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Error culture and its impact on rework: An exploration of norms and practices in a transport mega-project

Peter E.D. Love [a,*], Jane Matthews [b], Lavagnon A. Ika [c], Weili Fang [d]

[a] School of Civil and Mechanical Engineering, Curtin University, GPO Box U1987, Perth, Western Australia, 6845, Australia
[b] School of Architecture and Built Environment, Deakin University Geelong Waterfront Campus, Geelong, VIC, 3220, Australia
[c] Telfer School of Management, University of Ottawa, 55 Laurier Avenue East, Ottawa, Ontario, KIN 6N5, Canada
[d] Department of Civil and Building Systems, Technical University of Berlin, Gustav-Meyer-Allee 25, 13156, Berlin, Germany

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ABSTRACT

Rework has been and continues to be a problem during the construction of transport mega-projects. This article examines the error culture of an alliance that forms part of a transport mega-project to determine its effectiveness in mitigating rework. Our article reveals that an error management culture positively correlates with reducing rework and holds a divergent relationship with an error aversion culture. We further show a negative association between an error aversion culture and the ability to reduce rework. It is suggested that more can be done to reduce errors and rework despite the prevalence of a strong error management culture in practice. We thus call for an explicit focus on reducing negative error consequences and developing strategies to handle errors. The article argues that providing a psychologically safe work environment, understanding and focusing on what goes right, and coaching to ensure that learning is transferred from an individual to an organizational level can reduce rework. Our study is the first attempt to examine the homogeneity of error culture (i.e., how errors and their consequences are dealt with) in an alliance mega-project setting. In addition, it provides a new line of exploration to address the issue of rework.

1. Introduction

Transport mega-projects (>US$1 billion) are prone to experiencing cost overruns (Coultan, 2016; Terrill and Danks, 2016). While explanations of cost overrun causation abound the literature, there is no consensus amongst them (Hwang et al., 2014). However, a problem that has often been found to contribute to cost overruns in transport mega-projects is rework (Love et al., 2019; Love et al., 2020a).

Worldwide, transport mega-projects are confronted with rework during their construction. Rework can take various guises due to design and scope changes, errors, omissions, non-conformances and inclement weather (Barber et al., 2000; Construction Industry Institute (CII), 2001; Taylor et al., 2012; Li and Taylor, 2014). The Honolulu Rail Transit[1] system, for example, has been plagued with non-conformances associated with the quality of its precast segments. In one incidence, a collapse occurred between segments during the process of post-tensioning, necessitating costly rework to be undertaken (Berliner, 2012; Hrushka, 2016). In Australia, the geographical context for this research, numerous examples of transport mega-projects experiencing rework exist, including the Sydney Skytrain, Sydney Light Rail and Forrestfield Airport Link. While the literature is replete with studies determining rework causes and costs in construction (Davis et al., 1989; Burati et al., 1992; Love, 2002, 2020; Hwang et al., 2009; Love et al., 2015, 2018a, 2018b, 2018c, 2018d, 2019, 2020a, 2020b, 2021a, 2021b; Love and Smith, 2016, 2019; Love and Matthews, 2020), we are still none the wiser about the extent to which rework impacts project performance and the bottom-line of construction organizations (Love et al., 2020a, 2020b, 2021a, 2021b).

Differing definitions can be found in the literature (Lloyd-walker et al., 2014; Love and Smith, 2019). In this research, we adopt

* Corresponding author.
E-mail addresses: p.love@curtin.edu.au (P.E.D. Love), jane.matthews@deakin.edu.au (J. Matthews), ika@telfer.uottawa.ca (L.A. Ika), weili.fang@protonmail.com (W. Fang).

[1] An elevated 32 km (km); two standard gauge tracks with 750 V DC rail transit system comprising 21 stations. The project is financed by a surcharge on local taxes and a grant of USD$1.55 billion from the US Federal Transit Administration. Significant cost increases have occurred. In 2006, it was estimated to cost USD$3 billion; the project is still under execution and its estimated final cost could be close to USD$11 billion (Lincoln, 2016).

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Robinson-Fayek et al.'s (2004) definition of rework where it is "the total direct cost of re-doing work in the field regardless of the initiating cause and explicitly excluding change orders and errors caused during off-site manufacture" (p.1078). Methods to measure rework also vary (Davis et al., 1989; Burati et al., 1992; Barber et al., 2000; Hwang et al., 2009). However, an absence of integrated information systems to capture its causes and costs in construction have resulted in a *Kafkaesque* loop manifesting, impeding our ability to progress toward alleviating its adverse consequences (Love and Smith, 2019). A cursory glance at the literature, for instance, reveals that singular factors of rework causation such as insufficient communication, poor site management, improper supervision and inspection are still repeatedly identified. Though these issues were raised decades ago, they still form a present-day narrative that purports to explain the occurrence of rework (Ye et al., 2015; Yap et al., 2017, 2020). Indeed, rework remains a wicked problem and any attempt to identify a single causation factor is a futile line of inquiry (Love and Smith, 2019; Love et al., 2021a). Moreover, rework causation research focuses on heterogeneous samples, soliciting perceptions rather than direct observations from actual projects (Hwang et al., 2014; Ye et al., 2015; Yap et al., 2017, 2020).

We often come across reports on rework costs that offer no account for context and read literature that falls short of reflecting the reality of the challenge confronting practitioners and contractors in particular (Love et al., 2018b). For example, consider the finding of a study undertaken by the Construction Industry Institute (CII) in the United States, which stated that the average direct rework costs during construction were 5% of contract value (Construction Industry Institute (CII), 2005). The data used to determine rework costs were sourced from contractors completing an online questionnaire, an approach that should ring alarm bells as issues of reliability and validity of the data come to the fore.

Then, we see Hwang et al. (2009) repeating the CII's (Construction Industry Institute (CII), 2005) figure in their paper as they state "rework continues to affect both cost and schedule performance throughout the construction industry. The direct costs alone often tally to 5% of the total construction costs" (p.187). This figure of 5% has now been set in concrete and is often referred to as an industry baseline worldwide. Surprisingly, no questioning of this figure seems to have occurred. If we assume that the 5% figure includes scope and design changes, then these would typically be paid for by a client. But, with contractors' margins hovering around the 6% mark in Australia, they would not be in a financial position to withstand and sustain such rework costs in their projects even when the scope and design changes are deducted from this amount (Partnership, 2019).

Consequently, there is a need to develop a standard nomenclature for rework to facilitate benchmarking within the construction and provide a segue for enacting continuous improvement (Love et al., 2020a). Notwithstanding, there remains a widespread consensus that rework is a problematic issue in construction. In tackling this issue, the response of construction organizations has been to implement tighter procedures and controls, increase supervision, undertake lessons learned workshops, and employ lean tools such as Value Stream Mapping and the Last Planner®. At face value, this response may appear helpful, but evidence suggests otherwise as rework still prevails, and the same mistakes are often repeatedly made (Love et al., 2018a, 2018b, 2018c, 2018d, 2019, 2020a, 2020b).

If we are to redress rework in projects effectively, we need to understand people's work norms and practices. After all, it is generally the errors committed by people that result in rework, with an organization's work culture[2] setting the tone and influencing its response and how information is shared (Love, 2002; Westrum, 2014). Understanding the pattern of shared norms and values that prevail in a project toward errors can enable effective practices to mitigate the negative consequences of rework to be developed. Put differently, the error culture of a project and how errors and their consequences are dealt with impacts its ability to learn and innovate (Van Dyck et al., 2005). We acknowledge that mega-projects comprise highly interdependent and differentiated organizations with their own error cultures, and that sub-cultures may also co-exist. Indeed, this cultural divergence may well stymie the effort to mitigate rework (Love., 2020).

Interestingly, collaborative project delivery methods such as Alliances[3] and Integrated Project Delivery (IPD) can address the problem of cultural divergence by institutionalizing 'best for project' approach where participating organizations agree to put aside their self-interests and commit to a 'no blame, no fault' culture (Lloyd-walker et al., 2014; Walker and Rowlinson, 2020). In this instance, organizations agree that in the event of an error or poor performance, they will not attempt to assign blame but instead accept joint responsibility and its consequences (Lloyd-walker et al., 2014). Additionally, organizations agree to proactively work together to find a solution in the project's best interests (Lloyd-walker et al., 2014).

