Praxis of Rework Mitigation in Construction

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Abstract: Rework is a pervasive problem within the construction industry, but many firms are reluctant to openly acknowledge it is an issue because it can potentially damage their reputations. Using a case study approach, this paper aims to examine how an AU$375 million program alliance, which experienced cost and schedule overruns and an increase in safety incidents as a result of rework, addressed this problem. The case analysis revealed that rework could be significantly reduced by having an authentic leadership style in place, empowering as well as actively engaging with contractors, and focusing on continuous improvement. As a result, the alliance was able go beyond lessons that were superficial (i.e., identifying procedures that were not followed) and undertake new and improved ways of doing business that encompassed context-specific learning. The novelty of the case study findings highlights the need to reduce rework by focusing greater attention on changing behaviors, particularly the motivations of alliance team members, by cultivating an error management culture. Such a culture needs to be harnessed in construction projects if rework is to be reduced and adopted industrywide, which necessitates the need for significant steps toward improving performance and productivity. **DOI: 10.1061/(ASCE)ME.1943-5479.0000442.**

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Introduction

The tasks of correcting errors, attending to changes in scope, quality deviations, and nonconformances are commonly referred to as *rework*, which is a wasteful and nonvalue-adding activity. Rework has been defined as "the unnecessary effort of re-doing a process or activity that was incorrectly completed the first time" (Love 2002, p. 19). It can have an adverse influence on productivity (Rojas and Aramvareekul 2003), cost and schedule performance (Hwang et al. 2009), and safety (Wanberg et al. 2013). Reported costs of rework have been found to range from 3.5 to 25% of a project's contract value (e.g., Barber et al. 2000; Josephson et al. 2002), though this variance is primarily attributable to the way in which it is calculated and how it is determined (i.e., case studies and questionnaires). Despite such disparities, rework remains a pervasive problem in construction and engineering projects (Han et al. 2013). Surprisingly, rework has largely been ignored and deemed to be a normal function of operations (Moore 2012).

Rework costs are implicitly accommodated within a project's cost contingency (Baccarini and Love 2014), though an explicit allowance for it is unacceptable to clients and contractors because it is deemed a process that should not occur. Indeed, contractual tenders that include cost, time, and disruption due to rework render consultants and contractors potentially uncompetitive. With increasingly tighter profit margins and lower productivity rates being experienced, particularly in Australia (Eslake and Walsh 2011), rework is untenable as business competitiveness is severely jeopardized. To prevent rework, various approaches are being promulgated, which include visualization enabled technologies [e.g., building information modeling (BIM)], modularization, lean construction, constructability reviews between design and construction teams, and relationship-based procurement (RBP). Research has revealed that there was no significant difference between the cost and causes of rework experienced with projects procured using traditional and nontraditional procurement methods (Love et al. 2009). However, a caveat was placed on these findings, as alliances were not sampled. Subsequent research, however, has implied that the risk/reward compensation models, which are an innate feature of cost-competitive alliances in conjunction with predetermined key performance indicators (KPIs) could reduce rework (Walker and Lloyd-Walker 2014).

Alliances provide an environment where shared responsibility and accountability are generated between a client (also referred to as the *owner participant*) and "key design and contractor organizations" (referred to as *non-owner participants*) so that optimum outcomes can be achieved (Walker and Harley 2014, p. 6). Alliances also provide the underlying framework to establish people-orientated values, a no-blame culture, and consensus decision-making, which can ensure that a "we all sink or swim" mindset prevails within a project team (Walker and Harley 2014). According to Bresnen et al. (1986) and Rowlinson et al. (2006), a project manager's leadership style can influence a project's outcome and the project team's ability to learn and adapt to change. A manager's leadership style is therefore central to ensuring a

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culture of collaboration within a project (Lloyd-Walker and Walker 2011).

Using a case study approach (Eisenhardt 1989), the aim of this paper is to examine a program alliance, which recognized rework had adversely impacted the cost and schedule performance of water infrastructure projects they were delivering. Explicitly conceding this was a problem, the alliance, leadership, and management ream reexamined the alliance's structure and processes to ensure their future projects achieved their specified outcomes. In conjunction with the alliance, leadership, and management team, the nonowner participants and their contractors initiated a dedicated project-wide rework prevention program in an effort to combat rework. A specific objective of the paper is to examine the context that gave rise to this initiative and its effectiveness in preventing future rework. The program alliances' experience in addressing the problem of rework offers a learning opportunity for the owner participant, nonowner participants, and contractors who are seeking to ameliorate the performance, productivity, and safety of their projects. In this case study, the nonowner participants to the alliance consisted of a Tier 1 contractor and an engineering design firm. The Tier 1 contractor in this case acted as project manager, and solicited tenders from a contractor (generally a Tier 2 or 3) to undertake the works for each project. Prior to introducing the case study, a brief review of the alliance literature in construction and engineering projects is presented next.

Alliances: Configuration and Learning

Definitions of alliances abound in the literature (e.g., Walker et al. 2002; Walker and Lloyd-Walker 2014). However, a common thread is apparent. This concerns the establishment of interorganizational relations and the encouragement of collaborative behavior. An alliance exists when the value chain between at least two organizations (with compatible goals) are combined for the purpose of sustaining and achieving a significant competitive advantage. An alliance structure can take a number of forms, but essentially they are either collaborative (i.e., parties working together) or cooperative (i.e., parties operating together) (Holt et al. 2000). Walker and Lloyd-Walker (2014) and Walker and Harley (2014) have undertaken a comprehensive global review and study of alliances that have been used to deliver infrastructure projects and subsequently identified three specific configurations: (1) project alliances, (2) design alliances, and (3) program alliances. For the purposes of this paper, project and program alliances will be reviewed as they are akin in nature (Department of Treasury and Finance 2006) and provide a necessary contextual backdrop for the case study presented. Noteworthy design alliances may be used in the initial stages of a project from the briefing to detailed design stage. Walker and Hurley (2014) suggest that these alliances provide the essential means for improving and understanding the information and knowledge required by nonowner participants throughout the design stage and are beneficial for minimizing rework.

