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Building absorptive capacity in a mega-project program alliance: Learning to mitigate rework

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ABSTRACT

Collaborative procurement forms such as program alliancing can create a burgeoning environment for absorptive capacity to materialize, enabling learning and rework to be mitigated. However, little is known about the learning routines and practices enabling program alliances to tackle their rework effectively. As a result, this has stymied best practices that can be used to reduce rework from being made available to other construction organizations. This paper fills this void by addressing the following research question: *How does a program alliance develop its absorptive capacity to learn and mitigate its rework?* We use an illustrative case study approach to draw on the practices of a transport mega-project (>AU19 billion) delivered using a series of program alliances to address our research question. We reveal how one of its program alliances utilized its absorptive capacity to assimilate and apply new knowledge to manage errors and mitigate rework. Additionally, we unearth the presence of desorptive capacity, as the alliance exploited its error knowledge and transferred it to others as part of an incentivization scheme manufactured by the client authority to stimulate learning and continuous improvement within the project. The knowledge gleaned from the program alliance case examined in this paper provides an opportunity for organizations to learn how to deal with errors and rework, which has been absent in the literature.

1. Introduction

The perils of rework have preoccupied research and practice for decades, as it causes time, cost, and schedule increases in infrastructure projects and adversely impacts safety performance (Burati et al., 1992; Robinson-Fayek et al., 2004; Hwang et al., 2009; Asadi et al., 2021; Love et al., 2022a). The work of Industry bodies such as the Construction Industry Institute in the United States (CII, 2001, 2005), the United Kingdom's 'Get Right Initiative, and Construction Quality Australia is a fitting example. However, despite a wealth of research and the tireless efforts of industry, rework remains an unresolved issue (Taggart et al., 2014; Matthews et al., 2023). While the meaning of rework can vary, we define it as the "total direct cost of re-doing work in the field regardless of the initiating cause and explicitly excluding change orders and errors caused during off-site manufacture" (Robinson-Fayek et al., 2004: 1078).

Conventional procurement strategies (e.g., traditional and Private Participation in Infrastructures) are often subjected to economic (mis) behaviors of *moral hazards*, *information asymmetry*, and *adverse selection* (Hart and Moore, 1988). These behaviors provide the environment to trigger latent conditions (e.g., low-profit margins, absence of collaboration, and inequitable risk allocation) and produce adverse social interactions (e.g., opportunistic behaviors) between organizations that can result in the occurrence of errors and the need for rework in construction (Love et al., 2022a). The Australian Contractors Association (ACA), for example, has been calling for changes to procurement practices and the greater use of collaborative (relational) procurement approaches to improve the performance and productivity of infrastructure mega-projects (ACA, 2021). Such mega-projects are generally over US$1 billion and complex, requiring many years to construct, involving multiple stakeholders, and having a transformative impact on society (Flyvbjerg, 2017).

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Collaborative procurement strategies, such as alliancing - which aim to create mutually beneficial relationships between all parties involved in a project - have been used to deliver projects that have not only met their expected deliverables but also provided social and environmental value (Matinheikki et al., 2019; Walker et al., 2023). Alliancing can take two forms (Department of Infrastructure and Regional Development 2015: 35): (1) a *project alliance*, which is generally formed for a single project after which the team is disbanded; and (2) a *program alliance*, which typically lasts between 5 and 10 years and incorporates multiple projects under a single framework, where the specific number, scope, duration, and budget of each project may be unknown and the same participants are delivering all projects.

While a body of work about the practices of project alliances and collaborative learning is nascent (Manley and Chen, 2015, 2017; Walker, 2020; Walker and Rowlinson, 2020), less is known about the learning environments of program alliances, despite an increasing interest in their use to deliver mega-projects (Walker et al., 2023). Anecdotally, alliances experience lower levels of rework during construction than other procurement methods (Love et al., 2022b). Thus, how program alliances learn about errors, mitigate rework, and use this knowledge derived from their developed absorptive capacity (i.e., the ability to value, assimilate, and apply new knowledge) (Cohen and Levinthal, 1990) to improve their performance is a line of inquiry that has not received empirical attention. As a result, little is known about the learning routines and practices that enable program alliances to mitigate their rework, which has stymied best-practice propagation within the construction industry. Hence, we present the motivation for the research in this paper.

