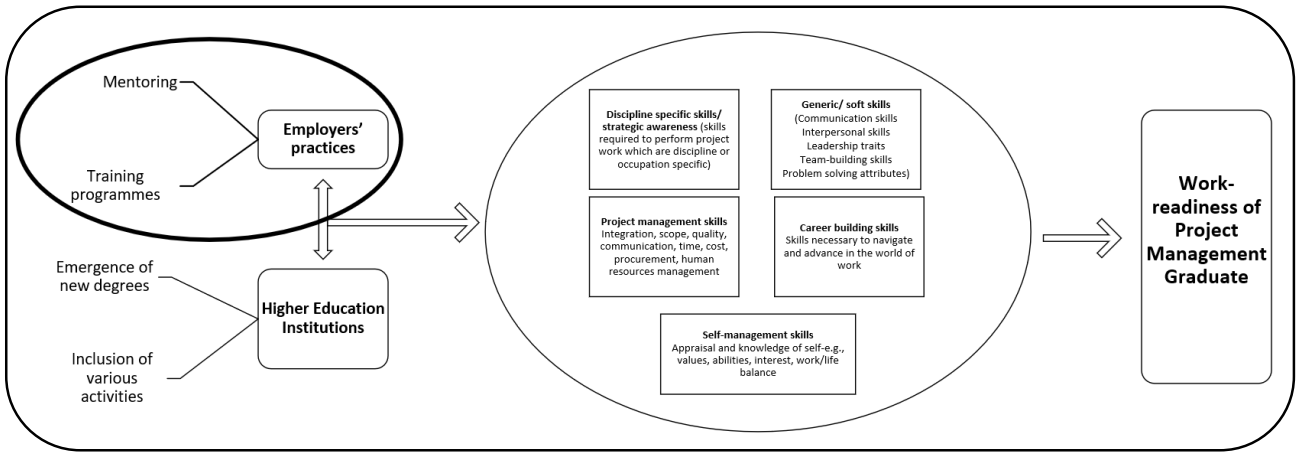

Figure 2: The modified conceptual framework

Conclusion

The aim of the scoping review was to investigate the role of HEIs to develop work-ready attributes in project management graduates, thus contributing to their employability. While there is no agreed definition around employability, it was established that it is not a mere accumulation of technical and generic skills. The employability of project management graduates is multi-dimensional. Therefore, it is impractical to expect that HEIs can ensure graduates' absolute employability. However, HEIs can contribute to one aspect of employability: the work-readiness of project management graduates. The reviewed literature indicates that project management graduates' work readiness encompasses the accumulation of both soft and technical skills. In recent years, HEIs are being put under pressure to enhance project management graduates' work readiness to contribute to a sustainable economy. The literature illuminates that HEIs are slowly making progress in developing work-ready attributes in project management graduates and helping them make a successful transition into the labour market. The new emergence of the Bachelor of Project Management is a recent invention. The conclusion of this review shows alignment with the 'Human Capital Theory' which posits that students invest in higher education to hone their employability skills. While project management employers seem to be satisfied with the preparedness of project management graduates, there are still some elements such as poor quality of graduates' writing and their lack of basic construction knowledge which are not aligned with their expectations. Looking at this result through the lens of Matching theory, it can be inferred that there are still areas for improvement. Higher education providers need to maintain their consistent effort to develop employable project management graduates to tackle complex and dynamic project environment. To improve work readiness and employability of project management graduates, a partnership and open dialogue is necessary between universities and employers to improve the work readiness and employability of project management graduates.

The profusion of research in employability is evident in the extant literature. However, what constitutes project management graduates' employability seems to be scarcely discussed. Future

research might shed light on this area. As discussed in this paper, the work-readiness of project management graduates has been underscored recently in the literature. The studies limit the generalisation of the findings as they were based on the construction industry. As many universities around the world offer Bachelor degree programs in project management, their graduate attributes will be able to be scrutinised to investigate the alignment with employers' demanded skills and attributes. Subsequently, future research might seek opinions from employers beyond those of the construction industry to explore their satisfaction around project management graduates' preparedness. Additionally, employers advocated their contribution to making project management graduates more job ready. There is a dearth of research investigating the initiative which should be taken by employers. Further studies might explore this narrowly researched area.

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Modelling Risk Interdependencies to Support Decision Making in Project Risk Management: Analytical and Simulation-based Methods

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Abstract

Project risks are mostly considered to be independent, ignoring the interdependencies among them, which can lead to inappropriate risk assessment and reduced efficacy in risk treatment. The purpose of this research is to investigate how cause-effect relationships among project risks influence risk assessment results and to develop comprehensive network-based risk indicators which allow project managers to identify critical risks and important risk interdependencies more effectively. This study establishes three analytical methods-based project risk assessment models, namely, a Fuzzy Bayesian Belief Network-based risk assessment model, an Interpretive Structural Modeling-MICMAC analysis-based risk assessment model, and a Social Network Analysis-based risk assessment model. In addition, one simulation-based project risk assessment model, i.e., the Monte Carlo Simulation-based risk interdependency network model, is developed to capture the stochastic behavior of project risk occurrence when modeling risk interdependencies. Case studies are provided to illustrate the application of the proposed project risk assessment models. The research findings have highlighted the importance of considering risk interdependencies in project risk assessment and verified the performance of the proposed models in practical use.

Keywords: Project risk assessment, Risk interdependency, Fuzzy Bayesian Belief Network, Interpretive Structural Modeling, Social Network Analysis, Monte Carlo Simulation.

1. Introduction

The successful delivery and operation of projects remains a critical issue for contemporary project-driven organizations. As projects are potentially plagued with diverse risks and face a growing complexity from both internal (e.g., organizational, and technical aspects) and external (e.g., economic, social, and environmental aspects) (Fang & Marle, 2012), effective project risk management is of great importance for creating a proactive environment and achieving project objectives, such as to avoid budget overruns, schedule delays, quality deficiencies, and lower reputation (Guan, Abbasi, et al., 2020). Risk management is a formal and fundamental process to improve project performance by mitigating or controlling the consequences of risks associated with project objectives (El-Sayegh, 2008; Islam et al., 2017), usually including risk assessment (involving risk identification, risk analysis, and risk evaluation), risk treatment, and risk monitoring and review

throughout a project life cycle (BSI, 2018). Among these phases, risk assessment is a very essential activity that allows project decision makers to have an overall risk perception of a project (at an early phase or during its implementation) and therefore to make appropriate risk response decisions proactively.

In real-world situations, project risks are interdependent, meaning there are cause-effect relationships among risks, where an identified risk is likely to trigger the occurrence of one or more other risks (Guan, Abbasi, et al., 2020; Marle & Vidal, 2008; Wang et al., 2019). These project risk interdependencies can result in a propagation from one upstream risk to numerous downstream risks, or a situation that one downstream risk arises from the occurrence of several upstream risks. If the effects of risk interdependencies are not considered and treated in project risk management, the occurrence of one risk can aggravate the probability or impact of other related risks over the course of a project lifecycle, even leading to domino effects which can threaten the final project results (Hwang et al., 2016).

The classical Probability–Impact (P–I) risk model, assessing project risks purely through their probability of occurrence and corresponding impact on project objectives (if the risks occur) with the assumption that risks are independent from their environment, has been gradually extended and incorporated additional parameters to reflect the complexity of projects (Aven, 2016; Taroun, 2014). Researchers have investigated various theories, tools, and techniques for aiding project risk assessment. Network-based risk assessment methods, where nodes and directed edges represent project risks and risk interdependencies, respectively, are more capable of modeling complex interdependencies among project risks than the classical P–I risk model (Marle et al., 2013; Yang & Zou, 2014). In such methods, the evaluation of a given risk is based on the risks which can trigger it directly or indirectly within a risk interdependency network (RIN). However, the existing studies into applying the RIN to project risk management are still limited and needs to be improved by analyzing multiple characteristics of risks (e.g., stochastic behavior, risk loops, and risk position within a network). Therefore, developing effective risk assessment methods is pivotal to better reflect actual project risk conditions and to provide decision makers with more objective, repeatable, and visible decision-making support for project risk management.

The main objective of this research is to develop comprehensive and effective risk assessment indicators that can better reflect actual project risk conditions to provide project risk management practitioners with more objective, repeatable, and visible decision-making support for project risk management. To achieve this objective, three main questions should be solved — Q1: How to represent cause-effect relationships among project risks (i.e., risk interdependencies)? Q2: How to consider the risk stochastic behaviour, risk loops, and risk position in network-based project risk assessment? Q3: What risk indicators considering risk interdependencies can be developed using analytical methods and simulation-based methods, respectively?

The remainder of this paper is structured as follows. Section 2 provides an overview of the existing research on modeling project risks. Section 3 introduces the research methodology of developing project risk assessment models based on analytical and simulation-based approaches. Case studies of the applications of proposed risk assessment models and corresponding computational results are demonstrated in Section 4. The implications of this study are discussed in Section 5. Section 6 presents conclusions and future work.

2. Literature Review

According to whether or not risk interdependencies are considered in project risk assessment, existing project risk assessment methods can be classified into two main groups: assuming risks are independent and considering risk interdependencies (as shown in Table 1).

Table 1. Examples of existing project risk assessment methods.

	Existing project risk assessment methods	References
Assuming risks are independent	Classical *P–I* risk model	BSI, 2018; PMI, 2017
	Analytical Hierarchy Process (AHP)	Wang et al., 2016
	Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)	Zavadskas et al., 2010
	Fuzzy Synthetic Evaluation (FSE)	Islam et al., 2017; Zhao et al., 2016
	Monte Carlo Simulation (MCS)	Sadeghi et al., 2010
Considering risk interdependencies	Fault Tree Analysis (FTA)	Shoar et al., 2019
	Bayesian Belief Network (BBN)	Hu et al., 2013; Ojha et al., 2018
	Structural Equation Modeling (SEM)	Ahmadabadi & Heravi, 2019
	Design Structure Matrix (DSM)	Marle & Vidal, 2008
	Social Network Analysis (SNA)	Yang et al., 2016; Yang & Zou, 2014
	Interpretive Structural Modeling (ISM)	Kwak et al., 2018

In most cases, project risk management practitioners usually develop a two-dimensional risk matrix given the classical P–I risk model as a tool to assess and categorize individual project risks (BSI, 2018; PMI, 2017). Gradually, many complex methods have been developed to improve the classical P–I risk model in assessing project risks. For example, Multi-criteria Decision Making (MCDM) methods are introduced such as Analytical Hierarchy Process (AHP) (Wang et al., 2016) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Zavadskas et al., 2010). The Fuzzy Set Theory (FST), first introduced by Zadeh (1965), is usually combined with the MCDM methods during the project risk assessment to handle the uncertainties of risk data due to the imprecision, vagueness and subjectivity of human thoughts. As an application of the FST, the Fuzzy Synthetic Evaluation (FSE) method can deal with complicated risk evaluations with multiple levels and attributes and is able to represent empirical knowledge of practitioners (Islam et al., 2017; Zhao et al., 2016). However, the main limitation with adopting these analytical methods during project risk assessment is that they just assess project risks individually while ignoring their interdependencies, which can lead to the inevitable underestimation of project risks to some extent.

To incorporate risk interdependencies in project risk assessment, many researchers have proposed more sophisticated approaches and frameworks, including Fault Tree Analysis (FTA) (Shoar et al., 2019), Bayesian Belief Network (BBN) (Hu et al., 2013; Ojha et al., 2018), Structural Equation Modeling (SEM) (Ahmadabadi & Heravi, 2019), Design Structure Matrix (DSM) (Marle & Vidal, 2008), Social Network Analysis (SNA) (Yang et al., 2016; Yang & Zou, 2014), and Interpretive Structural Modeling (ISM) (Kwak et al., 2018). For instance, Shoar et al. (2019) proposed a Fault Tree (FT)-based approach for quantitative risk analysis in the construction industry that can consider both objective (aleatory) and subjective (epistemic) uncertainties; Hu et al. (2013) proposed a BBN-based model with causality constraints to discover the causality between risk factors and project outcomes in software projects; Ahmadabadi and Heravi (2019) developed a risk assessment framework in public private partnership megaprojects based on SEM method to rank risks focusing on risk interactions and to identify critical risk paths that can be used to offer proper risk responses; Marle and Vidal (2008) explored the DSM principles and defined a binary risk structure matrix to represent project risk interactions; Yang et al. (2016) built an SNA-based risk model that is capable of analyzing stakeholder associated risks and their

interrelationships in complex green building projects; and Kwak et al. (2018) investigated the interactions between international logistics risks within the prevailing structures of international supply chains and highlighted how these risks may be inter-connected and amplified using the ISM method. These analytical methods are all based on a network structure to assess risks instead of viewing risks independently, but they still have several limitations in practice. Specifically, the FTA, BBN, and SEM methods cannot model complex risk interdependencies with loops. Simply using the measures in SNA cannot quantitatively evaluate to what extent the risks will influence project objectives. The ISM method is unable to evaluate the strengths of interdependencies among interrelated risks.

In the context of project management, comprehensive experimental studies on projects are costly and infeasible. Thus, simulation is proposed as an alternative tool for empirical research in decision support systems (Law, 2007). Some researchers have applied simulation-based methods to project risk assessment. For example, Sadeghi et al. (2010) proposed a fuzzy Monte Carlo Simulation (MCS) framework for risk assessment and cost-range estimation in construction projects. To further investigate project risk interdependencies using simulation-based models, Fang and Marle (2012) analyzed project risk networks through a simulation using ARENA software and re-evaluated project risks; and Wang et al. (2019; 2020) developed RIN simulation models to support the evaluation of project risk response decisions and proposed new network indices using the SNA method to quantify the significance of risks and risk interactions. Although simulation-based methods tend to be popular in project risk assessment, related studies on assessing the influence of project risks on project objectives considering risk interdependencies and analyzing the risk propagation phenomenon in an RIN with risk loops have been quite insufficient.

Overall, based on the literature review, the identified research gap is that there is no systematic study that investigates project risk management process considering multiple additional characteristics of risks, such as the risk stochastic behavior, complex risk interdependencies with loops, and risk position within a network. This work tries to fill this gap by developing appropriate project risk assessment models based on analytical and simulation-based methods for managing project risks considering their interdependencies in a project RIN.

3. Research Methodology

3.1. Identification of project risks and risk interdependencies

As the first phase for project risk assessment, risk identification is a process to find, recognize and describe potential risks that might help or prevent achieving project objectives (BSI, 2018; PMI, 2017). When identifying individual project risks, three main sources can be referred to: (1) previous academic research on relevant project risks; (2) historical risk data of completed projects; and (3) expert opinions on potential project risks. It is important to identify project risks according to relevant, appropriate and up-to-date information. Then, the interdependencies (i.e., the cause-effect relationships) among project risks need to be further identified. To increase the accuracy of the identification of risk interdependencies, the interrelations among project objects such as work-packages, tasks, or product components can help to determine the causal relationships among the risks related to these objects (Fang & Marle, 2012). Additionally, risk interdependencies can be identified across different contexts or domains of a project because risks associated with quality, cost or schedule may be linked. As a result, developing a proper project risk list and determining the cause-effect relationships among identified risks are the basis of structuring a project RIN in the next stage.

3.2. Representation of project risk interdependency network (RIN)

This research explores a FT-based BBN method and an ISM method to present interdependencies among project risks. In these two methods, nodes and directed edges represent the project risks and involved interdependencies, respectively. The FT-based BBN method is used in the development of FBBN-based project risk assessment model (in Section 3.3.1), while the ISM-based method is employed in the development of ISM-MICMAC analysis-based project risk assessment model (in Section 3.3.2), SNA-based project risk assessment model (in Section 3.3.3), and MCS-based RIN model for project risk assessment (in Section 3.4).

In the FT-based BBN method, FT analysis and BBN are merged to present risk interdependencies (Kabir et al., 2016; Wilson & Huzurbazar, 2010). As shown in Fig. 1, an FT structure can be set up in a top-down fashion based on the preliminary results of identified project risks and risk cause-effect relationships. Furthermore, a BBN structure can be constructed based on the FT transformation for fully presenting cause-effect relationships among identified risks. The events and vertical links in an FT structure should be directly transformed into corresponding nodes and fundamental links of a BBN structure according to conversion algorithms (basic (BEn), intermediate (IEn) and top (TE) events of an FT structure are mapped into root (RNn), intermediate (INn) and leaf (LN) nodes of a BBN, respectively). Further, overlapping nodes are combined into one node, and supplementary links can be inserted into the BBN structure according to experts' opinions. The edges in the BBN-based RIN structure, directed from a parent node (e.g., RN2) to a child node (e.g., IN1) through probabilistic gates, denote the interdependencies among project risks.

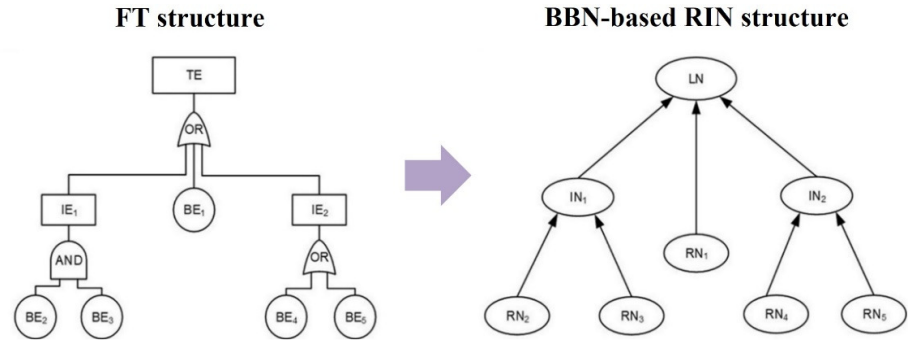

Fig. 1. Example of a BBN-based RIN structure transformed from an FT structure.

The ISM method, first introduced by Warfield (1974), has proven to be a practical tool for representing and analyzing relations and interdependencies among complex factors within a system. Based on the results of project risk identification, the ISM method can be used to develop an RIN and then to classify the nodes into levels, considering both direct and indirect relationships (Kwak et al., 2018). Firstly, a binary structural self-interaction matrix (SSIM) is established to represent the interactions among identified project risks. Contextual relationships between each pair of risks can be determined through existing studies or expert opinions via Delphi-based approaches. Secondly, indirect relationships between two risks are identified by transforming the SSIM into a reachability matrix (RM), where the transitivity among risks is taken into consideration. Then, the identified risks can be partitioned into levels in the RM using judging rules according to each risk's reachability set and intersection set (i.e., the overlap of the risk's antecedent set and reachability set). After removing the indirect links added in the RM and reviewing the conceptual inconsistency of risk interactions, a directed graph, i.e., an ISM-based network, is constructed to illustrate the hierarchical structure of complex project risk

interdependencies. Fig. 2 shows an example of the developed ISM-based RIN structure with four hierarchical levels.

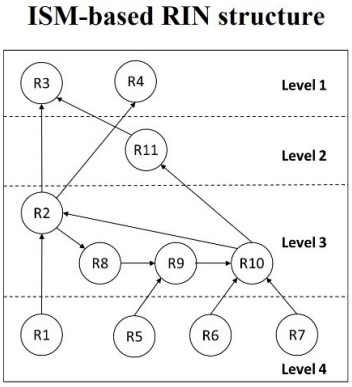

Fig. 2. Example of an ISM-based RIN structure.