Acknowledging the impact of culture on the ability to deal with errors in a project, the 'Getting it Right Initiative'[4] in the United Kingdom (UK) aims to develop an error-free culture through behavior modification and improving communication in projects. However, no baseline exists to determine the type of error culture that prevails in projects. In filling this void, this research explores whether a specific error culture influences rework levels in projects. The context for the study is a transport mega-project as they are prone to experiencing significant cost increases during their construction due to rework (Barber et al., 2000; Li and Taylor, 2014; Love et al., 2020a)

Against this contextual backdrop, we address the following research question in this paper: "*Can an error culture reduce rework in transport mega-projects*?" Our research is exploratory as there have been no studies to date that have examined error culture in construction, though it has been studied in other business sectors (Heimbeck et al., 2006; Fischer et al., 2018; Guchalt et al., 2020). We commence our paper by introducing the theoretical underpinning for the research (Section 2). Then, we present a case study of a mega-transport project, which provides a setting to examine our research question using Van Dyck's et al.'s (2005) error culture instrument (Section 3). The results of our study are then presented (Section 4). We next discuss our results and identify the strengths and limitations of the research (Section 5) before submitting the paper's conclusions (Section 6).

2. Theoretical background

Research has overlooked the influence and role of people's actions contributing to errors and violations and the subsequent need for rework

[2] Culture is defined as "a pattern of shared basic assumptions learned by [an organization] as it solved its problems of external adaptation and internal integration, which has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems" (Schein, 2010, p.18).

[3] Alliance contracting is relationship-based and characterised by a culture of collaboration and cooperation between the parties working together to deliver a project. The parties to an alliance are normally the purchaser of services (the owner) and one or more service providers or non-owner participants such as head contractor and operator. The parties' interests are aligned and risks are shared through incentives offered by the owner for how well the project is delivered, as measured against agreed objectives.

[4] A group of industry experts, organizations and businesses in the UK dedicated to eliminating error and improving the UK's construction industry. Details of the 'Getting It Right Initiative' can be found at: getitright.uk.com.

(Love et al., 2019). The corollary is a lack of a theoretical foundation to support rework studies. This absence of research has complicated and frustrated the ability to mitigate rework as measures to contain (i.e., measures designed to enhance detection and recovery and minimize adverse consequences) and reduce (i.e., measures designed to limit occurrence) errors are under-developed (Love and Smith, 2016, 2019; Love, 2020).

Errors are an innate and recurring aspect of work and our daily lives. Most of the errors we make can be readily corrected, but others may result in negative consequences (e.g., loss of productivity or accidents) (Van Dyck et al., 2005; Frese and Keith, 2015). Similarly, errors can positively affect learning, innovation and resilience (Sitkin et al., 1996). While the negative consequences of errors in construction projects can be readily observable to contractors, the public can also view them. A tragic example where a litany of errors resulted in the death of 35 people occurred in 1970 when the Westgate Bridge in Melbourne (Australia) collapsed. In response, a Royal Commission (Report for the Royal Commission, 1970) was held, and the following conclusion was made:

> "The reason for the collapse is found in the acts and omissions of those entrusted with building a bridge of new and highly sophisticated design. The various companies who supplied the materials used were shown not to be at fault and must be held blameless. However, among those engaged upon the design and construction of the steel spans, there were mistakes, miscalculations, errors of judgement, failure of communication and sheer inefficiency" (p.97).

The commission report was widely circulated, and its conclusions were noted by engineers and construction companies worldwide. As a result, similar bridges constructed in the UK and Europe were temporarily closed and tested for safety. However, construction of the bridge resumed in 1972, and it was finally completed in 1978.

At this juncture, we define an error as "unintended deviations from plans, goals, or adequate feedback as well as incorrect action that results from lack of knowledge" (Van Dyck et al., 2005: p.1229). Thus, our research eschews violations, as "they involve a conscious intention to break a rule" (Frese and Keith, 2015: p.681) and failures, "which are negative or unintended organizational outcomes that might be caused by a combination of errors, violations, risks and chance factors" (Frese and Keith, 2015: p.663). Fig. 1 illustrates the relationship between rework, errors and violations. Notably, while risks refer to the likelihood of loss, harm or danger and often reside within a construction project's environment, errors, however, are acts committed, in an unpredictable way, by people or through their interaction with the environment (Frese and Keith, 2015; Lei et al., 2016).

One final issue that requires clarification is the difference between inefficiencies and errors. We may make an error by initially selecting the wrong objectives and reaching the final goal (Frese and Keith, 2015). An inefficiency in pursuing a goal is not an error, but managers often confuse them. Elaborating further on this point, Van Dyck et al. (2005) proffer that after an error is committed, people typically have an adverse feeling that "one should have known better" (p.1229). Merely detracting from planned actions is not an error (Frese and Keith, 2015).

2.1. Dealing with errors

We can use two strategies to deal with errors in an organization (Frese and Bullinger, 1991): (1) error prevention and (2) error management. A comparison between these two strategies can be seen in Fig. 2. More often than not, construction organizations rely on error prevention (Love., 2020; Love et al., 2020a; Love et al., 2020b). It is natural for organizations to prevent people from making errors, but they are invariably construed as a nuisance, resulting in negative consequences. There is also a propensity to associate errors with poor performance and negligence and blame people for their occurrence. So, when people are caught making an error or admit to it, they may 'lose face'[5] (Goffman, 1955; Goffman, 1967; Fischer et al., 2018). Like organizations, people work hard to prevent errors (Zakay et al., 2004), but no matter what we do, they cannot be wholly avoided (Pope, 1711; Reason, 2000).

In Fig. 3, we present our theoretical framing to contain and reduce errors. Before an error occurs in a project, people go about their daily tasks to perform efficiently and effectively. Errors can be prevented by blocking erroneous actions and installing systems, procedures, tools, and training. However, even with these preventative measures, errors can still materialize. For example, in normalizing error-making, Frese and Keith (2015) suggest people "make two to four errors per hour in every task they do" (p.665). While there has been no research in construction to affirm this suggestion, if we accept this as an axiom, then there is a likelihood that some tasks or processes will be subject to rework.

It is widely acknowledged that errors are an effect or symptom of an organization's norms and practices, particularly the project environment within which people work. Markedly, errors befall during all phases of a project's life-cycle (e.g., design, construction, and manufacturing). They are not random acts but are systematically connected to aspects of people's tools, tasks, and work environment (Dekker, 2006). While people make mistakes, organizations make it possible for them to be serious. Thus, "we cannot change (the) human condition, but we can change the conditions under which people work" (Reason, 2000: p.768). Rather than preventing errors, we need to accept that errors happen and "block negative error consequences or reduce their negative impact through design or training" through the adoption of error management (Frese and Keith, 2015: p.665).

When construction organizations engage in error prevention, particularly in the context of managing quality, they seek to exercise control over their performance by implementing a zero-vision and eliminating the source of errors. Control-oriented principles often used by organizations as part of their quality initiatives include (Sitkin et al., 1994: p.546): (1) increasing control and reliability; (2) exploiting existing skills and resources; (3) first-order learning[6] (cybernetic feedback) (Green and Welsh, 1988); and (4) monitoring and assessing known customer needs. However, a singular emphasis on the control of quality is not "suited to conditions of high task uncertainty", yet such settings form an innate feature of construction (Sitkin et al., 1994 p.573).

The engagement of error prevention and control-orientated principles (i.e., 'learning from errors' by having in place error correction mechanisms) has hindered the ability of construction organizations to engage in the process of 'learning through' (i.e., how to handle errors) a rework event (Love and Smith, 2019; Love and Matthews, 2020). Contrastingly, error management is aligned with the learning-oriented principle of quality whereby emphasis is placed on issues such as: (1) actively searching for new customers, testing and developing new services and products; (2) stressing improvement in learning capability by exploring new skills and resources and resilience; and (3) second-order

[5] Goffman (1955) defined face as "the positive social value a person effectively claims for himself by the line others assume he has taken during a particular contact" (p. 213).

[6] Learning within the context of a given problem definition and the analysis of the chosen solution for that problem, while retaining the underlying theoretical insights or deep convictions and values. The feedback loop is represented by using "standards of performance, measuring system performance, comparing that performance with standards, feeding back information about unwanted variances in the system, and modifying the system" (Goffman, 1967; p.289).

