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Quality II: A new paradigm for construction

Peter E.D. Love [a,*], Jane Matthews [b], Stuart R. Porter [a,**], Brad Carey [c], Weili Fang [d,e]

[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] School of Design and the Built Environment, Curtin University, GPO Box U1987, Perth, Western Australia, 6845, Australia
[d] National Center of Technology Innovation for Digital Construction, Huazhong University of Science and Technology, 430074, Wuhan, China
[e] School of Civil and Hydraulic Engineering, Huazhong University of Science and Technology, Wuhan, 430074, China

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ABSTRACT

The Quality I paradigm utilizes an error prevention strategy to avert rework in construction. The effectiveness of this paradigm is questionable as rework has become an innate feature of practice. If rework is to be mitigated in construction projects, a new paradigm is needed to challenge conventional thinking and offer a different perspective on managing errors. We introduce a new paradigm, Quality II, by drawing on a narrative review, emerging best practices deployed in construction, and contemporary developments in safety (e.g., Safety II and III). The implications of a Quality II paradigm for theory development and practice are also examined. The contributions of this paper are twofold as we: (1) provide construction organizations with a new approach for managing and learning how to handle (i.e., learning through) errors, and thus provide them with the ability to adapt and respond to varying conditions effectively; and (2) align Quality II with contemporary safety paradigms to offset competing demands enabling construction organizations to maximize the use of their limited resources better. By curbing rework, the performance and productivity of projects and the profitability of construction organizations will improve.

1. Introduction

"Paradigm shift is for the mindful; but those who refuse to adopt to new ways of looking at things will always catch yesterday's train, flight or bus" – Dr. Lucas D. Shallua

A paradigm defines how we perceive reality and behave – it provides us with a lens to view the world. Our perceptions and behaviors are subject to change when new ways of thinking, practices, and technology emerge. Thus, the emergence of new paradigms can lead to new business models and production techniques, forms of collaboration and cooperation, financing and ownership types, and learning modes. New paradigms enable us to view situations from different perspectives and examine the opportunities that they provide.

Over the last 50 years, the construction industry has been subject to several paradigm shifts as new management and production methods (e.g., Business Process Re-engineering, Lean Construction, and Relational Contracting) and technologies (e.g., Additive Manufacturing, Artificial *Intelligence*, Building Information Modelling (BIM) and Industry 4.0) have come to the fore. More recently, a new paradigm, Quality II, has emerged as a response to redress errors and rework in construction (Love et al., 2023a).

Rework can be costly, derail the performance and productivity of a construction project, and adversely impact the profitability of organizations participating in its delivery (Love et al., 2022a). However, despite the wealth of research that has sought to understand *why* and *how* rework occurs and accordingly propagate mitigation strategies, it remains a problem for construction organizations (Asadi et al., 2021). Markedly, this problem is not unsolvable like the Gordian Knot. Some projects are delivered with minimal and, in some cases, no rework (Love and Matthews, 2020). Indeed, construction organizations can learn from such projects and implement changes to their practices to effectively manage errors and mitigate rework with a Quality II lens, as shown in Love et al. (2023a). However, with a Quality I mindset tending to be the mainstay of practice in construction organizations, their ability to 'learn through' (i.e., how to handle) errors to enact profound continuous improvement and stimulate innovation is stymied.

* Corresponding author.
** Corresponding author.
E-mail addresses: p.love@curtin.edu.au (P.E.D. Love), jane.matthews@deakin.edu.au (J. Matthews), stuart.porter@curtin.edu.au (S.R. Porter), brad.carey@curtin.edu.au (B. Carey), Weili_fang@hust.edu.cn (W. Fang).

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Our paper conducts a narrative review[1] and draws on the empirical observations derived from practice to explain the rationale for the new Quality II paradigm and identify and describe its key concepts. We proffer that adopting Quality II will mitigate rework, improve a project's productivity and performance, and reduce safety incidents on construction sites. By embracing the new paradigm of Quality II, construction organizations will be better positioned to communicate and share experiences with their errors and rework, enabling learning and innovation to permeate throughout the portfolio of projects they manage and deliver and supply chains (Love et al., 2023a).

We commence our paper by briefly reviewing the context of rework in construction (Section 2). In setting this context, we then describe the Quality I paradigm, which forms the mainstay of practice in construction, which we argue has hindered progress towards rework mitigation in projects (Section 3). Drawing on best practices emerging from construction, we introduce and explain the Quality II paradigm, which has begun to surface due to the need to contain and reduce errors and rework (Section 4). Next, we discuss the implications of a Quality II paradigm for theory development and practice (Section 5) before concluding our paper (Section 6).

2. Setting the scene: the error and rework problem

There is no commonly accepted definition of rework as its scope of determination varies, influencing the reported costs of rework found in the literature (Robinson-Fayek et al., 2004; Love et al., 2022a). For example, Burati et al. (1992) reported that rework costs, on average, accounted for 12.4% of total project costs, with 78% credited to design changes. Thus, such reported costs should be treated cautiously as they consider quality-related problems and changes to [client] requirements (Burati et al., 1992). Such changes are not a product of a project's quality but are attributable to unresolved problems associated with its design and scope before construction commences.

Another critical point that requires consideration when looking at rework costs is who in a project is financially responsible for undertaking the work, an issue often overlooked in the literature (Love et al., 2022a). In the case of changes, these are typically instructed on behalf of the client's representative through an instruction (i.e., variations to work). The contractor may be paid and granted an 'extension of time' to perform the change if required. The contractor can also plan for the (re) works undertaken. Ultimately, in this instance, the client is financially responsible for any costs that materialize from undertaking rework.

We also need to be mindful that empirical studies that have sought to quantify rework as a portion of total project costs have been limited and based on a small number of cases - they are unrepresentative of general practice within construction (Burati et al., 1992; Willis and Willis, 1996; Barber et al., 2000; Love and Li, 2000a, 2000b; Josephson et al., 2002; Taggart et al., 2014). Moreover, the ontologies for classifying and quantifying rework are inconsistent, and as such, any comparison between studies is akin to likening 'apples with oranges' (Matthews et al., 2022a, 2023).

A main contractor ensures that a product or service conforms to a desired specification during construction. Thus, quality is defined as attaining acceptable performance levels (i.e., meets or exceeds requirements). When acceptable performance is not achieved, rework may be needed. Here, rework is defined as correcting defective, failed, or non-conforming items after an inspection in the field. Similarly, ISO 9000: 2015 deems rework to be the action on a non-conforming product or service to make it conform to specified requirements. Non-conformances requiring rework generally, on average, cost less than 1% of contract value (Love and Li, 2000a, 2000b). However, there are exceptions to this rule.

As mentioned above, not all projects incur rework, and equally, some experience significant amounts of non-conformances costing considerable sums of money to rectify. As a case in point, Love and Matthews (2020) analyzed 19,314 non-conformances that materialized in 569 projects constructed over seven years by a Tier 1[2] construction organization. They found 9098 non-conformances required rework, which occurred in only 210 projects costing AU$ 82 million. Furthermore, 48% of the rework costs, due to events exceeding AU$ 100,000, were found to occur in 42 projects. The impact of these rework costs resulted in an annual reduction of 15% in the construction organization's profitability (Love and Matthews, 2020).

According to Love and Matthews (2022b), previous studies have been predisposed to taking a reductionist view of rework identifying and attributing a single proximal and root cause instead of providing an explanation and contextuality to an event to provide meaning (e.g., Hwang et al., 2014; Ye et al., 2015; Yap et al., 2020; Grag and Mistra, 2021; Asadi et al., 2021). The upshot is that proposed solutions for preventing rework, such as lean construction techniques (e.g., Last Planner®) and BIM, have fallen short of expectations as they are unable to address the conditions that result in its manifestation (Love, 2020; Love et al., 2023a).

This situation has arisen as there has been an explicit assumption that providing people with new tools, techniques, and technologies will remove the error that led to rework. However, instead, they relocate or change their nature, presenting "new complexities and error traps" (Dekker, 2006, p.19: Love, 2020). Furthermore, construction organizations traditionally believe that rework materializes due to people's shortcomings or failings – blame is the preferred remedy (Love et al., 2018a).

When a non-conformance is raised and its rework potentially costly, management's immediate response is often to reprimand the individual (s) responsible and introduce new rules and procedures, so it does not happen again (Love et al., 2018a). However, management's inability, perhaps even reluctance as it is easier to apportion blame, to engage and enact a process of organizational introspection to understand the 'whys and wherefores' of rework often contributes to similar events being repeated in projects (Love et al., 2018a). It is outside the remit of this paper to provide a detailed examination of rework causation, but a state-of-the-art review can be found in Asadi et al. (2021) and Love et al. (2022a).

2.1. Quality and safety: competing demands

Quality (e.g., ISO 9000/9001) and safety (e.g., ISO 45000/45,001) share a symbiotic relationship (Das et al., 2008; Love et al., 2023a, 2023b). Nevertheless, paradoxical tensions between quality and safety invariably play out in construction organizations as they struggle to balance their competing demands (Love et al., 2023b). Ever-increasing legislative changes to ensure workplace safety, including financial penalties and the potential for criminal convictions, have resulted in construction organizations diverting resources away from their ability to manage quality in projects effectively (Love et al., 2023b).

Over the last two decades, we have seen significant strides toward reducing construction-related injuries and fatalities (Safe Work Australia, 2023). In stark contrast, rework perpetuates practice. Our intention is not to provide an in-depth discussion on the developments of safety. However, by reinforcing the 'quality-safety' relationship and piggybacking off prevailing safety paradigms, we can ensure our proposed new quality approach aligns with them. After all, reducing rework

[1] A narrative review is a comprehensive, critical, and objective analysis of current knowledge on a subject and is used to develop a theoretical framework or paradigm from which theory can emerge.

[2] A Tier 1 construction organization (i.e., contractor) that can self-perform most of the required work on a project with its employees and equipment. They also usually have a large balance sheet that can take on the project risk and major procurement functions.

will improve a project's safety performance (Love et al., 2018a).