3.3. Development of project risk assessment models using analytical methods

Three new project risk assessment models using advanced analytical methods are introduced respectively as follows: an FBBN-based risk assessment model, an ISM-MICMAC analysis-based risk assessment model, and an SNA-based risk assessment model.

3.3.1. Proposed FBBN-based risk assessment model

There are three major phases in the proposed FBBN-based risk assessment model, as shown in Fig. 3, and they are explained in detail as follows.

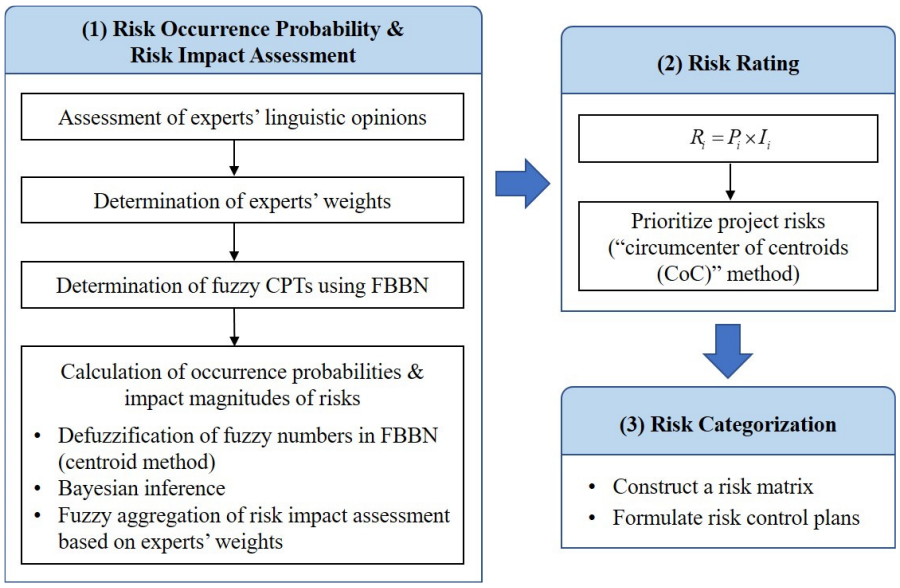

Fig. 3. Three major phases of the proposed FBBN-based risk assessment model.

(1) Risk occurrence probability and risk impact assessment: Experts estimate the occurrence probability and impact of all identified project risks in form of fuzzy linguistic scales. When experts are making judgments based on their knowledge and experience, it would be much easier for them to use qualitative descriptors than to provide crisp numerical values directly. The concept of linguistic

variables allows for ambiguities, uncertainties or incomplete information of experts' judgments (John et al., 2014). Fuzzy linguistic scales can be designed with a set of linguistic variables, and each linguistic variable is represented by a fuzzy number and a corresponding fuzzy membership function that covers the universe of discourse (Samantra, Datta, & Mahapatra, 2017). In addition, the determination of experts' weights on their judgments' confidence to conduct fuzzy aggregation of their judgments can increase the reliability of data acquired from questionnaire surveys. The link between any two project risks in a BBN structure can be evaluated by means of a conditional probability distribution. Before the determination of fuzzy conditional probability tables (CPTs), fuzzy prior and conditional probabilities of risks should be estimated at first based on experts' judgments. Through the Bayesian inference (i.e., causal and diagnostic inference), different types of risk occurrence probabilities (i.e., prior and marginal occurrence probability, and posterior occurrence probability) can be calculated and the final results are in the form of crisp values after defuzzification. From the causal inference, risk occurrence probabilities are predicted considering existing cause-effect relationships. However, the diagnostic inference can provide reliable references for fault diagnosis and risk probability updating analysis when risk data are updated during the project implementation. In terms of calculating each risk's impact on project objectives, the experts' judgments represented by linguistic variables are transformed into trapezoidal fuzzy numbers according to a presumed fuzzy scale and then, a fuzzy aggregation of the judgments of risk impact based on experts' judgment weights is conducted. Therefore, an average preference fuzzy set is obtained to represent the impact magnitude of each project risk.

(2) Risk rating: This is a process for assessing severities of undesired events, which helps developing risk control and mitigation strategies. This phase rates project risks by multiplying their occurrence probability and impact magnitude. Due to the application of FBBN method to occurrence probability assessment of risks, different types of risk ratings can be obtained. As a result, corresponding fuzzy risk ratings are calculated by multiplying the fuzzy impact magnitude of risks with different types of risk occurrence probabilities. Finally, critical project risks having a significant effect on project objectives will be identified by prioritizing risks based on the crisp values of risk ratings.

(3) Risk categorization: This phase categorizes project risks based on the concept of risk matrix, where horizontal and vertical axes represent risk occurrence probability and risk impact, respectively. A referential risk matrix can be constructed through the product of the linguistic scale of occurrence probability and that of impact magnitude. Every project risks will be distributed in the referential risk matrix with a certain value of risk rating from the FBBN method, and different risk levels of the identified risks can also be divided. Based on the results of risk categorization, project risk management practitioners can devise appropriate risk control plans to maximize the project success.

3.3.2. Proposed ISM-MICMAC analysis-based risk assessment model

After developing an ISM-based RIN, the importance of project risks associated with project objectives can be calculated based on the influence transmission from risks to objectives through network paths, as shown in Eq. (2). The weight of different levels (W_l) in the ISM-based RIN calculated using Eq. (1), are also considered.

$$W_l = \frac{1/l}{\sum_1^m (1/l)}, \quad l = 1, 2, \cdots, m \tag{1}$$

where, l is the numerical order of the partitioned levels (the smaller the l, the higher the level in a hierarchy), and m is the total number of levels.

$$I_{S_\sigma, O_\varphi} = W_l \left(\frac{1}{N_1+1} + \frac{1}{N_2+1} + \cdots + \frac{1}{N_i+1} + \cdots + \frac{1}{N_t+1}\right), \quad \sigma = 1, 2, \cdots; \varphi = 1, 2, \cdots; t = 1, 2, \cdots \quad (2)$$

where, S_σ represents project risks, O_φ represents project objectives, I_{S_σ, O_φ} denotes the importance of S_σ to O_φ, t denotes the number of network paths from S_σ to O_φ, and N_i is the number of intermediate nodes on the ith path excluding two endpoints.

In this proposed risk assessment model, the Matrice d'Impacts Croisés Multiplication Appliquée á un Classement (MICMAC) analysis is used to complement the ISM method in the aspect of analyzing the drive and dependence degree of each element in the risk assessment model. The values of drive/dependence powers can be calculated based on the RM which is obtained from the ISM method. Moreover, the MICMAC analysis can classify project risks into four clusters through a drive-dependence diagram, i.e., autonomous factors (Ⅰ), dependent factors (Ⅱ), linkage factors (Ⅲ), and independent factors (Ⅳ) (Chandramowli et al., 2011; Tavakolan & Etemadinia, 2017), which helps clarifying how each risk will behave interactively in a project. Through the MICMAC analysis, critical project risks can be identified as those have very strong drive power which fall into the category of independent or linkage factors.

3.3.3. Proposed SNA-based risk assessment model

In the proposed SNA-based risk assessment model, an ISM-based RIN is first developed, and then, a series of path-based network risk indicators are tailored based on general SNA measures and classical P–I risk model. Fig. 4 displays the commonly used three node measures (i.e., degree, closeness, and betweenness) and one edge measure (i.e., betweenness) in traditional SNA method, which are further improved in proposed risk indicators.

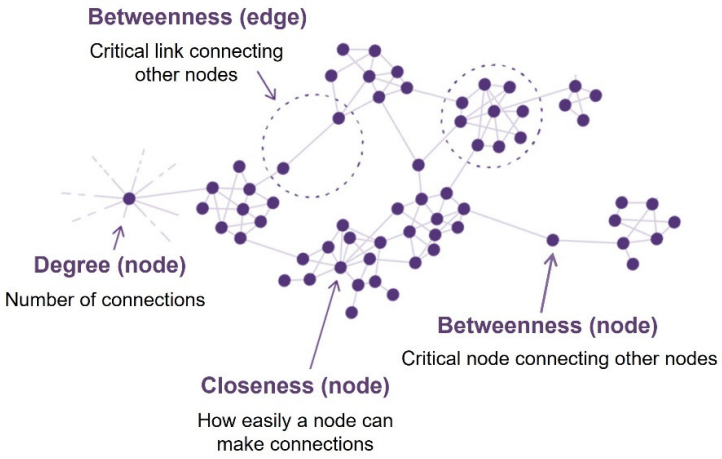

Fig. 4. General measures for node/edge in traditional SNA method.

In traditional SNA, the shortest path between any pair of nodes in a network is a key factor in most of node/edge measures. The "distance" is employed to measure the length of a path between any pairs of nodes in the network, i.e., the number of edges between the two nodes in a binary network or the sum of the values of edges in a weighted network (Scott, 1991; Wang et al., 2020). Considering the edge values in the project RIN are probabilities between 0 and 1, in such case, the use of "distance" is not appropriate. Therefore, we use the term "path probability strength" to replace the "distance", i.e., the product of transition probability (TP) values of all the edges in that path. Then, the weighted edge betweenness centrality is proposed to evaluate the significance of risk interdependencies. Four indicators, namely, out-degree centrality of node, betweenness centrality of node, out-closeness

centrality of node, and hybrid structural centrality of node (developed based on the weighted edge betweenness centrality), are devised to evaluate risk significance from the perspective of SNA method. In addition, another two indicators, i.e., risk local and global significance, are proposed based on the concepts of risk probability and risk impact from the classical P–I risk model to evaluate risks. As a result, project risk rankings based on different risk indicators can be obtained, which support the determination of critical project risks and related risk interdependencies from different aspects.

3.4. Development of project risk assessment model using simulation-based methods

Monte Carlo method is used in the proposed simulation-based RIN model to capture the stochastic behavior of project risk occurrence and then to generate numerous risk scenarios during a project life cycle. We make the following assumption in the proposed simulation model: the status of risk occurrence (i.e., occurred or not) for each project risk in the RIN is determined once in each simulation run (Guan et al., 2021). In the Monte Carlo method, random numbers (RNs) representing occurrence probabilities of a risk are generated in the interval (0, 1) following a certain probability distribution. To improve the traditional MCS, this work proposes calculated occurrence probability (COP) of each risk as a dynamic threshold to evaluate a risk's occurrence status by comparing the generated RNs with its COP. A risk's COP is calculated based on the spontaneous probability (SP) of the risk and TPs from other related upstream risks (varied with the dynamic change of RIN in each simulation run) using probability theory. Therefore, if a generated RN of risk R_i in the t^{th} simulation run (i.e., $RN_{i,t}$) is no more than its calculated COP (i.e., $COP_{i,t}$), then R_i occurs in this simulation run and its occurrence status $mc_{i,t}$ = 1, otherwise R_i does not occur and $mc_{i,t}$ = 0. In addition, a "hypothesis-test" process is designed and incorporated in the proposed MCS-based RIN model to solve risk loops which could appear in a project RIN, and related four major steps are presented in Fig. 5. As shown in Fig. 6, the inputs of the proposed MCS-based RIN model for project risk assessment includes: an ISM-based project risk interdependency network, each risk's spontaneous probability (SP), transition probability (TP) among interrelated risks, and each risk's impact on project objectives. To evaluate individual project risks and the overall project risk level, the outputs of the proposed model can be classified into two groups, where the simulated occurrence probability (SOP), simulated local influence (SLI), and simulated global influence (SGI) are related to each risk, while the total risk loss (TRL) and total risk propagation loss (TRPL) are related to the overall project. The obtained project risk assessment results can be used for planning and evaluating risk treatment actions, including planning appropriate risk treatment actions, testing them using the proposed risk indicators, and finally making a decision on the selection of the best risk treatment action among alternatives.

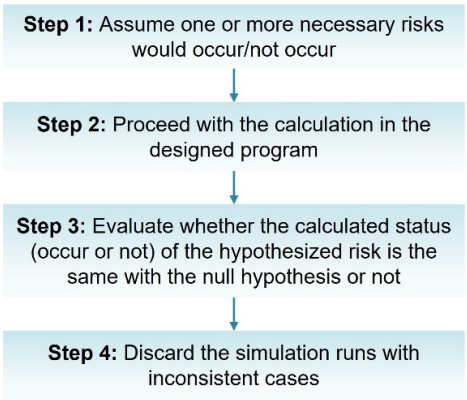

Fig. 5. A flow diagram of the "hypothesis-test" process in the proposed MCS-based RIN model.

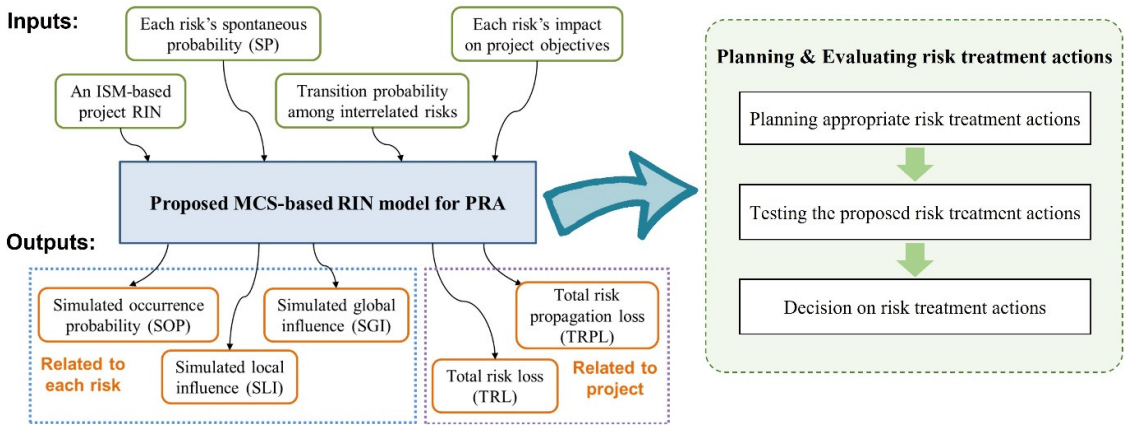

Fig. 6. The inputs and outputs of the proposed MCS-based RIN model for project risk assessment (PRA).

4. Results of Case Studies

4.1. Risk assessment results using FBBN-based risk assessment model

An international construction project in Turkey, i.e., the Ankara-Istanbul high-speed railway project, was used to demonstrate and verify the application of the proposed FBBN-based risk assessment model. This project was commenced in 2008 by a consortium of four companies (two from China and two local) through the Engineering, Procurement and Construction agreement. It was into operation in 2014. The total length of the high-speed railway is around 158 kilometers. The project scope mainly insists of railway beds and tracks, bridges, tunnels, electrification and communication infrastructure. Based on a thorough literature review, a generic network structure of potential project risks from the perspective of contractors was preliminarily built. Then, seven domain experts were invited to take part in separately organized exploratory interviews and gave their opinions on the cause-effect relationships among the existing project risks of the generic network structure, which led to the addition of several other project risks and risk interdependencies. A BBN risk structure of the project was therefore developed, involving a total of 91 project risks and 111 risk interdependencies. In addition, a questionnaire survey for the collection of project risk data (i.e., conditional probability tables of potential risks for occurrence probability assessment, and the magnitudes of risk impacts for impact assessment) was conducted. Seven distributed questionnaires were all retrieved from the experts and then analyzed as the input data for risk assessment using the proposed FBBN-based method (as explained in Section 3.3.1).

The risk degrees of potential project risks considering risk interdependencies were assessed, and critical risks were therefore determined. According to a six-level referential risk matrix, the project risks were categorized into four risk levels (Categories 2–5) within corresponding sub-ranges of risk ratings from the FBBN method, and the results are shown in Table 2. Category 5 represents the highest risk level while Category 0 is the lowest risk level.

Table 2. Risk categorization for the Ankara-Istanbul high-speed railway (Guan, Liu, et al., 2020).

Risk level	RFs	
	Causal inference	Diagnostic inference
Category 5 (Risk rating: 0.70929 – 0.96028)	R_{34}, R_{42}	R_{34}, R_{42}; I_3, L
Category 4 (Risk rating: 0.54975 – 0.70928)	R_{41}, R_7, R_2, R_{11}, R_{23}, R_6, R_{33}, R_{13}, R_{20}, R_{45}, R_{25}, R_{22}, R_{54}, R_{16}; I_{26}, I_2, I_{24}, I_8, I_{25}, I_5, I_4, I_{30}, I_{28}, I_{10}, I_{16}, I_{14}, I_7, I_1, I_{12}, I_{35}, I_{11}, I_9, I_{22}, I_{29}, I_3, L	R_{41}, R_7, R_2, R_{11}, R_{23}, R_6, R_{33}, R_{13}, R_{20}, R_{45}, R_{25}, R_{22}, R_{54}, R_{16}; I_{26}, I_{24}, I_2, I_{25}, I_8, I_5, I_4, I_{30}, I_{28}, I_{10}, I_{16}, I_7, I_{14}, I_{12}, I_1, I_{11}, I_9, I_{35}, I_{22}, I_{29}
Category 3 (Risk rating: 0.46600 – 0.54974)	R_{53}, R_9, R_{39}, R_{35}, R_4, R_{36}, R_{19}, R_{21}, R_{52}, R_5, R_{15}, R_{30}, R_{28}, R_{12}, R_{43}, R_{55}, R_{26}, R_{51}, R_{17}, R_{14}, R_{27}, R_{38}, R_{18}, R_{37}, R_3; I_{19}, I_{27}, I_{32}, I_{13}, I_{15}, I_{34}, I_{18}, I_{21}, I_{17}, I_{23}, I_{31}, I_{33}, I_6, I_{20}	R_{53}, R_9, R_{39}, R_{35}, R_4, R_{36}, R_{19}, R_{21}, R_{52}, R_5, R_{15}, R_{30}, R_{28}, R_{12}, R_{43}, R_{55}, R_{26}, R_{51}, R_{17}, R_{14}, R_{27}, R_{38}, R_{18}, R_{37}, R_3; I_{19}, I_{27}, I_{32}, I_{13}, I_{15}, I_{34}, I_{18}, I_{21}, I_{17}, I_{23}, I_{31}, I_{33}, I_{20}, I_6
Category 2 (Risk rating: 0.42399 – 0.46599)	R_{48}, R_{31}, R_{10}, R_{47}, R_8, R_1, R_{40}, R_{44}, R_{50}, R_{29}, R_{24}, R_{46}, R_{49}, R_{32}	R_{48}, R_{31}, R_{10}, R_{47}, R_8, R_1, R_{40}, R_{44}, R_{50}, R_{29}, R_{24}, R_{46}, R_{49}, R_{32}
Category 1 (Risk rating: 0.41708 – 0.42398)	Not identified	Not identified
Category 0 (Risk rating: 0.00000 – 0.41707)	Not identified	Not identified

The project risk categorization results in Table 2 show that from both causal inference and diagnostic inference, "different construction standards and measurement system (R_{42})" and "variations in design (R_{34})" are the top-two critical root risks, and "project implementation risk (I_3)" is the most critical intermediate risk of the project. The overall project risk, i.e., the leaf node "ICP failure (L)", is located in the risk level of Category 4 after the causal inference, denoting that the project risk level is relatively high. The project risk manager should pay more attention to the risks located in Category 5 and Category 4 and formulate risk control and mitigation plans at the commencement of the project.