Project and Program Alliancing

A project alliance is a consortium of design professionals and contractors who join with an owner participant representative to form a collaborative team that is guided by specific and explicit assumptions about how they will assume joint responsibility and accountability and behave toward one another during a project's duration (Walker and Harley 2014). Walker and Harley (2014) suggest that project alliances have a "single-team mentality with a 'we all sink or swim together' level of collaboration and commitment to each other" (p. 10). This mindset is supported by the contractual form, which explicitly specifies and determines the amount paid to nonowner participants and their expected behaviors (Love et al. 2011).

A program alliance involves the delivery of a number of projects that are bundled into a single program. For example, it may involve a series of smaller projects, each of similar scope, where performance criteria can only be assessed on a programwide basis (Department of Treasury and Finance 2006). The Sydney Water's SewerFix Alliance's scope included the planning phase in addition to delivery of a capital works program of more than AU$200 million worth of projects between 2007 and 2012, which comprised a large number of individual projects and provided an opportunity to optimize resources and outcomes through effective programwide planning and management (Department of Treasury and Finance 2006; Hall 2010). Program alliances may involve a series of works that are outsourced and require both capital (e.g., upgrades or major repairs on roads) and operational (e.g., maintenance, such as resurfacing roads) expenditures, though the rationale for their use should be linked to the strategic intent of the owner participant (Walker and Harley 2014). The primary characteristics of project/program alliances are described next (Walker and Harley 2014).

Determination of the Target Outturn Cost

There are two types of project alliance: pure and cost-competitive (Love et al. 2010). The pure alliance form has generally been used in the private sector where selection is based upon experience, capability, and attitude with limited regard for price, particularly the target outturn cost. Consequently, within the context of the public sector, the determination of the target outturn cost within a pure alliance is deemed uncompetitive. In addressing the cost competitiveness concern, a price competitive alliance model is generally used for public sector projects (Love et al. 2010). In this case, two independent interim teams are selected in the first instance on the basis of experience, capability, and attitude with limited or no regard to price. Each of these teams with the owner participant input and support develops its own design, execution strategy, and target outturn cost. The owner participant selects the winning team based upon a comparison of the target outturn cost juxtaposed with nonfinancial criteria.

Painshare and Gainshare

A typical contract comprises three limbs as illustrated in Fig. 1. Limb 1 is cost reimbursement for direct costs (e.g., supervision and administration). Limb 2 comprises nonowner participants, corporate overhead, and profit. Limb 3 is an incentive-based "painshare" and "gainshare" agreement that establishes the level of risk, profit, and corporate overhead for each nonowner participant so that any surplus or shortfall generated from below or above the agreed target outturn cost is shared. Underpinning the contract are the key result areas (KRAs), which require the nonowner participant to work in a collaborative manner to ensure they are successfully achieved and the project meets predefined deliverables.

The weighting placed on the KRAs may influence the emphasis placed on containing and reducing rework. For example, if the KRAs are people and well-being (25%), functionality (20%), delivery (50%), and environment (5%) then there is a likelihood that less rework may arise as increasing emphasis will be placed on cost and schedule performance. The KRAs serve as the cornerstone of the "gainshare/painshare regime" and stimulate commercial alignment between the owner participant and nonowner participants. Moreover, they act as a decision-making tool that drives "best-for-project" decisions. Such decisions are consistent with the established alliance principles and objectives and are based solely on what is in the best interest of the alliance without regard to the impact on the individual participants.