2.2. Safety: A point of reference to develop a New quality paradigm

The pursuit of safety in construction has tended to rely on mechanistic thinking and formal rationality (i.e., bureaucratic rules, regulations, and laws) by conceptualizing safety as an absence of failure. In this instance, safety is achieved via "minimizing [safety] performance variation" and "maximizing compliance (through standardization, regulation and measurement" in construction to assuming variability in everyday routines provides the adaptations that are needed to respond to varying conditions (Smaggus, 2019: p.667; Martin et al., 2022). This mechanistic and rational view of safety is called the Safety-I paradigm and focuses on preventing 'bad' things from happening (Hollnagel et al., 2015). Even though adopting a Safety I paradigm has contributed to enhancing safety in construction (Martin et al., 2022), it has been unable to provide organizations with the performance improvements needed in their projects, which are complex socio-technical systems (Love et al., 2019a).

Safety II is suited for managing safety in complex socio-technical systems (Hollnagel, 2014; Hollnagel et al., 2015). Due to their emergent properties, non-linearity, and complex interdependencies and interactions, such systems do not respond predictably to improvement efforts. Thus, Safety II assumes that everyday performance variability provides the adaptations needed to respond to varying conditions, hence why things go right. As such, some construction organizations have been slowly embracing this paradigm, or aspects thereof, in conjunction with Safety I as projects have become more complex and demand to improve safety has increased. In Australia, Laing O'Rourke, for example, received the '2016 SafeWork NSW Excellence in Workplace Health and Safety Culture Award' for its 'Next Gear' safety agenda based on Safety II (Laing O'Rourke, 2016). The safety developed agenda aimed to address the shortcomings of the traditional approach to safety (i.e., Safety I) and build safety resilience in the organization based on three principles (Laing O'Rourke, 2016): (1) people are the solution; (2) safety is the presence of positives; and (3) safety is an ethical responsibility and a not a bureaucratic activity.

We can see from Table 1 that Laing O'Rourke's approach to safety marries with some aspects of Safety II. The differences between prevailing safety paradigms are presented in Table 1 (Aven, 2022). While Safety I and II paradigms can be seen in their various guises in construction, Safety III, proposed by Leveson (2020a), is underpinned by the systems theory and utilizes the Systems Theoretic Accident Model and Processes (STAMP) model (Leveson, 2020b), has received limited, if not any attention, in an empirical context in construction (Zhang et al., 2021). This is not to say we should discount Safety-III; quite the contrary, but its application in its purist sense to the construction context is open to questioning, considering its scope is a broad church.

In short, Leveson (2020a) defines safety as freedom from unacceptable losses determined by a system's stakeholders. The goal of management is to eliminate, mitigate, or control hazards, which are the states that can lead to losses (Leveson, 2020a:c). Accidents are caused by inadequate control or enforcement of safety-related constraints. The focus is on preventing hazards and failures, learning from events, accidents, incidents, and audits about how the system is performing. Thus, the system must be designed to allow humans to be flexible, resilient, and handle unexpected events.

Equally, Leveson (2020a) suggests that "it is not reasonable to characterize whole groups and industries as having one approach to safety [i.e., Safety I]" (p.4). Indeed, this is a valid point, but within the context of construction, Safety I and II provide a 'loose' framing to understand the nuances and ebbs and flows of safety management – they are not definitive. They will evolve as new knowledge, practices, and technologies emerge. Leveson (2020a) is critical of Hollnagel's (2014) Safety I and II paradigms, suggesting that they are unrepresentative regarding how safety practice is viewed in the workplace. Leveson (2020a) cogently argues that Hollnagel's (2014) Safety I and II paradigms have been based on a strawman argument and draws on "unproven assertions" to "prove" that Safety II will provide improved safety outcomes if implemented (p.5).

While Leveson (2020a) clearly articulates the strawman arguments of Hollnagel (2014) to justify Safety I and II, the notion that Safety III can provide better alternatives is by no means demonstrated whatsoever. As it happens, Leveson (2020a;c) shoehorns an event retrospectively into STAMP to explain why it may have occurred; at no point does Leveson (2020a,c) demonstrate that Safety III is superior to Safety II. However, both Safety II and III have their merits and can provide pathways to improving safety in construction. Still, details about their operationalization remain scant, particularly in the context of the change needed to adapt a prevailing safety culture to the new paradigm.

It would be prudent to say that 'most' construction organizations prioritize people's well-being and safety and perpetually strive to improve these areas. In doing so, they are adapting and embracing, though slowly, the changing conditions and circumstances that are imposed on them. We take heed of Leveson's (2020a) view that it is inappropriate to shoehorn construction organizations into possessing a particular safety paradigm. Thus, based on our observations from practice, we concur that one size does not fit all (Love et al., 2016a; b). Indeed, construction organizations may cherry-pick various features from differing safety paradigms to meet their needs and requirements and those of their stakeholders.

With unwavering attention placed on managing safety over the last two decades, its sibling, quality, has been treated metaphorically as the 'spare' by construction organizations. The attention to quality has typically focused on the administration and execution of ISO 9000/9001:2000 'Quality Management Systems (QMS)', albeit often with a tick box mindset (Love et al., 2018a).

We note that the standards and procedures presented in ISO 9000/9001:2000 are not rigid requirements. Construction organizations are provided the flexibility to establish, maintain, and improve their QMS as they see fit. Moreover, ISO 9000 adopts a process-oriented approach, requiring organizations to take a 'big picture' view of quality instead of focusing on departments and individual processes. This motivation necessitates the organization to identify the important aspects of their products and services, look at how their processes interact, and determine if they can be integrated.

Due to several public inquiries (e.g., 'Independent Inquiry into the Construction of Edinburgh Schools'[3] and the 'Grenfell Tower Inquiry')[4] and the work of the 'Get it Right Initiative' (GIRI),[5], increasing attention is paid to 'quality'. The predominant *modus operandi* for managing quality in construction aligns somewhat with Safety I (Love et al., 2023a). As such, the term Quality I was coined to provide a contextuality for its application to practice in construction.

2.3. Errors and violations

The common denominator that binds quality and safety in the workplace is *human error* (including violations) (Reason, 1990). However, rarely, if at all, is the term error used forms part of the quality performance lexicon (Love et al., 2019b). The word error tends to be

[3] This inquiry was established after the collapse of a wall at Oxgangs Primary School in Edinburgh and the subsequent closure of a further 16 schools requiring immediate relocation of over 8000 pupils.

[4] This independent inquiry examined the circumstances leading up to and surrounding the fire at Grenfell Tower, North Kensington, West London in the United Kingdom (UK) on 14th June 2017. An independent review of the building regulations and fire safety was published 17th May 2018 [Online]. Available at: http://www.grenfelltowerinquiry.org.uk/.

[5] GIRI is a UK-based organization whose details can be found at: https://getitright.uk.com/.

Table 1
A comparison between Safety I, II, and III.

Feature	Safety I 'What goes wrong' (Reactive)	Safety II 'What goes right' (Proactive)	Safety III 'Design for Safety' (Prevention)
Safety definition	• Absence of accidents and incidents • Freedom from unacceptable risks	• The ability to succeed under varying conditions	• Freedom from unacceptable losses
Risk definition	• Events, consequences, and associated probabilities.	• The likelihood that something unwanted can happen.	• Combination of severity and the likelihood of an unwanted outcome • Risk as an assessment of safety
Variability	• Variability is harmful. Goal to control (limit, reduce, prevent) variability through rules, procedures, standardization, and policies. • Commonly expressed through frequentist probability and probability models • Counting (e.g., Lost Time Injury Frequency Rate) • Goal to achieve 'zero' accidents/harm.	• Inevitable but also useful. It should be monitored and managed. Variability is acknowledged as critical for obtaining success and avoiding failures.	• Design the system so performance variability is safe and conflicts between productivity. Achieving system goals and safety are eliminated or minimized. • Design so that safety is maintained when performance (of project managers, engineers, subcontractors, and the like) varies outside safe boundaries (fault tolerance and fail-safe design).
Causality	• Failures and malfunctions cause accidents. • Failures are caused by unreliable, irrational, and erratic people who make inaccurate assessments, wrong decisions, and bad judgments – people viewed as being a liability. • The purpose of an investigation is to identify causes and contributory factors.	• Emergent outcomes (i.e., accidents) can be understood as arising from surprising combinations of performance variability, where the governing principle is resonance rather than causality. • People are seen as a resource necessary for system flexibility and resilience. • The purpose of an investigation is to understand how things usually go right as a basis for explaining how things go wrong	• Accidents are caused by inadequate control over hazards. • Accidents result from inadequate control or enforcement of safety-related constraints. • Linear causality is not assumed. There is no such thing as a root cause. • The entire socio-technical system must be designed to prevent hazards; an investigation aims to identify why the safety control structure did not prevent the loss.
Models and system characterization	• Assumed to represent the actual system or activity accurately. • System characterizations: Simple, linear, tractable, complicated systems that allow for decompositions and accurate models based on system components.	• Accurate models do not exist for intractable systems. • System characterizations: Intractable, complex, sociotechnical.	• People use models to understand complex phenomena. By definition, they leave out factors (otherwise, they would be the thing itself and not useful). For abstractions or models to be helpful, they must include the important factors or factors of interest in understanding the phenomena and leave out the unimportant. The simple linear chain-of-events causality model leaves out too much to be useful in understanding and preventing accidents in complex sociotechnical systems. Alternatives exist based on STAMP. • System characterizations: Linear and more complex sociotechnical systems
Risk assessment	• Traditional technical risk analysis methods like Fault Tree Analysis, Event Tree Analysis, and Probabilistic Risk Analysis are used (Quantitative Risk Analysis). • Accurately estimate risk using probabilistic-based methods	• Not highlighted. Traditional methods are not relevant for intractable systems. • Focus on understanding the conditions where performance variability can become difficult or impossible to monitor and control.	• Traditional use of risk assessments to identify design flaws and functional glitches, highlighting events, consequences, and likelihood.
Safety management principles (Anticipation)	• Reactive: respond when something happens or is categorized as an unacceptable risk.	• Proactive, continuously trying to anticipate developments and events.	• Concentrates on preventing hazards and losses but does learn from accidents, incidents, and audits of how the system is performing
Safety management principles (Learning and improvement)	• Learning and improving due to failures and mistakes.	• Learning should be based on frequency rather than severity; thus, weight is given to 'what goes right', not only failures.	• Learning and improving due to failures and mistakes.