By comparing the results calculated using the proposed FBBN-based risk assessment model with the real risk situations of the investigated project, many identified risks appeared during the implementation of the project and mostly complied with the obtained critical risks. For example, variation in design was one of the most serious problems due to the project owner's multiple requirements and inaccurate geological prospecting documents. In addition, the project contractors had a higher pressure to master the required standards and specifications of the implementation process of the project. Furthermore, the contract risk, in terms of unclear contract clauses and excessive contract variations, caused difficulties in coordination among project participants. Language barrier and information asymmetry also raised challenges to achieve the project objectives. Given the above analyses, the proposed FBBN-based risk assessment model has manifested its effectiveness to be applied in practical projects.

4.2. Risk assessment results using ISM-MICMAC analysis-based risk assessment model

Using the proposed ISM-MICMAC analysis-based risk assessment model, the general green building (GB) project risks were investigated and assessed. Firstly, a systematic literature review was conducted for differentiating the GB project constraints from the GB project risks, in which 16 constraint factors I and 22 risk factors I throughout a GB project life cycle were identified. Then, 11 GB project objectives (O) were selected based on related existing researches. In this work, four types of relationships among constraint factors, risk factors and objectives in GB projects were considered, as illustrated in Fig. 7. These contextual relationships were determined based on the relevant literature and domain knowledge of the authors. Therefore, based on the steps of the ISM method to present risk interdependencies (mentioned previously in Section 3.2), a hierarchical ISM-based RIN of GB projects was developed. Further, the importance of constraints and risk factors associated with GB project objectives was calculated based on Eq. (1) and Eq. (2). Table 3 shows the sample results of the

importance of identified critical GB project constraints and risks which can highly affect the GB project objectives. In addition to the determination of critical factors (i.e., constraints and risks), the GB project objectives which are highly affected by risks and constraints can also be identified. For example, "O2 Completed on time", "O8 Anticipated return on investment & payback period", and "O1 Completed within budget" are easily to be affected by all the GB project risks and constraints. GB Project risk managers should constantly monitor the risks especially related to these three project objectives and try to mitigate their negative effects.

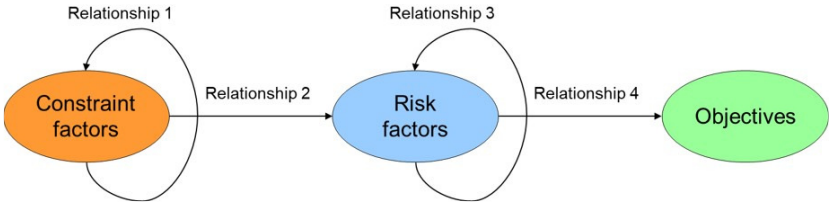

Fig. 7. The investigated relationships among GB project constraints, risks and objectives (Guan, Abbasi, et al., 2020).

Table 3. The importance of critical project risks and constraints associated with GB project objectives (Guan, Abbasi, et al., 2020).

	Top-ten critical GB project risks and constraints										Total influence
GB project objectives	C7	C4	C13	C6	C12	R1	C16	R2	C9	C14	
O1 Completed within budget	1.71	1.69	1.26	0.90	0.54	0.46	0.46	0.31	0.28	0.28	11.43
O2 Completed on time	2.92	2.86	2.15	1.51	0.90	0.79	0.55	0.52	0.28	0.47	17.26
O3 Comfort & artistry	0.74	0.72	0.56	0.41	0.27	0.25	0.16	0.18	0.11	0.13	4.33
O4 Long-term performance	0.39	0.39	0.30	0.23	0.14	0.15	0.09	0.11	0.04	0.06	2.26
O5 Safety in construction	1.07	1.07	0.78	0.58	0.32	0.26	0.18	0.18	0.25	0.15	7.10
O6 Safety in operation & maintenance	1.02	1.02	0.75	0.55	0.31	0.26	0.18	0.18	0.21	0.15	6.56
O7 Green certification	0.37	0.36	1.02	0.75	0.45	0.36	0.25	0.25	0.28	0.22	8.58
O8 Anticipated return on investment & payback period	2.50	2.49	1.84	1.28	0.78	0.67	0.49	0.45	0.28	0.44	15.96
O9 Customer satisfaction	0.93	0.93	0.67	0.50	0.26	0.20	0.15	0.13	0.21	0.15	5.96
O10 Promotion of brand image	0.98	0.98	0.71	0.53	0.28	0.20	0.15	0.13	0.25	0.15	6.42
O11 Promotion of new technologies & materials	0.93	0.93	0.67	0.50	0.26	0.20	0.15	0.13	0.21	0.15	5.96
GB project success (O1–O11)	14.54	14.42	10.71	7.74	4.49	3.82	2.67	2.58	2.38	2.34	-
No. of influenced objectives	11	11	11	11	11	11	11	11	11	11	-

In addition, the MICMAC analysis was further used to analyze the drive and dependence power of each element of the GB project constraints, risks, and objectives. A drive-dependence diagram was then constructed in Fig. 8, and all the elements were classified into three groups. In this work, drive power is more important than dependence power. Thus, in the independent cluster (Ⅳ), "R1 Unclear requirements of a project implementation", "R2 Ambiguity in contracts", and "R7 Design errors" are the top-three critical GB project risks from the overall network perspective, which should be controlled early to decrease the occurrence probability of the risks that they will influence; while "C7 Inadequate experienced designers/contractors/suppliers for GB projects", "C4 Limited GB benchmarks & shared information", and "C13 Inadequate communication & cooperation among project stakeholders" are the top-three critical GB project constraints which should also be paid more attention to by project

risk managers. In contrast, "R3 Inaccurate estimate of project ROI (return on investment) & payback period", "R20 Not getting materials/equipment on approved period/phase", and "R22 Injuries and accidents" are the risks located in the dependent cluster (Ⅱ), which means they have weak drive power but strong dependence power. For such risks, they should also be controlled in a timely manner to reduce the influence of dependent risks on certain objectives through risk paths. In addition, if risk/constraint factors have the same drive power (e.g., "R18 Equipment breakdown" and "R21 Unlawful disposal of waste"), the factor with the higher dependence power should be addressed earlier. From the above analysis results, the critical GB project risks and constraints with higher drive power also have stronger influence on project objectives, which tend to be located in the lower levels of the ISM-based GB project RIN.

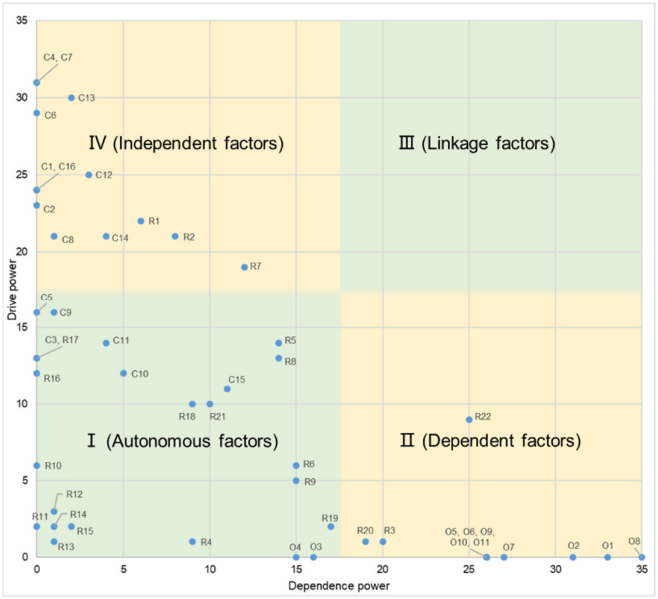

Fig. 8. A MICMAC diagram for GB project constraints, risks and objectives (Guan, Abbasi, et al., 2020).

4.3. Risk assessment results using SNA-based risk assessment model

The proposed SNA-based risk assessment model model was applied to a specific project to verify its feasibility and applicability in project risk assessment. The sample project (from Wang et al. (2020)) concerns employing artificial intelligence technology for predicting medical items, which belongs to a program related to logistics and healthcare. There are 16 risks and 26 direct risk interdependencies of the sample project originally identified by Wang et al. (2020). In addition, the evaluated values of risk spontaneous probability (SP) and risk impact on the project objectives (denoted by cost) are also provided. These risk-related data were initially collected by a primary member of the project who was in charge of the project plan, implementation, and risk management.

Based on these risk data, we first developed a two-level hierarchical ISM-based RIN of the project using the ISM method. Several risk loops can be identified in the project RIN due to complex risk interdependencies. Then, the project risk assessment process was performed by calculating the values of six proposed risk indicators, respectively. Critical project risks which can highly affect the project objectives were therefore determined based on the local and global risk measures from the network perspective. The obtained results are presented in Table 4. Locally, "R08 Building and training the model repeatedly", "R06 Poor selection of the medical items", and "R05 Poor analysis of the factors

regarding medical items" are the top-three risks which have the highest values of the out-degree centrality; and "R03 Unclear milestone and technical route", "R16 Too much rework for the team in charge of the modeling", and "R09 Interfaces problem among the software platforms of different terms" are the the top-three risks which have the highest values of the risk local significance. Globally, "R13 Tense partnerships among the teams", "R02 Communication problems between the teams", and "R03" are ranked highest in the betweenness centrality; "R06", R05", and "R03" are the top-three risks which have the highest values of out-closeness centrality; "R08", R06", and "R05" are highly ranked in the hybrid structural centrality (the same with the top-three risks evaluated by the out-degree centrality); and "R03", "R04 Lack of professional medical knowledge", and "R06" are ranked highest in the risk global significance. These identified risks from six different aspects of risk positions in a network are essential to the project, specific risk mitigation measures need to be formulated in advance and the project risk manager should pay more attention to these critical risks during the project implementation.

Table 4. Project risk assessment results from the SNA-based risk assessment model.

Node No.	SNA-based indicators				P-I risk model-based indicators	
	Out-degree centrality	Betweenness centrality	Out-closeness centrality	Hybrid structural centrality ($*10^{-2}$)	Risk local significance ($*10^{-2}$)	Risk global significance ($*10^{-2}$)
R01	0.027	0	0.098	0.024	0.267	1.505
R02	0.053	0.552	0.178	0.107	0.533	1.348
R03	0.067	0.471	0.254	0.194	1.167	3.238
R04	0.047	0	0.227	0.077	0.400	2.696
R05	0.087	0.410	0.260	0.436	0.100	1.829
R06	0.113	0.467	0.359	0.312	0.480	2.635
R07	0.087	0.048	0.146	0.146	0.267	1.383
R08	0.140	0.190	0.181	0.324	0.600	1.198
R09	0.040	0	0.107	0.076	0.800	1.653
R10	0.053	0.224	0.135	0.257	0.187	0.694
R11	0.053	0.267	0.105	0.237	0.533	0.341
R12	0.040	0	0.079	0.030	0.133	0.133
R13	0.033	0.557	0.067	0.125	0.400	0.490
R14	0.027	0	0.047	0.112	0.267	0.228
R15	0.020	0	0.094	0.034	0.427	0.745
R16	0.027	0.162	0.053	0.137	0.800	0.349

4.4. Risk assessment and treatment results using MCS-based RIN model

The project case used here to illustrate the proposed MCS-based RIN model is the same with the sample project used in Section 4.3. Thus, the project RIN developed based on the ISM method is also the same. By inputting the original project risk-related data (i.e., each risk's spontaneous probability (SP), transition probability (TP) among interrelated risks, and each risk's impact on project objectives) into the proposed MCS-based RIN model in project risk assessment, evaluated values of the proposed risk indicators (i.e., simulated occurrence probability (SOP), simulated local influence (SLI), and simulated global influence (SGI)) were calculated. Table 5 shows the obtained project risk prioritization results, compared with those evaluated by spontaneous probability (SP) and risk criticality (RC) from the classical *P–I* risk model.

Overall, the project risk prioritization results have changed after using the proposed MCS-based RIN model. In respect to risk occurrence probability, "R14 Too many tests on the model", R05 and R16 have lower values of SP, while in terms of SOP, they are top ranked with the highest values, indicating that although this kind of risks are unlikely to occur spontaneously, they are highly affected by others due to direct and indirect cause-effect relationships. Some risks' occurrence probabilities may be evaluated as similar (e.g., R03 and "R15 Project scope spread") using the classical *P–I* risk model (SP_i) and the proposed simulation model (SOP_i), however, they are still underestimated to some extent. Except for the source risk "R01 Language problems and cultural conflicts", all the other risks have increased occurrence probabilities calculated by the proposed method, demonstrating that risk interdependencies can increase risk occurrence probability.

From the aspect of risk influence, the SLI of each risk (excluding R01) is higher than its evaluated RC from the classical *P–I* risk model due to the different values of risk occurrence probability, indicating that the risk propagation across the RIN has amplified the risk influence on project objectives. The SGI of a risk reflects to what extent the occurrence of this risk can increase other risks' influence on project objectives. Some risks have lower SLI, but their SGI may be higher, such as R05 and "R07 Poor selection of the existing database".

Table 5. Risk prioritization by different indicators.

Ranking	From the proposed MCS-based RIN model						From the classical P–I risk model			
	SOP_i		SLI_i ($100)		SGI_i ($100)		SP_i		RC_i ($100)	
	Risk No.	Value	Risk No.	Value	Risk No.	Value	Risk No.	Value	Risk No.	Value
1	R14	0.895	R11	2.950	R05	18.574	R01	0.8	R03	1.75
2	R05	0.853	R16	2.516	R14	18.041	R03	0.7	R16	1.2
3	R16	0.839	R08	2.345	R07	17.256	R04	0.6	R09	1.2
4	R03	0.830	R03	2.074	R13	17.185	R09	0.6	R08	0.9
5	R13	0.825	R14	1.791	R01	17.095	R02	0.4	R01	0.8
6	R07	0.811	R02	1.321	R03	16.322	R06	0.4	R02	0.8
7	R01	0.799	R06	1.250	R16	16.243	R07	0.4	R11	0.8
8	R08	0.782	R09	1.246	R10	15.711	R13	0.4	R06	0.72
9	R11	0.737	R13	1.238	R08	15.546	R15	0.4	R15	0.64
10	R10	0.736	R10	1.031	R06	14.597	R16	0.4	R13	0.6
11	R06	0.694	R15	0.879	R11	14.049	R05	0.3	R04	0.6
12	R02	0.661	R07	0.811	R04	13.676	R08	0.3	R07	0.4
13	R04	0.651	R01	0.799	R02	13.442	R10	0.2	R14	0.4
14	R09	0.623	R12	0.746	R09	12.730	R11	0.2	R10	0.28
15	R15	0.549	R04	0.651	R15	11.423	R14	0.2	R12	0.2
16	R12	0.373	R05	0.427	R12	8.131	R12	0.1	R05	0.15

Moreover, the results of project level risk assessment indicators, i.e., the project total risk loss (TRL) and project total risk propagation loss (TRPL), were further calculated. Specifically, the obtained probability distribution of the project TRL was illustrated in Fig. 9. From the curve of cumulative distribution function (CDF), the project TRL in the interval value of $1500–$2820 accounts for around 79% of all the possible project risk scenarios, denoting that the project TRL caused by the project risks is highly possible to distribute in this range. Additionally, the expected (average) value of the project TRL was evaluated as around $2207 (locally), while the expected value of the project TRPL was calculated as $24002 (globally). These results can provide project risk managers with a holistic risk perception from the level of an overall project at its earliest stage.

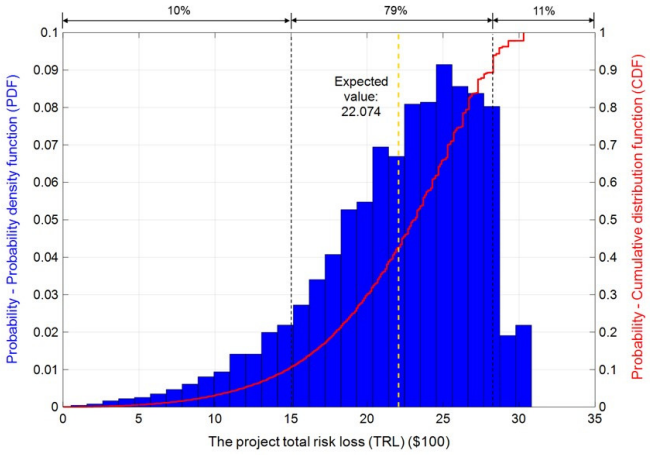

Fig. 9. Probability distribution of the project total risk loss (Guan et al., 2021).

Base on the above project risk assessment results, a series of risk treatment actions can be formulated, and their performance can be further evaluated using proposed five risk indicators. Fig. 10 shows the comparison of the values of the indicators related to each risk (i.e., SOP, SLI, and SGI) after four different risk treatment actions. The lower the line in the figures, the better the performance of risk treatment action. Therefore, the Action 4 outperforms the other three risk treatment actions. From the level of overall project, the performance of different risk treatment actions were evaluated by the reduced value of project TRL and the reduced value of project TRPL. As shown in Table 6, the Action 4 can reduce the highest values of both project TRL and TRPL among these four actions, so it also works the best in the project risk treatment.

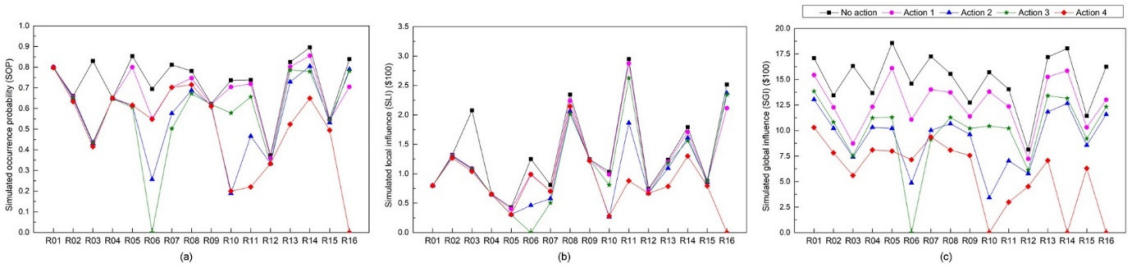

Fig. 10. Comparison of (a) the SOP, (b) the SLI, and (c) the SGI of risks after different project risk treatment actions (Guan et al., 2021).

Table 6. The performance of different risk treatment actions from the project level.

Performance	Risk treatment actions			
	Action 1 (Classical *P–I* risk model)	Action 2 (Wang et al., 2019)	Action 3 (Wang et al., 2020)	Action 4 (Proposed model)
Reduced value of project TRL	$217	$489	$412	$826
Reduced value of project TRPL	$3711	$9274	$7978	$14717

5. Discussion

Throughout this research, investigation of the influence of project risk interdependencies is based on both analytical and simulation methods, which improves the accuracy of project risk assessment results. A series of network-based risk indicators are proposed to quantify risk influence on project objectives and further to facilitate the formulation of effective risk treatment actions. Fig. 11 illustrates how multiple characteristics of project risks are analyzed by four proposed project risk assessment (PRA) models: the FBBN-based PRA model, the ISM-MICMAC analysis-based PRA model, the SNA-based PRA model, and the MCS-based RIN model for PRA. All these models have considered risk interdependencies during the project risk assessment. Further, the FBBN-based PRA model also uses the concepts of the classical *P–I* risk model; the ISM-MICMAC analysis-based PRA model additionally analyzes risk position in a network; the SNA-based PRA model also considers the classical *P–I* risk model, risk position, and risk loops in its analysis; and the MCS-based RIN model for PRA incorporates the classical *P–I* risk model, risk stochastic behavior, and risk loops as well. Based on the analysis of case studies, the proposed four project risk assessment models can provide more reliable risk assessment results and reflect more accurate project risk conditions than the methods only based on the classical *P–I* risk model.