Against this backdrop, we address the following research question: *How does a program alliance develop its absorptive capacity to learn and mitigate its rework*? We commence our peregrination to address this research question by providing the theoretical setting of absorptive capacity and learning in alliances. We do not provide a detailed review of rework, as this can be found in Asadi et al. (2021) and Love et al. (2022a). Then, we introduce the methodological framing adopted to address our research question, which uses a case study approach to acquire insights and experiences from a transport mega-project delivered using a series of 'program alliances'. The insights emerging from the case study are then analyzed to determine how its absorptive capacity was established and maintained and how learning routines were used to address the rework problem. We next discuss our research's theoretical and practical implications before identifying the paper's contributions and conclusions.

2. Theoretical setting

As we mentioned above, the ability of organizations to value, assimilate, and apply new knowledge is called 'absorptive capacity' (Cohen and Levinthal, 1990). Thus, to determine the potential of new knowledge, some prior knowledge is essential to assess its potential value. An organization's absorptive capacity depends on how its individual members, as well as their knowledge structures, overlap with and transfer knowledge between various functional units (Pavlou and El Sawy, 2006; Manley and Chen, 2015, 2017). Markedly, the development of absorptive capacity within an organization is *path-dependent as* "accumulating [it] in one period will permit its more efficient accumulation in the next" (Roberts et al., 2012: 627). So, within the context of program alliancing, knowledge accumulated from one project can be assimilated or transformed into its knowledge base and applied to other projects through innovation or competitive actions (Manley and Chen, 2017).

Through continuous improvement activities, a program alliance can develop collective knowledge about the performance of its projects (e.g., quality, safety, and environment) and how they contribute to Key Result Areas (KRAs) (e.g., the environment, delivery, functionality, people and their well-being, and stakeholders). Exposure to new knowledge and its usage to manage performance is insufficient; it must be assimilated and absorbed into an alliance's knowledge base (Manley and Chen, 2015, 2017).

While a program alliance's knowledge base enables "the associated connections needed for insights related to new knowledge, the organizational assimilation of new knowledge depends more so upon the transfer of knowledge across and within" its projects (Roberts et al., 2012: 627). Fittingly, program alliances can apply their newly absorbed knowledge in several ways, such as replenishing their knowledge base and reconfiguring existing capabilities (Roberts et al., 2012). By absorbing such knowledge, an alliance's performance can improve indirectly and directly (Lane et al., 2006; Lin et al., 2012; Seo et al., 2022).

The case of the Barwon Water Program Alliance (BWPA), an AU $-375 million water infrastructure project, is interesting as it came to the fore after two and half years that rework was adversely impacting the performance of its projects (Love et al., 2023a). To address this problem, the alliance reconfigured its existing processes and capabilities. It developed new systems and methods to capture and share knowledge about rework events between its members and across projects. Rework knowledge-sharing forums were regularly undertaken with subcontractors to stimulate inter-project learning, improving project performance and the overall alliance.

2.1. Absorptive capacity and organizational learning

Absorptive capacity can be viewed as an organization's asset where it is considered to be a 'stock' of prior related knowledge or an organization's capability where a profound 'ability' exists to absorb knowledge into its processes (Lane et al., 2006; Roberts et al., 2012). While there is consensus that absorptive capacity depends on prior knowledge, the predominant theoretical view considers it a dynamic capability (Zahra and George, 2002; Lane et al., 2006; Helfat et al., 2007; Roberts et al., 2012). In this instance, improved performance is maintained when organizations can adapt their knowledge configurations and routines through organizational learning (Zahra and George, 2002). Hence, absorptive capacity "is purposely developed to explore, transform, and exploit knowledge from both internal and external sources to achieve superior performance outcomes" (Manley and Chen, 2017: 1).