Adapted from Hollnagel (2014: p.187), Hollnagel et al. (2015), Aven (2022: p.3) and Martin et al. (2022: p.2).

associated with individual misgivings. The common phrase "to see the errors in one's ways", for example, "implies a person has engaged in some wrongdoing" (Armitage, 2009: p.194).

Regardless, the unforgiving nature of work in construction projects can take a heavy toll on an individual's cognitive load, knowledge, and skills, increasing the propensity for errors and violations to manifest (Love et al., 2019b). Thus, within the Quality I paradigm, there is an explicit focus on 'error prevention' whereby error-making is eschewed, and violations are not tolerated. So, let us briefly define what we mean by error and violation before introducing the concept of error prevention, which underpins Quality I.

There are distinct differences between an error and a violation. Nevertheless, before identifying these differences, we must note that errors can take various guises. In a nutshell, they can be categorized as errors in judgments in decision-making (e.g., cognitive biases and heuristics), "Freudian slips or linguistic errors", or action errors (Frese and Keith, 2015: p.662). In this paper, we are concerned with action errors, which are "unintended deviations from plans, goals, or adequate feedback processing, as well as incorrect actions resulting from lack of knowledge" (Van Dyck et al., 2005: p.1229). They can take the form of.

- *Slips* occur when the human automation process loses conscious control, and the individual's routine is disturbed, even though the original mental plan is correct (Reason, 1990; Armitage, 2009).
- *Lapses*: Arise when we forget, which involves a failure in memory retrieval and can happen in most healthy people (Reason, 1990); and
- *Mistakes*: Occur when an "action proceeds as planned but does not achieve its intended outcome as the plan was wrong" (Reason, 1990: p.196).

As opposed to action errors, violations are intentional acts. They are deliberate deviations from rules and procedures "established to restrict self-interested behavior and protect organizational members from the predations of others" (Busby and Iszatt-White, 2016: p.36). Violations originate from psychosocial factors such as individual and organizational motives rather than cognitive ones (Reason et al., 1998; Parker and Lawton, 2003). The propensity for people to commit a violation increases when "risks thought to be controllable (i.e., preventable by personal action) is likely to evoke unrealistic optimism about judgments in susceptibility" or, more colloquially, described as the 'it will not happen to me' phenomenon or further still "I should have known better" (Weinstein Neil, 1984; Armitage, 2009).

When there is an intention to cause damage, the violation is *sabotage* (Reason, 1990). However, suppose there is some degree of intention but no desire to damage. In that case, a violation can be categorized as *routine* "(i.e., habitual, forming a part of an individual's behavioral repertoire") (Reason, 1990: p.195) or *exceptional* "(i.e., singular violations occurring in a particular set of circumstances" (Reason, 1990: p.196). The context of an error and violation presented provides a segue to explain Quality I.

3. Quality I paradigm

The concept of error prevention, which Love et al. (2023a) draw upon to provide a framing for Quality I and align with the same conventions of safety, was identified by Frese (1991). The key features of Quality I presented in Table 2, are derived from empirical findings from empirical studies presented by Love et al. (2019a;b), Love and Matthews (2022a;b), and Love et al., 2023a).

3.1. Zero tolerance for errors

There is a belief that errors result in adverse outcomes, and thus, there is no tolerance for their occurrence by organizations. We often see construction organizations ideologically shaping their projects' mindsets to manage quality by channeling their 'zero vision' through slogans such as 'zero-defects' (Love et al., 2018a). Yet, putting up a slogan does not improve an organization's approach to quality. But instead, it blames people for not delivering what the slogan aims to guarantee.

As an individual makes errors, the general idea is that by putting in place the right systems and designs and through training (i.e., individuals/teams), it becomes possible to "block erroneous actions" (meaning goal-directed behaviors and communication acts) and prevent errors (Reason, 1990; Hofman and Frese, 2011; Frese and Keith, 2015: p.665). Thus, if people comply with quality management procedures and standards and others (e.g., safety and environmental), projects will not experience non-conformances, failures, or defects and necessitate rework.

Consequently, individuals strive to mitigate errors by adhering to existing procedures and standards. In doing so, they become anxious about making errors as the organization and other individuals may view them as indicators of poor performance, negligence, or even low intelligence (Mangels et al., 2006). Hence, the reluctance to report errors in their various formats for fear of being blamed and reprimanded.

3.2. Non-reporting of non-conformances

A case in point often arises in construction when a non-conformance occurs and is not reported and documented. Project engineers, for example, often consider the process associated with raising a non-conformance cumbersome and time-consuming. There is also a belief that non-conformances are a product of poor supervision and management of subcontractors. For this reason, there is an unwillingness to document their occurrence (Love et al., 2018a). If an individual commits a quality violation, a warning may be given depending on its severity, or they may be immediately dismissed and requested to leave the site (Love et al., 2016). Equally, this also applies to safety infringements.

The disinclination and consternation to report non-conformances by a contractor's rank-and-file can result in more senior individuals taking advantage of the situation as they aim to suit their agendas (Love et al., 2018a). For example, during an inquiry into rework causation in an Australian Tier 1 contractor, we learned that a project manager had

Table 2
A comparison between Quality I and II.

Feature	Quality I 'Errors are Negative' (Prevention)	Quality II 'Errors Happen' (Adapt and Respond)
Quality definition	• The absence of errors (non-conformance, defects, and failures) results in the need for no rework • Freedom from unacceptable risks	• The ability to 'Get it Right the First Time' under varying conditions. • Ability to respond quickly to mitigate the negative consequences of an error or failure once it has happened
Risk definition	• Events, consequences, and associated probabilities • The perception that rework is a one-off event	• Combination of severity and the likelihood of an unwanted outcome • Errors happen and are inevitable. Rework is always a risk • Psychological safety: An environment that encourages, recognizes, and rewards individuals for their contributions and ideas by making individuals feel safe when taking interpersonal risks is provided
Variability	• Variability is costly and unproductive. Goal to control (i.e., limit, reduce, and prevent) variability through rules, procedures, standardization, policies, and deployment of technology (e.g., BIM) • Counting and costing of non-conformances • Goal to achieve 'zero' defects. • Absence of incentives to ensure quality outcomes (e.g., mitigate rework)	• Variability should be monitored, measured, and managed to determine if problems exist. • Preparedness: Variability is accepted and critical for understanding 'what works' and 'what does not' in varying project conditions. The impact of workplace demands and constraints on people's performance is anticipated to enable them to understand, embrace, and adapt. • Awareness: Providing insights about people's performance to determine the extent of problems and the current state of defences. • Flexibility: Adapt to new or complex quality problems in ways that maximize people's ability to solve them without disrupting work • Opacity: Monitoring costs, workload, quality, and safety and where effort needs to be invested in ensuring defences are not degraded. • Design of a system to ensure quality by introducing an incentivization scheme, such as a pain-gain-share regime to mitigate rework (e.g., collaborative project delivery such as Alliancing)
Causality	• The need for rework is caused by people's poor knowledge, skills, and	• Organizations and projects provide the conditions for error-making through decision-

(*continued on next page*)

Table 2 (*continued*)

Feature	Quality I 'Errors are Negative' (Prevention)	Quality II 'Errors Happen' (Adapt and Respond)
	management (also breaking the rules) • Errors are caused by unreliable, irrational, and erratic people who make inaccurate assessments, wrong decisions, and bad judgments – people are viewed as a liability. • The purpose of an investigation is to identify the root (including proximal) causes and contributory factors	making (sometimes for breaking the rules). Thus, rework is a product of an organization's and project's work settings. • Determine why people's actions and assessments made sense at the time, given the circumstances that surrounded them (i.e., local rationality principle) • People are flexible and constitute a solution to a quality problem
Models and system characterization	• Assumed to represent the actual system or activity accurately. • System characterizations: Simple, linear, tractable, complicated systems that allow for decompositions and accurate models based on system components	• Accurate models of quality do not exist for intractable systems (e.g., infrastructure projects) • People draw upon examples to make sense of the systemic nature of error-making. • System characterization: Intractable complex socio-technical system
Risk assessment	• Traditional technical risk analysis methods like Fault Tree Analysis, Event Tree Analysis, and Probabilistic Risk Analysis (Quantitative Risk Analysis). • Accurately estimate risk using probabilistic-based methods	• Traditional 'probabilistic' methods are irrelevant for intractable systems. • Apply fast-and-frugal heuristics to assess risk and uncertainty, drawing on environmental cues when making ecologically rational judgments. • Focus on understanding the conditions where performance variability can become difficult or impossible to monitor and control
Quality management principles (Anticipation)	• Reactive, respond when something happens or is categorized as an unacceptable risk	• Proactively trying to 'anticipate what might go wrong' (i.e., requisite imagination) • Constantly monitoring for errors and potential rework
Quality management principles (Learning and improvement)	• Learn and improve from errors (defects, failures, and rework)	• Learning through errors (defects, failures, and rework) • Seek to understand 'what goes right' and 'what goes wrong.'

requested that an engineer not report a non-conformance estimated to cost over AU$ 100,000 to rectify. Instead, the project manager asked that the non-conformance be divided into smaller ones not exceeding AU $ 10,000 so as not to attract the attention of senior management. In this case, the 'company rule' was that any non-conformance over AU$ 100,000 must be immediately reported to senior management for scrutinization and approval. In this case, the project manager exercised their power to suppress the reporting of the non-conformance to deflect attention away from themselves and a potential caution about the project's performance.