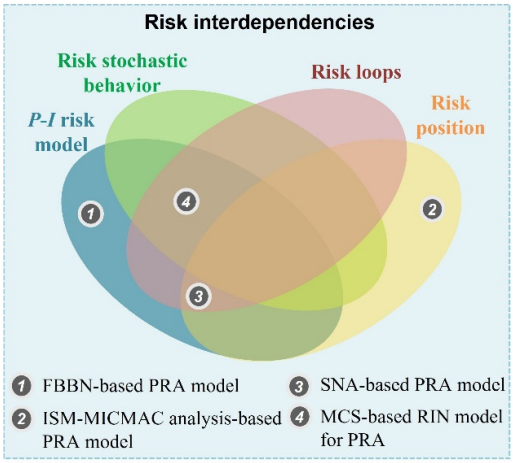

Fig. 11. The related project risk characteristics analyzed by proposed risk assessment (PRA) models.

This study makes some academic contributions to project risk management and in particular, to risk assessment. Firstly, effective analytical methods and simulation-based methods are investigated and designed to develop project risk assessment models considering the effects of risk interdependencies. Secondly, apart from involving the identification of cause-effect relationships among risks in the proposed decision-support system for project risk assessment, more aspects of the RIN complexity are taken into account, including the stochastic behavior of risk occurrence, risk loops, and risk position within a project RIN. Thirdly, proposed interdependency-based risk indicators can help planning of more appropriate project risk treatment actions.

Additionally, there are a number of managerial implications of our work, which are listed as follows:

(1) Project risk management practitioners can have more comprehensive perception of project risk through considering complex risk interdependencies in project risk assessment from a “network” perspective.

(2) The proposed risk assessment models try to mitigate the gap between theory and practice of the project risk management, so the basic concepts of the classical *P*–*I* risk model (i.e., risk's probability and impact), which are widely used by practitioners in managing project risks, are considered. Therefore, all related project risk management practitioners can engage their knowledge and experience in the risk assessment process. More importantly, the proposed risk assessment processes are easy to be conducted in practice because all complicated calculations are solved by program codes and/or software and practitioners only need to collect the project risk-related data as the inputs for project risk assessment.

(3) The proposed project risk assessment models have high universality and flexibility, which can be applied to projects in different fields (e.g., software, civil, or business), and even to large and complex projects. In particular, the proposed decision-support system for project risk assessment developed using the MCS-based RIN model outperforms many existing analytical project risk assessment methods which mainly rely on complicated calculations.

(4) The proposed project risk assessment models can be used at the commencement stage of a project when there is high uncertainty about project risks, and the project risk assessment results can update periodically to reflect risk conditions of the project over time when the new risk information is available.

6. Conclusions

This study has explored different project risk assessment models in the context of risk interdependencies using both analytical and simulation-based methods. The FT-based BBN and ISM methods were proposed to develop a project RIN based on identified project risks and their cause-effect relationships. The proposed FBBN-based risk assessment model, ISM-MICMAC analysis-based risk assessment model, and SNA-based risk assessment model are analytical methods-based models. In addition, the MCS-based RIN model is simulation-based model for project risk assessment. The corresponding risk prioritization results can support project managers in formulating appropriate risk treatment actions. The related results of different case studies highlight the importance of considering risk interdependencies in project risk assessment and verify the performance of the proposed models in practical use.

Compared with the proposed analytical methods-based risk assessment models, the proposed risk simulation model can address stochastic behavior of project risks as well as deal with risk loops in the complex project RIN. Through modeling the propagation behavior of risks in an RIN, the model enables project managers to gain innovative insights into interdependencies among project risks and possible risk influence on project objectives from a network perspective. However, the obtained risk assessment results from the simulation-based model do not consider the risk position in a project RIN. In order to obtain comprehensive risk assessment results, there is a need to integrate analytical methods-based and simulation-based risk assessment models.

There are a number of potential extensions of this research in the future, particularly: (1) the MCS-based RIN model for project risk assessment can be improved by integrating with SNA method to incorporate more analysis of risk position in the RIN; (2) as projects are time-related dynamic systems, project risks and risk interdependencies may vary with project phases, so the dynamic behavior of project RIN throughout a project lifecycle will be further investigated under current project risk assessment framework; (3) additional parameters, such as project budget and cost of risk treatment actions, will be involved to further optimize project risk treatment actions; and (4) an integrated

practical tool for project risk assessment can be developed to incorporate the proposed models with the aim of further smoothing and reducing the workload of project risk management practitioners.

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The Role of Benefits Owner in Effective Benefits Management

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Abstract

In the Project Management (PM) literature debates on Benefits Management (BM), the benefits owner has emerged as one of the key roles (Patanakul et al. 2016, Zwikael et al. 2019). However, there is still a visible lack of clarity in the PM literature and practice, as to who should be the benefits owner and what are the responsibilities of this role. The findings of a doctoral research on the applicability of BM in the Australian Public Sector organizations (PSOs), identified the lack of clarity around benefits ownership and the benefits owner's role is seriously inhibiting benefits management in the case organizations. This study also found that poor benefits ownership is also directly linked to ineffective project/program governance, as the benefits owner plays important role as the Senior Responsible Officer/Owner (SRO) in project assurance and gate reviews. This paper looks at the role of the benefits owner in the PM literature, PM methodologies, impressions, and observations of the PM practitioners in PSOs and how this role can enhance benefits management in the public sector.

Key Words: Benefits management, Senior Responsible Owner, accountability, governance, outcomes, Australian Public Sector

Introduction:

Benefits Management, later rebranded as benefits realization, was floated, first time as a concept in the 1980s by Bradley (2010). Though, it received the researchers' attention from the year 2000 and by 2010 it received visible traction in the project management (PM) literature debates. Benefits management has gradually been suggested as a new criteria of project success in addition to the traditional Iron Triangle of scope, cost and time. However, as expected the benefits management permeated into the PM practice as a concept but it has not been accepted as an important variable of project success. The Benefits Owner has been highlighted as an important player in the effective management of benefits (Zwikael et al. (2019) and Patanakul et al. (2016). Similarly, in the interviews conducted for a doctoral study (in progress), benefits owner has been pointed out as a linchpin role for benefits management in the Australian Public Sector organizations. There is no consensus in the PM literature, as to who is the most appropriate person in the PM roles to perform as the benefits owner. Zwikael and Meredith (2017) echo this opinion by saying that inconsistent and conflicting terminology is used for key project roles, which includes project owner and benefits owner's roles as well. They identify ten PM roles and combined the project owner and benefits owner into one role. Similarly, Morris (2013) and Krane et al. (2012) suggest project owner as a potential candidate to be the benefits owner. Olsson (2018) identifies type 1 and type 2 project owners, where according to Olsson, in the PM literature, type 1 project owner is responsible for the business case, project execution and benefits realization, but their case study did not find this type of project owner, therefore, a type 2 project owner has been identified, who would normally support the project manager and is mainly responsible for ensuring project deliverables (Olsson 2018). The existing ambiguity around the benefits owner's role is adversely impacting the accountability and responsibility for the success/failure of benefits management in programs/projects implemented in the Australian public sector organizations. Therefore, it is important to explore how and who is playing the role of a benefits owner and with what impact, in the Australian Public Sector.

Literature Review:

The PM literature witnessed a significant focus on project success between 1960- 1980 (Snyder 1987, Muller and Jugdev 2012), when the researchers started looking at project success beyond the Iron Triangle. Pinto and Slevin (1988) published 10 factors of a project's success, and Ballard (2014) considers this as the pioneering work in the project success debate. Shenhar et al. (2007) argue that 'one size does not fit all' to project types and the same is true for the project success criteria. Similarly, Muller and Jugdev (2012) point out that project success is multidimensional and subjective, therefore, we will come across varying opinions and interpretations of project success. We state that the project success is a dynamic concept, and it has been evolving from its focus on the delivery of the outputs to stakeholders' satisfaction. But quite recently, Zwikael and Smyrk (2019, 2012) argue for making project outcomes rather than the outputs as the criteria for project success. The authors endeavour to modify the conventional view of projects from Input-Process-Output (IPO) to Input-Transform-Outcome (ITO) of project activity. In this regard, Zwikael and Smyrk (2019, 2012) argue for changing the definition of project, as they consider the existing definition is misleading in the sense that projects are expected to result in outputs. They emphasise that terms such as goals and results refer to a definition built around project outcomes and not the outputs. They argue that the outcomes and benefits are more important to the project funder rather than the outputs. We argue that this shift from outputs to outcomes rejects the old notion of projects delivering outputs even if the organization accrues no benefits. Zwikael and Smyrk (2019, 2012) state that project benefits are the value that

flows into the organization and Badewi (2016) defines project benefits as a measurable advantage owned by a group of stakeholders incurred by changing the current state through project management mechanism. Both definitions emphasise on results in the form of benefits that would eventuate once the project product/service has been operationalised. Therefore, it signifies the need for two definitions such as the project management success and the project success (Cook-Davies 2002). A lot has been written on the success of project management but the debate on project success during last 20 years has turned the researchers' attention to outcomes, benefits management and value accruing to the project sponsor/funder.

Breese (2012) states that the quest for measuring the benefits was initiated in the IT industry to evaluate hefty investments in technology, but benefits management is equally applicable to other sectors that employ project management as a strategy to achieved organizational goals. Mossalam and Arafa (2016) state that benefits realization has now become a key factor in project success. The survey results by APM Special Interest Group (2017) highlight that its members acknowledged an increasing awareness in their organizations seeking to make benefits management an integral part of project management practices, particularly at Project, program and portfolio management (P3M). Marnewick (2016) argues for integrating benefits management into the project life cycle and suggest the PMBOK should include benefits management as another knowledge area. Badewi (2016) sees a correlation between project management and benefits management and calls for integrating both under a single governance framework for enhanced project success. The role of poor project governance with regards to benefits management has been criticised by the researchers. Saeed et al. (2019) state that 80 percent of the research participants expressed dissatisfaction with the existing project governance practices in the Australian public sector organisations. They maintain that the current program/project governance is focused on the delivery of outputs rather than the outcomes. The research participants highlighted that the lack of understanding about the governance roles and responsibilities by the senior executives sitting the governance boards, is adversely impacting benefits management. There is a lack consistency on the reporting requirements for benefits management in project status reports to the governance boards for intermediate project benefits (Saeed et al. 2019). The role of benefits owner has been highlighted as critical by many researchers such as Peppard et al. (2007), Winch and Leiringer (2015), Badewi (2016) and Zwikael (2019), who argue the benefits owner should be identified at the outset and the owner should be accountable for benefits realization. Saeed et al. (2019) state that research participants have unanimously called for assigning benefits ownership, to the operations/business managers, whose department would be the end user of the project product/service. Our research indicates that in the public sector organizations, mostly a Senior Responsible Owner/Officer (SRO) is nominated as the benefits owner with the project initiation. The SRO is normally a senior executive of Band 2 or 3 level (www.finance.gov.au), who is a division head and is accountable for a number of projects running in a program. However, Saeed and Rashid (2020) state the role of the benefits owner has become ineffective due to the lack of mandatory requirements and accountability for benefits realization during the post project delivery period of 12 to 18 months.

In this article three roles such as project owner and benefits owner and the SRO have been repeatedly used, therefore, it is pertinent to briefly define these roles. The project owner is a person who has identified a problem and fervently seeks to resolve it (Goff-Dupont 2020). Bradley (2010) states the benefit owner is responsible for realising benefits. The SRO is recognised as the owner of the business case, the driver of a business change, and accountable for successful delivery (finance.gov.uk). Therefore, being the owner of the business case, where the high-level benefits are identified, the SRO assumes the benefits owner role in the public sector organizations. However, the SRO per se has not been mentioned in the PM literature, therefore, it would be pertinent that we briefly introduce the

SRO, before we discuss the SRO's role, as benefits owner in the case study organizations. The UK Government (2019) Infrastructure and Projects Authority, states the SRO role was established over two decades ago, and is now mandatory in the governmental functional standards for major projects portfolio. Outlining the SRO's role, it says, SRO is accountable for ensuring that a program or project meets its objectives, delivers outcomes, and realises benefits. Besides, the SRO is the owner of the project business case, ensuring governance and assurance regime for the project, and project transition into service (UK Government 2019). OGC (2009) describes SRO's role as "the individual responsible for ensuring that a project or programme of change meets its objectives and delivers the projected benefits. They should be the owner of the overall business change that is being supported by the programme/project" (P312). Bradley (2010) states the SRO can a business manager, who supported the project idea during the initiation phase or could be a senior manager from amongst the stakeholders' group, who is likely to receive majority of the benefits. Figure 1 shows the accountability and responsibility of three key project roles: SRO, project manager and benefits owner.

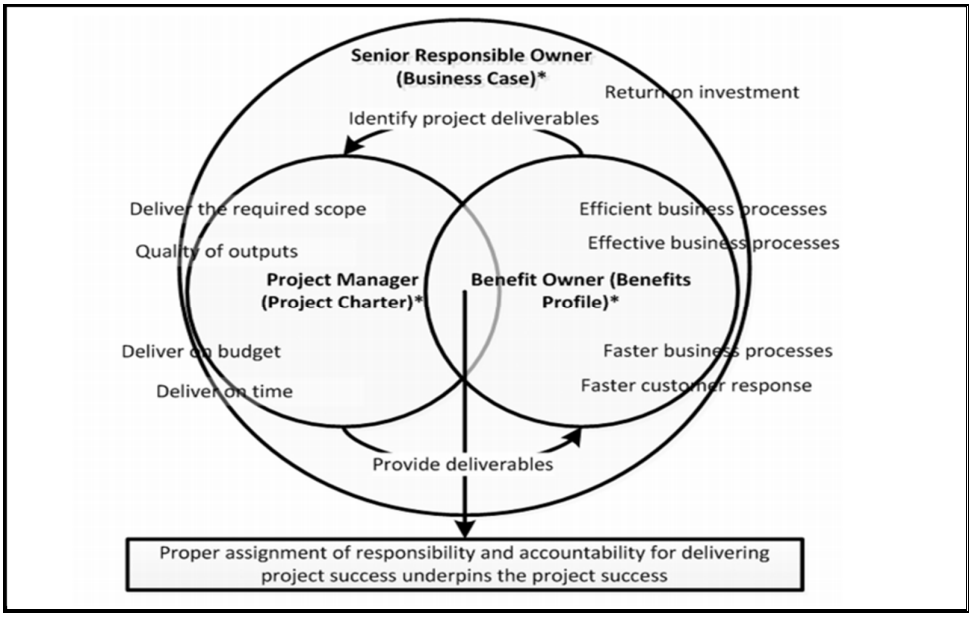

Figure 1: Accountability and responsibility of the SRO, Project Manager and Benefits Owner Badewi (2016, p 5)

The BM literature has not specifically discussed the enablers and inhibitors of benefits management, except Coombs (2015) who highlights enablers and inhibitors for information system, but these are of technical nature rather than cultural and organizational factors impeding benefits management. Coombs states that technical inhibitors include matters such as poor design of reports and low system response in function response time. Similarly, technical facilitators are training on the use of system, mapping and redesign of existing processes. Some other authors such as Young et al. (2017) highlight top management support, change in organizational culture and effective communications as the BM enablers. Similarly, Serra and Eduardo (2017) also identify stakeholders' engagement and effective communication as the BM enablers. Young et al. (2014) argue that one of the reasons for poor benefits management is the managers' mindset that the benefits will automatically be realised with the delivery of the product. Young et al. state that programs and portfolios do not deliver strategy and there is a lack of interest in government agencies for project outcomes and benefits management. The BM literature forcefully argues for the adoption of benefits management, as the basis of decision making on project success, it also seeks the top management support for the establishment of necessary processes, accountabilities, and the integration of BM into the project life cycle. It also

argues for an active benefits tracking, measuring and realisation after the project delivery, so that organizations get expected value from investments into projects. Our research found the following benefits management enablers:

- Change management for benefits realization
- Assurance and accountability for benefits realization (of the benefits owners)
- Top management support for benefits management
- Effective PMO and P3M practices
- Project/program governance focus on benefit realization during the delivery and post-delivery periods

As briefly noted above the effective benefits management requires enabling environment, which may include strong commitment and support of the top leadership, robust contestability at the business case approval stage and continuous accountability for benefits during the life cycle of the project/program, and beyond. The SRO's role attains critical significance in making benefits management a success story, thus enabling the public sector organizations to achieve their strategic goals through investment in projects and programs.

Research Methodology:

The research is based on qualitative methodology which employed the case study method. The case study method has the inherent ability to answer, 'how and why' questions (Yin 2009, 2014). The case study enables exploring a phenomenon, which is current, observable and does not require control over the behavioural phenomenon and focuses on contemporary events. Blomquist et al. (2010) call for 'project as practice' research in order to resolve challenges faced by the project managers and managers. Our research endeavours to enhance our understanding of the challenges faced by organizations in benefits management and responds to a call by Blomquist et al. (2010) for project as practice. This research reached out to the project practitioners to identify current benefits management practices in the public sector organizations. This study employed interviews as a tool to collect data and conducted 45 semi-structured interviews and these interviews were conducted in six Commonwealth Government departments. The research investigated a number of important issues concerning benefits management, but this article is limited to the role of the benefits owner for benefits realization in the case study organizations. These interviews lasted between one to one and half hour and the transcripts were read through to develop codes and the emerging themes. This study used the content analysis method to analyse the interview data. Maxwell (2012) argues that a qualitative research study must specify how the data analysis will be conducted and this decision should 'influence and be influenced' by the rest of the design. He specifies three types of qualitative data analyses, such as 'Categorizing Strategy' (coding and thematic analysis), 'Connecting Strategies' (narrative analysis and individual case study analysis) and lastly 'Memos and Display'. For this research we employed the categorizing Strategy involving the identification of codes and the development of themes from the codes. A code is "a short word or phrase that symbolically assigns a summative, salient and essence capturing, and or evocative attribute for a portion of language based or visual data" (Saldana 2012, p 3). It is also important how the codes are generated whether on the basis of the research data or the concepts borrowed from the existing literature. Schreier (2012) identifies three strategies for structuring and generating codes, such as Concept driven, Data driven and a Combination of both. Braun and Clark (2014) consider concept driven approach as top down, in which a researcher comes up with a series of questions, concepts and ideas. Braun and Clark also agree that

it is near impossible to be completely inductive or deductive. Therefore, Schreier (2012) prescribes a 'typical mix' in which we can start the process with already known important concepts, as a first step and then add more categories, which were not known initially. Therefore, this research employed, Schreier's mixed method starting with the research questions. However, the effectively identify yet the hidden concepts we read through all the transcripts line by line, resulting in a large number of codes and later on themes. We also used the qualitative analysis software, NVIVO to ensure rigour, redundancy, and validity to our coding process. In the first round 23 themes were identified, in the second round these themes were merged into 14 main themes and the third round resulted in 8 final themes. In the process of revision, no theme was dropped out and all the initial 23 themes were consolidated into the last 8 themes making these theme more comprehensive and inclusive. The themes consolidation process was based on similarities of meanings, and relevance. One of these themes is 'benefits ownership' and hence this article focusses on benefits owner in effective benefits management and realization. Following are the research questions of the doctoral study.