Organizational learning is intrinsic to developing an alliance's absorptive capacity (Zahra and George, 2002; Lane et al., 2006; Helfat et al., 2007; Roberts et al., 2012; Manley and Chen, 2017), though there are subtle differences, as shown in Table 1. In the broadest sense, organizational learning is a set of processes to obtain and apply new knowledge, behavior, tools, and values. Consequently, insights, associations, and conclusions about the effectiveness of past actions and their influence on the future are developed (Fiol and Lyles, 1985; Huber, 1991).

Table 1
Difference between absorptive capacity and organizational learning.

Difference	Absorptive Capacity	Organizational Learning
Construct *versus* Concept	A construct with well-defined assumptions and boundary conditions	A broad concept that encompasses a variety of processes and constructs
Active *versus* Passive	Organizations must actively increase their absorptive capacity	Organizations can learn either actively or passively
External *versus* Internal	Focuses on the role of external knowledge	Spans both internal and external knowledge

Source: Roberts et al. (2012: 630).

Two pillars underpinning organizational learning are (March, 1991: 73): (1) "*exploration*, which includes things captured by terms such as search, variation, risk-taking, experimentation, play, flexibility, discovery, and innovation; and (2) "*exploitation*, which includes such things as refinement, choice, production, efficiency, selection, implementation and execution". Both exploration and exploitation are required for organizations to survive and remain competitive; exploitation ensures its current viability and exploration its future sustainability.

Within the context of an alliance, an ephemeral organizational form, it comprises diverse capabilities and expertise, which must be integrated to realize its potential for learning and innovation. Thus, knowledge integration can be facilitated by engaging in organizational ambidexterity whereby exploration and exploitation are simultaneously adopted (Tiwana, 2007). In this instance, "emphasis is placed on accessing and utilizing rather than acquiring" partners' complementary knowledge, joint capabilities, and expertise by applying them to specific activities to create value (Tiwana, 2007: 255).

Building on the exploitation and exploration pillars, Lane et al. (2006) proposed that three absorptive capacity processes (i.e., identify, assimilate, and apply external knowledge) underpin three learning activities (i.e., exploratory, transformative, and exploitative). Here, exploratory learning routines identify, acquire, analyze, and seek to understand critical external knowledge (Zahra and George, 2002). For their part, transformative learning routines select, retain, disseminate, and codify internally generated and externally acquired new knowledge. Finally, exploitative learning routines integrate acquired and developed knowledge into existing operations to refine and extend their functioning (Lane et al., 2006). Learning routines are specific to each project organization due to their governance structure, interdependencies, capabilities, expertise, and knowledge base (Manley and Chen, 2017).

So, in the case of a program alliance used to deliver infrastructure projects, such as the BWPA identified above, learning routines often arise from developing knowledge processing systems implemented across their projects, where experiential learning, which is the process of 'learning through' experience, materializes (Farzad et al., 2019). Thus, rather than pursuing "a new to the world" approach to innovation, we often see alliances adopting a "new-to-the-organization" tactic, which is less radical and risky but still positively contributes to improving their performance (Hauck et al., 2004; Aribi and Dupouet, 2016: 107).

2.2. Alliances and learning routines

Considering the contextual backdrop presented, absorptive capacity can be seen as an essential dynamic capability for organizations participating in the delivery of infrastructure projects (Manley and Chen, 2015, 2017). As organizational learning is a "routine-based, history-dependent and target-oriented" activity, it can materialize in several ways, such as through direct experience (i.e., learning by doing), trial and error, interpretation (e.g., stories, paradigms, and frames), superstitiously, conversations and dialogue (Levitt & March 1988: 319; Senge, 1990; Cheng et al., 2004). Within the context of absorptive capacity, each learning routine is unique and an imperfectly mobile resource (Love et al., 2016). This imperfect mobility enables an organization to achieve and sustain an advantage relative to its competitors.

Nevertheless, construction organizations, which typically rely on delivering projects via fixed-priced contracting, struggle to learn from one project to the next. This situation arises as routines are attuned to a framing of *single-loop learning* (Senge, 1990). Thus, organizations are unable to capture and transfer knowledge from within effectively and between their projects – each project acts as an island – as there is an overt emphasis on correcting (in)actions or errors rather than addressing the causes behind them (Senge, 1990; Love et al., 2023a, 2023b).