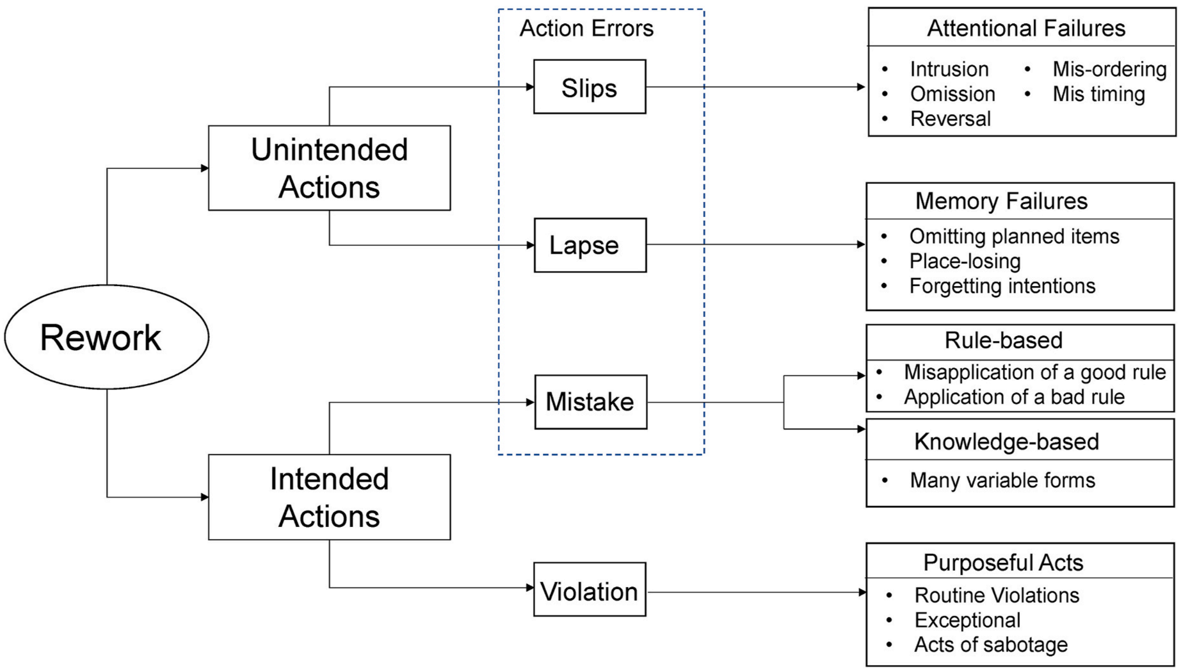

Fig. 1. Rework, errors and violations. Adapted from Reason (1990: p.207).

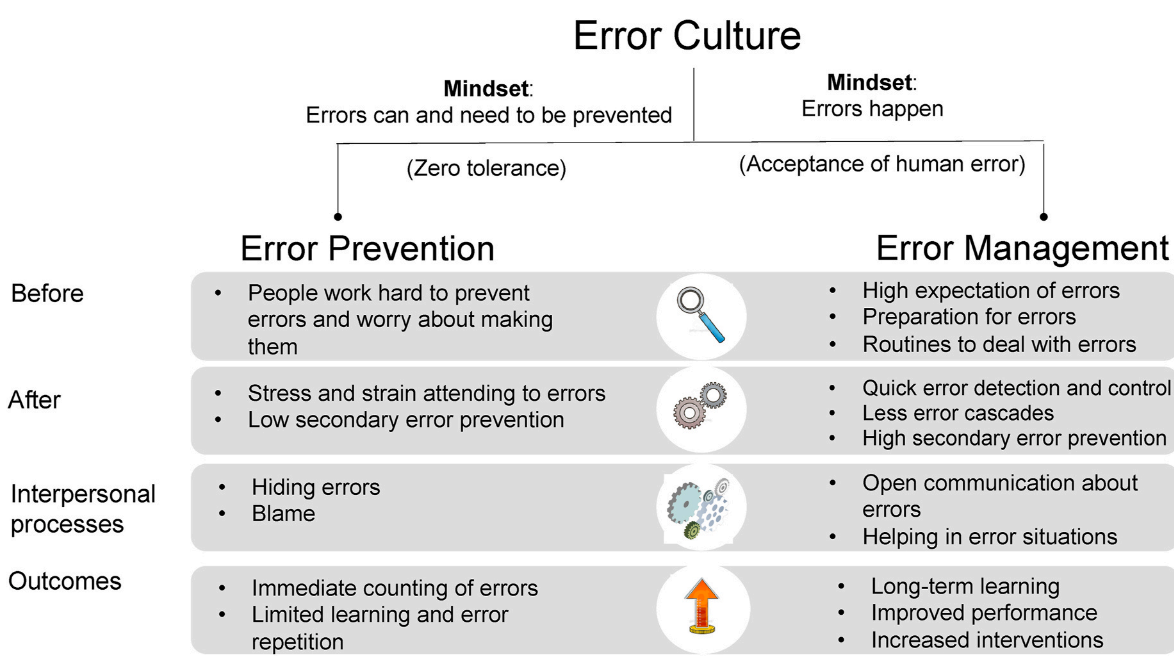

Fig. 2. Error culture, processes and outcomes. Adapted from Frese and Keith (2015).

learning.[7]

While the control and learning perspectives of quality may be viewed as being "antithetical" (Sitkin et al., 1994: p. 545), "organizations may be able to benefit from simultaneously pursuing" both goals through the use of an error management strategy (Van Dyck et al., 2005: p.1229). In actual fact, error management was developed to be an add-on to error prevention (Frese and Bullinger, 1991; Van Dyck et al., 2005), even though "they differ in their underlying belief about errors and the mindset of acceptance or tolerance" (Frese and Keith, 2015: p.667).

2.2. *Error culture and alliances*

Alliances, the empirical setting for this paper, are typically chosen as a preferred delivery method when projects are highly complex (e.g., stakeholders and environment), are subjected to tight schedules, and when it is difficult to define scope (i.e., unfeasible to complete design before making a call for bids). Moreover, alliances are "appropriate when there is likely to be a long term relationship" (Mc Nair, 2016: p.5). The 'no blame, no fault' culture, which characterizes alliances, may enable "collaboration, knowledge, sharing and organisational learning"

[7] The rethinking of dominant mental and action models, particularly of theoretical insights and deeply rooted values and convictions.

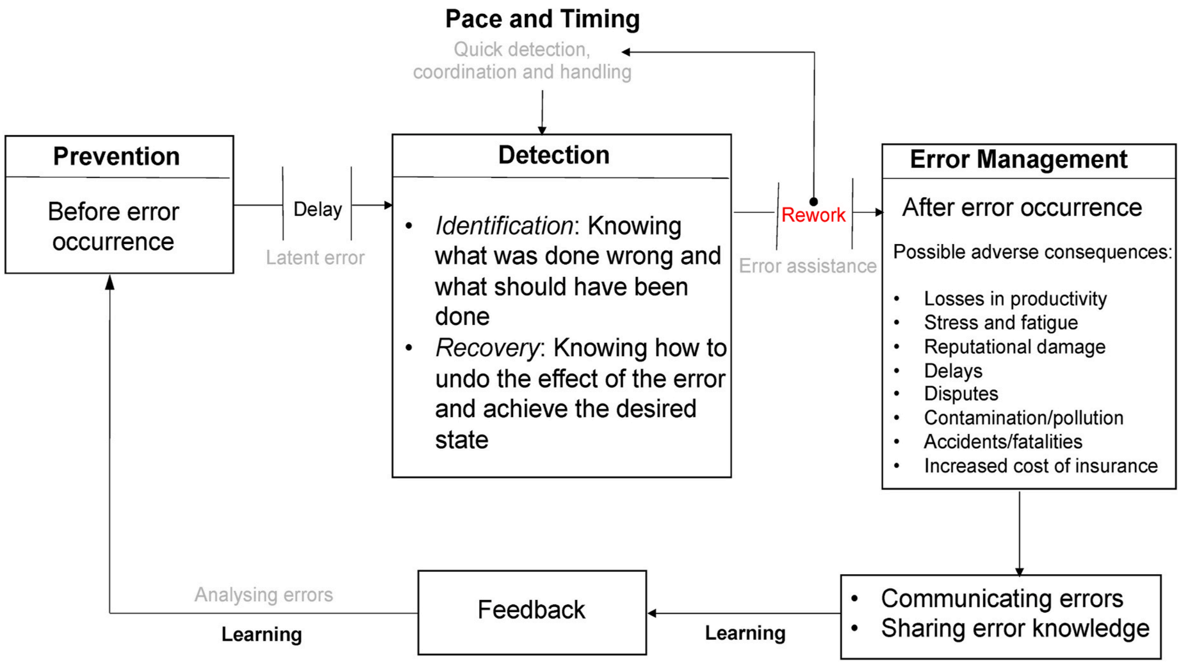

Fig. 3. Conceptualizing the error management process. Sourced from Love et al. (2019: p.1356).

(Lloyd-walker, 2014: p.229).

In theory, the 'no blame, no fault' culture should result in an alliance being able to deal with errors and their consequences positively. Indeed, this may be the case for safety, and environmental performance issues, typically identified in Key Result Areas (KRA) and aligned with the 'gain-share/pain-share regime' [8] regime used to incentivise alliances. However, quality is not typically identified as a KRA and therefore is overlooked or not given the credence it deserves in alliance projects (Love et al., 2021a).