Research Questions:

1. How project benefits realization is being practiced in organizations?

1.1. What are the current frameworks, processes and practices employed?

1.2. How project target benefits are formulated and appraised in practice?

1.3. What is the role of governance in project benefits realization?

2. What are the enablers and inhibitors of benefits realization in organizations?

Results and Discussion:

Similar to the PM literature debates on benefits management (Patanakul et al. 2016, Zwikael et al. 2019) the role of the benefits owner figured repeatedly during the interviews with the participants of this research. Query results of interview transcripts show that the word 'SRO' and 'Owner' were mentioned 116 and 149 times respectively. When the text was searched using NVIVO, overall made 39 statements overall were made by 18/35 interviewees, in which they highlighted the role of benefits owner and the Senior Responsible Owner/Officer (SRO) and discussed how the benefits owner's role is being performed currently in the case study organizations and to what effect?

In the case study organizations, the SRO is a key player in benefits management as notionally the SROs is the project/benefits owner by virtue of being the head of a division or the business area consuming the expected project product/service. In the case organizations, the SRO's performance as benefits owner has been lacklustre due to many factors such as their lack of understanding of benefits, their focus on delivery on time and cost and too busy with managing other matters. Identifying the causes behind the SRO's poor performance particularly on benefits, Bartolomew (2017) states that the lack of understanding of SRO's role, wrong people are nominated for this role, not having real accountability, the SRO not devoting enough time to this role, not having sufficient skills and experience and the short stints as SRO. This research found several similar factors, Bartolomew highlighted, as at times the SROs are from finance or management backgrounds, therefore, they find it hard to effectively perform a different role in the PM space. Our research found that the executives playing the SRO's role are possibly accustomed to dealing with the matters on outputs rather than something measurable such as benefits. Confirming the focus of the SRO on outputs, one participant said, when the SRO was asked about benefits of a project proposal, *"the SRO turned around and said, I will tell you, what the benefits are, when the project is delivered"*. The understanding and knowledge

of SROs, about project management has been questioned by a number of participants in their interviews with these researchers. Some of the participants are of the opinion that people performing project governance roles try to run it like managing an organization. Senior executives who are not brought up in the project world, need training and coaching. As one research participant commented on the knowledge of SROs about benefits management and said,

> *"I would have to say half the reasons why we are struggling; our SROs do not understand benefits. Senior executives don't understand benefits, so they talk about it, this is the benefits and that's benefit, but they don't understand that for it to be benefit, you have to measure it, got a baseline, got a methodology for it. Due to the lack of understanding of benefits by the senior executives, they keep trying to push the benefits to the program managers and project teams, who of course won't be there after the project has been delivered ... and the project team lives in ICT [department] and of course the benefits are in the business world. SROs need to be made aware that you have to do it, your business team has to do it with the project, and I have been battling that for two years".*

As noted above, the SRO is the business case owner and thereby the ultimate benefits owner and the interest SROs take in business case is evident from this comment by a research participant, *"I have SRO, who have never read the business case, which defines why are you doing it and what are you getting out of it. This SRO had been here for two years saying, she has never read the business case… because such executives are really focussed on outputs and products, and not benefits and outcomes"*. The SRO is nominated in this role by default for being head of a division, which is problematic, as one participant commented, *"You have just been made the SRO, because you happen to be responsible for that branch, you do not necessarily know of it"*. Our research highlights that some SRO's lack of knowledge about the PM matters is exploited by the program managers, who are most contractors and they do not provide accurate and real time information to the SROs on programs and particularly benefits. *"They [SROs] heavily rely on their program managers to advise them if there is anything wrong with the project, and the program managers are very highly paid contractors and lot of them hide a lot. So, they [SROs] don't get told the full story of what is going on"*. This research found that the program managers present reports in such a way that these do not tell the entire story about the state of programs and projects, as one participant said, *"he [SRO] sees that status reports are green, but they could be watermelon projects, when effectively just below the surface is very red and to a large extent, we are not aware of that"*. The SRO reports to assurance committees on the state of the programs under their supervision but when the SROs get stale and incorrect updates programs, they just relay the same inaccurate advice to the governance and assurance committees. This research also discovered that some SROs in fact discourage program directors for telling the truth, as one participant said, *"My SRO would say at the outset of the meeting, do not give me bad news"*. We conclude that the sanitised information provided to the SRO, is perhaps packaged knowing the attitude and expectations of a particular SRO. The communication and consultation with the SRO are refined and the story the SRO gets told is that he probably wants to hear.

Zwikael et al. (2019) state that the PM literature uses inconsistent and conflicting terminologies about PM roles. The PM literature describes project owner as a person, who has the authority to finance and receive the benefits from a project (Krane et al. (2012). The benefits management literature offers different views as to who should be responsible for benefits management and the program manager, senior user and senior responsible owner are all candidate roles for being a benefits owner (PMI 2017, OGC 2009). Senior Responsible Owner/Officer is exclusively accountable for outcomes and benefits of any project or program (OGC 2002, 2003). This lack of clarity about the role of benefits owner leads to a lack of accountability on benefits management in the public sector organizations. Zwikael et al.

(2019) argue for the operations manager to play a proactive role in benefits management throughout the project life cycle. This is ideally a good proposition, but it is not common in practice because appointing the operations manager as benefits owner has some practical impediments. Figure 2 shows the involvement of the SRO from pre-project and across delivery to transitioning phase and it also shows over lapping responsibility of the operations manager for benefits realization.

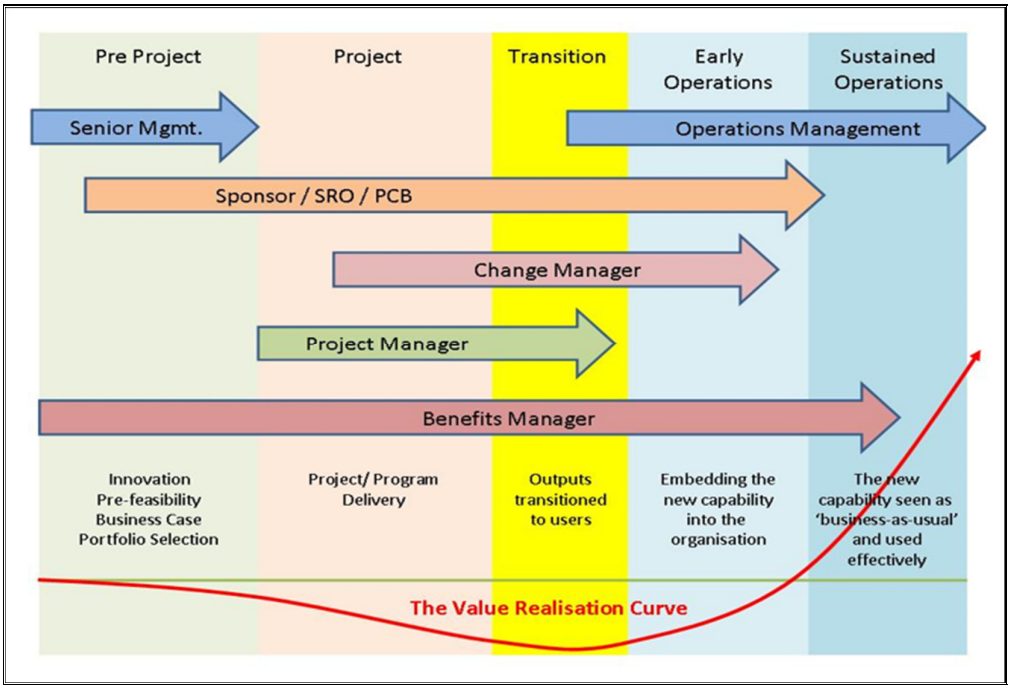

Figure 2: The overlapping roles and responsibilities of the SRO and Operations Manager for benefits. (Weaver, 2012)

Our research found that the operations managers don't commit to benefits without seeing them happening. They keep themselves busy with the day to day running of the branch under their management. The operations managers also state they do not have the skills and resource to perform the role of a benefits owner. Therefore, we argue that the SRO is an ideal candidate for being a project/benefits owner, as they have the authority to spend money and make decisions on benefits. OGC (2009) suggests the delegation of responsibility of project owner to an executive as a focal person to ensure the project objectives are achieved and benefits are realised. Therefore, the accountability for benefits should remain with the SRO but the program manager (during the delivery) and the operations managers (after delivery) can be delegated benefits ownership by the SRO, which will not only relieve the SRO for many other urgent matters and also enhance benefits ownership early on by the operations manager, rather than becoming benefits owner once the project service has been transitioned BAU. Zwikael and Meredith (2017) state that due to their busy schedules, the senior executive cannot do justice with their role as project owners, therefore, the responsibility to realise benefits can be delegated to someone else possibly from the same department that invests in the project. However, there are some cultural impediments to the delegation of benefits owner's responsibility to program director or the operations manager, a senior consultant explained the interesting process of ducking the responsibility for benefits:

> *"I think part of the problem is getting ownership from the right levels in the public service to actually take responsibility for that and what I found is that they do not want to do that. They don't feel comfortable taking ownership often, so what they tend to do is they*

> *push the ownership up, so if we looked at a typical public service organization with a fairly large reform program, you would suggest that the majority of the operations would be run by EL2s or EL2.2s. My experience is, if you try to get an EL2 to own benefits realisation plan, they won't do it, they shall just try to push it up. So it gets pushed up to Band 1, because it has been pushed up the Band 1, and the Band 1 then says, oh, I don't know whether I want to own it, so they push it to Band 2, and then you have got a Band 2, then that's at the umbrella level saying, I have got the overall ownership of it but the benefits realization funds is not real, it's sitting right at the top, so what happens is, it translates back to financials again".*

The above comment highlights that the responsibility for benefits ownership is avoided as much as possible by pushing it upward and where it is not possible to further pass the buck then it is performed poorly due to the lack of accountability for benefits.

In PRINCE2 methodology, project board has three important roles such as Executive- represents business, Senior User- represents end users and Senior Supplier – represents suppliers, which can be internal branch or external provider (OGC 2005). The Executive, in the project board among others, 'has the responsibility to throughout the project to ensure that the business benefits will be achieved' (OGC 2005, p209. The Supplier represents the interests of the final users of the product that will deliver the benefits ultimately. The Supplier, represents those who contribute to designing, developing, and implementing the product/service for the Senior User (OGC 2005). Since the Senior User represents the end user branch/a group of users, therefore can the Senior User be assigned the role of benefits owner? Zwikael and Meredith (2019) suggest the operations managers be assigned the responsibility of benefits ownership. But one very experienced participant expressing his opinion on this question said,

> *"The Senior Supplier and Senior User are notionally members of the project board, but Senior Supplier will hire someone to deliver the project so that s/he can focus on business as usual and similarly, the Senior User will say, ' it is still in the project world, I am BAU, I am not interested in this until it comes to me, and I have got better things to do".*

Therefore, we argue that ideally the operations managers seem to be the right candidates for the role of benefits owner, as recommended by Zwikael and Meredith (2019), but as highlighted by the above noted comment by our research participant with a vast PM experience, the practical realities do not bode well for such a suggestion. However, we suggest that during the delivery of the product/service the SRO should remain accountable for benefits but after the operationalisation of the product/service, the operations managers (Senior User) be delegated the role of benefits owner, reporting to the SRO. We recommend that benefits reporting be made a part of performance reporting of the concerned operations managers. However, the operations managers must be provided with the necessary training and resources enabling them to perform this role effectively.

The BM literature does not specifically stipulate a particular candidate role for benefits owner, but researchers have listed a number of roles, who are mainly responsible for benefits realization. However, there no is clarity as to who can be a project/benefits owner and number of roles have been nominated as possible project/benefits owners (Zwikael et al. 2019). Whoever is made the project/benefits owner, there should be strict accountability and the decisions on the future projects should be based on the performance benefits realization in the previous projects. This research found that among the 16 responsibilities of a typical SRO in a public sector organization include, 'ensuring the program delivers capability that achieves the department's strategic outcomes and realises

benefits and providing regular reports on the health of the program and progress towards achieving outcomes and benefits.

The SRO facilitates independent gate reviews of large programs through six gate reviews, Gate Review 5 is exclusively focussed on benefits realization and value for money. In principle, gate review 5 is conducted within 6-12 months after the commissioning of the product or the introduction of the service, and when it is expected that sufficient information of benefits is available (finance.gov.au). However, our research found that in some cases, the gate review 5 was conducted just before the product/service was due to be operationalised, which means, the review was carried out too early on. This research also found that the gate review 5, looks at the plans for benefits realization rather than investigating the real benefits gains on the ground.

This research found, the gate reviews are limited to external programs (approved by Cabinet, Parliament) costing $30 million or above. And for the internal projects (funded internally by the agency), the SRO is equally responsible for benefits realization but there is hardly any independent oversight, similar to gate reviews, therefore, the lack of accountability for benefits realization of the internal projects enfeebles the focus on benefits realization. Therefore, this research argues that there should be an 'at arm's length' contestability mechanism to ensure impartial contestability and accountability for the promised benefits in the business case in the internal projects at the time of business cases approval so that only the genuine and realistic benefits are listed in the business case. Since the SRO is the business case owner, therefore, the SRO should be held accountable for benefits realization, when the project product/service is operationalised. The SRO is required to initiate the Project Implementation Review (PIR), but this research found that in one of the case organizations, hardly any PIR was conducted for many years, which means internally there is a serious lack of accountability for benefits realization for the internal projects.

We argue that the poor performance on benefits realization by the benefits owners, project owners and SROs, is due to the lack of accountability for benefits realization, particularly for the internal projects. However, for the external project the situation is slightly better, due to the gate reviews particularly, Gate Review 5, which is exclusively about benefits realization of major projects. Though there are question marks about the effectiveness of gate reviews, as the gate reviews are not sharp enough and it has almost become an objective to get through the review, rather than using this opportunity to improve the program. Further, gate reviews are audit focused than improvement focused, as these just make sure that standards have been followed and what was promised to the government has been delivered. A number of participants think gate reviews are just the checkpoints that need to be crossed and, in most cases, just before a review is due, project benefits documents are updated for compliance, as one participant commented,

> *"So, they shift their whole emphasis into how do we get them off our backs rather than how do we actually succeed, so actually it is not valid anymore, it is actually a negative, it is causing these guys to actually to put a smoke screen".*

We argue, there is a need for a properly defined and regulated way, which puts the ownership and accountability for benefits realisation on the SRO, project owner or the benefits owner. They should be responsible for reporting on benefits realisation, and for this to happen, there is a dire need for strong leadership and ownership of benefits, and effective program governance on the part of senior executives. Ideally, benefits owners should be engaged during the development of the business case, if not, they should be on board during the planning process as when a benefit profile is produced, it needs to be signed off by the benefits owner to say yes, this makes sense, and we agree that this is the likely impact of the project that has been done. By engaging with the benefits owner at that point

having them commit and then putting in place through the governance requirements will increase accountability.

The BM literature emphasises the role of the project owner, which is confirmed by our research findings. However, some recommendations in the literature are impractical as Mossalam and Arafa (2016), Ward and Daniel (2012) argue for each benefit to have a clear owner, as we have seen that having a clear benefit owner for the entire project is a challenge, let alone for every benefit (Saeed and Rashid 2020). The SRO's role as project owner and the benefits owner is extremely important for ensuring that the benefits are properly identified and formulated, tracked and realized after the project product/service has been operationalised. The SRO as a project/benefits owner can be effective due to the authority vested in the senior executive, but recognising the fact that SROs are busy executives, the responsibility can be delegated to a role such as the Benefits Manager at the PMO during the delivery period and once the product/service is delivered, the operational manager, whose department will consume the project outputs and accrue benefits, should be accountable for benefits realization and reporting. However, we argue, whoever performs the role of the benefits owner, there is a need for strong accountability for benefits realization particularly for the internally funded projects, and external projects as well.

Conclusion:

This article discussed the role of benefits owner in effective benefits management in the Australian Public Sector Organizations. Benefits are considered important when a project business case is initiated and the Senior Responsible Owner/Officer (SRO) is the project and benefits owner. There is a lack of clarity around the role of the benefits owner within the PM literature and practice. Therefore, this research highlights the lack of accountability of the owner for benefits. Benefits management is impeded by various inhibitive factors such as the busy executives, lack of skills and resources to carry out benefits realization activities, ineffective change management, poorly defined benefits and the lack of commitment of the senior executives to benefits. This article argues for the integration of benefits management into the project/program life cycle, effective governance, benefits tracking and measuring processes as well as strong accountability for the promised benefits.

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The Probability of Project Recovery

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Abstract

A few years ago, a theoretical study was made of the To Complete Performance Index of Earned Value Management. The study concluded that when the value of 1.10 is exceeded recovery of the project is very unlikely. Recent analysis using real data has shown that the value 1.10 for the To Complete indexes from Earned Value Management and Earned Schedule is a reliable threshold, adding credence to the conclusion from the theory assessment. This paper describes how to use project performance measures with the established threshold to compute the probability of schedule and cost recovery. Knowing the probability provides additional and beneficial information, thereby enhancing the decision-making capability of project managers.

Introduction

Recent research, using real data from 25 projects, indicates that the value 1.10 is a reliable threshold for the To Complete Performance Index (TCPI) and the To Complete Schedule Performance Index (TSPI) [Lipke, 2016]. The research affirmed the conclusion made from a theoretical assessment that when the threshold is exceeded after 20 percent project completion, recovery is very unlikely [Lipke, 2009-1]. As well, it was shown that when the index value is equal to or less than the threshold, a successful project can be expected; i.e., the product is achieved within the total budget and delivery to the customer is made on or before the negotiated completion date.

With the establishment of the threshold value, it becomes possible to compute the probability of project recovery (PRcv) for both, cost and schedule. In turn, having knowledge of the probability is

envisioned to be useful to project management. For example, when final cost is forecast to exceed the total budget, yet TCPI is less than 1.10, indicating there may be opportunity for recovery, the project manager (PM) has a decision to make: Should he/she take action to effect recovery or not? The value of PRcv is a needed component in the PM's decision process.

Succinctly, there is need for knowing and using the PRcv. The remainder of the article is devoted to developing the method of its calculation. To create the foundation for understanding we will begin from a common point with the definitions of the To Complete Indexes, and proceed to an introduction of probability theory.

To Complete Formulas.

The TCPI from Earned Value Management (EVM) describes the cost performance efficiency required for the remainder of the project to achieve the desired final cost [Project Management Institute (PMI), 2011]. The index formula is defined as follows:

$$\mathbf{TCPI = (BAC - EV) / (TC - AC)}$$

where BAC = Budget at Completion
EV = Earned Value
TC = Total Cost (BAC plus cost risk reserve)
AC = Actual Cost

TSPI is the time-based To Complete indicator, derived from the application of Earned Schedule [Lipke, 2009-2]. The indicator yields the schedule performance efficiency required for the remainder of the project to achieve the desired project duration [PMI, 2011]. The formula for TSPI is shown below:

$$\mathbf{TSPI = (PD - ES) / (TD - AT)}$$

where PD = Planned Duration
ES = Earned Schedule
TD = Total Duration (PD plus schedule risk reserve)
AT = Actual Time Duration

Probability Theory.