Routines are simply the rules, heuristics, and norms that are operationalized at different levels through the activities and processes of an organization (Lewin et al., 2011). They form the building blocks of an organization's capabilities and memory, which can develop due to organizational learning and process re-configuration (Greve, 2003). In this manner, routines embedded in an organization coordinate the actions of multiple units and people working within a given context, which can be modified in response to unexpected events (Nelson, 1994; Feldman, 2003; Becker, 2004). Accordingly, routines are context-dependent and are akin to 'situated action' whereby external structures help to control, prompt, and coordinate individual actions (Suchman, 1987). As contexts vary, general rules and procedures can only be partly specified and applied to a new one (Reynaud, 1998; Becker, 2004). It follows that "interpretation and judgment skills are required for completing general rules, such as, for example, to know what routines to perform when" (Becker, 2004: 651).

To reiterate, a program alliance is a temporary collection of organizations that come together for a specified purpose. Each organization will invariably possess its own cultural settings, embedded learning routines, and working methods. Consequently, a program alliance's ecological structure for learning becomes complicated as each organization is required to adapt its behavior to the environment of the project and the requirements of the 'Program Alliance Agreement' (PAA) (i.e., the contractual form specifying behavioral requirements and expectations) (Walker et al., 2023). Thus, the challenge for a program alliance is ensuring collaborative learning occurs so routines and expected outcomes simultaneously happen.

On the face of it, this challenge may appear an unachievable task within a program alliance due to the varying contexts of projects and the high degree of organizational differentiation that prevails within the alliance team, where the goals and objectives of parties traditionally conflict. In Fig. 1, we illustrate the structure of a program alliance and its network projects, which aligns with the case study examined in this paper.

Due to the varying nature of projects and participants within a program alliance, its learning routines may produce different outcomes at varying times, and "different routine [s] may produce the same outcome [s] at different times" (Levitt & March 1988: 331). Moreover, "an ecology of learners" can "complicate the systematic comprehension and modeling of learning processes" as the environment of projects within a program alliance may "endogenously change" (Levitt & March 1988: 331). However, we have seen through adopting authentic leadership, bolstering psychological safety (i.e., 'speaking up'), and nurturing the organizational practices of error management within alliances that routines can be readily modified, re-configured, and adapted in response to unexpected events (Love et al., 2023a, 2023b).

2.3. Conceptualizing absorptive capacity in a program alliance

We present our conceptualization of absorptive capacity within a program alliance in Fig. 2, with supporting examples in Table 2. The program alliance comprises *projects* and the *alliance entity*, akin to Lewin et al.'s (2011) internal and external absorptive capacity, respectfully. We divide the absorptive capacity this way as the PAA only exists within the alliance entity, not the supply chain involved in delivering projects. While both are interdependent, the entity acts as the organizational form that focuses on acquiring and utilizing knowledge from the external environment (e.g., best practices) and projects. Consequently, new knowledge is generated, shared across projects and their supply chains, and used to instigate changes to routines, processes, and systems.

Within and between projects, routines facilitate variation, enable new ideas to emerge and to be shared, and encourage "reflection on, updating and replacing 'old' practices" (Lewin et al., 2011: 85). This does not mean replaced practices are obsolete; they cannot aptly replicate knowledge within projects and support collaborative learning. The interface between the alliance entity and its projects requires adaptive tensions to be consciously managed. Such tensions determine the "strategic urgency or the impetus for stimulating exploration" of the learning and innovations that materialize and for "exploring new ideas" and generating best practices that may be used outside the program