We hasten to note that construction organizations resources are subjected to competing demands. As safety and environment are bound by legislation, quality is not afforded the same priority and resource allocation in their projects, irrespective of project delivery method (Love et al., 2021a). Non-conformances are considered a poor measure of quality by the senior management of construction organizations. Consequently, they often go unreported or are hidden, particularly in the case of rework. This situation arises as project managers feel their construction sites would be judged to have been poorly managed (Love et al., 2019; Love and Matthews, 2020).

In a study of the Barwon Water Alliance (BWA), a five-year program of work, it was revealed that it had been the recipient of numerous industry awards (Love et al., 2015). For example, in 2011, BWA and a civil contractor were selected finalists for the Victorian Engineering Excellence Awards for environmental best practices. In 2013, the BWA also received the National Safety Council of Australia 'Pinnacle Award' for Best Safety Leadership Program. Despite receiving such accolades, the alliance's performance and productivity had been adversely impacted (Love et al., 2015; Love et al., 2021a).

Two and half years into the five-year program of works, and after 75 of the 129 projects had been completed, the cost and time blowouts had become a norm. Projects had been, on average, experiencing three-week delays and 4.5% cost increases with fixed-price contracts in place. Notably, no non-conformances had been reported. At a lesson learned workshop organized by the alliance (including its contractors) to examine how they could improve their performance, it was unearthed that rework was the primary cause of project mis-performance (Love et al., 2015; Love et al., 2021a). Even though a 'no blame, no fault' culture was in place, it still was aligned with an error prevention mindset (Love and Matthews, 2020; Love et al., 2021a). A detailed review of the alliance's KRAs, structure and processes were undertaken, and a change management process was initiated, resulting in an error management culture and a reduction in rework. The alliance unconsciously adopted the principles of error management as it recognized that errors happen. Initially, the shift from an error prevention mindset where "errors can and need to be prevented" to error management in which "errors happen" was counterintuitive for project team members. But, with the commitment and support from the Alliance Leadership and Management Teams (ALT/AMT), it was successfully able to learn and innovate (Frese and Keith, 2015: p.666). A detailed account of the BWA experience with its approach to contain and reduce errors and its rework mitigation strategies can be found in Love et al. (2021a).

As shown in the BWA, error management can be applied to create a project's culture (Van Dyck et al., 2005) by generating a system of shared norms, values and a set of common practices "through a process of socialization; that is, the way we do things around here" (Love, 2020: p.422). Our conceptualization of the error management process is presented in Fig. 2, which encompasses the organizational practices of error management, which relate to (Van Dyck et al., 2005):

- Communicating errors;
- Sharing error knowledge;
- Helping in error situations;
- Quick error detection and damage control;
- Analyzing errors;
- Coordinating error handling; and
- Effective error handling.

Communication about errors was critical in the BWA to reduce their rework (Love et al., 2018c). According to Van Dyck et al. (2005), communicating about errors is the most important organizational practice of error management as it enables people to share their knowledge about errors. As noted earlier, the sharing of errors and

[8] The objective of the gain-share,/pain-share regime' is to share with the Non-Owner Participants (NOPs) the benefits or dis-benefits derived by the owner from excellent or poor project outcomes. Thus, commercial objectives of the NOPs become aligned with those of the owner.

knowledge is one of the key features of alliancing. However, in the context of errors resulting in rework, this was not the case before BWA initiated a change in its cultural orientation. By being able to talk about errors and rework events openly, people can develop a "mutual understanding of high-risk situations (i.e., error traps)" and strategies to handle them (Van Dyck et al., 2005: p.1230). Communicating about errors also enables others to help.

Based on the experiences observed from the BWA study (Love et al., 2018c; Love et al., 2021a) that focused on how it learned to abate rework, we suggest an error management culture can improve a construction project's ability to address this pervasive problem. For example, in the BWA case, after it instigated its change initiative, a subcontractor, who had experienced rework due to the failure of a poorly fitting valve, provided another subcontractor facing the same situation on a different project with the solution to address the problem (error) before any rework was required (Love et al., 2018c). In this case, open communication facilitated the quick detection and handling of errors.

The time between the occurrence and detecting an error is crucial (Fig. 2). The longer that errors remain undetected, the more likely they produce negative consequences. Conversely, errors unidentified and hidden can manifest as latent errors and have disastrous consequences (Pope, 1711). A befitting and tragic example occurred during the I-35w Mississippi River Bridge collapse in 2007, which killed 13 and seriously injured 98 people. Design flaws in the bridge's gusset plates (i.e., incorrect specification and installation) connected to the girders in its truss structure were identified after the collapse. However, they went undetected for 40 years during maintenance inspections (Davy and Wald, 2007).

Research by Edmondson (1996) reveals that in environments that promote and support psychological safety,[9] teams report more errors as people are allowed and encouraged to talk about them, increasing their detection and correction. Moreover, the willingness to report and discuss errors provides a basis for engendering learning (Edmondson, 1999). In the case of the BWA, regular forums, in the form of knowledge exchanges, were conducted with the project team and subcontractors to report rework events, describe how the issue was resolved, and offer solutions to prevent their future occurrence (Love et al., 2018c).

In line with Rochlin (1999) and Van Dyck et al. (2005), we agree there is a cultural dimension to how construction projects handle errors. However, homogenous cultural dimensions are often not present throughout an entire construction organization as each of their projects tends to create its own sub-culture, which can be influenced by the delivery method employed and its size (e.g., contract period and cost).

Research examining error culture has been limited to and confined to alliances in construction where error management practices have unconsciously been displayed (Love et al., 2018c). However, the influence of error management culture on an alliance's ability to contain and reduce errors has yet to be empirically examined. To reiterate, it is this gap in research that we aim to contribute to filling in this paper. Thus, in line with the research of Van Dyck et al. (2005) and the findings of Love et al. (2018c), we propose the following hypothesis:

Hypothesis I. An error management culture is positively related to an alliance's ability to reduce rework.

[9] Describes "individuals' perceptions related to the degree of interpersonal threat in their work environment" and involves "beliefs about how others will respond when one puts oneself on the line, such as by taking a risk, asking a question, seeking feedback, reporting a mistake, or proposing a new idea" (Nembhard, 2012: p.491). Thus, psychological safety and error management are akin as they place emphasis on the response of organisational members to errors as predictors to learning. While both these concepts are similar, error management is more action-oriented, as it comprises shared practices when dealing with errors. Psychological safety rather focuses on what individuals in a team experience (Frese and Keith, 2015).

The opposite dimension of an error management culture is error aversion, which is aligned with error prevention. Error aversion comprises covering up and experiencing strain from errors, being blamed, hiding errors, coping with the negative self-image that may materialize from errors, and fearing punishment (Van Dyck et al., 2005). After Van Dyck et al. (2005), we, therefore, propose our second hypothesis:

Hypothesis II. An error aversion [prevention] culture is negatively related to an alliance's ability to reduce rework.

To test our proposed hypotheses, we used a single case study to acquire a homogenous sample of individuals who work in an environment of shared values and norms and where a set of common practices and procedures are in place.

3. Research method

Due to the research context's novelty, an exploratory case study approach was adopted to determine an alliance project's error orientation and its influence on rework. Thus, our research setting is the transport mega-project that comprises a program of works initiated by a State Government to remove existing and construct new road and rail infrastructure throughout the metropolitan area of a major Australian city. The project is being delivered using a series of program alliances. Thus, the unit of analysis in this research is one of the program alliances contracted to deliver a series of projects (i.e., work packages). For reasons of confidentially and political sensitivity, we are unable to provide any more detail about the nature of the project.

Notably, the rationale for the case's selection for this study is based on the authors' involvement in an alliance's continuous improvement initiative (ConIP) seeking to reduce its waste (i.e., non-value adding activities). Apart from non-conformances requiring rework, no measurement of it, per se, is undertaken due to the absence of standard terminology and an integrated information system to record and document its costs and causes.

Design changes and errors in the Issue for Construction (IFC) drawings and non-conformances have resulted in rework during construction, issues the alliance actively seeks to reduce. In addition, there is a mindfulness by the ALT/AMT and ConIP team that many errors requiring rework are not being captured. Therefore, acquiring a baseline of error culture indicates prevailing shared values and norms and the effectiveness of practices and procedures to contain and reduce errors.