3.3. Adherence to rules and procedures and reliance on technology

By following developed and established rules and procedures set out by a QMS, there is a perception that quality can be assured. Furthermore, digital technologies (e.g., Augmented Reality, BIM, and Virtual Reality) are advocated as solutions to minimizing errors and rework (Hwang et al., 2018; Autodesk Construction Cloud, 2023). Indeed, BIM can help with decision-making, reducing design changes often required in construction and enabling greater vigilance around the auditing and checking structural tolerances. However, using BIM to mitigate the errors that can result in poor quality-related outcomes occurring on-site is highly questionable. Such technology cannot accommodate or even be used to simulate people's (in)actions (Love et al., 2017; Love and Ika, 2022).

3.4. Measuring non-conformance and rework

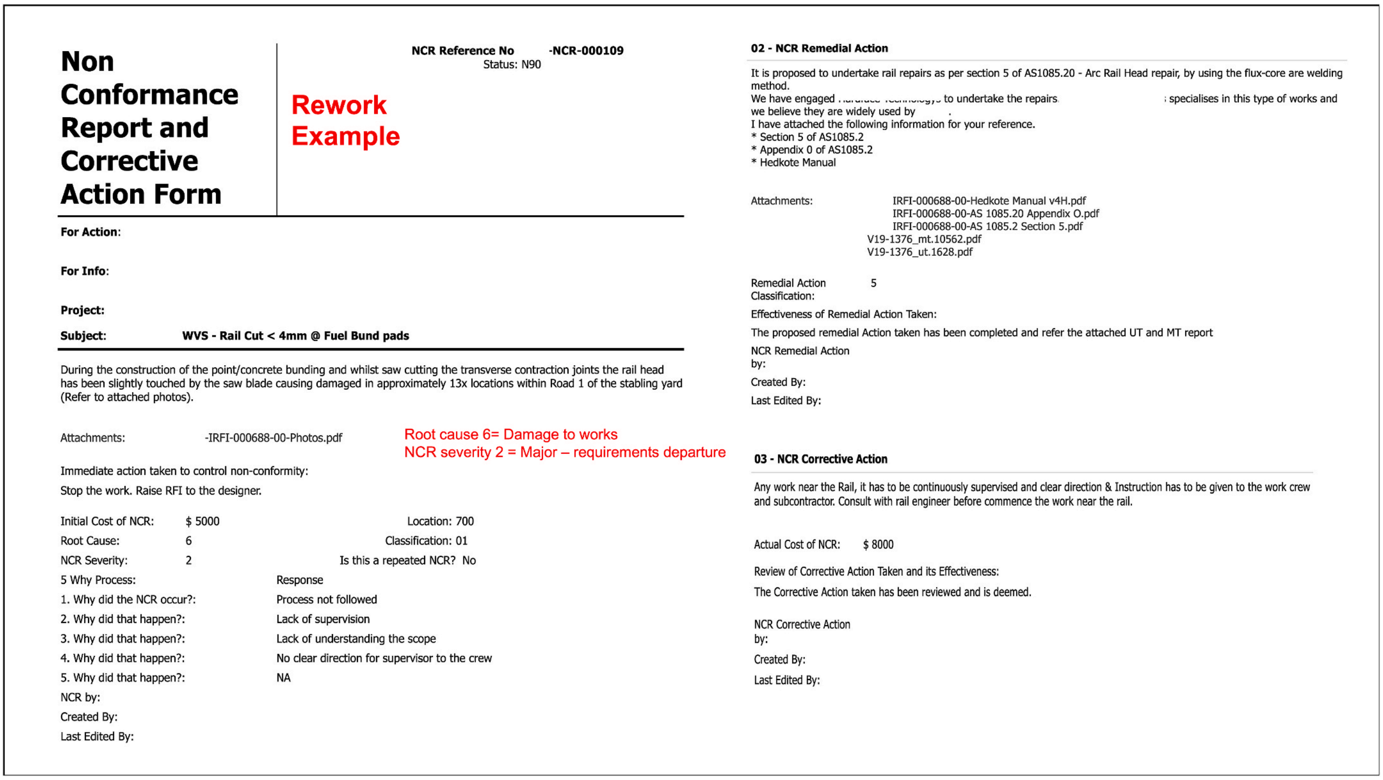
Many construction organizations only measure their rework based on the cost and number of non-conformances raised, even though poor quality may prevail and go unreported (Love and Teo, 2017; Olanrewaju and Lee, 2022). Furthermore, they seldom have a dedicated system to trace its rework costs (Matthews et al. 2022a, 2023) and causes, even though it can adversely impact organizational and project performance and productivity (Love et al., 2017; Love and Matthews, 2020).

The level of detail about non-conformance events and their classification can vary between construction organizations. However, there is a degree of commonality as a non-conformance report (NCR) will invariably include: (1) a description of the event; (2) type (e.g., rework, scrap, use-as-is and undefined); (2) root cause (e.g., design mistakes, inappropriate resourcing, and inadequate planning\construction method); (3) severity (e.g., >AU$ 100k, AU$ 20-$100k, <AU$ 20k); and impact (e.g., delay to work in progress, safety incident, and decrease in productivity). Additionally, we often see the '5 Whys' being applied to drill down to determine the root cause of a non-conformance and its contributory factors (Matthews et al. 2022a, 2023). Then, when a countermeasure becomes apparent, it is followed through to prevent the issue from recurring.

Examples of NCRs obtained from a construction organization involved with delivering an infrastructure project are presented in Figs. 1–3. It can be seen that the information contained within the NCR is scant, with the root cause identified as 'damage to works' requiring repair. Notably, within ISO 9000:2015, a repair is an action on a nonconforming product or service to make it acceptable for its intended use – basically re-doing work. There is little difference between the terms repair and rework, so construction organizations often use them interchangeably (Love and Teo, 2017). Thus, in this paper, we treat rework and repair to be synonymous.

3.5. Risk of rework

Our lines of inquiry into error and rework causation have led us to conclude that construction organizations eschew undertaking formal risk assessments of quality deviations (e.g., rework). This does not mean that all construction organizations do not undertake risk assessments for quality deviations, as traditional technical risk methods and probabilistic approaches are available and used to manage costs, time, and safety in projects (CII, 2001; Love and Sing, 2013; Senesi et al., 2015; Hulett, 2016; Tan and Khalid, 2019; Mostofi et al., 2022). Construction organizations have traditionally viewed rework as 'uncomfortable knowledge' (i.e., denied, deflected, displaced, or dismissed) – an *unacceptable risk* (Love et al., 2019c). As knowledge about rework has become available to construction organizations, efforts have started to try and predict its occurrence using probabilistic methods. However, such efforts have had minimal impact on mitigating its occurrence. Even though a construction organization may have no formal process to determine the likelihood of rework, site supervisors make judgments and decisions 'on the go', drawing on information immediately available to them to prevent it from happening (Love and Matthews, 2022c).



Non Conformance Report and Corrective Action Form

Rework Example

NCR Reference No **-NCR-000109**
Status: N90

For Action:

For Info:

Project:

Subject: **WVS - Rail Cut < 4mm @ Fuel Bund pads**

During the construction of the point/concrete bunding and whilst saw cutting the transverse contraction joints the rail head has been slightly touched by the saw blade causing damaged in approximately 13x locations within Road 1 of the stabling yard (Refer to attached photos).

Attachments: -IRFI-000688-00-Photos.pdf

Root cause 6= Damage to works
NCR severity 2 = Major – requirements departure

Immediate action taken to control non-conformity:
Stop the work. Raise RFI to the designer.

Initial Cost of NCR: $ 5000 Location: 700
Root Cause: 6 Classification: 01
NCR Severity: 2 Is this a repeated NCR? No

5 Why Process:	Response
1. Why did the NCR occur?:	Process not followed
2. Why did that happen?:	Lack of supervision
3. Why did that happen?:	Lack of understanding the scope
4. Why did that happen?:	No clear direction for supervisor to the crew
5. Why did that happen?:	NA

NCR by:
Created By:
Last Edited By:

02 - NCR Remedial Action

It is proposed to undertake rail repairs as per section 5 of AS1085.20 - Arc Rail Head repair, by using the flux-core are welding method.
We have engaged to undertake the repairs specialises in this type of works and we believe they are widely used by .
I have attached the following information for your reference.
* Section 5 of AS1085.2
* Appendix 0 of AS1085.2
* Hedkote Manual

Attachments: IRFI-000688-00-Hedkote Manual v4H.pdf
IRFI-000688-00-AS 1085.20 Appendix O.pdf
IRFI-000688-00-AS 1085.2 Section 5.pdf
V19-1376_mt.10562.pdf
V19-1376_ut.1628.pdf

Remedial Action Classification: 5

Effectiveness of Remedial Action Taken:
The proposed remedial Action taken has been completed and refer the attached UT and MT report

NCR Remedial Action by:
Created By:
Last Edited By:

03 - NCR Corrective Action

Any work near the Rail, it has to be continuously supervised and clear direction & Instruction has to be given to the work crew and subcontractor. Consult with rail engineer before commence the work near the rail.

Actual Cost of NCR: $ 8000

Review of Corrective Action Taken and its Effectiveness:
The Corrective Action taken has been reviewed and is deemed.

NCR Corrective Action by:
Created By:
Last Edited By:

Fig. 1. An example of an NCR requiring rework in the form of a repair is required due to damage.