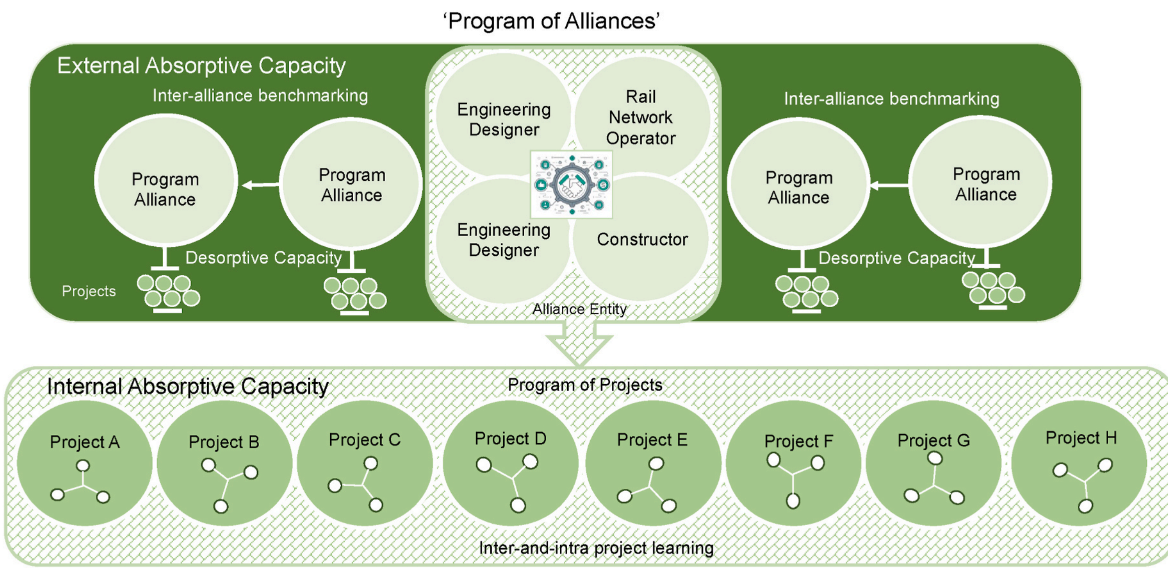


Fig. 1. Program alliances and their projects.