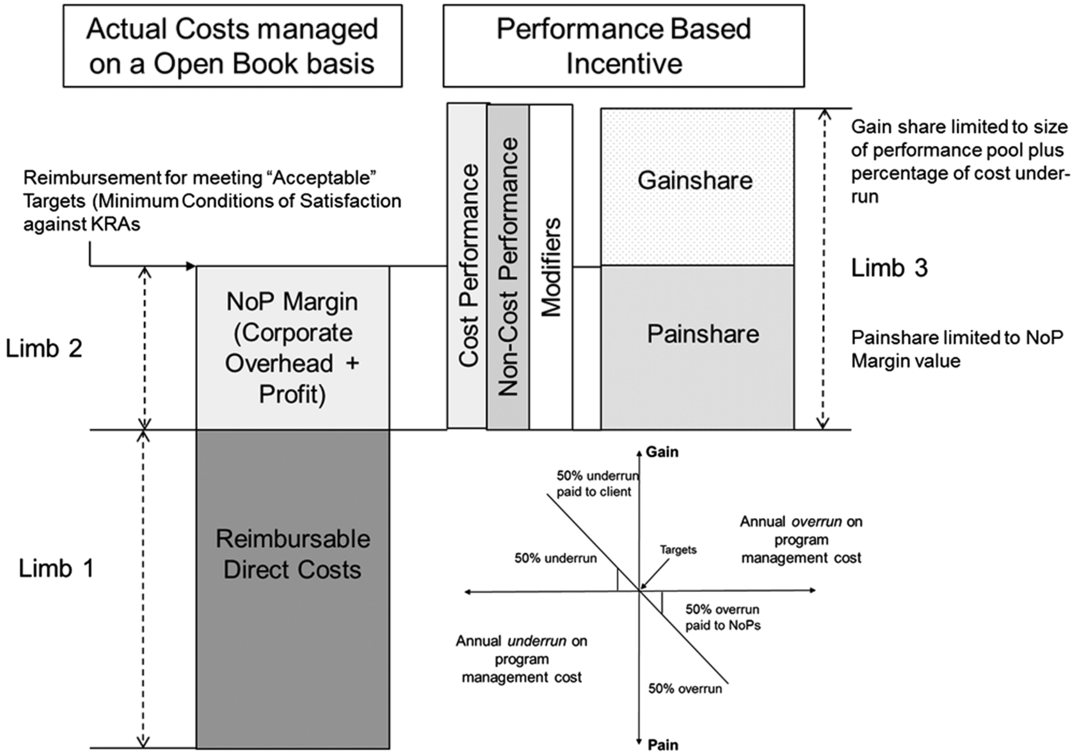

Fig. 1. Compensation model: gainshare and painshare regimes

A modifier may be used in relation to the KRAs, such as safety and quality compliance, where less-than-minimum conditions of satisfaction are not acceptable and placing a weighting value in the "painshare" regime would undervalue their level of importance to the owner participant and nonowner participants. A modifier may be used to place emphasis on preventing this occurrence because a significant positive relationship exists between recordable injuries and the incidence of rework (Wanberg et al. 2013). The inclusion of noncost performance indicators or "gainshare modifiers" in an alliance agreement is designed to take into account the performance of the nonowner participants in the noncost areas of the project or program of projects that are important to the owner participant (Department of Infrastructure and Transport 2011). In this instance, the modifier works by adjusting the "gainshare" entitlement that the nonowner participants can earn from the other KRAs. The modifiers are essentially used to reflect the impact of both positive and negative behaviors and outcomes concerning safety and quality. If owner participant safety and quality, commitments, and requirements are embedded into alliance core values, financial incentives may not be required, as performance becomes absolute.

Collaboration

The owner participant is typically involved as an alliance participant and works in close collaboration with nonowner participants. This is in stark contrast to other forms of project delivery where the owner participant shifts risk to the design and delivery team. The active and collaborative involvement of an owner participant can assist with reducing design changes and thus, with rework. More often than not, owner participants are asset owners, particularly in the case of water infrastructure in Australia (e.g., Sydney Water's SewerFix Alliance), and therefore it is necessary for them to not only reduce the capital expenditure in their projects, but also operational expenditure. Errors that arise during construction may not manifest until the asset is in operation, which can result in rework. Asset owners have explicit knowledge about how their facilities function and the key issues that can hinder effective and efficient maintenance. The involvement of the owner participant in an alliance enables their specific information and knowledge to be directly incorporated into the design process to reduce maintenance requirements, errors, defects, and subsequent rework in operations. When such information and knowledge is coupled with the use of BIM, it may enable decisions about design and the way in which the asset is maintained and managed to be undertaken on the basis of complete information and their existing asset management program during the formative stages of a project.

No Blame

The alliance agreement is underpinned with no-blame provisions to develop a culture of collaboration and joint accountability values. The no-blame provision may be reinforced with a no-litigation clause. Walker and Hurley (2014) particularly note that "common law prevents a complete no-litigation condition, but the alliance agreement 'no litigation' refers to all conditions excluding criminal activity, willful misconduct, or hostility or gross ineptitude on the part of any participant" (p. 11).

While project and program alliances share many commonalities, there is a subtle, yet distinct difference in the way that learning occurs within them. Project alliances are collaborative in nature and focus on a single project, whereas program alliances may be cooperative and comprise many projects over significant time periods and so their structure, objectives, and learning capabilities may invariably differ (Holt et al. 2000). Collaboration is an implicit feature of a program alliance, but undertaking a series of projects requires parties to also commit to operating together (Love et al. 2002). Cooperation between organizational (alliance) members can provide an environment in which trust and commitment is first nurtured and subsequently becomes the basis of all commercial transactions. However, when partners are not known to each other, there may be (implicitly or otherwise) ambiguity over, for example, project goals, and any agreement reached is likely to be tentative and open to reinterpretation. By encouraging a cooperative learning environment, the risk associated with these negative factors can be minimized, allowing members to have a clear understanding of a program's objectives, along with constraints and expectations of the nonowner participants involved (Holt et al. 2000). Moreover, such alliances provide an opportunity for continuous improvement to be implemented and the effective planning of safety, quality, and environment (SQE).

Learning

Program alliances are constructed to transfer knowledge, skills, and resources to involved partners, particularly owner participant (Walker and Harley 2014). They are reliant upon having mechanisms in place that engender learning so that tacit and explicit knowledge can be transparently transferred. Without a learning environment to encourage the effective and accurate transfer of knowledge, the benefits to the formed alliance are minimal. Nonetheless, cooperative learning is more intense in comparison with those that are collaborative in nature.

Learning involves the detection and correction of error (Argyris and Schon 1978, p. 2). When something goes wrong, an initial instinct for many is to look for another strategy that will address and work within the governing variables that exist within their organization or project. Argyris and Schon (1974) refer to this process as *single-loop* learning. Within construction there is a proclivity for this type of learning to predominate (Henderson et al. 2013) because emphasis is on "techniques and making techniques more efficient" (Usher and Bryant 1989, p. 87). Any form of reflection is directed toward simply making a strategy more effective. According to Love et al. (2011), learning opportunities are not typically exploited in a consistent form within alliances, irrespective of their configuration. The primary barrier to learning is considered to be at an individual level where opportunities for knowledge acquisition are not exploited as the alliance experiences conflicts with existing managerial beliefs (Love et al. 2002). An alternative response is to question the governing variables themselves and subject them to critical scrutiny (Henderson et al. 2013). This approach is referred to as *double-loop* learning. Such learning may then lead to an alteration in the governing variables, and thus a shift in the way in which strategies and consequences are framed.