The probability that the mean (M) of a number of observations (O), having a normal distribution, is larger than a selected value (V) is determined from the following equations [Crowe et al, 1960]:

$$X = (M - V) / (\sigma/\sqrt{n})$$
$$\sigma = \sqrt{(\Sigma(O_i - M)^2 / (n - 1))}$$

where X = the statistically normalized difference of M minus V
σ = the estimated standard deviation of the observed measures
n = the number of measures
O_i = one of the observations

The computed value of X is converted to probability using either the normal or t-distribution. The t-distribution is applied when the number of observations is less than 30.

When the observations are from a finite data set, the denominator of the equation for X is multiplied by the adjustment factor $\sqrt{((N - n) / (N - 1))}$, where N is the total number of observations and n is the number in the sample [Crowe et al, 1960]. Because projects are finite, the adjustment factor is pertinent to the calculation of PRcv.

Probability of Recovery

To compute the probability for when the value of TCPI or TSPI is, say, less than or equal to the threshold value (1.10) two characteristics must be determined:

1) Are the values from the periodic measures of the index distributed normally?
2) Is the number of index measures finite?

For TCPI and TSPI, the number of status values is limited by project completion, and therefore finite. However, the indicators behave oddly, especially for poor performing projects. For projects performing well, the indicators monotonically decrease in value, reaching zero at completion. For poor performing projects, the indicator values increase past the threshold, have a divide by zero condition, then turn negative and finally return to zero at completion. From this odd characteristic behavior along with the lack of meaning for periodic values of the indicators, it is logically inferred that their respective statistical distributions are indeterminate. Thus, the To Complete indexes do not satisfy the requirements and we have a conundrum:

The probability of project recovery is dependent upon the TCPI and TSPI values relative to the threshold, 1.10. How can the probability be computed without discerning their statistical characteristics?

Resolving the Dilemma.

Let's begin by viewing TCPI and TSPI in a different form. For TCPI, the changed form is created by dividing the numerator and denominator of the defining equation by BAC. And, for TSPI, the numerator and denominator are divided by PD. The transformed equations are shown below:

$$TCPI = (1 - EV\%) / (CR - EV\%/CPI)$$
$$TSPI = (1 - ES\%) / (SR - ES\%/SPI(t))$$

where $EV\% = EV/BAC$, $ES\% = ES/PD$, $CR = TC/BAC$, $SR = TD/PD$, $CPI = EV/AC$, $SPI(t) = ES/AT$

The acronyms, CPI and SPI(t), are the Cost Performance Index and the Schedule Performance Index (time), respectively [PMI, 2011].

Upon setting TCPI and TSPI to the threshold value, 1.10, the above transformed equations are solved for CPI and SPI(t), respectively. The resultant solutions follow:

$CPI_T = 1.10\ EV\% / (1.10\ CR - 1 + EV\%)$
$SPI(t)_T = 1.10\ ES\% / (1.10\ SR - 1 + ES\%)$

The subscript T denotes that these formulas provide the threshold values for which the performance values of CPI and SPI(t) are to be compared. When the performance value is less than the comparable threshold value, the To Complete index threshold has been breached.

To enhance understanding, graphs of $SPI(t)_T$ are shown in figure 1. Three plots are depicted to illustrate the effect of various values of SR; the value of SR is in parenthesis for each of the legend identifiers. For the value 1.0, TD equals PD, indicating there is no schedule reserve; for the value 1.1, 10 percent of TD is reserve and for 1.2, 20 percent is reserve. From analysis of the three graphs, we observe that as SR increases the $SPI(t)_T$ value decreases for the same value of fraction complete (ES%). Thus, it is easily deduced that as reserves increase, the performance values of SPI(t) can decrease and not cause TSPI to exceed 1.10. The above description may be applied, analogously, to CPI_T, CR, CPI, and TCPI for cost performance analysis.

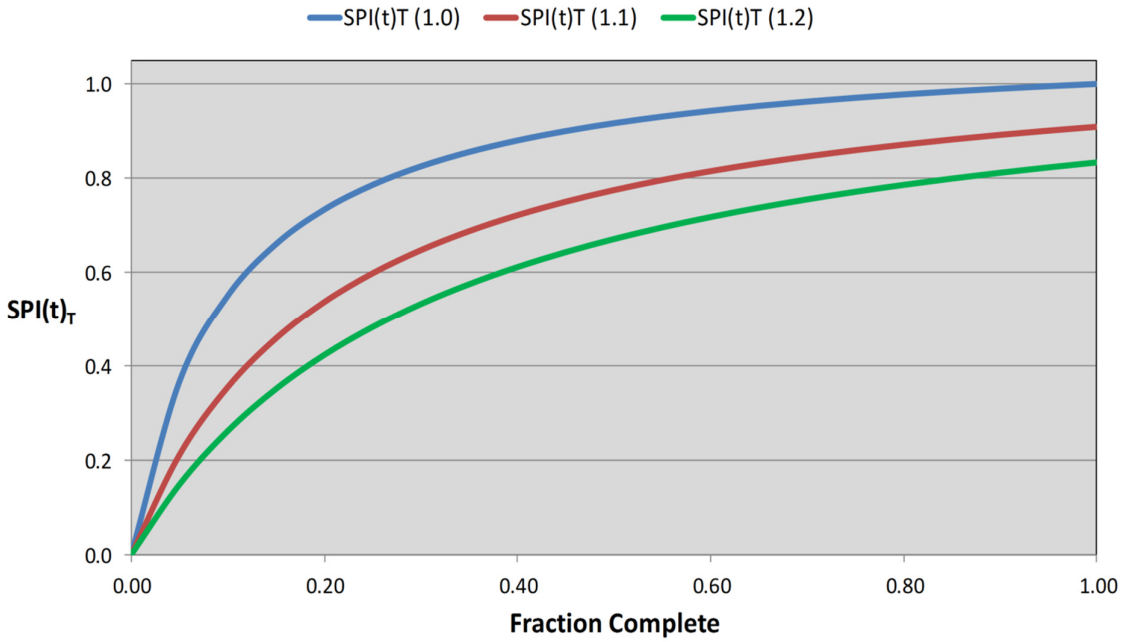

Figure 1. $SPI(t)_T$ Behavior

Application of Statistics.

The periodic values of CPI and SPI(t) from real projects have been tested and determined to be lognormally distributed [Lipke, 2002 and 2012]. Furthermore, it can be shown mathematically that the mean of the lognormal distribution is equal to the log of the cumulative value of the index. To clarify, using the schedule indexes: $\ln SPI(t)_C = \Sigma(\ln SPI(t)_i)/n$, where the subscripts C and i denote cumulative and periodic, respectively, and ln is the logarithm function.

By transforming the threshold for TCPI and TSPI to CPI_T and $SPI(t)_T$ functions, the statistical characteristics of CPI and SPI(t) can be utilized. Figure 2 illustrates the normal distribution of the periodic values of ln SPI(t), as well as the placement of $\ln SPI(t)_C$ and $\ln SPI(t)_T$. For the pictorial example, the project has an estimated 90 percent probability of recovering to its TD. The probability is determined from the area beneath the normal curve beginning at $\ln SPI(t)_T$ and extending to plus

infinity. At 90 percent, the PM has a good opportunity to take positive action and have a successful project.

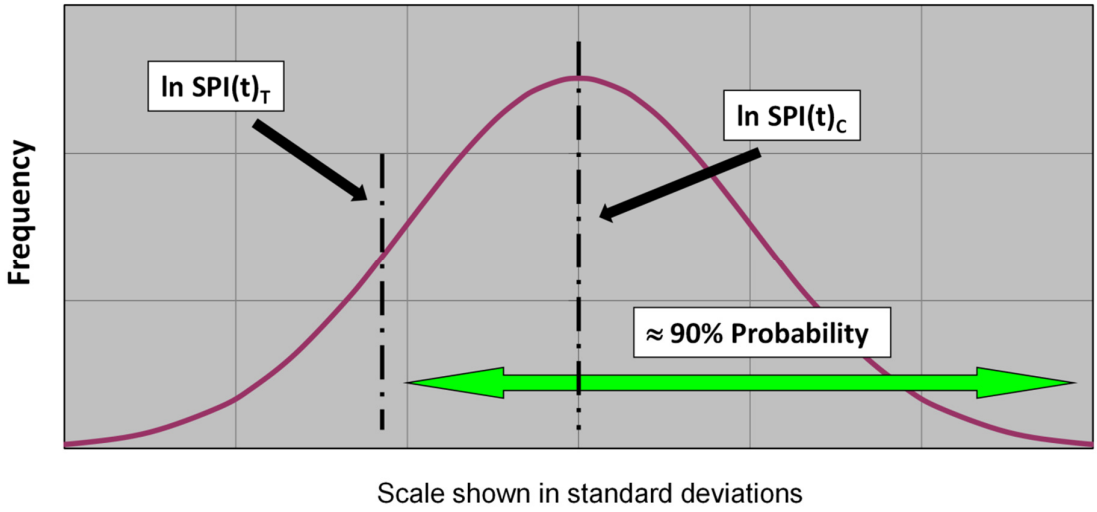

Figure 2. Probability Example

Probability Calculation.

To perform the probability of recovery calculation, substitutions for variables, M, V, and O_i, are made in the equations for X and σ described previously in the Probability Theory section. Table 1 is a compilation of the cost and schedule substitutions. Included, as well, are the finite data adjustment factors required for projects[2].

Three graphs of computed results for probability of recovery are portrayed in figure 3. For the calculations, the values for $SPI(t)_C$ and σ are held constant at 0.87 and 0.30, respectively, as ES% increases to 1.0. The value of 0.87 is purposely chosen to demonstrate poor schedule performance, while the σ value is typically observed. Each of the graphs, PRcv(1.0), PRcv(1.1), and PRcv(1.2), is an example of probability behavior over the duration of the project. The number in parenthesis is the value of SR used in the calculations. For instance, 1.0 in the notation, PRcv(1.0), indicates the total duration is equal to PD.

Variable	Cost	Schedule
M	$\ln CPI_C$	$\ln SPI(t)_C$
V	$\ln CPI_T$	$\ln SPI(t)_T$
O_i	$\ln CPI_i$	$\ln SPI(t)_i$
$\sqrt{((N - n) / (N - 1))}$	$\sqrt{((BAC - EV) / (BAC - EV/n))}$	$\sqrt{((PD - ES) / (PD - ES/n))}$

Table 1. Cost and Schedule Substitutions

The figure illustrates the influence of schedule reserve on PRcv. The graph of PRcv(1.0) shows a decreasing probability value until, at approximately 85 percent complete, actual duration has exceeded PD. From that point until completion PRcv equals 0.0; it is impossible to recover. The

[2] Explanation of the finite adjustment factors for cost and schedule is available in the reference [Lipke, 2009-2]

PRcv(1.1) graph indicates there is good opportunity for recovery until the project has progressed to approximately 70 percent complete. The probability decreases rapidly thereafter until the actual duration exceeds 1.1 PD. For the PRcv(1.2) graph, TD is greater than the actual duration at completion. The probability approaches 1.0 very early and at completion equals 1.0.

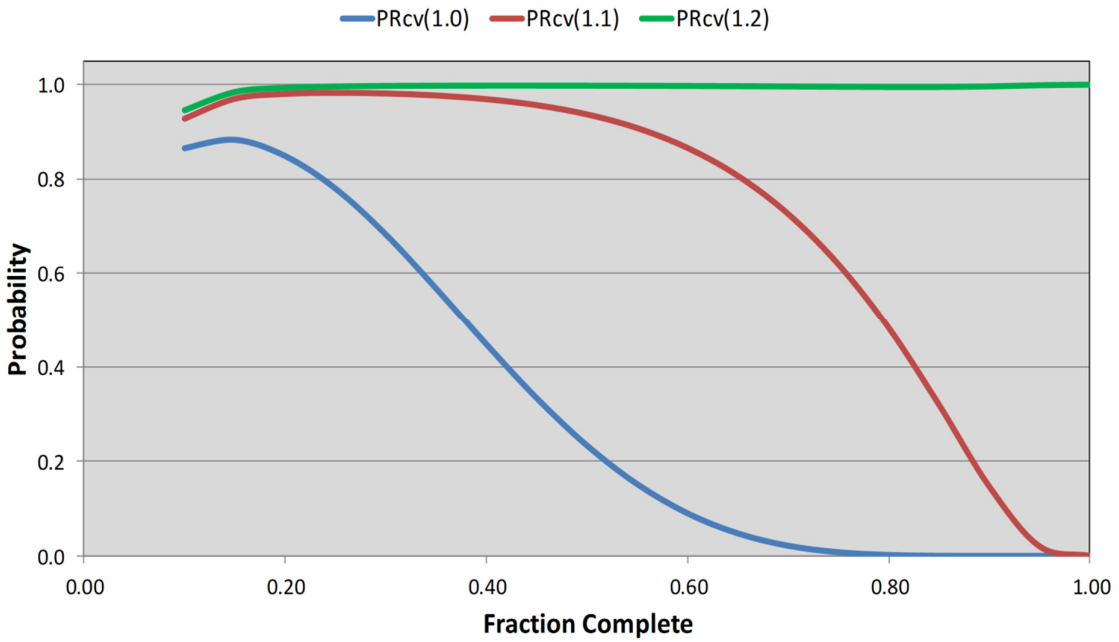

Figure 3. Probability of Recovery

The examples and figures throughout the article have been presented in reference to schedule performance. However, the discussion points are equally applicable to cost. In this confined context, cost and schedule analysis are perfectly analogous. The threshold behavior of CPI_T is identical to $SPI(t)_T$ in figure1. As well, the interpretation of figure 2 is unchanged when CPI is substituted for SPI(t). And lastly, the PRcv graphs in figure 3 are identical for cost, when performance and risk reserve mimic the values employed for schedule.

Notional Data Example

A small set of data has been created to demonstrate the management application of PRcv. The data and computed results are consolidated in Table 2. The majority of the headings have been introduced previously; however, four have not: Mo, PV, PO%, and IEAC(t). The abbreviation Mo is month, while the abbreviations PV and IEAC(t) are Planned Value, and Independent Estimate at Completion (time), respectively [PMI, 2011]. The heading PO% is the Period of Opportunity percentage [Lipke, 2009-1]. The value of PO% represents the portion of PD from the present status point until the threshold is exceeded if present SPI(t) continues; i.e., it provides management with information concerning the opportunity to take corrective action.

Mo	PV	EV	ES	SPI(t)	TSPI	PO%	IEAC(t)	PRcv
1	3023	928	0.307	0.307	1.099		26.1	
2	7828	7152	1.859	0.930	1.023	31.3%	8.6	0.574
3	13951	13302	2.894	0.965	1.021	35.1%	8.3	0.591
4	19967	17077	3.520	0.880	1.120	Unlikely	9.1	0.477
5	24286	23061	4.716	0.943	1.095	1.2%	8.5	0.505
6	30989	28681	5.656	0.943	1.172	Unlikely	8.5	0.440
7	36709	32526	6.269	0.896	1.731	Unlikely	8.9	0.219
8	38140	34513	6.616	0.827	#DIV/0!	None	9.7	0.000
9		36709	7.000	0.778	-1.000	None	10.3	0.000
10		38140	8.000	0.800	0.000	None	10.0	0.000

Table 2. Analysis Example

From the PV data, we can see the project has a planned duration of eight months. The effort is considered low risk and has no reserve; i.e., product delivery is to occur upon completion of the 8th month. However, the EV column shows performance lagged expectation with the project completing two months late.

For delivery to occur as planned, SPI(t) must equal 1.000 at project completion, and should be maintained close to that value throughout execution. Correspondingly, the forecast duration shown in column, IEAC(t), needs to hover around 8.0 to have the expectation of delivering on time. As the project progresses, neither SPI(t) nor IEAC(t), provide confidence of project success; SPI(t) is consistently less than 1.000 and IEAC(t) is always greater than 8.0 periods.

Early in the execution, the PM can see that the project is in trouble. However, utilizing only SPI(t) and IEAC(t), there is not enough information to determine if recovery action is possible, or practical. To be possible, the PM needs to know that TSPI has not exceeded the threshold value. To decide whether a recovery action is appropriate and worthwhile, the PM must answer two questions:

1) Is there opportunity to make necessary performance corrections?

2) What is the probability of having a successful recovery?

The value of PO% answers question 1, while PRcv answers 2.

Although we may be able to answer the above questions, there is another aspect to consider. Some amount of execution is needed to have confidence in the management information. Generally, to achieve a level of performance data sufficiency, the execution required for EVM analysis is the initial 15 or 20 percent of the effort. Choosing 15 percent, the table values for analysis of the hypothetical project are considered when ES is equal to or greater than 1.2 months. Thus for the first month, the values shown may be ignored; ES is less than 0.4 months. For month 2, ES equals 1.859 making values for months 2 through 10 usable for analysis.

Examining the values in the table for months 2 and 3, we can see that the PM has information for SPI(t) and IEAC(t), indicating poor performance. Also, we observe that TSPI has not exceeded the threshold and recovery is possible. With PO% greater than 30 percent and PRcv close to 60 percent, the PM can feel reasonably confident that recovery intervention is appropriate.

Of course during execution of months 2 and 3, our PM does not know that if he/she chooses not act, TSPI will exceed the threshold in period 4 and project delivery is not likely to occur as planned. The PM, recognizing poor performance, must balance the inefficiency caused by intervention with the possibility that improvement can be made. Inherently, the PM reacts either from intuition and experience, or from external pressure. By utilizing PRcv in the analysis process, improvement can be expected; it becomes possible to make decisions earlier with greater confidence. And, by taking reasoned and appropriate action, TSPI just might not exceed the threshold in period 4 and the project achieves success with the product delivered on time.

Summary

Theoretical and recent empirical research has shown that the value of 1.10 is very likely a valid threshold for both, TCPI and TSPI. When the To Complete index exceeds 1.10, the project most likely will not meet its commitment, i.e., target cost or delivery date.

Having evidence the threshold is valid it was thought the probability of recovery could be computed. From inspection, however, the characteristic behavior of the To Complete indexes was deduced to be erratic. Understanding the TCPI and TSPI cannot be directly used, an alternative approach was created. The method incorporates the 1.10 value and the established lognormal characteristics of CPI and SPI(t). Conceptually, although there is complexity, the method for computing PRcv is essentially identical for cost and schedule.

An example analysis was made using notional data. The analysis illustrates how PRcv in conjunction with TSPI and PO%, along with schedule performance efficiency and forecasting must necessarily be used together for making the decision to take recovery action.

The probability of recovery is foreseen to be a very useful aid in determining when project management intervention can be beneficial.

Calculation Aid

To promote uptake and use of PRcv, the Probability of Recovery Calculator for both cost and schedule is freely downloadable from the Earned Schedule website (www.earnedschedule.com). The calculator is an easy-to-use Excel spreadsheet, requiring only EVM and ES data normally available.

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Walt Lipke retired in 2005 as deputy chief of the Software Division at Tinker Air Force Base, where he led the organization to the 1999 SEI/IEEE award for Software Process Achievement. He is the creator of the *Earned Schedule* technique, which extracts schedule information from earned value data.