3.1. Sample and procedures

We sought to solicit representatives' perceptions within the alliance concerning its existing error culture. Four organizations form part of the alliance: (1) a constructor); (2) two design partners; and (3) a rail network operator. The alliance was formed in 2015, and the four organizations have been working together in unison in a co-located office for six years at the time of the study in 2021. Works are expected to be complete in 2024, but it has been anticipated that the contract of the alliance will be extended to deliver additional projects. To ensure the sample is representative, we invited all people involved with removing existing and installing new infrastructure in the alliance to participate in the study.

An email, which explained the study's aim and purpose, was distributed to 500 members of the alliance by a representative from its ALT. Embedded within the email invitation was a link to an online questionnaire survey developed using Qualtrics. A total of 175 members agreed to complete the survey, but only 106 responses were useable. Thus, the response rate for the survey was 21%.

3.2. Measures

The questionnaire survey comprised of three sections: (1) background information (i.e., functional area and location); (2) rework performance and goal achievement; and (3) error culture. As we have seen, once an error occurs, it may require an individual or team to perform rework, the definition of which was proposed above by Love (2002). Therefore, we initially asked respondents to determine the extent to which rework was reduced once drawings had been IFC and how design requests and non-conformances influenced its occurrence.

To examine the alliance's ability to reduce rework (in this case, our dependent variable, DV, which is ordinal because there was no available data on actual rework costs and its quantity) and compare its level with other projects, we introduce the construct of 'rework goal achievement'. Both items contained within this construct were measured using two items based on a five-point Likert scale ranging from '1' (Not at all) to '5' (Completely agree): (1) the alliance's success in reducing rework compared to other projects respondents had been involved with; and (2) the success of the alliance in achieving its goal of reducing rework in its projects. We did not consider control variables such as age and gender, as there is no evidence that they influence error-making in multi-task work and dynamic environments such as construction. As a matter of fact, research examining the propensity for error-making amongst individuals has been only experimental and confined to singular tasks (Dimitrova et al., 2015, 2017). Moreover, during the piloting of the survey, the issues of gender neutrality and ageism were brought to light. There was potential that a respondent would not complete our questionnaire if these variables were included, so it was decided not to include them to improve our response rate. To this end, the functional area and project location can be categorized as control variables.

Error culture measures were derived from Van Dyck et al. (2005) and based on the Error Orientation Questionnaire (EOQ) developed by Rybowiak et al. (1999). The EOQ scale comprised: (1) error competence; (2) learning from errors; (3) error risk-taking; (4) error strain; (5) error participation; and (6) covering up errors. Van Dyck et al. (2005) adapted the items of the EOQ "in such a way that they referred to common organizational practices and instructed participants to rate the extent to which each statement applied to the people in their organization in general" (p.1231). A factor analysis was performed by Van Dyck et al. (2005) on these items to derive their overall measure of error culture.

The overall measure for error culture consists of two items (Table 1): (1) error management, which consisted of 17 items; and (2) error aversion, which consisted of 11 items, but we have added another five to reflect additional practices that have been observed in projects (Love and Smith, 2019). The extra five items, numbers 12 to 16, can be seen in Table 1. Items were answered on a scale ranging from 1 (Does not apply at all) to 5 (Applies completely). The Cronbach alphas for both error items were respectively 0.92 and 0.89, which are marginally more reliable than Van Dyck et al.'s (Van Dyck et al., 2005) scales. The alliance comprises several functional areas that all serve to remove and install new infrastructure to ease congestion and improve traffic flow. In Fig. 4, a summary of respondents from each of the functional areas is presented. For example, we can see that 70% of responses were obtained from the 'Delivery' (i.e., construction teams) and 'Engineering and Design' areas.

We sought to determine if there was agreement on the ratings of error culture and rework reduction within the alliance (i.e., across the functional areas). Notably, the function 'Delivery' is akin to staff working on a construction project in a given location. Thus, we compute the Intraclass Correlations (ICC) to estimate interrater reliability to determine the consistency of ratings by rates. A high degree of reliability was revealed for our error culture measures. In the case of error management, the average measure ICC was 0.92 with a 95% confidence interval from 0.90 to 0.94 ($F(104,1664) = 13.02$, $p = 0.00$). Similarly for error aversion the ICC was 0.89 with a 95% confidence interval 0.86 to 0.92 ($F(103,1545) = 9.40$, $p = 0.00$).

4. Results

Four projects had been completed at the time of the study, and another four were under construction. We obtained survey responses from each of these projects, with 59% originating from three projects (A, B, G) (Appendix A). Responses were also received from 'Program' referring to individuals not allocated to a specific project (i.e., fixed location) but operated between them by providing advice and support to daily operations (e.g., Innovation and Continuous Improvement Manager). Our survey responses provide a barometer of individuals' perceptions of the prevailing shared practices and procedures used to manage errors and any rework, if required, during actual construction activities.

4.1. Rework performance

The survey commenced by asking respondents about the occurrence of rework once documentation and drawings had been IFC. The results indicate that rework had been reduced to a moderate degree (mean (M) = 3.16, Standard Deviation (SD) = 0.87). According to several respondents, the interface between design and construction required attention as changes (due to errors) were often required post-IFC resulting in rework. For example, a respondent provided the following comment:

> "Project design changes due to mistakes … So, during construction, we have to ask the design team for clarification where things are different or cannot work".

Following on from this point, the results indicate that respondents generally perceived that rework occurred to a moderate degree (M = 2.98, SD = 0.82) as a result of a design-change request (due to mistake), and only 'to some degree' (M = 2.4, SD = 0.79) due to non-conformances. Thus, from the responses received, it would appear that design changes and non-conformances are everyday issues confronting practice. Still, the extent to which they impact rework on-site within the alliance remains unknown.

We need to point out that rework is not a vexing issue in every construction project, quite the contrary. But, when it does 'raise its ugly head', it can adversely affect a project's productivity and performance. Research undertaken by Love et al. (2018a), for example, examined the prevalence and cost of rework materializing from non-conformances in 346 projects constructed by a 'Tier 1' contractor. It was revealed from the 19,605 non-conformances analyzed that 34% of the total cost of rework incurred originated from 36 projects and 88 events. Moreover, 13 of the events occurred in a single project. A significant proportion of non-conformances issued in a project will invariably be minor (e.g., patching and cleaning). Most will go unreported as on-site supervisors and engineers deem it time-consuming to record and document them.

Responses came from the various functional areas and projects, so a Kruskal-Wallis (a non-parametric test referred to as a one-way analysis of rank variance) was applied to determine statistical differences between the rework performance across the functional areas and four projects. However, no significant differences were found to exist ($p > 0.05$).

4.2. Rework goal achievement

A continuous improvement strategy has been established, and effort is put into addressing waste, particularly rework through the ConIP initiative. Despite the positive impact on reducing rework, more can be done to enhance the effectiveness of the alliance's continuous improvement strategy. Several respondents raised concerns about the effectiveness of the lessons learnt processes. Reinforcing this point, a respondent made the following comment on the completion of the survey:

Table 1
Descriptive statistics summary for error management and aversion scores.

Item	Error Management	Mean (N = 106)	Std. Deviation	Item	Error Aversion	Mean (N = 106)	Std. Deviation
1	For us, errors are very useful for improving the work process	3.20	1.04	1	In this alliance/project, people feel stressed when making a mistake	2.98	0.99
2	After an error, people think through how to correct it.	3.97	0.82	2	In general, people in this alliance/project feel embarrassed after making a mistake	2.59	0.92
3	After an error has occurred, it is analyzed thoroughly	3.63	1.08	3	People in this alliance/project are often afraid of making mistakes	2.65	0.99
4	If something went wrong, people take the time to think it through	3.57	0.96	4	In this alliance/project, people are often upset and irritated if an error occurs	2.80	0.94
5	After making a mistake, people try to analyze what caused it	3.60	1.00	5	During their work, people are concerned that errors might occur	2.93	1.04
6	In this alliance/project, people think a lot about how an error could have been avoided	3.38	0.90	6	Our motto within the alliance/project is, “Why admit an error when no one will find out?”	1.54	0.87
7	An error provides important information for the continuation of the work	3.57	0.97	7	There is no point discussing errors with others	1.52	0.96
8	Our errors point us to what we can improve	3.94	0.97	8	There are advantages in covering up one’s errors	1.41	0.76
9	When mastering a task, people can learn a lot from their mistakes	4.06	0.82	9	People prefer to keep errors to themselves	2.29	0.96
10	When an error has occurred, we usually know how to rectify it	3.63	0.87	10	Employees who admit to errors are asking for trouble	1.56	0.96
11	When an error is made, it is corrected right away	3.52	0.85	11	It can be harmful to people to admit their errors to others	1.82	0.88
12	Although we make mistakes, we don’t let go of the final goal	4.18	0.92	12	In this alliance/project, we don’t talk about errors	1.95	1.09
13	When people are unable to correct an error by themselves, they turn to their colleagues	3.74	0.94	13	In this alliance/project, we have a zero- vision in place for errors	2.15	1.10
14	If people are unable to continue their work after an error, they can rely on others	3.54	0.85	14	When errors occur, it takes time before they are rectified	2.89	0.94
15	When people make an error, they can ask others for advice on how to continue	4.02	1.06	15	People are discouraged from reporting errors	1.51	0.88
16	When someone makes an error, they share it with others so that they don’t make the same mistake	3.30	0.99	16	It is difficult to ask other people for help to address a mistake	1.92	0.86
17	In this alliance/project, people think a lot about how an error could have been avoided	3.32	1.06				