It has been suggested that double-loop learning is needed to reduce and contain rework in construction projects; this involves questioning the role of the framing and learning systems that underlie actual goals and strategies (Usher and Bryant 1989; Holt et al. 2000). In many respects, the distinction at work here is the one used by Aristotle when exploring technical or practical thought. The former involves following routines and some sort of preset plan—and is both less risky for the individual and the organization, and affords greater control. The latter is more creative and spontaneous, and involves consideration for notions of the good. In this context, the basic assumptions behind ideas or policies are confronted, hypotheses are publicly tested, and processes are unconfirmable and not self-seeking (Argyris 1982, p. 103-4). Argyris (1974, 1982, 1990) has consistently argued that double-loop learning is necessary if practitioners and organizations are to make informed decisions in rapidly changing and often uncertain contexts.

Errors and fault are inseparable and therefore people generally assume admitting failure results in taking the blame (Edmonson 2011). In the case of construction organizations, openly admitting to errors may lead to reduced profits and loss of reputation and confidence within the marketplace. Errors are inevitable and may in some instances be beneficial because they can stimulate learning and creativity (Edmonson 2011). In addressing errors, Edmonson (2011) proffers that organizations need to go beyond lessons that are superficial (i.e., identifying procedures that were not followed) and undertake new and better ways of doing business that encompass context-specific learning, which occurs in a specific setting.

Case Study

Rework is considered to be taboo within construction and engineering infrastructure projects, and is often abhorred by management. In spite of its negative connotation, a program alliance openly recognized that there was an ongoing problem, which would negatively impact its performance if not addressed. In examining this issue, a case study is used to understand why and how the program alliance went about preventing rework through a process of context-specific learning that was engendered by authentic leadership, engagement and empowerment, and a strong focus on continuous improvement. A case study of this nature provides a line of inquiry that can be used to demonstrate best practice.

Data Collection

Triangulation formed the basis of the data collection, as it can be used to overcome problems associated with bias and validity (Patton 1990). Unstructured interviews, documentary sources (e.g., lessons learned, workshop notes, and reports), and nonparticipant observation, which involved site visits, formed the cornerstones of the data collection process that focused on the gamut of rework. Twenty-six unstructured interviews were conducted with a variety of personnel such as the alliance manager, design manager, SQE manager, commercial manager, site supervisors, and contractors. Purposeful sampling was employed to select the interviewees from various functional areas (e.g., commercial, design, delivery, and project support) who were actively involved in initiating and implementing the rework prevention program (Patton 1990).

Interviews were used as the mechanism to examine why rework emerged and how the alliance implemented a formal rework prevention program. Interviews were conducted at the interviewees' offices and onsite and were digitally recorded, and then transcribed verbatim to allow for any finer nuances to be detected. Interviews were kept open using phrases such as "Tell me about it" or "Can you give me an example?" The open nature of the questions stimulated avenues of interest to be pursued because they arose without introducing bias into the response. Additional notes were taken during interviews to support the digital transcription process to maintain validity and safeguard against the digital recorder's failure. Each interview varied in length from 45 min to 2 h, and a conscientious effort was made to break down any barriers that may have existed between the interviewers and interviewee. Data from workshops conducted by the alliance team members with contractors was made available for analysis. Moreover, the researchers acted as nonparticipant observers during these workshops and recorded their observations, particularly ideas and the emergent discourse that arose from participants interacting with the facilitator.

Case Study: Water Infrastructure

The program alliance was established in 2009 to deliver 129 water infrastructure projects, comprising pipelines, water treatment plants, pump stations, tanks, storages, and channel works throughout a regional area of Victoria in Australia. After an extended period of drought in 2008/2009 and significant growth in the region, the demand for water increased. As a result, there was a need to upgrade existing and construct additional infrastructure to meet this demand. The alliance team was comprised of three organizations, the owner participant who was responsible for delivering water to its customers over an area of 8,100 km^2 to five municipalities and 275,000 customers, an engineering consultancy who provided design, environmental, and stakeholder management expertise, and a contractor who provided commercial and construction capabilities. The program of works to be undertaken cost AU $375 million over a 5-year period. At the onset of the alliance, a set of core values were established: safety, teamwork, respect, innovation, vibrancy, and excellence (STRIVE), which were later aligned to a set of KRA [e.g., environment (noncompliance criteria) 15%, delivery 30%, functionality 15%, regional benefit 15%, people and well-being 15%], which had a total of 21 KPIs. In 2014, the program of works was transitioned to the owner participant, as it was always intended that, during the alliances' life, both the engineering consultancy and contractor would provide the knowledge and capability to enable them to continue with their projects alone.

In 2011, approximately 2.5 years into the 5-year program, the alliance, leadership, and management team became aware that a number of projects were incurring unnecessary cost and time delays due to rework. This coincided with the first batch of projects, which reached the end of their 2-year asset proving period' (i.e., defects liability). An average 3-week delay per project was experienced due to rework issues, which at the time equaled more than AU $1 million in costs to the alliance alone (e.g., management and supervision). Over the life of the program, *ceteris paribus*, the costs that would have been incurred by the alliance were estimated to be in excess of AU$3 million. The costs borne by contractors due to this rework were estimated to be at least five times this estimation. The costs of rework did not vary among the project types. Yet, the number of product quality nonconformances formally raised and reported by contractors was zero, although it was known that this did not reflect reality, largely due to the fear of blame and damage to the organization's reputation. Moreover, rework was deemed to be a norm and thus business as usual. It was not until the contractors became aware of the problem that they began to work with the alliance to prevent its future occurrence.