Research Report

Social Media Use in Project Management – An Exploratory Study of Multiple Transport Projects

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Abstract

The research aims to explore the opportunities that social media could offer to project managers of transport projects. We focus on how social media could be used to evaluate benefits realisation and create public value. Multiple case studies are the research method. We chose to study the Sydney Metro Northwest project in Sydney, Australia and Chennai Metro Phase-1 in Chennai, India. Python and Twitter Search API were used to retrieve social media data on Twitter. Although the analysis of tweets from these two projects indicated that citizens who use these transport facilities report benefits, they do not seem to use the same terms as the project's promoters to describe these benefits. The article proposes some ideas on how social media can supplement current methods used in evaluating benefits from transport projects. It is also validated that transport agencies can use social

media as a helpful tool to monitor operational issues, collect recommendations to improve, and capture live sentiments.

1. Introduction

Due to global trends such as urbanisation, there is an increasing need for the delivery and maintenance of transport infrastructures, such as roads, railways and metro rails. These kinds of endeavours are typically organised and managed as transport infrastructure projects (Volden and Samset, 2017). Transport infrastructure projects have at least two characteristics that make them especially interesting. First, the scale of these types of projects tends to be very large and the delivered infrastructure is designed to be in use for several decades. The value created in these kinds of projects is realised over an extended period of time. Consequently, the overall project success is challenging to evaluate thoroughly when the projects are completed but not yet fully used. Second, transport infrastructure projects are of interest not only to internal stakeholders such as the project supplier (e.g., contractors) and client (e.g., government agencies responsible for infrastructure delivery), but also to the people who use the delivered infrastructure. One important stakeholder group to be considered is citizens who are the future users of the transport infrastructure.

Although citizens can, especially in collaboration, have a strong influence on projects (Aaltonen and Kujala, 2016), their capacity for making their voices heard is limited by their peripheral location in stakeholder maps. However, a critical avenue for individual citizens to be heard is social media, which has become widely used in recent times to express opinions publicly. There is a wide range of research evidence of people, especially customers, having significant effects on organisations through social media (Alalwan et al., 2017; Salo, 2017). Recently, the interest in the role of social media in project management has grown as well. Hence, this project aims to explore the opportunities that social media could offer to project managers at different stages of transport projects.

This article is structured as follows. First, we analyse recent literature on the role of social media in project management and identify the potential roles to be validated. Then, we present the methods used for an empirical study of metro rail projects in India and Australia. This is followed by the empirical findings and discussion of the contributions. Finally, we provide our conclusions and recommendations for using social media in projects.

2. Literature Review

2.1 Social Media in Project Management

One of the most significant developments enabled by the internet is the advent of social media. In April 2021, it was estimated that roughly seven-in-ten Americans said they used any kind of social media (Pew Research Center, 2021). According to Pew Research Center (2021), 84% of adults ages 18 to 29 said they ever used any social media sites, similar to the share of those ages 30 to 49 who say this (81%). By comparison, a somewhat smaller share of those ages 50 to 64 (73%) said they used social media sites, while fewer than half of those 65 and older (45%) reported doing this.

Social media is increasingly adopted by companies and studied by scholars as well. However, there is a dearth of research on social media in project management. The published studies combining social media and project management have focused on topics such as improved project learning through social media (Rosa et al., 2016; Winter and Chaves, 2017), better intra-project communication or collaboration through social media (Kanagarajoo et al., 2019; Zhang et al., 2018), and social media as

a platform for branding (Ninan et al., 2019) or managing external stakeholders (Ninan et al., 2020) in megaprojects. Although the number of studies is still low, the combined message of this early research seems to indicate several possibilities for utilising social media in project management (see also Hysa and Spalek, 2019).

In contrast to project management, social media has received more scholarly attention in the fields of general management, especially in marketing and sales. This is illustrated by a few review articles published on the topic (Alalwan et al., 2017; Andzulis et al., 2012; Salo, 2017). Electronic word of mouth (e-WOM) has more reach and influence than traditional word of mouth (Alalwan et al., 2017; Salo, 2017). In other words, social media enables the general public to share opinions about products, firms and services quickly and easily. In a similar vein, customers use social media as a source of information when making purchasing decisions (Erkan and Evans, 2016; Powers et al., 2012) and, consequently, companies invest more and more on strategic marketing in social media (Alalwan et al., 2017; Salo, 2017).

The rationale behind this study is the broader application of social media in marketing and sales. In particular, whether customers using transport infrastructure such as metro rail actively shared opinions about these projects using social media. The study will focus on how social media could provide an opportunity to evaluate benefits realisation and create public value, as explained in the following literature review sections.

2.2 Assessment of Benefits Realisation

The benefits from a transport infrastructure project are typically evaluated before, during and after project implementation. These pre-project, mid-term and post-project evaluations focus on topics such as value for money and funding decisions, assessment of project progress and assessment of project success, respectively. Although the viewpoint of the citizens is implicitly present in, for example, value-for-money assessments (e.g., Volden, 2019), their voice is seldom heard directly. However, if the main goal of a project is to deliver flows of value to stakeholders (Zwikael and Smyrk, 2012), is it not important that we listen to the stakeholders themselves?

2.2.1 Pre- and Mid-Project Reviews

The most established pre-project reviews acknowledging project value creation are cost-benefit analyses (CBAs) and benefits management. CBA is a method for measuring the project's "value for money" by assessing the relationship between resources invested in a project (i.e., "the money"), and the benefits that can be achieved from the project (i.e., "the value") (Volden, 2019). More precisely, the aim of a CBA is to compute the net present value (NPV) of a project or several competing project alternatives (Volden, 2019). Regarding value creation, the critical aspect of CBA is the inclusion of both financial and non-financial benefits in the analysis; in other words, the aim of CBA is to be comprehensive in terms of coverage of a project's impacts. There are various challenges in CBA, or value-for-money assessment in general, such as measurement problems (Volden, 2019) and appraisal optimism (Flyvbjerg, 2009). Despite the possible shortcomings, different versions of value-for-money assessments are in use for project appraisal around the world (Volden and Samset, 2017), especially for public sector projects (Volden, 2019).

Benefits management is a stream of literature with solid roots in the information system projects literature (e.g., Breese et al., 2015; Coombs, 2015). Regarding pre-project reviews and value creation, a critical element of benefits management is the definition of target benefits (Zwikael et al., 2018). Target benefits can be defined as "those benefits set prior to project commencement which the project funder seeks thorough an investment in a project" (Zwikael et al., 2018); in other words, target benefits are the desirable flows of value resulting from the project (see Zwikael and Smyrk, 2012).

Although defining target benefits is not a guarantee of realised benefits (e.g., Coombs, 2015), setting effective target benefits has been argued to support project investment decisions (Zwikael et al., 2018).

Especially in large projects, such as transport infrastructure projects, there is typically a project governance model or a project management methodology (e.g., PMI, 2017) in place. While conducting pre-project reviews, a typical consideration in these kinds of models is the assessment of a business case. Regarding mid-project reviews – that is, reviews during project implementation – project management methodologies or governance models often include some types of performance review (PMI, 2017), stage-gate model (e.g., Narayanan and DeFillippi, 2012), or similar. However, typically these kinds of mid-project reviews are mostly concerned with project performance; for example, this is the case with performance review in the PMBOK model (PMI, 2017) or in earned value analysis (e.g., Kwak and Anbari, 2012).

2.2.2 Post-Project Reviews

In the benefits management literature, the post-project phase is labelled as benefits realisation or benefits realisation management (BRM) (e.g., Coombs, 2015; Zwikael, 2016). The BRM literature discusses the linkages between BRM and project success (Serra and Kunc, 2015) and the inhibitors and facilitators of benefits realisation (Coombs, 2015). The core message of this stream of literature is that benefits are not realised automatically; instead, benefits realisation must be managed and promoted actively. For example, project sponsors may have an important role in promoting benefits realisation (Breese et al., 2015). However, this stream of literature has paid less attention to assessing the delivery of project benefits.

After a project's completion, most project management guidelines or methodologies include some sort of a post-project review (e.g., PMI, 2017). The assessment of value creation is included in some of these assessments as well. An illustrative example is the UK-based OGC Gateway Process (Klakegg et al., 2008). Tailored versions of the Gateway Process have been introduced in various other countries, for example, in Australia (Xu et al., 2013). The core idea of the Gateway Process is the independent review of major projects and programs at critical points of their lifecycles (Klakegg et al., 2008). Regarding post-project benefits assessment, main reviews include "Review 4: Readiness for service" (OGC, 2007a), and "Review 5: Operational review and benefits realisation" (OGC, 2007b). Regarding benefits management, the key question of these reviews is the delivery of the expected benefits, with respect to the original business case (OGC, 2007a, 2007b).

However, the traditional method of evaluating projects using methods used in project management reviews has come under criticism in an article evaluating megaproject success (Fahri et al., 2015). These authors suggested that post-project evaluation should benefit from using ideas from the evaluation literature (Vedung 2010).

2.3 Value Creation in Infrastructure Projects

We view projects as vehicles for defining, creating and delivering value (Laursen and Svejvig, 2016; Martinsuo et al., 2019a), and consider the desirable outcomes of a project (i.e., the goals of a project) as flows of value from the project to the stakeholders (Zwikael and Smyrk, 2012). To set the scene for this review, Table 1 summarises recent empirical studies on value creation in infrastructure projects. This list is limited to empirical studies that have focused on infrastructure projects and considered value as the worth of a project (Martinsuo et al., 2019b), or as benefits for the stakeholders (Zwikael and Smyrk, 2012), instead of other perspectives as value related to ethical and moral considerations (Martinsuo et al., 2019a) or beliefs (Martinsuo, 2020).

Table 1. Recent Empirical Studies on Value Creation in Infrastructure Projects

Article	Context and method	Key findings for this study
Kivilä et al., 2017	Context: Transport infrastructure projects Method: A qualitative single-case study	- Focus on the project implementation phase and sustainability as a dimension of value. - A holistic control package with control mechanisms for different dimensions of sustainability.
Liu et al., 2019	Context: Infrastructure development programs Method: Action research, single case	- Focus on value co-creation at the program front end. - Client's intended value (value-for-firm) was competing with market partner's values. - Three sets of values (value-in-use) as results of value co-creation: commercial, intellectual and collaborative values.
Martinsuo et al., 2019b	Context: Transport infrastructure projects Method: A qualitative multiple-case study	- Focus on the stakeholders' framing of value at the project front end. Framing of value relates to project funding decisions. - Three dimensions of value: financial, social and comparative values. - Positive and negative dimensions of value, and four themes of lifecycle-oriented framing of value: uncertainties, timing of cost and benefits realization, project relations and external sponsorship.
van den Ende and van Marrewijk, 2019	Context: Transport infrastructure projects Method: A qualitative, longitudinal two-case study	- Focus on community resistance to large subway projects. - An institutional theory perspective to understanding project actors' responses to community resistance. - Community resistance prompted institutional work by project actors to socially (re)construct the projects in pursuit of legitimacy.
Vuorinen and Martinsuo, 2019	Context: Transport infrastructure projects Method: A qualitative multiple-case study	- Focus on the stakeholders' influence efforts during project implementation. - Stakeholders' value perceptions explain the stakeholder influence strategies utilized. - Three dimensions of value: environmental and social value, financial value and systemic value. - Four stakeholder influence strategies in transport infrastructure projects differentiated according to their different value priorities.

Three observations can be made based on Table 1 and the broader literature on value creation in projects (e.g., Laursen and Svejvig, 2016). First, value in projects is not a unidimensional concept but extends to multiple interrelated dimensions. The multidimensionality of value is demonstrated in studies referred to in Table 1 (Kivilä et al., 2017; Liu et al., 2019; Martinsuo et al., 2019b; Vuorinen and Martinsuo, 2019) as well as in studies published on value creation in other types of projects (e.g., Ahola et al., 2008; Ang et al., 2016; Green and Sergeeva, 2019; Martinsuo, 2019).

Second, recent empirical studies illustrated the importance of stakeholder considerations in value creation. Martinsuo et al. (2019b) demonstrated how stakeholders shape value at the project's front end, and the case studies of van den Ende and van Marrewijk (2019) and Vuorinen and Martinsuo (2019) illustrated how the perceived (especially negative) value of a project could drive stakeholders to seek influence on projects. Liu et al. (2018) discussed similar findings in the context of major construction projects.

In summary, the recent empirical studies have focused mostly on the front end of a project (Liu et al., 2019; Martinsuo et al., 2019b) or its implementation phase (Kivilä et al., 2017; van den Ende and van Marrewijk, 2019; Vuorinen and Martinsuo, 2019). Less attention has been placed on the value created in the project operations phase. Thus, this stream of literature reviewed provides few answers to the question of assessing value creation at the operations phase.

3. Research Method

The philosophical underpinning for this study is interpretivism. In particular, we looked for meanings from the perception of social reality constructed by citizens as expressed in social media. We designed this study as a multiple case study. Case studies are useful to study a phenomenon in-depth within a context to retain the holistic and meaningful characteristics of real-life events (Yin, 2014). Case studies are particularly useful to study a phenomenon that focuses on contemporary events and where the researchers have no control over the behaviour of the informants (Yin 2014, p. 9). We studied two purposefully sampled cases, which were completed over the past two years in two different countries, to allow us to have cross-case analysis and also because multiple cases are analogous to multiple experiments (Eisenhardt, 1989). Eisenhardt and Graebner (2007) noted that the findings from multiple case studies are better grounded, more accurate and more generalizable than single-case research. Multiple case studies also help us not to misjudge the representativeness of events that occur within a single case (Tversky and Kahneman, 1989).

We chose to study metro rail projects in Chennai (India) and Sydney (Australia) for two theoretical reasons. First, both projects were in the operational phase and hence would help us evaluate the benefits. Second, both projects had social media presence and activities, thereby enabling us to use social media for evaluating the benefits realisation. We now present a brief overview of these projects.

3.1 Case Description

Chennai Metro Phase-1 is a rapid transport system serving the city of Chennai in Tamil Nadu, India. The network is managed by the Chennai Metro Rail Limited (CMRL), a joint venture with equal equity holding between the Government of India and the Government of Tamil Nadu. The Chennai metro rail project's phase one started in June 2009 with an estimated cost of USD 2.2 billion and was fully commissioned on 10 February 2019. The project covers 45.1 kilometres, has 32 stations and operates on two lines – the green and the red. The green line connects Chennai Central railway station to St. Thomas Mount station via the central bus terminal called Chennai Mofussil Bus Terminus (CMBT). The

red line connects Chennai International Airport to Washermanpet. The two lines intersect at Alandur station and Chennai Central railway station, where passengers can switch between the lines.

The Sydney Metro Northwest is a rapid transit link to the north-western suburbs of Sydney in New South Wales, Australia. The link is managed by Transport for NSW through its Sydney Metro agency, and it connects the suburbs of Rouse Hill and Chatswood via Castle Hill and Epping. The link, which includes the Epping to Chatswood Rail Link, opened to service on 26 May 2019, with Metro Northwest Line services running on the link between Tallawong and Chatswood. The project involved 15 kilometres of new tunnels. The metro provides a fast transport link for suburbs experiencing significant growth in the northwest region of Sydney to CBD.

3.2 Data Collection

Data were collected through tweets from the Sydney and Chennai metros. We used Python and the Twitter Search Application Programming Interface (API) to retrieve tweets from Twitter. Twitter provides a search API for the public to search their database with user-defined keywords and time range. The API returns 500 records for each call, and a program written in Python was executed to recursively retrieve tweets containing the keywords. The keywords are the titles of two projects, i.e. “Chennai Metro” and “Sydney Metro”. It is acknowledged that some tweets would not be retrieved if they discussed the two projects without using the keywords. No duplicates were observed on checking the unique ID of each tweet, and the collected data were stored as a comma-separated values file. We collected the tweets for a 90-day period from 1 July 2019 to 30 September 2019, during which both the metro rail projects were operational. The selected study period enables us to retrieve tweets relevant to the research objective, i.e., whether the conceptualised benefits during the planning phase were realised during the operation phase. There were 1064 tweets relating to the Chennai metro rail project and 5960 tweets relating to the Sydney metro rail project. All the tweets were in English. Even though the local language of Chennai is Tamil, we found the tweets in English representative of the total discourses around the project as Chennai is one of the largest English-speaking cities in India.

3.3 Data Analysis

We used content analysis and open coding of the tweets collected to understand what each tweet conveyed. We went through each tweet and looked at the meaning/message of the tweet. We focused on the contextual meaning of the text (McTavish and Pirro, 1990) rather than merely ranking message variables based on the frequency with which they occurred. For example, a tweet that read “Thank god for @cmrlofficial I reached from Teynampet to Central in less than 15 mins #ChennaiMetro” was coded as ‘time saving’, even though the tweet did not have the words ‘time’ or ‘saving’. The focus was on the content and meaning of the tweet rather than on word choice or frequency of occurrence. The process was very iterative, and we took multiple readings of the tweets as some categories are often not apparent until the second or third reading due to the focus on content and meaning. We employed manual coding as automatic methods could create a barrier to understanding (Kozinets et al., 2014).

To enhance the rigour of our approach to data analysis, first, we conducted an exploratory coding to understand the different categories of tweets extracted. Along with tweets of benefits of the metro rail project, there were also negative tweets, interest group tweets, and operational issues tweets. The coding structure along with sample tweets for our initial analysis is given in Table 2. We then organised the tweets of benefits realisation into first-order observations and then assembled them into a more structured aggregate dimensions of benefits. This was done by collapsing or clustering the first order observations that seemed to share some unifying benefits. The results of the benefits of the Chennai metro rail project and the Sydney metro rail project are presented in Tables 3 and 4, respectively.