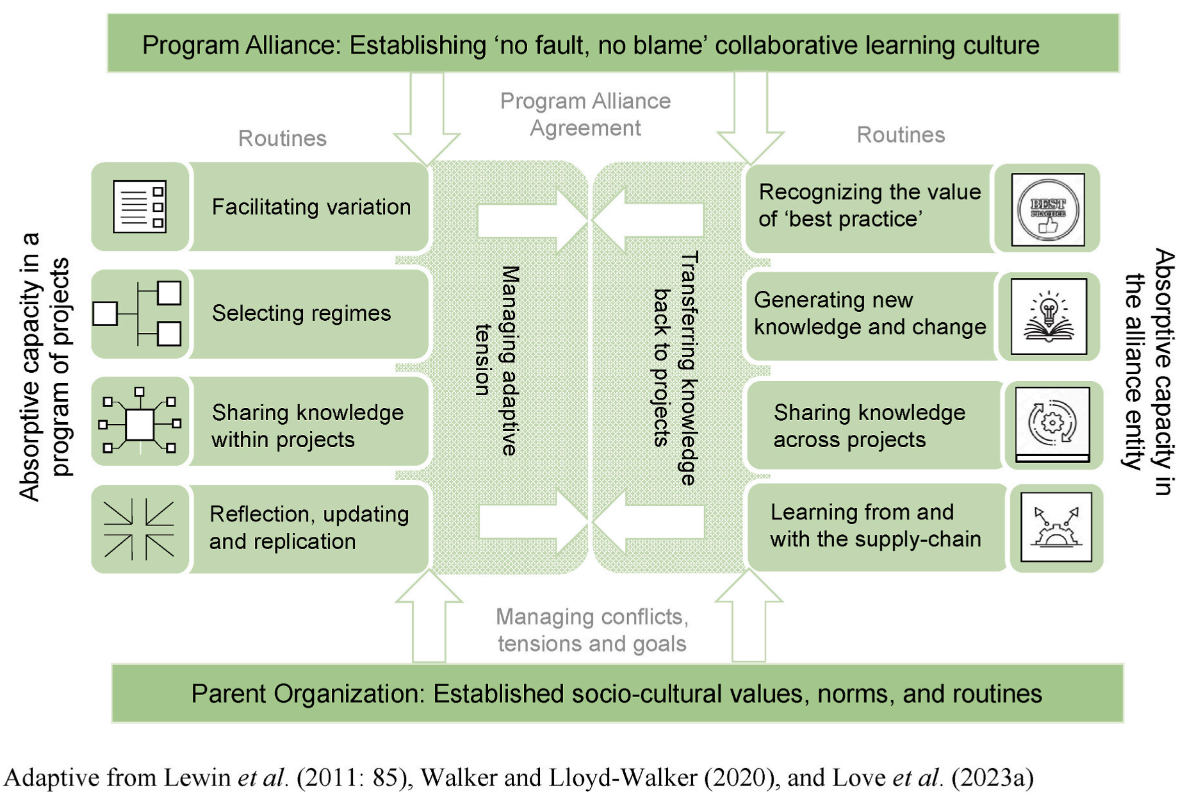


Fig. 2. Conceptualizing the development of absorptive capacity in a program alliance
Adaptive from Lewin et al. (2011: 85), Walker and Lloyd-Walker (2020), and Love et al. (2023a).

alliance (Lewin et al., 2011: 86). The assimilation of acquired knowledge and best practices by the alliance entity requires routines for transferring them into its program of projects (Lewin et al., 2011).

A good example where a program alliance can draw upon best practices of collaborative working is the BWPA (Love et al., 2023a). The BWPA received numerous awards for its best practices, including the National Safety Council of Australia award for the 'Best Safety Leadership Program' and the Civil Contractors Federation Earth Award for its 'Environmental Excellence' while constructing a pipeline. Furthermore, due to the routines, processes, and practices developed within the BWPA, the concept of QUALITY-II (i.e., 'why things go right') has been propagated (Love et al., 2023b).

In this instance, the alliance entity and its projects do not focus on following specified rules and procedures to ensure quality to prevent errors and rework. However, "people are deemed flexible and constitute an integral part of the solution to the quality problem, as they understand the nature of the work. Hence, they can continually adapt and adjust their performance to the prevailing conditions" (Love et al., 2016: 5). In this instance, QUALITY-II requires people to engage in 'requisite imagination', which is the "ability to imagine key aspects of the future

Table 2
Examples of absorptive capacity practiced in an alliance entity and its program of projects.

Routines in a program of projects (Internal)	Examples	Routines within the alliance entity (External)	Examples
Facilitating variation	• Actively engaging researchers from universities. Joint research projects to identify and develop innovations in projects. • Co-located office for the alliance team, which facilitates and manages projects. Site staff drop in and out and have direct access to design engineers and rail operator. • Solicitation of ideas from subcontractors to improve the design and construction propose	Recognizing the value of best practice	• Identifying 'best practices' from other successfully delivered infrastructure projects (e.g., technology and process innovations) • Coaching alliance team members to monitor the environment for new ideas/innovations. • Probing to identify new products. • Soliciting views of stakeholders about the impact of projects and considering their ideas about alternatives • Using the parent organization's standard systems/procedures/routines • Regular workshops to discuss continuous improvement (e.g., rework) and sharing experiences.
Selecting regimes to manage projects	• Development of a system for sharing knowledge (e.g., rework) • A shared sense of absorptive capacity ecologies with subcontractors/suppliers. • Autonomy of the alliance management team to support and allocate resources outside the alliance leadership KRAs.	*Generating new knowledge and change*	• Developing an error management culture (e.g., QUALITY-II mindset) • Collective learning • Lesson learned forums • Process re-configuration • Requisite imagination
Sharing knowledge within projects	• Visit constructions before the commencement of works by the design and project teams to aid constructability and engineering. • Joint problem-solving between projects. Subcontractors share experience and solutions with others from different projects. A mindset that 'no project is an island' and lessons learned are shared within and between projects.	*Sharing knowledge across projects*	• Inter-project benchmarking • Shared lessons learned and innovation • Learning through coaching • Sharing of errors and solutions on a 'daily' basis using mobile technologies • Communities of practice for specific knowledge themes (e.g., quality, environment, and well-being) • Target outturn cost development
Reflection, updating, and replicating	• Learning from 'what went right' and 'what went wrong.' • Engendering and enacting dialogue and retrospective sensemaking • Identifying best practices in projects and applying them to new ones (i.e., imitation)	*Learning from and with the supply-chain*	• Collaborating with suppliers/contractors • Collaborating with the public • Building the capacity and capabilities of local subcontractors and suppliers • Transferring knowledge to the parent organization
Managing adaptive tensions	• Intra-project benchmarking (e.g., time, cost, and safety measures) • Implementing stretch targets to stimulate innovation. • Using lessons learned to enact change and facilitate continuous improvement in projects	*Managing conflicts, tensions, and goals*	• Program Alliance Agreement specifying expected behavior • Establishment of a 'single team mentality' to ensure goal alignment • Focus on 'best-for-project' outcomes • 'Pain-gain share' incentive regime • Enabling participants to 'speak up' through emancipatory dialogue