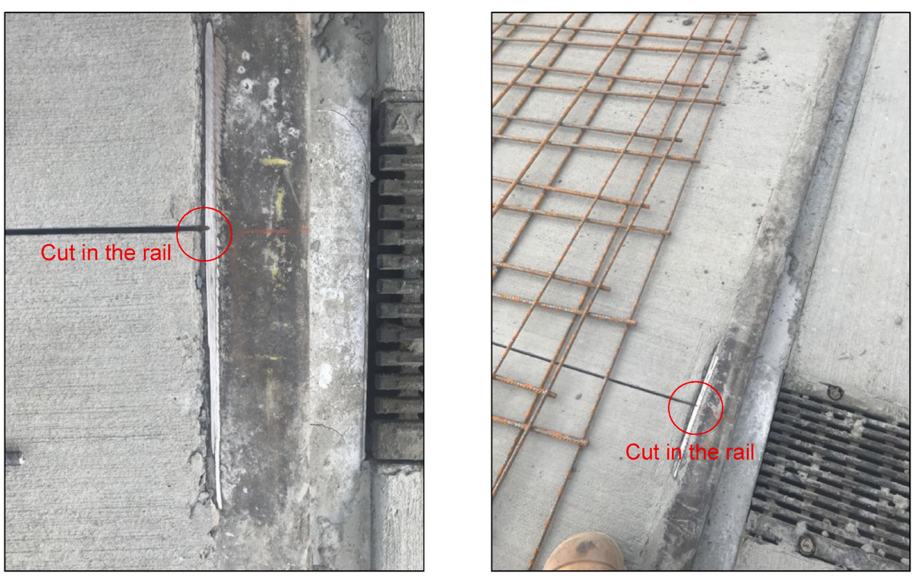


Fig. 2. A photograph of the damaged rail.

3.6. *Learning from errors and rework*

A reactive response is initiated when rework is required due to a non-conformance or another on-site issue (e.g., inclement weather). Resources are directed to undertaking the rework and also identifying who is accountable. Construction organizations seek to learn and initiate improvements (i.e., additional defenses are enacted) due to errors and rework to ensure they are not repeated.

Hindering a construction organization's ability to learn and improve from rework effectively is often attributable to not understanding *why* and *how* somebody made an error. People do not go to work to do a bad job; they do things that make sense to them given their goals, understanding of the situation, and focus of attention. In most cases, if something did not make sense to someone at the time, they would not have done it - this is known as the 'local rationality principle' (Dekker, 2006).

As the English poet Alexander Pope (1711) cogently remarked, "to err is human; to forgive, divine". It is only natural for people to commit errors. Construction organizations should accept that they happen and not seek to blame people should they occur. The problem facing construction organizations is not that 'bad people' cause errors and rework but rather that 'good people' work in poorly designed work settings.

Non Conformance Report and Corrective Action Form

NCR Reference No -NCR-000277
Status: N10

Rework (Human Error) Example

For Action:

For Info:

Project:

Subject: **Road Bridge Beam G11 Span 1 strand projection NCR**

After casting of Span 1 beam G11 the precast supplier Westkon have cut one of the projecting strands on one side of the beam at 100mm instead of cutting at 680mm from the concrete face.
The following information has been attached:
NCR form highlighting the strand location and images of the non conforming strand projection.
-Proposed solution using double couplers to extend the strand to 680mm projection with onion strand (pending designer approval).

Attachments: NCR 2035-02 Projecting strand cut.pdf
SKM_C554e21032517430.pdf

Immediate action taken to control non-conformity:

Once the issue was identified raised NCR form and provided details of a solution to rectify the issue which utilises double end couplers. This proposed solution was raised to the designers in IRFI-002878

Initial Cost of NCR: 2000 Location: 069
Root Cause: 1 Classification: 1.7
NCR Severity: 1 Is this a repeated NCR? No

5 Why Process:	Response
1. Why did the NCR occur?:	Human error resulted in the incorrect cutting of the strand at one end of the beam.
2. Why did that happen?:	Improper supervision by the precast supervisor.
3. Why did that happen?:	N/A
4. Why did that happen?:	N/A
5. Why did that happen?:	N/A

NCR by:
Created By:
Last Edited By:

Root cause 1 = Process *not* followed
NCR severity 1 = Minor

02 - NCR Remedial Action

Proposal - The proposed Remedial Action to rectify this non-conformance consists of...

Actual – The Remedial Action taken consisted of...

03 - NCR Corrective Action

Proposal - The proposed Corrective Action to rectify this non-conformance consists of...

Actual – The Corrective Action taken consisted of...

Actual Cost of NCR:

Review of Corrective Action Taken and its Effectiveness:
Proposal – The Corrective Action proposed has been reviewed and is deemed...

Actual – The Corrective Action taken has been reviewed and is deemed...

NCR Corrective Action by:
Created By:
Last Edited By:

One of the projecting strands cut at 100mm

Comments by Pre-cast subcontractor:
A beam had one of its projecting strands cut with 100mm projection instead of cutting at 680mm from the concrete face

Accidently cut due to human error

The use of 2 no, double ended coupler to extend the cut strand proposed by the pre-cast subcontractor.

The yard foreman was informed about this instance and told to pay more attention during the cutting of strands and to avoid recurrence

Fig. 3. An example of NCR requiring rework due to human error.

Quality II aims to redress the shortcomings of Quality I and provide construction organizations with a frame of reference to reduce and contain errors and mitigate rework in their projects. Error reduction incorporates measures designed to limit the occurrence of errors (Reason, 1997). Likewise, error containment focuses on measures designed to limit the adverse consequences of those errors (Reason, 1997).

4. Quality II paradigm

The Quality II paradigm accepts that errors happen. It was initially underpinned by error management (Love et al., 2023a). However, as a result of observations from practice, the concepts of psychological safety, psychological contract, and resilience have been added (Love and Matthews, 2022d). We suggest a Quality II paradigm provides a robust approach to ensure people perform their work within a 'Get it Right First Time' framing and feel safe about error-making. Hence, we view Quality II as an *organizational/project system that acknowledges that errors happen and, regardless of whether their outcomes are positive* (e.g., *innovation) or negative* (e.g., *rework), quickly adapts and responds by 'learning through' their occurrence to enable sustained continuous improvement.*

4.1. Errors, learning, and innovation

Errors can be good or bad (Gigerenzer, 2014). Good errors are those that need to be made as they can enable the discovery of something that we did not intend to unearth – such discovery is referred to as *serendipity*, which forms the grassroots for innovation (Weisenfeld, 2009). Traditionally, construction organizations have struggled to innovate for various reasons (Bygballe and Ingemansson, 2014; Brockmann et al., 2016). It is a high dollar value, low-profit margin, and competitive industry. There is an incentive to find cheaper and more efficient ways of doing things, which requires investment and may involve change. Construction organizations have tended to be reluctant to invest in technological and organizational innovations due to the risks involved and a fear that they will not deliver a return on investment (Matthews et al., 2018). Moreover, by focusing on error prevention, they have little chance to learn from errors as there is a reluctance to report them, hindering an organization from discovering new opportunities.

Besides the error types we identify above in Section 2.3, other sources of bad errors for construction organizations are the zero-risk[6] illusion and the turkey illusion.[7] Institutionalizing an organizational mindset where no errors can be made is a good example of a bad error (Gigerenzer, 2014). Thus, creativity, intelligence, and innovation "cease if people are prohibited from making errors" (Van Dyck et al., 2005; Gigerenzer, 2014: p.49; Frese and Keith, 2015).

4.2. Strategic decisions and latent conditions

Placing a prohibition order on error-making is impossible – the fragility of a human being would be negated. Thus, how organizations manage errors should be their focus. As Deming (2000) noted, it is not the errors that must be avoided, but rather its negative consequences. Furthermore, errors should be viewed "as consequences rather than causes, having their origins not so much in the perversity of human nature" but instead in "upstream" systemic factors" manifesting as latent

[6] In this case, construction organizations believe that errors and rework, for example, will not happen in their projects.

[7] The turkey illusion is a cognitive bias (Russell, 1912; Gigerenzer, 2020) and is also known as the 'problem of induction'. It is a philosophical concept that refers to the tendency of individuals to make inductive conclusions based on past experiences or observations. The illusion arises because of the assumption that what has happened in the past will continue to happen in the future. While we are only concerned actions errors in this paper, such an illusion can influence an organization's error culture and its approach to managing rework risks. If rework has not happened in past projects, it will not have in future ones. Hence, it is deemed to be uncomfortable knowledge.

conditions (Reason, 2000: p.768).

Such latent conditions arise from strategic decisions taken by senior management within a construction organization. Equally, they can arise in projects from client, financier, and stakeholder decisions (Love et al., 2019c). Two adverse effects can materialize from latent conditions as they can (Reason, 2000: p.769): (1) create weaknesses in the defenses (e.g., unworkable procedures and design and construction deficiencies); and (2) translate into error-provoking conditions within a project (e.g., acceptance/submission of low bids, production pressure, understaffing, inadequate equipment, and stress and fatigue).

4.3. Conceptual framing for quality II

In Fig. 4, we provide our conceptual framing for Quality II and its core concepts derived from exemplars of best practices that have arisen during the construction of infrastructure projects: (1) error management, (2) psychological safety; (3) psychological contract; and (4) resilience. Each of these concepts is described below.

Both error management and resilience are organizational mechanisms that engender and facilitate psychological safety in work teams and an individual's psychological contract. Expected outcomes, to name a few from Quality II, are innovation, learning, improved organizational performance, and individual physical and psychological well-being.

While four fundamental concepts form the basis of Quality II, the leadership and culture within a construction organization and its portfolio of projects will influence their effective implementation. The organizational practices of error management identified in Fig. 4 are by-products of a high-organizational error management culture. In this instance, reducing the negative and promoting positive error consequences forms the underlying cultural norms within the construction organization and its projects.

Indeed, leadership styles within a construction organization will vary. Enacting Quality II requires senior management level to embrace a transformational style of leadership (i.e., inspiring change) and focus on developing their managers (e.g., construction, engineering, quality, and safety) to become authentic leaders (i.e., emphasis on honesty, integrity, and transparency) when delivering their projects. Authentic leadership is needed to build trust and stimulate work engagement in teams, and in doing so, it facilitates psychological safety.