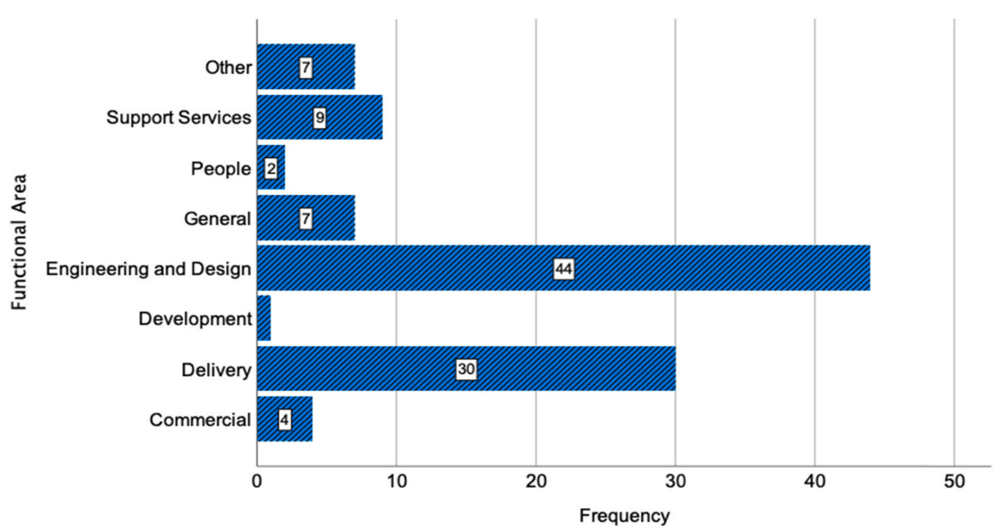

Fig. 4. Respondents by functional area.

“The actual lessons that can be learnt from errors are not being shared and developed, which is why we keep repeating the same issues”.

In a similar vein, another respondent stated:

“Lessons are reported, but not really scrutinized and without de-brief at the start of the project for a new team. So, how do we avoid errors? Similar issues keep reappearing”.

Notwithstanding these criticisms, the alliance was performing moderately better in reducing its rework (M = 3.15, SD = 0.96) compared with other projects that the respondents had been involved with delivering. Similarly, there was a general agreement that the alliance has been moderately successful in reducing the level (i.e., amount) of rework in its projects (M = 3.07, SD = 0.90). An issue impacting the alliance’s ability to mitigate rework in construction is the delays in approving design and scope changes. A misalignment between design programs of the collaborating organizations was recognized as a primary contributor to this situation. Therefore, we again performed a Kruskal-Wallis test to determine significant differences between the various functional areas and projects and the alliance's effectiveness (i.e., using prevailing work practices) in reducing its rework. Once more, no significant differences were present ($p < 0.05$).

4.3. Error culture

The descriptive statistics for the error management and aversion items are presented in Table 1. We offer additional analysis by 'Location' in the tables in presented Appendix A, though we have anonymized each project's location (A-G). In general, we can see that an error management culture moderately prevails within the alliance. In particular, people feel that they learn from their mistakes, ask for help, and focus on the goal when they are made (Table 1). Contrastingly, issues associated with an error aversion culture appear not to apply at all or only to a minimal extent. There is, however, a tendency for people to feel stressed when they make a mistake and concerned about making errors (Table 1).

As we mentioned above, these are natural feelings as making mistakes can remind us that we are in a challenging environment. The high-stakes and unfamiliar situations encountered during the design and construction of projects may have resulted in some respondents feeling fearful of missteps. This may well be the situation that confronts some people in the alliance. Taking heed of the English poet Alexander Pope's (1711) words of wisdom, we need to be mindful that "to err is human". While it is not realistic to completely eradicate mistakes, people can learn through coaching and support from leaders to harness a drive to prevent them and channel lessons learnt into better decision-making (Love et al., 2015).

In Table 2, the descriptive statistics and correlations of all the study variables are displayed. We can see that error aversion culture negatively related to error management ($r = 0.46$, $p < 0.05$). The result aligns with the findings of Van Dyck et al. (2005), though the correlation was not found to be significant in their study. Similarly, the correlation between error aversion and rework reduction was also significantly negative ($r = -0.24$, $p < 0.01$). Contrastingly, the correlation between error management and rework reduction is significantly positive ($r = 0.47$, $p < 0.05$). We decided not to include the control variables in the analysis to test our hypothesis in light of the Kruskal-Wallis tests we performed. In addition, there was no logical reason to include them in the analysis considering there is no evidence available to justify their inclusion.

As rework reduction (i.e., the DV) was measured using an ordinal variable, we used ordinal logistic regression (OLS) to test our two hypotheses. We used OLS to determine if responses to error culture questions can predict rework reduction. The model-fitting results are displayed in Table 3, containing the −2 Log Likelihood for the intercept only (or null) model and the full model (including the predictors of rework reduction).

The likelihood ratio or Chi-square test is used to test whether there is a significant improvement in the fit of the final model relative to the intercept only model. In this case, we see a significant improvement in the fit of the final model over the null model (χ^2 (2) = 31.079, $p < 0.001$). The 'Goodness of Fit', which contains the Deviance and Pearson Chi-square tests results, is presented in Table 4. In this analysis, we see that both the Pearson Chi-square test (χ^2 (378) = 380.477, $p = 0.455$) and the deviance (χ^2 (378) = 228.42, $p = 1.00$) were both non-significant. These results suggest we have a good fit model. This is also confirmed by the Nagelkerke Pseudo R^2 value (0.272), which indicates that an error culture explains a proportion of 27% of the variation of rework reduction. As a result, this suggests that other predictors, which we have not examined, might also impact rework reduction (e.g., coaching, the use of lean concepts, and leadership). We then evaluated the assumption of proportional odds[10] using the 'test of parallel lines' and presented the results in Table 5. In this case, the test is insignificant. Therefore, we can accept the presence of proportional odds ($p = 0.516$).

Table 6 presents the regression coefficients and significance tests for each of our independent variables in the model. The regression coefficients are predictors of change on the dependent variable. Thus, for every unit increase on an independent variable, there is a predicted increase on the dependent variable by its respective regression coefficient in the ordered log-odds scale. In contrast, other variables in the model are held constant. Our proportional odds model shows a positive effect $\beta = 1.954$, which is statistically significant ($p < 0.01$) according to the Wald test (sig. = 0.000).

Our results indicate that an error management culture has a statistically significant effect on rework reduction, and as would be expected, error aversion does not. The ratio of odds to higher ratings for those who perceive rework to be reduced and those who do not can be expressed as $e^{-\beta}$ and $e^{-1.954} = 7.05$. The cumulative and single probabilities for the error management culture items are presented in Table 7.

Table 2
Descriptive statistics and correlations among all variables.

Variable	Mean	SD	Rework Reduction	Error Management	Error Aversion
1. Rework Reduction	3.07	0.90	–	–	
2. Error Management	3.65	0.94	**0.49****	–	
3. Error Aversion	2.15	0.94	**−0.24***	**−0.46****	-

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Table 3
Ordinal logistic regression analyses for rework reduction on error management and aversion: Model fitting.

Model	−2 Log-Likelihood	χ^2	df.	Significance
Intercept only	266.688			
Final	235.609	31.079	2	0.000

5. Discussion

In line with Van Dyck et al. (2005), our research demonstrates that error management positively reduces rework within the transport mega-project we have examined. Reducing rework will minimize associated waste (e.g., transportation, stoppages, waiting and motion) and improve productivity and safety performance (Love et al., 2018d). Notably, Van Dyck et al. (2005) revealed that error management culture positively affected firm performance while reporting an $M = 3.43$, $SD = 0.41$ for their sample. Our case's error management culture is comparable ($M = 3.65$, $SD = 0.94$) with Van Dyck et al.'s (2005). Thus, we can reasonably assume that error management positively impacts the alliance's performance. However, we have no knowledge of its extent when our research was undertaken.