Adaptive from Lewin et al. (2011) and Love et al. (2016).

we are planning" or in other words, anticipating what might go wrong (Adamski and Westrum, 2003: 195; Love et al., 2023b).

Participants in a program alliance and its projects invariably have to serve two masters and participate in two cultures: the parent organization and the 'project'. The parent organization's established socio-cultural values, norms, and routines will differ from those of the program alliance, as will their goals. However, the PAA provides the framing to align goals and financial incentives for collaboration, but this only applies to those organizations that form the alliance entity and not subcontractors contracted by the alliance to construct works.

The PAA sets out expected behaviors providing "socially enabling mechanisms that facilitate variation and influence the direction and organizational configuration of knowledge generations and assimilation processes" within the program alliance (Lewin et al., 2011: 86). In this instance, the PAA enables shared values, norms, expectations, and collaborative behavior used to build connectedness between participants to be formally established, which helps knowledge to be developed collectively and shared across projects (Matthews et al., 2022a, 2022b; Walker et al., 2023).

Broadly speaking, social enabling mechanisms transcend all levels of a program alliance and are critical to building its absorptive capacity (Todorova and Durisin, 2007). While some "values and norms may be formalized and explicitly practiced" within a program alliance, they can "influence individual behavior in a very tacit, informal, and a subtle way" (Lewin et al., 2011: 86). Such behavior tends to be unobservable and imitable but can enable a program alliance to adapt and respond effectively to unexpected events. This situation arose in the BWPA. After its completion, the water authority struggled to imitate its previous success as it tried to 'shoehorn' its accumulated knowledge and developed routines and practices into new projects delivered using traditional contracting methods (Love et al., 2023a). Rework and conflicts between subcontractors arose in new projects, and remedial actions were needed; a coaching strategy was adopted and implemented to resolve the issues that arose (Love et al., 2023a).

We often see subcontractors appointed on a competitive lump sum basis in a program alliance. This form of contracting and pushing of risk onto subcontractors can contribute to mis-performance. In the case of the BWPA mentioned above, this very scenario came to the fore. However, when rework and safety issues impacted project performance, the program alliance re-configured how they approached and engaged their subcontractors. If the alliance had not embraced change, *ceteris paribus*, a rework cost of 4.5% of contract value for the remaining projects to be completed would have likely occurred – a potential loss of AU$17million – and safety performance would have been severely compromised (Love et al., 2023a).

While no financial incentives were provided to subcontractors,

Table 3
Sample of interviewees.

No.	Interviewee*	Time (Minutes, seconds)	Transcript word length
1	Project engineer	40:19	5615
2	Design manager	37:39	5561
3	Quality manager	60:14	9557
4	Project engineer	26:52	3585
5	Design manager	53:58	8653
6	Design coordinator	49:41	6257
7	Quality manager	41:39	5187
8	Project engineer	55:54	5321
9	Site Superintendent	36:01	5341
10	Project engineer	45:03	6776
11	Construction manager	26:21	3399
12	Subcontractor	48:24	6852
13	Planning manager	39:34	5485
14	Senior project engineer	31:40	4825
15	Engineering coordinator	43:49	7360
16	Planning manager	39:18	5015
17	Subcontractor	32:41	5159
18	Engineering manager	28:54	4333
19	Commercial manager	44:11	6128
	Total	**782:12**	**110,409**