The alliance, leadership, and management team knew that there were quality issues as a result of their inspections, but they felt at the time that the alliance lacked the systems, contractual power, relationships, and culture to support and enable the contractors to identify errors and mistakes which could lead to rework. A concerted effort had been made within the alliance to report safety and environmental incidents, which improved over time, but the existing processes in place were inadequate to equally capture quality assurance (QA) and potential rework. Furthermore, no effort had been made to account for rework because of the perception that it was a result of poor work practices and demonstrated failure. The alliance recognized that safety was being jeopardized as a result of rework incidents. On average, 10 incidents/near misses (of all types) were occurring per month, particularly during the months of November and December where 30 incidents/near misses occurred due to several issues, such as fatigue and stress. An initial observation of events revealed that there was a direct relationship between the number of incidents and rework. In fact, it was propagated that the likelihood of a person being injured while attending to rework was nine times greater when compared with normal work activities. This was of a great concern to the alliance as it was contradictory to their underlying value system that was developed at the onset of the project. Responsively recognizing the problem at hand, the alliance, leadership, and management team, collectively with the nonowner participants, embarked on a targeted safety improvement program to alleviate significant health, safety, and environment (HSE) issues that had been consistently emerging. In addition, they developed a rework prevention initiative to not only address project performance issues, but also those issues relating to safety.

Changing Culture

The alliance, leadership, and management team actively promoted the principles embedded within an alliance such as trust, honesty, and cooperation to engender an error management culture (i.e., an organizational culture that supports effective and productive error handling). The same level of promotion to safety was also afforded to rework. The development of this culture was a major challenge for the alliance, leadership, and management team, which required changing existing behavioral norms and values that had already been established within the alliance. To enable an error management culture, the adopted model for change focused on changing behaviors, its climate, providing motivation, and reexamining the way performance was being measured. Not only did the alliance, leadership, and management team develop an awareness to the nonowner participants of the opportunities that would be afforded of a cultural change, but they also actively engaged their contractors. To achieve this aim, the alliance, leadership, and management team recognized that they needed to demonstrate their commitment to change by providing additional resources to contain and prevent rework.

Another issue considered was the institutional politics that existed within nonowner participants' parent organizations. For example, within the contractor's organization, the issuing of nonconformances was deemed to reflect poorly on their ability to manage a program of works and therefore nonconformances tended to be avoided. Yet, the issuing of nonconformances provides a valuable learning opportunity and demonstrates that a detection system is in place, which is a pivotal aspect of rework prevention. An overreliance on rework prevention may reduce their detection. When people are convinced that rework prevention is successful, a form of *hubris* may manifest, which can lead to a decrease in its anticipation, rendering it difficult to detect. It was acknowledged by the SQE manager, however, that a duality was associated with rework. On one hand, it had negative consequences on safety, productivity, cost, and schedule performance, but on the other, it provided learning opportunities for other projects that were to be undertaken as part of the program of works.

The alliance had no clear strategy in place to address rework: it had simply not been recognized. In fact, when rework did occur, the alliance manager observed that the mindset of people changed drastically and they became demoralized. At the time when rework was identified as an opportunity for improved performance (e.g., cost, time, and team satisfaction), the alliance, leadership, and management team observed that their initial KRAs (each had three to four different KPIs) were not aligned with alliance values and the nature of work that was required. A total of 21 KPIs had been developed to measure performance, which the alliance team found difficult to understand and implement. As a result, the original 21 KPIs were reduced to eight, which the alliance team was able to comprehend and consider tangible. The revised KPIs for each KRA were:

- Delivery (40%) with earned value with a weighting of 40% and schedule 60%;
- Functionality (15%) with a weighting of 100%;

- Regional benefit (15%) with a weighting of 50% for subcontractor performance and 50% for legacy panels;
- People and well-being with a weighting of 33% for value add and 67% for the owner participant's transition; and
- SQE risk management (15%) with a weighting of 100% for the positive performance indicator frequency rate.

Values were redefined and aligned to the performance objectives that were established. For example, safety was aligned to no harm, and delivery to excellence. Climate implicitly pertained to the motivation to address rework, and focused on providing clarity about what people had to do. In addition, people were engaged and became part of the solution in conjunction with a genuine intent to understand people's challenges and allowed roles to be framed within the context of climate. An explicit feature in creating the new climate was learning through interaction and participation between alliance and its contractors. Particular emphasis was placed on feedback and knowledge acquisition derived from work processes, information, reflection, and discussion between alliance members and its contractors.

Leadership

The alliance manager acted as a consigliere and was able to build coalitions and devise strategies with the leaders of each respective function to enable the change process. The alliance manager was a highly respected member of the alliance team, and was best positioned to promote a new culture. While it was important the alliance met their respective KPIs, the alliance manager was also cognizant and steadfast that safety, environment, and rework also took centerstage. Moving the alliance toward an error management culture required the alliance manager and leadership team to eliminate any fear-of-failure mentality that may have prevailed. In doing so, they engendered an egalitarian culture through openness and honesty and made resources available to accommodate problems and challenges that individuals encountered in their daily tasks.