Table 4
Ordinal logistic regression analyses for rework reduction on error management and aversion: Goodness-of-fit.

	χ^2	df.	Significance
Pearson	380.477	378	0.455
Deviance	230.064	378	1.000

[10] The assumption is that the effects of any explanatory variable are consistent (i.e., proportional) across the thresholds. That is, the explanatory variables have the same effect on the odds regardless of the threshold.

Table 5
Test for parallel lines.

Model	−2 Log-Likelihood	χ^2	df.	Sig.
Null Hypothesis	235.351	–	–	–
General	230.133	5.218	6	0.516

Within construction, organizations are largely unfamiliar with the concept of error culture (Love et al., 2018c). As previously mentioned, the typical quality approach used to address rework is through control-oriented principles by engaging a prevention strategy. But error management practices fortuitously emerged within the alliance we have examined and the aforementioned BWA case. In the BWA case, the authentic leadership style within the alliance's leadership and management teams enabled psychological safety to flourish, which provided the grounding to engender and enact error management practices. Considering the results we have presented, it would appear that, at face value, a similar situation has arisen in the alliance. We are also cognisant that alliances are collaborative ventures, which possess a 'best-for-project' focus and promote a no-blame culture.

Considering the collaborative nature of alliances and the BWA experience, we ask the following question: Do alliances experience less rework than other projects procured using non-collaborative project delivery methods? While we were unable to obtain definitive evidence to address this question, there was a general agreement between respondents that the alliance had a healthier approach to reducing rework than the other projects they had been involved with delivering. This is not to say rework levels are less in alliances, but error handling appears to be more effective due to their collaborative nature.

Our results are consistent with previous studies emphasising the importance of free-flowing communication, reflexive and interactive learning, and nurturing people's coping capabilities (Edmondson, 1996, 1999; Rochlin, 1999; Van Dyck et al., 2005; Dimitrova et al., 2017). However, more can be done to reduce errors to lift people's ratings from a position of 'applies largely' where there is an 89% probability people will score a 4 to 'applies completely' where values, norms, and organizational practices of error management culture are legitimized throughout the alliance (Table 7). Unquestionably, this is a difficult task as creating a homogenous culture across the alliance will require constant maintenance to reinforce its values and shared beliefs and a drive to beget a process of continuous improvement and innovation.

Our results also reveal that error aversion negatively influences rework reduction. Indeed, error aversion dampens an individual's task-focus, amplifies negative self-evaluation, and adversely influences people's cognition and actual behavior (Dimitrova et al., 2017). Furthermore, training people during skill development to prevent errors can be detrimental to thinking and adapting to new tasks (Lloyd-walker et al., 2014; Dimitrova et al., 2017). Instead, emphasis needs to be placed on nurturing people's ability to cope and learn from errors, which puts them in good stead to mitigate rework. We should not discount that error prevention is intuitive and not negative per se. Still, it is often associated with adverse outcomes and behaviors such as hiding errors, lower levels of psychological safety in teams, and inhibiting learning (Edmondson, 1996, 1999; Van Dyck et al., 2005; Lloyd-walker et al., 2014; Dimitrova et al., 2017).

In novel situations, research has shown that when confronted with complex tasks, error management compared to error prevention has positive effects on affect, motivation, cognition, and performance (Bell and Kozlowski, 2008; Dimitrova et al., 2015). Therefore, if transport mega-projects are to address their rework and effectively deal with the novel and/or complex situations that may arise during their construction, then error management can explicitly provide them with the ability to understand, embrace, adapt to errors instead of the control and respond approach that is accentuated by error prevention (Love and Matthews, 2020).

5.1. Strategies for error handling and learning

The alliance has naturally created a culture where its members deploy error management practices. Though, if rework is to be reduced further, then weight needs to be formally placed on avoiding and reducing negative error consequences and developing strategies for handling errors through the: (1) communication of errors; (2) sharing of error knowledge; (3) helping in error situations as well as handling them quickly; and (4) coordinating error handling. Naturally, this will also benefit safety performance. Several strategies can be implemented to encourage error handling, but the following have been suggested to be practical enablers to contain and reduce errors (Love., 2020):

- Providing a psychologically safe work environment: Managers who view errors as a regular part of work activities consider learning opportunities. Thus, it is vital for "managers to actively and sincerely engage with and invite employees to help think about the best ways to manage errors" and mitigate rework (Van Steenbergen et al., 2019: p.64) In particular, the views of the rank-and-file workforce who operate at the coalface of production and operations should be solicited;
- Understanding what went right: Rather than focusing on 'what went wrong', managers should also determine 'what went right'. Concentrating solely on error creates a need to select the causes of 'what went wrong' and eliminate or inactivate the suspected cause-effect links (Hollnagel, 2010; Hollnagel, 2013). Focusing on 'what goes wrong' is an innate feature of a control-oriented approach to quality. This leads to counting how many fewer things go wrong and

Table 7
Cumulative and single rating probabilities for scale items for error management and rework reduction.

Prob (Cum Rating)*	Cumulative Probability	Prob (%)	Prob (Single Rating)	Probability	Prob (%)
1	$1/(1+e^{1.95})$	14.17	1 = Not at all	prob	14.17
1 or 2	$1/(1+e^{4.85})$	0.78	2 = To some Degree	prob(1 or 2) – prob(score −1)	13.39
1 or 2 or 3	$1/(1+e^{6.89})$	0.10	3 = Moderate Degree	prob(1,2,3) – prob (score = 1,2)	13.29
1 or 2 or 3 or 4	$1/(1+e^{9.51})$	0.01	4 = To a Large Degree	1 – prob(1,2,3)	89.32

*Note no respondent rated a five on the error management scale.

Table 6
Parameter estimates: Regression coefficients and significance.

Threshold	The Extent of Rework Reduction (Rating)	Estimate (β)	Std. Error	Wald	df.	Sig.	Lower Bound	Upper Bound
	1 = Not all	1.907	1.807	1.113	1	0.291	−1.635	5.448
	2 = To some Degree	4.85	1.787	7.368	1	0.007	1.348	8.351
	3 = Moderate Agree	6.893	1.852	13.848	1	0.00	3.263	10.524
	4 = Large Degree	9.517	1.964	23.489	1	0..00	5.668	13.365
Location	Error Management	1.954	0.419	21.751	1	0.00	1.133	2.775
	Error Aversion	−0.106	0.337	0.099	1	0.753	−0.767	0.555

formulating the 'hypothesis of different causes' (Hollnagel, 2010). In this instance, the causes of adverse events are different from those of events that succeed. If that were not the case, the elimination of such causes and their neutralization would also reduce the likelihood that things could go right and, hence, be "counterproductive" (Hollnagel, 2013: p.5). However, managers assume that people can adjust to their work environment and learn to identify and overcome flaws within their systems and processes. They can recognize actual demands and adapt their performance to match the conditions. In this instance, people would detect and correct something that goes wrong directly. Hence, people can succeed under varying conditions and ensure everything 'goes right' (Hollnagel, 2010; Hollnagel, 2013); and

- Learning from an individual to an organizational level through coaching: Organizations learn through individuals' actions and experiences. Thus, the interconnection between individual and organizational learning begins with the individual and is subsequently embedded at a collective level (Hogan and Warrenfeltz, 2003). The translation of individual into organizational learning occurs through intuition, interpretation, integration, and institutionalization (Crossan et al., 1999). Facilitating the transfer of learning from the individual to an organization level can be an arduous task in project-based environments. To improve the transfer of learning across the alliance, it is suggested that coaching can provide: (1) individuals with an increased awareness of the systemic relationships that existed within the alliance; and (2) an understanding of what motivates individuals and teams to learn. Therefore, this can enable the coach to challenge their existing behaviors and practices and allow them to engage in critical reflexion and transfer their learnings. New behaviors, which focus on learning by doing, role modelling and sharing experiences and learnings, may emerge. Peers may copy each other, and a coaching style of management can be adopted. This management style can lead to coaching the coach and learning through coaching, enabling a feeling of commonality to be engendered and facilitating the absorption of tacit and explicit knowledge by the coach (Swart and Harcup, 2012). As a result, learning can become embedded into practices and procedures, enabling the project to learn collectively to address errors and rework (Love et al., 2015).

Having access to information about errors and rework is critical for communicating and sharing knowledge about them. Therefore, it is essential to develop an information system that can record, store, and transfer data about errors and rework and their consequential impacts on other aspects of an organization and its project (e.g., safety). In our case, the alliance has recognized the need for a robust knowledge-based engineering system (KBES) to capture and share rework knowledge. At the time of writing, the architecture for the KBES is in development.