Traditionally, construction organizations have been slow to adopt technology in their projects. Nevertheless, with rapid developments in digital technologies brought about by artificial intelligence, construction organizations realize their benefits (e.g., improved quality control, safety, and productivity). Accordingly, digital technologies have a pivotal role to play in reducing and containing errors and, therefore, need to be integrated into the organizational practices of error management. It is out of the scope of this paper to provide a review of 'how' technology can mitigate errors and rework in construction. As a matter of fact, empirical studies examining the role of technology, in this case, have not been forthcoming (Matthews et al., 2022a, 2023). However, we must point out that technology should be treated as an 'enabler' and not a panacea for managing quality in construction (Matthews et al., 2022a, 2023).

Even though a construction organization may actively advocate and implement the concept of Quality II, its effective deployment within a project will be governed by the *design* of the project delivery system. Traditional forms of project delivery, for example, are a breeding ground for information asymmetry, adverse selection, moral hazards, and opportunistic behavior. Moreover, the goals and objectives of participating organizations often diverge and conflict. As a result, when errors arise, organizations look to apportion blame and accordingly seek financial compensation for any deviations in planned work to maximize their profit. The design of the traditional project delivery system (i.e., sequential and separated design-bid-build) is incompatible with the goal of Quality II and will undoubtedly hinder the ability of a construction organization to put into practice its concepts effectively (Love and Matthews, 2022a).

As mentioned above, the concepts of Quality II identified in Fig. 4 are garnered from experiences and practices identified from projects delivered through Alliancing, a collaborative form of project delivery (Love

Fig. 4. Conceptualization of the quality II paradigm.

and Matthews, 2022a; Love et al., 2023a). The design of an alliance focuses on three fundamentals (Love et al., 2015): (1) *one team* - creating a single integrated team to deliver a project; (2) *one voice* - developing and establishing a joint governance framework; and (3) *one outcome* - all parties 'sink or swim' together. Decisions are made on a 'best-for-project' basis, and a no-blame culture exists. A unique feature of an alliance is its commercial framework, as it is based on a three-limb remuneration regime (Love et al., 2015).

1. The client or Project Owner (PO) reimburses all direct and indirect, specific overhead costs incurred by Non-owner Participants (NOP, typically comprising the design team and construction organization) if the agreed target outturn cost is exceeded.
2. Each NOP is entitled to an amount for profit and contribution to overheads – referred to as the 'Fee' that the NOP would expect to receive for the 'business-as-usual' performance of the work.
3. Each NOP is entitled to a 'gain-share payment' *from the owner* or will be liable to make a 'pain-share payment' *to the owner*, depending on how the alliance performs against an agreed target cost and completion date and other agreed-on Key Result Areas (KRA).

Typical KRAs include innovation, safety, community engagement, sustainability, diversity, and social procurement. Seldom is quality identified as a KRA in an 'Alliance Project Agreement' (i.e., the contractual form specifying behavioral requirements and expectations). However, when it is, the NOP becomes incentivized, rework can be reduced, and safety performance can be improved (Love et al., 2016b).

4.3.1. Error management

The concept of error management commences after an error has occurred and "attempts to block negative error consequences or to reduce their adverse impact through design or training" (Frese and Keith, 2015: p.665). Examples of quotes derived from several studies that have uncovered the incidence of organizational error management practices in projects delivered using a collaborative project delivery system are identified in Fig. 5 (Love et al., 2015, 2016b, 2018b, 2019c; Love and Matthews, 2022a).

Error management was initially intended as an add-on to error prevention (Frese, 1991). In doing so, it is deemed to be a better way to handle errors. Thus, error prevention and management are mutually inclusive (Van Dyck et al., 2005; Frese and Keith, 2015; Dimitrova et al., 2017). Accordingly, the high-reliability organizations' literature indicates that combining error prevention with error management will be more adaptive than using either approach alone (Weick and Sutcliffe, 2007; Frese and Keith, 2015). As a result of this combination, their strengths are perceived to be amplified, and their weaknesses are minimized (Dimitrova et al., 2017). Despite the perceived benefits of using error management as an addition to error prevention, studies examining whether they individually or both contribute to producing beneficial performance outcomes for organizations have been limited (Dimitrova et al., 2017; Love et al., 2022b; Matthews et al. 2022b). In a controlled environment, error prevention has "negative effects on cognition[8] and adaptive transfer performance,[9], and error management alleviated worry and boosted one's perceived self-efficacy" (Dimitrova et al., 2017: p.658).

Within the context of construction projects, error management as an add-on to error prevention has been identified as an ineffective approach for error handling and reducing rework (Love et al., 2022b; Matthews et al., 2022b). It has been shown that error management (i.e., positive) and error prevention (i.e., negative) are contradictory to one another in their effect on reducing rework in projects (Love et al., 2022b; Matthews et al., 2022b). When an error prevention mindset prevails, people worry about making errors, which is counterproductive to creating psychological safety in teams. However, psychological safety is critical to well-being and enhancing employee voice and commitment (Edmondson, 1999; Edmondson and Lei, 2014).

4.3.2. Psychological safety

Psychological safety facilitates the sharing of knowledge, provides employees with a 'voice' (i.e., speak up) to suggest areas for improvement, the confidence to embrace innovation, the capacity to identify more productive ways to perform their work, and the ability to learn (Edmondson, 1999; Edmondson and Lei, 2014). In its basic form, psychological safety is defined as the "shared belief held by members of a team that the team is safe for interpersonal risk-taking" (Edmondson, 1999: p.350).

Construction organizations recognize that psychological safety is needed to combat workplace safety incidents and improve employee well-being (e.g., mental health issues) (Shen et al., 2015; Agarwal and Anantatmula, 2021; Green, 2022). However, organizations often struggle with implementing psychological safety as it is shoehorned into their established error prevention culture, neglecting to consider and nurture the corresponding behavioral changes needed to bolster its growth (Love et al., 2023a). Adding to the mix, it has been observed that the drive to improve project performance has been the sole motivation for embracing psychology safety (i.e., extrinsic value) rather than providing a 'healthier' work setting (i.e., intrinsic value) (Cunha et al., 2018). When this situation arises, any appeal to employees to speak up can result in them mulling over the risks and benefits before doing so (Clampitt, 2001; Cunha et al., 2018), as was shown to occur in Love et al.'s (2019b) study. In this case, people only decided to speak up to preserve their self-interests and to shield themselves from blame.

So, the justification for embracing psychological safety should not be based on "instrumental and managerial" assumptions (Cunha et al., 2018: p.842). However, creating a genuine work setting that fosters psychological safety requires construction organizations and their managers to ensure their employees are "cared for as people" (Cunha et al., 2018: p.842). Reinforcing this point, Love et al. (2019b) observed that the alliance management team not only focused on creating a safe environment where people's well-being was given priority and speaking up was valued within the NOP, but this was also extended to its subcontracting workforce. A KRA for the alliance was to engage local subcontractors and build their capacity to perform work for PO after the disbandment of the alliance. Providing subcontractors with a voice allowed the alliance to reassure them of its steadfastness in recognizing 'errors happen' and their desire to work collaboratively to mitigate any need for rework.

Psychological safety takes time to develop within an organization, but this can be accelerated and enabled effectively through institutionalizing and legitimizing the organizational practices of error management (Love and Smith, 2016). They can provide employees with the confidence to speak up about errors. However, building a psychologically safe work climate in the context of projects is challenging due to their ephemeral nature and the transience of the workforce, hindering the formation of trust. Indeed, building trust between organizations participating in a project has been and remains a ubiquitous problem in construction (Latham, 1994; Egan, 1998; PSIBouw, 2003; Laan et al., 2011). Within the context of public infrastructure procurement, governments worldwide have sought to redress this issue by re-evaluating their approaches to project delivery (Walker, 2018; Walker and Rowlinson, 2019; Love et al., 2021).

Collaborative project delivery, such as Alliancing and Integrated Project Delivery (IPD) and variants, emerged to engender trust and

[8] Cognition in this case refers to on-task thoughts and negative self-related off-task thoughts. "On-task thoughts are defined as directed attention towards a specific task whereas off-task thoughts involve disengaging attention away from goal-directed action" (Dimitrova et al., 2017, p.660).

[9] Adaptive transfer performance involves using one's existing knowledge base to change a learned procedure or to generate a solution to a completely new problem (Ivancic and Hesketh, 2000: p.1967).