To improve clarity within the alliance, manuals that were developed at the onset of the project and used to determine what and how something needed to be undertaken (e.g., in relation to quality management, project management, and governance) were replaced with flow charts. A new interactive governance and project management framework called the Alliance Process Architecture was developed. The existing manuals were deemed too cumbersome to use and were therefore ignored. Thus, each team leader was empowered and allocated the responsibility for mapping work processes for their respective areas, which forced people to consider what they actually did and how they interfaced within other areas on the alliance. A total of 120 new processes were established, which outlined all the alliance teams' responsibilities and how each interacted with one another. Direct links to the tools, forms, and systems used to perform daily tasks were also incorporated into the new processes. The high-level program processes were established for alliance management and the project processes' were developed for the management of the projects. The newly developed processes were customized and contributed to the owner participant departments' utilization as part of the alliance's legacy so they could manage their future projects.

The new processes developed significantly reduced the administrative burden placed on the nonowner participants and enabled them to dynamically attend to changes that arose in the project, such as recording incidents and rework. This enabled a reporting culture to be established, particularly for the construction team who were able to record, measure, and quantify the status of daily events and provide documentation of lessons to be learned in future projects.

Engagement

Under the auspices of engagement, the alliance management team recognized that the leadership capability of the construction team needed to be addressed. The project managers and supervisors had the technical know-how, but were perceived as lacking the skills required to lead and manage teams. As a result, mentoring programs and a series of workshops were introduced in which those attending were asked to identify what they would like to learn. Similarly, the alliance, leadership, and management team also organized and conducted a series of in-house workshops to identify ways to improve the capture and prevention of rework. Findings from the initial workshop forum revealed that inadequate knowledge of quality, site supervision, and construction methodology were the primary contributors to rework. The alliance also surveyed their contractors to determine key areas where rework was occurring. Notably, the project delivery phase was identified with pipe embedment, joints/fittings, survey/set-out, and concrete works acknowledged as being problematic. To keep abreast of ongoing quality and safety issues a number of initiatives were implemented or augmented which included:

- Contractor forums, which were undertaken by an independent facilitator to eliminate any potential bias and enable participants to openly engage in dialogue about why and how rework occurred in their projects and ways in which it could be prevented;
- A system to track and monitor rework costs by corrective action type;
- A system to feedback key project "lessons learned" and continuous improvement programs which were provided to the nonowner participants and contractors;
- Dedicated team workshop training sessions related to the prevention of rework, which focused on "getting it right the first time, every time"; and
- The creation of a visual symbol for rework by the management team.

A rework prevention register emerged from the workshops, which incorporated lessons to be learned, proposed KPIs, and actions to be undertaken by specific alliance team members. The register was then summarized by the alliance management team and incorporated into a strategy to detect and prevent rework (Fig. 2). The alliance management team identified three core topics to be addressed to improve safety and prevent rework:

1. Assess and plan: For example, to improve the delivery of projects and mitigate risks, the alliance management team visited each project; a site walk was undertaken with the construction team to identify how the project would progress before approving its commencement. Prior to implementing the change initiative, the alliance had focused on price rather than the contractor's capability and performance. As a result, the contractor evaluation process was revised to focus on their capability and those who were considered to be high risk were paired with a full-time construction supervisor who worked for the nonparticipant owner. The construction supervisor was an expert appointed from within the Tier 1 contractor's organization that was operating as project manager within the alliance.
2. Accountability: A code of conduct that focused on no harm was modified to reflect rework prevention. In this context, no harm is a belief that harm, damage, or rework can be prevented. To achieve this, contractors were required to take personal responsibility for their actions and formally sign the code of conduct card, which specified actions that would not be tolerated. For example, signing quality documents falsely or without understanding them, and not immediately reporting an incident, injury, or nonconformance.

Fig. 2. Rework prevention actions

3. Awareness: The alliance management team observed, for example, that their design engineers were divorced from what actually transpired onsite. For example, there were several incidences where what was being designed was difficult to construct or not understood by the construction team, which later caused rework. In addition, lessons learned during construction were not being fed back into the technical specifications to align the design intent with the preferred construction methods or materials. Thus, engineers were required to complete design intent site visits from the commencement of construction and engage face to face with the construction team to confirm understanding of the design and the specification that was in place. In addition, constructability reviews in the design phase were enhanced through the designer and construction team attending site visits at the 30% stage of the detailed design development to discuss a range of design topics, such as the extent of bulk excavations required, existing services, and site access. This process improved constructability and any unresolved design issues (e.g., exclusions) were clearly articulated to the contractor. A contractor site leadership-induction program was also established as part of a strategy to provide contractors with the skills and capability to improve the productivity and performance of the projects that they had been contracted to deliver.

Dedicated toolbox talks were regularly held and construction kick-off meetings were undertaken by the alliance with their contractors on a regular basis to increase awareness of the particular aspects of the work to ensure safety and quality was reinforced. Site and team weekly planning boards were implemented to assist site management and contractors to ameliorate the planning and management of day-to-day tasks. This was introduced and used in conjunction with a "start card," which required contractors and their subcontractors to identify the task they were about to undertake, assess their work area, consider safety issues, undertake a risk assessment, identify hazards, and ensure that risk controls were in place before each activity was undertaken. Notably, the implementation of this system led to a reduction of incidents onsite and reduced rework because it required supervisors, contractors, and subcontractors to engage and collaboratively work onsite as tasks and activities became transparent.