5.2. Strengths and limitations

Our study's strength is its determination of an existing homogenous error culture within a mega-transport project. Studies of this nature have seldom, if at all, been undertaken in the context of construction. We added items to the error aversion scale developed by Van Dyck et al. (2005), and its reliability improved, though marginally. We also demonstrated a significant negative correlation between error management and error aversion (i.e., show their divergence), which previous studies have not been able to do, even though they are antipodal constructs (Van Dyck et al., 2005). Considering this important finding, it would be reasonable to conclude that error management should not be viewed as a mere 'add-on' to error prevention. Similarly, we were able to show a significant association between error management and rework reduction. Additionally, the OLS analysis revealed that error management could explain a substantial proportion of rework reduction variance. Thus, error management has a positive effect on rework reduction.

Despite the strengths of our study, we need to acknowledge its limitations. While the research is unique and the first to examine the influence of error culture on rework in transport mega-projects, the ability to generalize the findings to projects that are not being procured using an alliance or other collaborative variants thereof such as IPD is questionable. Therefore, future research is required to examine how error culture may vary under differing project delivery approaches.

We did not consider the nuances of collaboration and the natural features of alliance contracts (e.g., non-blame culture and 'gain-share/pain-share' regime), which may have acted as mediating variables for error management. The influence of leadership style is another crucial issue we did not consider, which should also be considered in feature studies of error culture projects. Not having access to a legitimate quantitative measure of rework occurrence resulted in us creating an ordinal dependent variable. Consequently, we could only garner a perceived rating of rework reduction within the alliance's projects. Acquiring a reliable quantitative measure of rework is an issue that has stymied our ability to determine how it impacts the bottom-line of construction organizations and their projects. Finally, the survey was only distributed to the alliance members and not its contractors and rank-and-file workforce. To address this issue, we will, in our future research, seek out the views of contractors and their rank-and-file workforce about the error handling strategies in place to mitigate rework.

6. Conclusions

It is widely recognized that rework is an adverse outcome of human error in construction. Performing rework during construction adversely impacts the performance (e.g., cost and schedule), productivity and safety of projects. Strategies to mitigate rework during their construction abound but have had minimal impact. They focus on an error prevention approach (i.e., focusing on working faultlessly) rather than error management (i.e., focusing on increasing the positive and decreasing the negative consequences of errors). To our knowledge, there are some, albeit not many, construction organizations that incorporate a constructive orientation toward errors as part of their continuous improvement strategy. However, there has been no research to date that has examined the influence of error culture on a mega project's ability to reduce its rework.

Culture is defined by what an organization does and not what it says. Put simply, it is an organization's 'personality', characterized and shaped by its members' shared values, norms, and common practices. By determining the type of error culture that pervades practice during the construction of transport mega-projects, we can begin to understand the error handling process and why rework may materialize. Accordingly, we set out to address the following research question in this paper: "Can an error culture reduce rework in transport mega-projects?"

Using a transport mega-project as the research setting, which is being delivered through several program alliances, we adopted an exploratory case study approach to explore how the prevailing error culture at one of its alliances influences its ability to reduce rework. We examined two types of error culture: (1) error management and (2) error aversion. We found that despite the presence of an error management culture, an increasing emphasis still needs to be placed on avoiding and reducing negative error consequences and developing error handling error strategies that focus on: (1) communicating errors; (2) sharing knowledge of errors; (3) helping in error situations as well as handling them quickly; and (4) coordinating error handling.

We suggested that error handling strategies, such as providing a psychologically safe work environment, understanding and focusing on what goes right, and enacting coaching to ensure learning is transferred from an individual to an organizational level, could help avoid and reduce negative error consequences. Even so, research is required to examine if such strategies can lead to significant reductions in rework. To this end, our study of error management opens doors for other avenues of inquiry to be considered in construction, such as its influence on project performance and innovation and its relationship with a learning organization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Appendix A. Mean responses to error management culture items by location

Item	Error Management	A	B	C	D	E	F	G	Other	Program
1	For us, errors are very useful for improving the work process	3.35	3.15	2.50	4.00	3.35	5.00	3.00	4.00	3.07
2	After an error, people think through how to correct it.	4.15	3.80	3.50	4.00	4.20	4.00	4.10	4.50	3.76
3	After an error has occurred, it is analyzed thoroughly	3.90	3.76	1.50	3.00	4.14	3.00	3.80	2.50	3.23
4	If something went wrong, people take the time to think it through	3.70	3.57	2.50	3.00	4.00	3.00	4.00	2.50	3.23
5	After making a mistake, people try to analyze what caused it	3.90	3.65	2.00	4.00	4.14	4.00	3.46	3.50	3.34
6	In this alliance/project, people think a lot about how an error could have been avoided	3.85	3.34	2.50	3.00	3.42	3.00	3.46	2.50	3.11
7	An error provides important information for the continuation of the work	3.65	3.65	3.50	3.00	3.71	5.00	3.60	3.50	3.38
8	Our errors point us to what we can improve	4.25	3.80	1.50	4.00	4.28	5.00	4.00	3.50	3.73
9	When mastering a task, people can learn a lot from their mistakes	4.25	3.80	2.5	4.00	4.42	5.00	4.40	4.50	3.92
10	When an error has occurred, we usually know how to rectify it	3.65	3.57	2.00	2.00	3.85	4.00	4.00	3.50	3.50
11	When an error is made, it is corrected right away	3.80	3.42	2.50	3.00	3.85	4.00	3.67	3.00	3.26
12	Although we make mistakes, we don't let go of the final goal	4.55	3.88	3.50	4.00	4.42	5.00	4.46	4.00	4.19
13	When people are unable to correct an error by themselves, they turn to their colleagues	3.95	3.76	3.00	2.00	4.41	4.00	4.00	3.50	3.42
14	If people are unable to continue their work after an error, they can rely on others	3.90	3.46	3.50	1.00	3.42	3.00	3.73	3.50	3.42
15	When people make an error, they can ask others for advice on how to continue	4.15	3.92	2.00	3.00	3.50	5.00	4.33	4.50	3.80
16	When someone makes an error, they share it with others so that they don't make the same mistake	3.45	3.26	2.50	2.00	4.14	4.00	3.00	2.00	3.26
17	In this alliance/project, people think a lot about how an error could have been avoided	3.65	3.38	2.50	4.00	3.85	3.00	3.10	2.50	3.11

Appendix A. Mean responses to error aversion culture items by location

Item	Error Aversion	A	B	C	D	E	F	G	Other	Program
1	In this alliance/project, people feel stressed when making a mistake	2.75	2.92	3.00	3.00	3.41	1.00	2.93	2.98	3.15
2	In general, people in this alliance/project feel embarrassed after making a mistake	2.35	2.53	3.00	3.00	3.00	3.00	2.60	2.56	2.63
3	People in this alliance/project are often afraid of making mistakes	2.70	2.65	1.50	3.00	2.85	4.00	2.80	2.64	2.53
4	In this alliance/project, people are often upset and irritated if an error occurs	2.65	2.53	4.00	3.00	3.00	1.00	3.20	2.79	2.76
5	During their work, people are concerned that errors might occur	2.80	2.84	2.50	3.00	3.28	1.00	3.62	2.94	2.96
6	Our motto within the alliance/project is, "Why admit an error when no one will find out?"	1.30	1.69	2.50	1.00	1.71	1.00	1.80	1.58	1.46
7	There is no point discussing errors with others	1.20	1.42	2.00	2.00	1.57	1.00	1.60	1.52	1.76
8	There are advantages in covering up one's errors	1.20	1.69	2.00	1.00	1.42	2.00	1.53	1.44	1.32
9	People prefer to keep errors to themselves	2.10	2.23	3.00	3.00	2.28	2.00	2.46	2.33	2.50
10	Employees who admit to errors are asking for trouble	1.55	1.61	2.00	2.00	1.85	1.00	1.67	1.59	1.44
11	It can be harmful to people to admit their errors to others	1.75	1.73	2.50	3.00	2.00	3.00	1.73	1.85	1.96
12	In this alliance/project, we don't talk about errors	1.50	1.96	2.00	2.00	1.71	4.00	1.86	1.97	2.19
13	In this alliance/project, we have a zero- vision in place for errors	2.45	2.03	3.00	3.00	2.28	3.00	1.73	2.14	2.08
14	When errors occur, it takes time before they are rectified	3.15	2.84	3.00	2.00	2.57	2.00	2.93	2.95	3.07
15	People are discouraged from reporting errors	1.45	1.65	2.00	1.00	1.42	2.00	1.33	1.50	1.65
16	It is difficult to ask other people for help to address a mistake	1.85	2.00	2.00	4.00	2.00	1.00	2.00	1.98	2.03

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