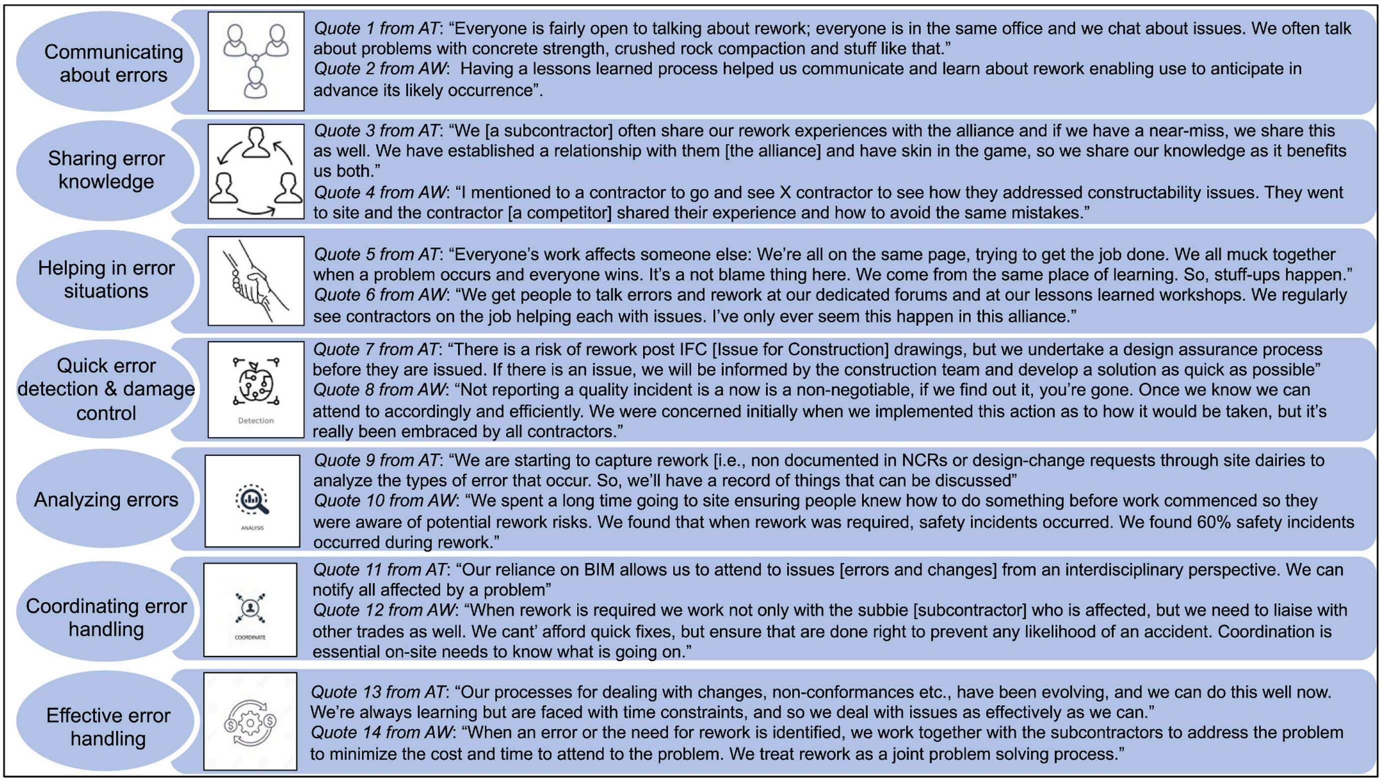


Fig. 5. Error management organizational practices.

establish and maintain relationships between organizations in projects (Walker, 2018; Walker and Rowlinson, 2019). However, procuring a project using a collaborative delivery system does not automatically establish psychological safety (Love et al., 2019b). Besides striving to execute error management practices in a project, it was observed in an alliance that a psychological contract needs to be introduced to help further nurture trust and goodwill not only between the PO and the NOP but also between the construction organization and its subcontractors (Matthews et al., 2022b). Thus, we consider the psychological contract an essential ingredient to shape the behaviors and attitudes desired to uphold Quality II.

4.3.3. *Psychological contract*

The concept of the psychological contract is grounded in social exchange theory, where employees are motivated by maintaining a balance between inputs and outputs when reciprocity is sought in social transactions (Blau, 1964; Rodwell and Ellershaw, 2015). In a psychological contract, promises, expectations, and reciprocal obligations are implied – a social exchange aims to overcome power imbalances between an employee and employer (Newaz et al., 2019). A psychological contract can be defined as "the idiosyncratic set of reciprocal *expectations* held by employees concerning their *obligations* (what they will do for the employer) and their *entitlements* (what they expect to receive in return)" (McLean Parks et al., 1998 p.697).

Four types of psychological contracts have been identified based on the attributes of 'time frame' and 'tangibility' (Rousseau, 1995; Van den Brande et al., 2003) marrying with the nature of projects and their contracts: (1) *transactional*, characterized by a short-term employment relationship where performance requirements or mutual obligations are unambiguously specified (i.e., high tangibility). In such contracts, there is "low ambiguity, low member commitment, high turnover, limited learning, and weak integration" (Van den Brande et al., 2003: p.1351); (2) *relational*, which is characterized by a long-term employment relationship where mutual obligations cannot be unambiguously specified. (3) *balanced or team player*, characterized by the high tangibility of the transactional psychological contract and long-time frame of a relational one; and (4) *transitional*, characterized by a short-term time frame and low tangibility.

Within the alliances examined by Love et al. (2023a), for example, the psychological contract between the PO and NOP tended to align with the 'balanced or team player' and was used to establish behaviors required to achieve the KRAs. According to Van den Brande et al. (2002), this type of contract is suited to dynamic workings where there is a "high-involvement [project] team with high member commitment, high integration/identification, ongoing development, and mutual support" (p.5). However, the psychological contract between NOP's construction organization and its subcontractors varies between transactional and relational due to the importance and consistency of the work. Irrespective of the forms of psychological contracts deployed in the alliances and projects examined by Love and Matthews (2022a) and Love et al. (2023a), trust and fairness formed the heart of its people strategy, which was enacted by maintaining open dialogue and managing all parties' expectations.

Beyond using psychological contracts in alliances to help them meet their KRAs, they are seldom *formally* considered when projects are delivered using traditional delivery systems and are only enacted to foster a positive safety climate (Newaz et al., 2019). During construction, supervisors and subcontractors assume the role of 'Safety Agents' where promises between them are implied, obligations reciprocated, and expectations about workplace safety are made explicit (Melia et al., 2008). For example, the site supervisor will be expected to develop safety plans, maintain equipment, and conduct regular safety training. Likewise, subcontractors must work diligently and adhere to a specific 'Code of Conduct' identified in Fig. 5. Pragmatically, the psychological contract can be viewed as a mechanism that can influence the behavior of parties and "at worst a management tool to help employers [i.e., the supervisor] effectively manage employees [subcontractors]" (Newaz et al., 2019: p.11).

Recognizing that many safety incidents arose due to rework, an alliance's construction organization extended its psychological contract with its subcontractors to incorporate quality-related actions (Love et al., 2015). As shown in Fig. 6, an alliance identified a series of actions that were 'non-negotiable'. It was made explicit in the 'Code of Conduct' that "No Harm is a belief that harm, damage or work can be prevented" and required all subcontractors to commit to working in accordance with their expectations and requirements. To this end, we suggest that when KRAs are established for an alliance project, quality is added and treated equally with safety when formulating a psychological contract. Simultaneously, considering quality and safety in a psychological contract makes construction organizations and subcontractors resilient to error-making.

4.3.4. Resilience

Resilience, the final Quality II key concept to be discussed, is often synonymous with being adaptive, robust, and flexible. It can help construction organizations and projects cope with whatever anticipated errors might emerge (Wildavsky, 1991) and absorb and proactively respond to "discrete environmental jolts" (Williams et al., 2017: p.740). Wildavsky (1991) refers to anticipation as a "mode of control by a central mind; efforts are made to predict and prevent potential dangers before damage is done" – an innate feature of error management (p.77).

Anticipation is a core feature of Westrum's (1991) 'requisite imagination', which focuses on the ability to imagine critical aspects of the future we are planning. So, 'anticipating what might go wrong' and how to test for problems when a design is developed form the basis of requisite imagination (Westrum and Adamski, 1999). However, it can also be extrapolated to visualize issues that manifest during construction, operations, and maintenance" (Love and Matthews, 2020: p.4).

It has been observed in projects where psychological safety and contracts implicitly thrive and are used as mechanisms to combat the issues associated with rework during construction, site supervisors constantly monitor work and engage in open dialogue with their team members and subcontractors to determine the direction from which trouble [e.g., errors] is likely to arrive (Love et al., 2023a). Harnessing an understanding and knowledge about *how failure* can be avoided and *how success* is obtained from communicating and sharing experiences in projects can enable 'learning through' errors to occur.

Such learning enables a construction organization to adapt to create a 'Get it Right First Time' mindset in settings fraught with gaps, hazards, trade-offs, and multiple goals (Weick, 1987). In this instance, this allows a construction organization to understand "what sustains and what erodes its ability to adapt to changing pressures" and how to learn to produce quality outcomes "rather than focusing on an error as an end in itself" (Jeffcott et al., 2009: p.256). So, rather than focusing on eliminating the risk of poor quality, which Quality I aims to do, Quality II, through its resilience dimension, seeks to implement strategies to cope with, reduce, and contain those errors that can result in rework and failure. Three rudiments of resilience enable construction organizations to anticipate failure and learn how to adapt and restore conditions after an adverse event (e.g., rework) (Jeffcott et al., 2009; Love et al., 2022a).

1. *Foresight*: the ability to predict something 'bad' happening;
2. *Coping*: the ability to prevent something 'bad' from becoming worse;
3. *Recovery*: the ability to recover from something 'bad' once it has happened.

Seven principles of resilience have been identified (Wreathall, 2006): (1) top-level managerial commitment; (2) just culture; (3) learning culture; (4) awareness; (5) preparedness; (6) flexibility; and (7) opacity. Without management commitment, none of the concepts making up Quality II can be enacted. Management commitment is needed to help build a positive workplace culture and facilitate employee empowerment and improved levels of job satisfaction. Both a 'just' culture[10] and a learning culture[11] are accommodated within an error management culture underpinning Quality II. The remaining principles (4–7) are defined in Table 2.

Methods and tools to effectively extract error and rework information to apply learnings from projects within the context of resilience have not been defined within the Quality II paradigm we have proposed (Matthews et al., 2022a, 2023). However, as a starting point, tools that focus on measuring, improving, and predicting resilience must be developed to align with its principles. Such tools can support resilience by "signalling how to make trade-offs in the face of performance pressures" while ensuring quality, and safety are not compromised (Jeffcott et al., 2009: p. 259).

5. Discussion

Many construction organizations will be comfortable adopting a Quality I paradigm where there is a need to prevent errors. This an understandable position to take, but this has not translated into improvements in quality. Explicitly, Quality I is not working, considering the level of error, rework, and failures that manifest during and post-construction. The belief that adhering to Quality I will make construction organizations competitive is no longer valid. Such a belief holds them hostage to repeatedly doing the same things but expecting different results.

When an organization challenges its *raison d'être,* its purpose (i.e., strategic goals and motivation) is questioned. As a result, new beliefs and expectations can materialize, and 'what used to work' is no longer appropriate to remain competitive and survive. Some construction organizations have begun to develop new beliefs and expectations about managing errors and rework. In doing so, they seek to develop breakthrough ways to deal with their productivity and performance issues and realize the benefits of adopting technology. Quality II is a new emerging paradigm that can help organizations understand 'old challenges' differently. The problems that may have appeared intractable under a Quality I paradigm can now be effectively addressed with Quality II (Love and Matthews, 2022a; Love et al., 2023a).