Learning Climate

Learning formed the nucleus of the alliance's new culture, which was championed by the design manager. The journey to reduce incidents and rework required the alliance to develop systems that could dynamically capture issues in real time that contributed to rework, as well as other events, so alliance members and contractors were aware of issues that may arise in future projects. To support continuous improvement, a lesson's learned system was developed and integrated into the alliance's compliance management system, which was implemented as part of the change initiative. Following the commissioning of each project, a close-out "lessons-learned workshop" was held with representatives of the alliance team who brought forward those lessons that had been previously captured and transferred from the compliance management system. The compliance management system tracked actions and responsibilities and mapped compliance requirements to an organizational hierarchy, with the ability to manage obligations derived from standards and codes of practice, permits, approvals and licenses, contracts, audits, and stakeholder engagements. An important aspect of the lessons close out was that the working alliance team implemented the changes into the systems that had been developed; lessons were not the responsibility of an individual or team to implement, but rather were embraced by all members of the alliance.

By having the compliance management system aligned with the lessons-learned system, the alliance developed the ability to close the feedback loop, which gave them the impetus to embrace learning. The system provided an environment to share and compare different experiences, insights, and responses. In addition, it helped establish shared responsibility for maintaining the process of getting, giving, and learning to be implemented in a proactive rather than a passive manner. Thus, learning within the alliance was embedded in a reciprocity process that emphasized mutual and equal balance between knowledge acquisition and sharing.

Evidence of this could be seen in the lessons-learned register where a rework issue was identified and an e-mail was distributed informing people of what had transpired, which then enabled them to take an appropriate action. Prior to the introduction of the lessons-learned processes, typical feedback from the alliance team was the lessons were not being used or the team was simply not made aware of them. A motivator for the alliance team to fully embrace the lessons-learned process was the introduction of a "top three lessons learned" summary sheet from each completed project, which was e-mailed to all alliance members. This demonstrated to the team that, not only had the lessons learned workshop been conducted, but it also resulted in inputs into the compliance management system for future reference. This created an enhanced learning environment where team members actively brought forward their lessons as they occurred during a project's construction.

Expost Evaluation

Several months after the initial launch of the rework prevention initiative, a workshop was held to examine the seven-point action plan that was put in place, which was attended by the alliance team (>60 members). At this forum, it was noted that people had positively embraced the change process and cross-functional communication had significantly improved. Major improvements to project outcomes had been achieved with a reduction in incidents (i.e., less than three per month) and rework (i.e., >50% reduction in change orders) being attained. Specifically, a KPI established on completion of projects on time achieved full compliance, which is a significant change from the average of three weeks late per project before the program was implemented. Variations submitted by contractors to the alliance were cut in half in comparison to the period prior to the rework initiative. Through an enhanced awareness of the impact of rework, the nonowner participants were working at a higher level of communication as a result of greater interaction throughout all phases of a project's delivery process. Designers were spending increasing amounts of time onsite and were actively interacting with operators and constructors to share design and construction knowledge and understand the practical needs of others. The rework initiative that was put in place was underpinned by the following key activities:

- More than 50 "lessons learned" project workshops had been undertaken, with the top three lessons for each completed project shared with all the alliance team members. Workshops provided an environment to share the different lessons and better understand the impact of decisions that had been made.
- Design guides, which outlined the owner participant's preferences and standards, were consistently reviewed, updated, and implemented as lessons arose. The benefit of the guides and standards was to clearly define the scope and functionality requirements of the owner participant's operations at the earliest stage of the project. The design guides further enhanced engagement with the owner participant's operations team at the commencement of design development through to the detailed design phase.
- A total of 1,060 "lessons learned" items had been identified and tracked, with most being actioned. The key lessons resulted in continuous system improvements and enhanced communication across the alliance team with lessons implemented into the compliance management system as they arose. In addition, teams within the alliance consistently used the lessons-learned register to review previous project lessons to learn from each other's experiences.

The new policies, procedures, and systems developed enabled the alliance to adapt and respond to change in an agile and systematic manner. The remaining challenge for the nonowner participants is for their parent organizations to recognize that rework is a prevailing issue within projects and an error management culture needs to be implemented that utilizes lessons learned to prevent its occurrence.

Discussion

Authentic leadership within the alliance was considered pivotal to stimulating the actions required to engender an error management culture and subsequently reduce and contain rework. According to Lloyd-Walker and Walker (2011), authentic leadership and alliance team leadership uses vocabulary such as positive behaviors, encouraging communication, building trust, commitment, shared values, and ethical behavior. In the case study, team members were able to identify the alliance manager as a leader at a personal and social level, especially as they were open to development and change (Avolio and Gardner 2005). This observation has been noted as a core characteristic that facilitates development of authentic leadership, particularly within an alliance (Avolio et al. 2004; Lloyd-Walker and Walker 2011). Thus, this requires team members to identify with leaders through their demonstrated hope, trust, and positive emotions (Lloyd-Walker and Walker 2011, p. 386); which were evident in this case study. The optimism and belief in the need to address the problem of rework displayed by the alliance manager and the leadership team resulted in team members committing to change because there was a purpose and meaning. Moreover, the streamlining of processes improved job satisfaction and engagement throughout the alliance.

The process of learning within the alliance for the first two years initially was based upon single-loop learning, as team members responded to detecting and correcting errors but maintained existing organizational norms. Consequently, opportunities for learning were not exploited in a form consistent with their initial learning objectives. The primary barrier to learning occurred at the individual level because the alliance experience conflicted with the nonowner participants' parent organization and their management beliefs. To improve the performance and productivity of the program alliances' remaining projects, the leadership team fundamentally questioned its purpose and role. In doing so, through engaging in authentic leadership, the nature and context of the alliance was able to shift from the position of being collaborative (i.e., working alongside organizations to achieve a goal) to cooperative (i.e., actually working with organizations to enable them to achieve their goals). This is not to say that collaboration was ignored. It was the shift to this cooperative learning mode that enabled an error management culture embracing double-loop learning, where the alliance incorporated a high level of evaluation and analysis of information into knowledge enabling changes to be made for mutual benefits. This also led to the development of creativity in problem solving, which is referred to as *deutro-learning*. Essentially, this arises when organizations discover how to carry out single- and double loop-learning simultaneously (Holt et al. 2000).