Table 2. Example Exploratory Coding of Tweets

First Order Exploratory Codes	Aggregate Category	Tweet Example
Travel time saved	Benefits	"Chennai metro line from the airport to the high court is awesome if a lawyer is flying in for a case. Comfy, economical and speedy. Seen nothing comparable in any other metro." (1 August 2019)
Customer satisfaction		
Well-connected network		
Inconvenience due to Construction	Negative Tweets	"Wow!! Finally after ten years! #Chennai's iconic #MtRoad aka #AnnaSalai near LIC buildings is now open for two-way traffic. Stretches of road were closed for (@cmrlofficial) #chennai metro work back in 2008? Now one straight road 4 m Munro statue to RajBhawan. Skip #ExpressAvenue" (29 September 2019)
High ticket prices		
No mobile connectivity in underground stretches		
Demolition of buildings	Interest group tweets	"We, poor people are cursing u how dare u could demolish>1000 Buildings? - Message to unnecessary Chennai metro rail phase 2 crew! Ask sorry to poor & Ban the construction" (29 September 2019)
Green roads than dusty metro station buildings and viaducts		
Complaints about doors	Operational issues tweets	"the USB points in car 0501 don't work FYI" (15 September 2019)
Non-functional facilities		
Lack of parking		
Lack of connecting buses		

Table 3. Data Structure of Benefits of Chennai Metro Rail

First Order Observations	Aggregate Dimensions	Tweet Example
Fast transport	Travel time saved	"Uncluttering myself inside the Chennai Metro Rail. It took just an hour to go all around my beloved Chennai! #metroride" (23 September 2019)
Time saving		
Getting through traffic		
Connectivity	Well-connected network	"@ChennaiMetRail Amazing work connecting the city! No Chennai citizen could have asked for more! Super convenient access to the airport! Looking forward to using it more regularly!" (30 September2019)
Convenient		
Accessible		
Efficient		
Safe	Enhanced customer satisfaction	"Used Chennai metro for first time today. Well built and clean. Stations modelled on Singapore (layout etc.). Makes me fall in love with the city more. Indeed makes life better. Well done!" (10 July 2019)
Air-conditioned		
Comfort		
Cleanliness of the metro		
Best metro rail		

Aesthetics of the metro stations	City landscape	"First time travelling in Chennai Metro … Service Platforms looks like Abroad." (5 August 2019)
Minimizing pollution Conserving water through innovations	Social benefits	"@chennaimetro has been running in full capacity for the past week. No place to sit. Not complaining. Happy that the service is being opted by many of us & thereby helping in minimizing pollution". (20 August 2019)

Table 4. Data Structure of Benefits of Sydney Metro Rail

First Order Observations	**Aggregate Dimensions**	**Tweet Example**
Fast Time saving	Travel time saved	"On the other side of the fence I'm actually having no problems and it's faster than the bus for me" (1/08/2019)
Impressive first experience Fun pretending they were the driver Cleanliness Quiet	enhanced customer satisfaction	"New, Sydney Metro driverless trains.... New experience. Pretty impressed, gotta say." (11/07/2019)
Aesthetics of the metro stations	City landscape	"There is so much new infrastructure and development happening within the CBD. Sydney's Pitt Street Station will become the city's newest landmark with a $463 million contract awarded to build the new metro railway station and the buildings above it. #sydneyproperty #cityliving" (24/09/2019)
More housing choices Better access to services	Social benefits	"Grand Cherrybrook home is just a quick walk to Sydney metro northwest https://ift.tt/2Gb31t8" (12/07/2019)
Complaints about doors Non-functional facilities Lack of parking Lack of connecting buses	Identified operational issues	"the USB points in car 0501 don t work FYI" (15/09/2019)

We also used the Python library TextBlob for sentiment analysis. First, we cleaned up the dataset by removing all links, special characters, split token, and removing all words in stop-words. The stop-words consist of all propositions, keywords used for data search and other non-meaning words, such as "an", "a", etc. Second, we defined three sentiments as the output, which are positive, neutral and negative. Classifying tweets into different categories is determined by the polarity generated from the packages. The positive category contains tweets with a polarity greater than zero, whereas a polarity equal to zero is categorised as neutral, and a polarity less than zero is classified as a negative view.

4. Results and Discussions

4.1 The Potential of Using Social Media for Assessing Benefits Realisation

The content analysis of social media posts helped us understand the types of benefits perceived by the public during the operational phase of the metro. We found some evidence of the benefits delivered by Chennai and Sydney metro rail projects reported by citizens in their tweets. The personal descriptions in the tweets provide authenticity to the benefits claimed. The true-to-life and meaningful stories enabled through the qualitative data (Sandelowski, 1993) provide credibility that the benefits of the project were realised.

We also noted that the benefits could not be quantified and evaluated. This is because of some of the issues in social media data. We noticed several tweets that represented some negative perceptions of the project. This echoed the literature that people are often more vocal about criticism than praise (Park, 2015; Golbeck, 2016). In addition, interest groups are stakeholders such as lobby groups or activists who have a vested interest in the project and pressurise decision-makers to get their preferred outcome in the project (Henisz & Zelner, 2006). The presence of interest groups resulted in most of the tweets about the metro rail project being negative. These interest groups are very vocal on the social media platform, often echoing their interests through similarly worded tweets. These repeated tweets make a quantitative analysis of benefits quite challenging as a few words are repeated many times by the interest groups. The predominance of negative tweets and the presence of interest groups result in the benefits being overshadowed in automated data analysis. The benefits were more personal and often had different personal stories, which would be missed in automated coding of data from social media.

4.1.1 Findings from Chennai Metro

In the case of the Chennai metro rail, there were opinions that the metro rail was fast as it beats traffic and saves time. These instances were personal stories in which the users gave descriptive accounts of how the metro rail project helped them save time. Examples are highlighted below:

“My husband and I took the Chennai metro rail from Meenambakam to Anna Nagar last weekend, and I must say I am impressed. It is so much better than finding a Uber/Ola, waiting for it, and getting through the traffic. @cmrlofficial” (a tweet dated 27 September 2019).

“Uncluttering myself inside the Chennai Metro Rail. It took just an hour to go all around my beloved Chennai! #metroride” (23 September 2019).

“Encourage public transport! 340 KM will surely make a lot of difference – more time at home and less time on the roads. Hi to chennai metro” (1 September 2019).

The users of the Chennai Metro rail project also highlighted the cleanliness of the metro, as shown in the tweets below:

“Annanagar to Airport, Chennai Metro costs only Rs 50, whereas ola/uber costs anywhere between 450 to 750. Metro is clean and punctual. You need not explain the driver in tamil [local language in the city] ....and knowing your destination a Metro driver will not cancel the trip” (18 September 2019).

“Chennai best metro, best people unlike BMRCL [acronym for the metro rail project of Bengaluru, a nearby city] most inefficient. Chennai metro station speaks for itself unlike ugly Bengaluru metro stations” (11 September 2019).

Other tweets also showed that the transport system is convenient, accessible and safe. The users stated that the trains are air-conditioned, without rush and offer quick rides. Some indicative tweets are below:

"Cab ride Chennai airport to T-nagar showed 55 minutes travel. So took the #chennaimetro for the first time. Easy access from arrival to metro station. Self-ticketing kiosk. Trains at multiple intervals. Air-conditioned, no rush, clean quick ride. Reached in 19 minutes. Underrated" (20 August 2019).

"@ChennaiMetRail Amazing work connecting the city! No Chennai citizen could have asked for more! Super convenient access to the airport! Looking forward to using it more regularly! #chennai #chennaimetro" (30 Sept 2019).

"Yes, of course. It's getting there. It's visible in office as there are many of us who leave our cars at the station and take the Metro. So many people exercising this option that safe and convenient and clean" (20 August 2019).

However, there was some dissent among the commuters regarding the cost of the metro rail services. People criticised the high cost of the fares and complained that ordinary people could not afford the services. Some indicative tweets are below:

"Volumes shud b the mantra & increased patronage vl automatically bring in more revenue & help in bridging gap btw cost & income. urban public transport shud not be subsidized but under bogey of market dynamics shud not made costly like chennai metro, Bengaluru Volvo buses" (30 September 2019).

"I do not understand what you mean by improving mass transit. Chennai metro is an improved mass transit system but no point having it if people can't afford it. The section of society that Chennai suburban system [another mass rapid train system operational in the city] serves are happy with the services" (25 September 2019).

The benefits of using the Chennai Metro rail as seen from the social media comments by the users were speed, accessibility, and convenience. When compared with the mission statement of the project, i.e. "We shall provide a safe, fast, reliable, accessible, convenient, comfortable, efficient and affordable public transport service preferred by all in a sustainable manner," the tweets indicated that several planned benefits were perceived to be met during the operations phase. It was seen that most of the planned benefits were realised during the operational phase. However, the tweets also pointed to the lack of affordability of the metro rail as they included complaints about the cost of the fares. Thus, the project failed to deliver on the benefit of affordable public transport as the users complained about the cost of the fares. It is to be noted that the community did not use the same terms in their tweets to describe the benefits as the project promoters used in their mission statement.

4.1.2 Findings from Sydney Metro

There were some tweets describing commuters' impressive first experience of riding the Metro, such as:

"Having my first Sydney #metro experience. So far very impressed." (3 July 2019)

"First ride in @SydneyMetro, wow, very clean and on time" (10 July 2019)

"Loving the @SydneyMetro first time on it." (11 July 2019)

Some users explained specifically why they were satisfied with the Metro as shown in the tweets below:

"Insanely fast mobile speed on the @SydneyMetro [a speed test result by Ookla]" (23 August 2019) and a reply on the same day "That's crazily fast. Is that underground?";

"First day, first ride on board Sydney metro from Kellyville to Chatswood. What's so great about it.? Oh boy these Sydney metro coaches were 'MADE IN INDIA'. I conceited telling this to co passengers. Superb finish, excellent acceleration, extremely quiet" (a retweet on 4 July 2019).

Another benefit of the Sydney Metro Project confirmed by the tweets is the aesthetics of the metro stations. Many users would start their days by sharing photos of the stations on Twitter, such as "Our beautiful Sydney Metro. @SydneyMetro @TransportforNSW" (a tweet with three photos on 29 September 2019)

"A #beautiful morning and a beautiful #metro station. @SydneyMetro #thebestmetro" (a tweet with a photo on 9 July 2019).

Some users had fun on the driverless Sydney Metro, pretending they were the driver or a proton beam while the train travelled through a tunnel.

"Almost six months in, people still love pretending to be the driver on @SydneyMetro #SydneyMetro" (a tweet on 19 September 2019)

"Pretending I'm a proton beam on the #sydneymetro" (a tweet on 6 August 2019)

Besides transport benefits such as travel time saved, enhanced customer satisfaction, and enabling network growth, there was also evidence for other benefits like increased economic activity, jobs, more housing choices, and better access to services. For instance, a tweet stated that

"With the opening of the Sydney Metro North West line, the hills are well and truly alive!" (See "My story from last night's #sydneyweekender featuring the new North West Metro and a gem of a restaurant tucked away in Baulkham Hills [a link to an article on sydneyweekender.com.au on riding the Sydney Metro to Quoi Dining]", a tweet dated 9 September 2019)

The opening of the Metro also brought an opportunity to provide more choice of housing and more affordable housing along with the metro line, as evident from the announcement tweet issued by Landcom:

"Landcom and Sydney Metro will deliver up to 55 dwellings reserved for Affordable Rental Housing to accommodate workers on low to moderate incomes at the Sydney Metro Tallawong station precinct" (26 August 2019)

In addition, more development opportunities for business service providers were seen through some tweets such as:

"Construction of a new international fresh food marketplace and underground Sydney Metro link at Castle Towers is underway – with dozens of new specialty stores and food outlets expected to open by Christmas" (7 September 2019)

On the other hand, the operation of the Metro was found to be not always perfect. A series of service disruptions marred the first few months of operation caused by some teething problems like train doors sometimes closed too quickly to allow passengers to get on and off. There were, in fact, many complaint tweets about the train doors, such as:

"@SydneyMetro Your 15-second door opening is stupid and dangerous. People cannot get off the train in the fifteen seconds. Fix it before people get hurt" (16 September 2019)

A typical example is an incident where a distraught mother was separated from her two-year-old boy when the new driverless train took off from a station before she could get on board:

"Latest fiasco with Sydney Metro driverless trains. Mother trying to get on with baby in pram, doors shut 2yr old on train by itself. Mother frantic as she is left behind on the platform" (24 August 2019).

Other users have complained about non-functioning facilities such as train display, USB point, air conditioning, thermometer, escalator, as well as a lack of parking and connecting buses.

4.2 The Potential of Using Social Media for Creating Value

For the analysis of the social media tweets collected from the Sydney metro rail and Chennai metro rail, we find the potential to use social media for generating value in infrastructure projects. Value can be created by using big data in social media to address real-time operational issues, collate suggestions to improve, and capture the live sentiments associated with the project.

4.2.1 Addressing Real-Time Operational Issues

Issues relating to the operation of the infrastructure service have to be addressed as soon as possible for smooth service. The users widely shared operational issues relating to the project on Twitter across both projects. In Chennai metro rail, one user complained on Twitter that the doors were not opening in one of the stations as below:

"Crazy. @chennaimetro rail's doors didn't open when it stopped @Pachaiyappas metro station, at around 11am today, putting the passengers to hardships. What's happening?" (2 September 2019)

Similarly, in the case of Sydney metro rail, a user complained about lifts being out of service in one of the stations.

"The lift between the concourse and the platforms at North Ryde is out of service" (29 September 2019)

An interesting observation regarding those complaints is that social media can play a role in service requests. People may complain on social media because they feel they are not being seen or heard through the official channel provided by the service provider or because they would like to get attention from others. It then becomes useful for service providers to handle requests or complaints on social media. A tweet dated 31 July 2019 stating "@SydneyMetro Please clean N5432 carriage upper deck #trains #sydney" with a photo of the situation was responded to on the same day with "Thanks for bringing this to our attention. It has been passed onto our cleaning team."

Social media provides an excellent platform where users of the infrastructure service post day to day operational issues surrounding the projects. We can create more value in infrastructure projects if we systematically collect this big data, analyse it through algorithms, and efficiently communicate it to the service team to mitigate the current issue through timely action.

4.2.2 Collating Suggestions to Improve

Many users are active stakeholders offering multiple suggestions to improve the services. In contrast to operational issues, suggestions to improve are more than addressing an operational defect on a particular day. For example, in the case of the Sydney metro, a user suggested fixing the 15-second door opening duration before people get hurt, as below.

"@SydneyMetro Your 15 second door opening is stupid and dangerous. People cannot get off the train in the fifteen seconds. Fix it before people get hurt" (16 September 2019).

Similarly, in the case of Chennai metro, a user suggested bringing down the ticket costs, which will lead to more traffic and hence revenue, as below.

"Volumes shud b the mantra & increased patronage vl automatically bring in more revenue & help in bridging gap btw cost & income." (30 September 2019).

Collating such suggestions to improve can help the project create more value for the society as decision-makers would know the main issues raised by the community.

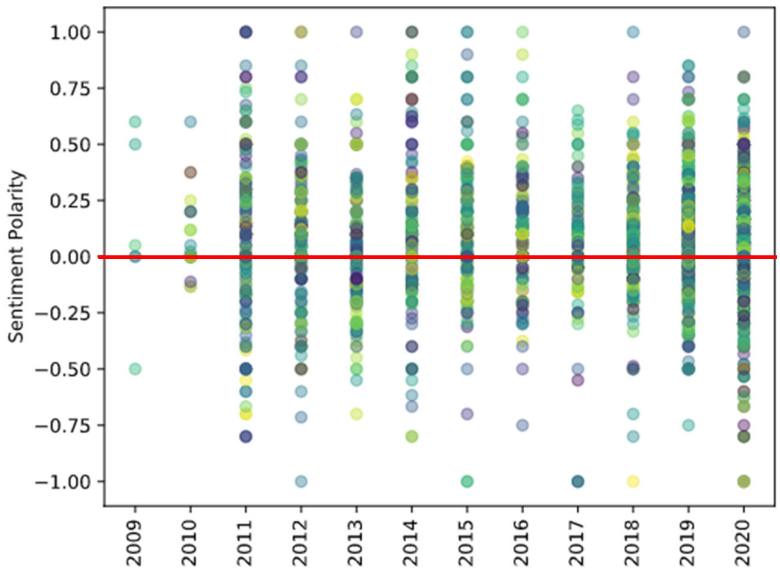
4.2.3 Capturing Live Sentiments

By using big data from social media to analyse sentiments, decision-makers can take proper strategic decisions to create more value to the public. Capturing live sentiments can guide investors to make long term strategic decisions, such as which route has to be expanded. It can also help the project take practical steps to improve the sentiment associated with the project, such as offering complimentary rides for school children or celebrating a regional festival (Ninan et al., 2019).

Taking the Sydney Metro project for example, among the total tweets, 41.4% of them are positive, 18.5% are negative, and 40.1% are natural. Given that people are often more vocal about criticism than praise (Park, 2015; Golbeck, 2016), it can be reasonably concluded that the Sydney Metro project is highly supported by the general public. In addition, it seems promising that we can use the sentiment results to measure public acceptance towards the project, which may serve as supplementary evidence for social license to operate.

Since tweets automatically record the time and location information, we can then conduct timeline sentiment analysis, which places the sentiment results on the timeline. Figure 1 illustrates an example scatter chart that includes sentiment results of each year. We could not see an apparent pattern from the scatter plot. But in 2020, we can observe more negative comments emerged comparing to other years, which may be due to the impacts of the COVID-19 pandemic on the operation of transport services.

Figure 1. Yearly Sentiments



If a more extensive set of tweets data is available, we could place monthly or even weekly sentiments on the timeline, which would allow the project manager to identify some critical timings when there are significant changes in sentiments. Project managers can then review the content of tweets in the identified period of time and understand factors influencing public sentiment changes. Decision-makers can take proper strategic decisions accordingly to improve the sentiments, thereby creating more value to the public.

We also identified the most frequently used words amongst positive and negative tweets, as shown in Figures 2 and 3. They offer a big picture of what people like and do not like.

Figure 2. Common Words for Positive Tweets

Figure 3. Common Words for Negative Tweets

5. Conclusions and Future Research

This study focused on the potential of social media for assessing benefits realisation and creating value in transport infrastructure projects.

Some evidence of the benefits delivered by Chennai and Sydney metro rail projects were reported by citizens in their tweets. However, the predominance of negative tweets and the presence of interest groups make the quantitative evaluation of benefits quite challenging as the tweets related to benefits are overshadowed. We suggest that transport agencies can use social media as an additional way of studying public perception about benefits derived besides their existing benefit realization assessments. We also noticed that the terminology used by the public to describe perceived benefits was different from the terminology used by the project sponsors to describe benefits expected from the project in their business case or mission statement. This confirms the criticism of strategic misrepresentation of large public projects to get them funded (Flyvbjerg, 2006) as sponsors do not use the language used by stakeholders such as citizens to justify spending on a project but terms that appeal to the political system.

The citizens discussed different kinds of benefits on social media. This is in line with several studies that have emphasised the multidimensional nature of value in infrastructure projects (Kivilä et al., 2017; Liu et al., 2019; Martinsuo et al., 2019b; Vuorinen and Martinsuo, 2019). The nature of the social media discussion, for example, the presence of interest groups, also illustrates the subjectivity of value (e.g., Ang et al., 2016; Green and Sergeeva, 2019). In other words, different stakeholders, in this case, citizens, can perceive and value and express these perceptions quite differently. Taken together, the multidimensionality and subjectivity of values set additional challenges for assessing benefits realisation in infrastructure projects.

Most of the studies on value creation in infrastructure projects have focused on the front end or implementation phases of infrastructure projects. This study contributes to the existing literature by studying value creation in the operation phase of infrastructure projects. We have analysed social media data to see if we can indicate how the value created is perceived by the public from two metro projects. The evidence shows that social media could be a helpful tool for transport agencies to monitor operational issues, collect recommendations to improve, and capture live sentiments. All these can then generate more value in operation.

The findings from this study could also contribute to our evolving understanding of what project success means (Judgev and Müller, 2005). They also support the recent calls for the use of mass media

in stakeholder engagement of megaprojects in the planning and operation stages (Ninan et al., 2020; Cuppen et al., 2016; Flyvbjerg, 2012).

This study focused on projects from Chennai and Sydney and used a manual scan of the tweets. We suggest similar research in different transport infrastructure projects across countries. We only studied tweets in a 90-day period in both projects. While this duration was adequate for the purpose of this article, continuous monitoring of these messages could provide an idea of a change of public perception over time. Also, the research team used Twitter as a single source for sentiment analysis. The limitation also includes the use of only Twitter data as no single source can cover entire demographics. We suggest expanding the social media sites to include Facebook, WeChat, YouTube, etc., to cover broader demographics. This analysis worked as the number of tweets were just sufficient for a manual scan. If the number of tweets is large, a manual analysis is time-consuming and prone to error. We suggest expanding the scope to include artificial intelligence and machine learning models to conduct sentiment analysis. Future research could explore this avenue. Shortly, we also plan to engage with the Transport for NSW to develop prototypes of social media use to translate the research into practical use.

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