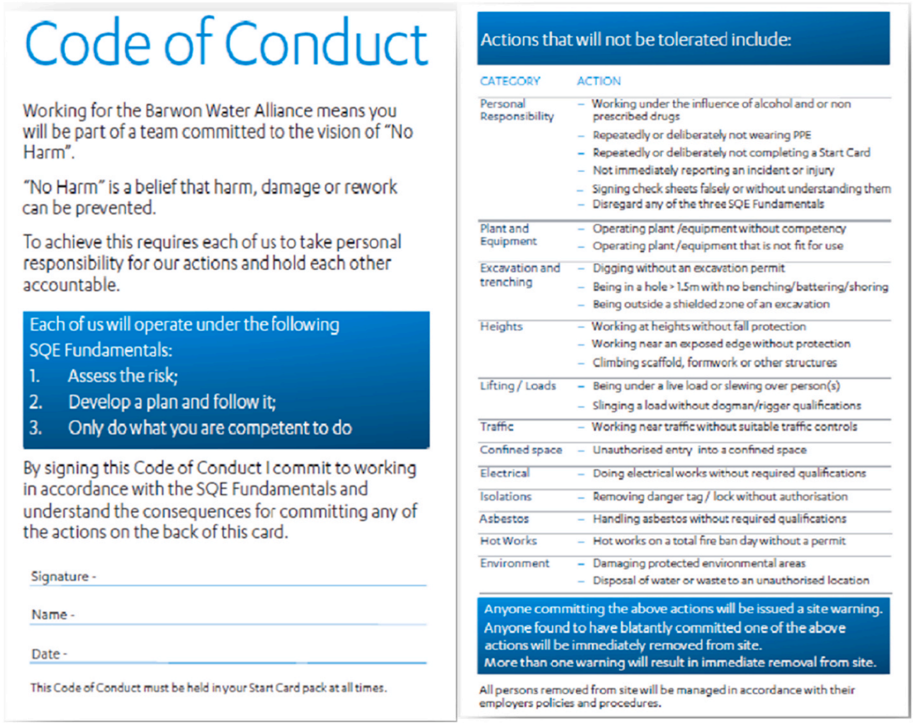
5.1. Implications for theory

To reiterate, we use the terms Quality I and Quality II to align with contemporary thinking and developments in safety, even though the literature in construction has tended to overlook the importance of the relationship between quality and safety. The situation has arisen due to quality being generally viewed as an abstraction. In this case, it does not exist as a discrete entity but instead, as a construct based on the "interaction among relevant actors who agree about standards (the norms and values) and components (the possibilities)" (Mitchell, 2008: p.11). The corollary is that safety performance is treated separately from quality as its outcomes are immediately tangible and of concern, and legislation dictates the requirement for a 'no harm' workplace.

For example, quality and safety are given equal credence within the medical literature – they are indistinguishable – especially within the context of addressing errors (Corrigan et al., 2004). In Australia, safety performance in construction has improved marginally over the last decade, but fatalities and accidents remain a problem (Safe Work Australia, 2022). While this is somewhat heartening, it is still unacceptable despite the continued effort made by construction organizations to improve workplace safety. Alas, we are also seeing a significant

[10] A 'just' culture attempts to manage human fallibility through system design and behavioral choices within an organization.

[11] A learning culture in construction is comprised of a set of organizational values, processes, and practices that encourage employees, and the organization (and projects), to continually learn and add new skills (Holt et al., 2000).



Code of Conduct

Working for the Barwon Water Alliance means you will be part of a team committed to the vision of "No Harm".

"No Harm" is a belief that harm, damage or rework can be prevented.

To achieve this requires each of us to take personal responsibility for our actions and hold each other accountable.

Each of us will operate under the following SQE Fundamentals:
1. Assess the risk;
2. Develop a plan and follow it;
3. Only do what you are competent to do

By signing this Code of Conduct I commit to working in accordance with the SQE Fundamentals and understand the consequences for committing any of the actions on the back of this card.

Signature -

Name -

Date -

This Code of Conduct must be held in your Start Card pack at all times.

Actions that will not be tolerated include:

CATEGORY	ACTION
Personal Responsibility	– Working under the influence of alcohol and or non prescribed drugs – Repeatedly or deliberately not wearing PPE – Repeatedly or deliberately not completing a Start Card – Not immediately reporting an incident or injury – Signing check sheets falsely or without understanding them – Disregard any of the three SQE Fundamentals
Plant and Equipment	– Operating plant /equipment without competency – Operating plant /equipment that is not fit for use
Excavation and trenching	– Digging without an excavation permit – Being in a hole > 1.5m with no benching/battering/shoring – Being outside a shielded zone of an excavation
Heights	– Working at heights without fall protection – Working near an exposed edge without protection – Climbing scaffold, formwork or other structures
Lifting / Loads	– Being under a live load or slewing over person(s) – Slinging a load without dogman/rigger qualifications
Traffic	– Working near traffic without suitable traffic controls
Confined space	– Unauthorised entry into a confined space
Electrical	– Doing electrical works without required qualifications
Isolations	– Removing danger tag / lock without authorisation
Asbestos	– Handling asbestos without required qualifications
Hot Works	– Hot works on a total fire ban day without a permit
Environment	– Damaging protected environmental areas – Disposal of water or waste to an unauthorised location

Anyone committing the above actions will be issued a site warning.
Anyone found to have blatantly committed one of the above actions will be immediately removed from site.
More than one warning will result in immediate removal from site.

All persons removed from site will be managed in accordance with their employers policies and procedures.

Fig. 6. Example of a 'Code of Conduct' for quality and safety.

increase in severe claims for mental health conditions (e.g., anxiety and stress) (Safe Work Australia, 2022). As prevailing safety paradigms in construction are implemented as discrete entities, they ignore how they impact other aspects of a project's system. A case in point is treating rework as uncomfortable knowledge despite its significant impact on safety performance. This has contributed to limited progress being made in reducing on-site fatalities and injuries (Love et al., 2018c).

While safety paradigms have been propagated and grounded in overarching, general assumptions about the world in which construction projects are procured, no such paradigms have been developed for quality. This paper fills this void. It promulgates Quality II, which aligns with Safety II and aspects of Safety III. The four main concepts that constitute Quality II are each supported by a robust theoretical underpinning and can be applied equally to address quality and safety. Therefore, Quality II provides the foundation for developing a theory to describe the 'quality-safety' phenomena that pervade practice. Such a theory is absent from the construction literature. In making headway to develop a holistic theory, our Quality II paradigm provides the set of assumptions, concepts, values, and practices that represent state-of-the-art thinking, routines, and procedures needed to explain error-making and rework and the influence on safety performance.

5.2. Implications for practice

We have developed Quality II based on observed values, expectations, and practices from projects procured using collaborative forms of delivery. Such projects are 'designed' to create mutually beneficial relationships between contracted parties. The project team is financially incentivized to deliver pre-determined outcomes and adhere to implementing a 'no-blame' culture. Generally speaking, these principles cannot be found outside collaborative project delivery systems, though in the case of Design and Construct methods, 'guaranteed maximum price' with savings sharing can sometimes be found in contracts.

The operationalization of Quality II as an entity will be challenging for construction organizations accustomed to enacting Quality I proclivities and delivering projects using traditional means. At the organizational level, Quality II can be applied and transferred to the project they are delivering, but the values and practices established may not align with other parties' view of managing error; managing conflicts and tensions that may arise will have to be negotiated so as not to cause disputes.

A clarion call by the Australian Constructors Association (2022) has been made to address the industry's low productivity levels and inability to innovate by using collaborative forms of contract so that organizations focus on "achieving best for project outcomes rather than what is best for any one particular party" (p.5). The public and private sectors need to take heed of this call if they want to obtain value for money from their projects. The Quality II paradigm proposed in this paper can contribute to overcoming productivity problems confronting organizations. It proactively aims to mitigate the negative consequences of errors and harness the benefits of good errors to enable innovation.

Switching from a mindset of 'errors must be prevented' to 'errors happen' requires an organization to question the 'status quo' and embrace change, which many struggle to embrace successfully. At the organizational level, resistance to change is often driven by fear of being unable to adapt to new ways and uncertainty. Nevertheless, with commitment and support from a construction organization's senior management, the change process can be nurtured and navigated efficaciously as long as employees are actively involved, consulted, listened to, and made to feel an integral part of the Quality II journey.

6. Conclusion

Adherence to the Quality I paradigm has resulted in many construction organizations focusing on incremental improvements, which has been ineffective in mitigating rework. The assumptions underpinning Quality I have gone unchallenged, which has hindered the ability of construction organizations to learn, innovate, and improve their productivity. In this paper, we introduce a new paradigm derived from best practices unearthed during the construction of alliance projects that can be drawn upon to manage errors and mitigate rework. We have called this paradigm Quality II so that it aligns and can be used in conjunction with contemporary safety approaches (e.g., Safety II and III) that have been developed. After all, quality and safety have a symbiotic relationship.

Our Quality II paradigm comprises four theoretical constructs: (1) error management; (2) psychological safety; (3) psychological contract; and (4) resilience. Indeed, each construct can be individually implemented in construction and contribute to incremental improvements in practice. However, when they are combined under the umbrella of a Quality II paradigm and subsequently used to support the procurement of projects using a collaborative delivery system, their impact is likely to be profound as learning through errors will occur, resulting in improved productivity (e.g., reduced rework and safety incidents) and innovation.

While our Quality II paradigm has emerged as a response of construction organizations with an alliance to mitigating rework in their projects, whether it is fit for purpose for the industry remains to be seen. Undoubtedly, there will be cynics of the Quality II paradigm as it fundamentally questions existing views of the world in construction. However, if organizations refuse to embrace new ways of looking at their problems, we anticipate that they will not survive.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Peter E.D. Love and Jane Matthews reports financial support was provided by Australian Research Council.

Data availability

No data was used for the research described in the article.

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