Such learning is derived from containing the negative and promoting the positive consequences of rework through error management. This perspective has been repeatedly echoed throughout the literature on error management (e.g., Reason 1990; van Dyck et al. 2005). This approach assumes that rework *per se* can never be completely prevented because it invariably arises due to human error. Thus, it is necessary to ask the question "what can be done after the rework has occurred?" Such questioning was whole-heartedly embraced by the alliance team members as a new culture was established that focused on error management and learning through experience.

Culture implies that there is a system of shared norms and values and a set of common practices (Riechers and Schneider 1990). Error-management culture encompasses organizational practices related to communicating about errors, sharing knowledge, and handling errors, which may eventually manifest as rework. Van Dyck et al. (2005) revealed that high-error management cultures, such as in the case presented, translate into improved performance organizations via mediators that decrease error consequences (i.e., by the control of these consequences) and increase the positive consequences (i.e., by learning, problem solving, and innovation) (p. 1,230). Communication about rework constitutes the most important facet of error management practice as it facilitates the obtaining of shared knowledge for events.

A high degree of communication about rework, which was enabled by the "lessons-learned" workshops and compliance management system, allowed for the development of shared knowledge. Open communication facilitates the speedy detection of an error and the handling of the subsequent rework that may be required (Van Dyck et al. 2005). The period of incubation (that is, the time between the occurrence and the detection of an error) is critical as the longer the error remains undetected, the more severe its impact (Reason 1990). This ensured that errors were detected and an efficient and well-coordinated approach to undertaking rework was executed. Moreover, rework can allow and encourage exploration, which in turn can foster learning and a deeper understanding of the event and conditions that lead to its occurrence (Frese 1995). A high-error management culture can stimulate innovation, as people accept errors as a natural part of work and are confident they will not be blamed for them (Edmonson 2011). Furthermore, they are likely to communicate about the errors with their peers and therefore encourage individuals to explore and experiment.

Edmonson (1996) suggests that human error will never disappear from organizational life, and suggests that managers should therefore design and nurture work environments that encourage people to learn from their mistakes and collectively avoid making the same ones in the future (p. 25). An error management culture is supported by a *mastery orientation* toward errors (Dweck and Legget 1988; van Dyck 2000). The case study presented in this paper demonstrates the alliance's mastery orientation toward rework. That is, it was able to overcome the difficulties associated with it and develop improved strategies for each future project.

Conclusions

Studies have repeatedly identified that rework is a major problem and significantly contributes to cost and schedule overruns, reductions in productivity, and increases the likelihood of safety-related incidents onsite. Despite the accumulated knowledge about the costs, causes, and consequences of rework, construction organizations, particularly in Australia, have ignored its occurrence. In this paper, we report on a case study of a program alliance that was charged to deliver 129 water infrastructure projects over a five-year period that acquiescently acknowledged rework was an issue and subsequently, by addressing it head on, saw it as an opportunity to improve their performance. Two and a half years into the project, the alliance management team abjured using the established systems and processes that were aligned with the nonowner participants' parent organization and began changing its culture to improve safety and rework in the remainder of the projects it was to deliver. To enable the creation of an error management culture, a change process that focused on changing behaviors, the climate, providing motivation, and reexamining the way performance was being measured was implemented.

The change process was enacted through authentic leadership, which provided team members with the confidence, optimism, and belief that the change would bring significant benefits to the alliance and its contractors. Active engagement with alliance team members through workshops enabled the alignment of KRAs with KPIs, the development of a seven-point rework action plan, a lessons-learned system that was integrated with a compliance management system that enabled the alliance to close the feedback loop, and actively engage in the process of double-loop learning. In addition, the alliance's contractors were intimately involved in establishing ways to prevent rework. As a result of consistent dialogue through regular rework forums, leadership training, and weekly toolbox talks, changes were made onsite with the introduction of a revised code of conduct that articulated rework was not acceptable, and a new site-planning board that was directly associated with their start card. The cooperative learning and error management culture established resulted in a significant reduction in incidents (less than three per month) and rework (>50% due to change orders). Furthermore, nonconformances were reported, which had previously been overlooked despite a QA system being in place.

Alliances provide an environment for learning and continuous improvement to be engendered through trust, open communication, positive behaviors, shared values, and ethical behavior. It is due to these innate characteristics that alliances have been consistently identified as a preferred delivery strategy for infrastructure projects, particularly their no-blame ethos and focus on collaboration. Such attributes are pivotal for ensuring projects are delivered successfully. Australia is a pioneer of alliances with countries such as Finland, the Netherlands, and the United Kingdom being attracted to their success and ability to deliver value for money and have thus begun to utilize them in their own jurisdictions. Yet, some state governments in Australia are tending to shun program alliances for major infrastructure projects in favor of more traditional forms of delivery, where price rather than value for money predominates. Previous research has highlighted that when price becomes a focal point, projects are more likely to experience cost and schedule overruns as a result of rework. However, the lessons derived from the case study demonstrate the effectiveness of program alliances to reduce rework because they can provide a platform for cooperative learning and the establishment of an error management culture. Further research is required to develop tools to measure and monitor the effectiveness of behavioral and cultural changes they may influence a program alliance.

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