emphasis was placed on engaging in emancipatory dialogue and collaboration with the alliance to determine a realistic lump sum for construction works. Additionally, any change orders required were discussed and agreed upon as soon as they were identified to ensure a win-win outcome for the alliance and subcontractors. Suffice it to say that not extending the PAA, in particular, including some form of incentivization regime for key subcontractors, can stymie the effective development of absorptive capacity in projects (Love et al., 2016; Walker et al., 2023). However, to the authors, no reported examples exist of alliance entities providing their subcontractors with financial incentives to meet their contracted deliverables.

3. Research approach

We use an illustrative case study approach in conjunction with sense-making to elaborate on the existing theory of absorptive capacity and learning routines and practices unearthed in the BWA to garner an understanding of how a (mega-project) program alliance has learned to mitigate its rework (Yin, 1994). Indeed, case selection is a crucial part of empirical research and will influence the ability to generalize the findings unearthed from the case study. However, program alliances are unique projects and provide an environment for 'best practice' to emerge, providing opportunities for the broader industry to learn and improve its performance and productivity. The case project examined in this study is transforming the rail infrastructure of a metropolitan area of a major Australian city. The authority responsible for planning, delivering, and constructing the project on behalf of the state government is committed to fostering an environment of collective learning to stimulate continuous improvement and innovation. Consequently, we were invited in 2019 to examine rework and associated wastes (i.e., non-value-adding activities) and determine how they can be mitigated in the project.

3.1. Research context

The transport mega-projects current contract value is >AU$19 billion, but this is expected to increase due to changes in scope. The project was established in 2015, with its portfolio of works expected to be completed by 2030. A production mindset drove the decision to adopt a 'program' approach to development and delivery rather than a bespoke approach to single projects. The total allocation of projects (or work packages) to a program alliance provides certainty and continuity of work. It thus attracts and retains large-scale, high-performing teams that drive continuous improvement. Additionally, this certainty and continuity of work enable the program alliances to invest in skills development, establish long-term supply chain agreements, and create safe and healthy working conditions, standardization, and reuse.

Using a program approach allowed the state government's representative authority to 'slice up' the mega-project into smaller, more manageable packages. As a result, this enabled greater emphasis on front-end engineering, planning, and development, augmented by the delivery model's collaborative nature. The project's commercial and governance frameworks incentivize performance in key areas such as continuous improvement, innovation, and safety. Community engagement, sustainability, diversity, and social procurement.

The project comprises five program alliances. This study focuses on one of these alliances, forming our unit of analysis. The selected alliance has completed eight projects to date, which required the removal of existing and the construction of new road and rail infrastructure. For reasons of confidentiality and political sensitivity, we cannot provide any more details about the transport infrastructure project.

3.2. Sense-making

Our adopted sense-making lens focuses on the individual experiences and observations within an organizational setting (i.e., the program alliance), our observations (of the context) from being involved as a participant observer and having access to project documentation. We use a hermeneutic approach to understand the individual's perspective about the routines used to generate and share knowledge and stimulate learning in the program alliance within the context of errors and rework (Dervin, 1992). The corollary is that we focus on understanding and promoting agency, enabling the individual and researcher to engage in an unfettered communicative process.

We also sought to capture a *dialogic surround* by capturing different people's views to "hear how they construct their worlds in such a way that hearing can become fodder for active sense-making rather than knee-jerk argument and resistance" (Dervin and Reinhard, 2006). We make use of our observations by taking a retrospective approach to organizational sense-making, which is realized through collective communication, interpretation, and meaning shaping of what is seen and heard (Weick, 2001).

3.3. Data collection

Data for this research is drawn from multiple sources to make sense of the program alliance's absorptive capacity and its development as a consequence of learning from error-making. As mentioned above, we have been involved with one of the program alliances since 2019 and regularly attended its fortnightly continuous improvement team meetings. We were privileged to have access to the program alliance's documentation, such as quality (e.g., non-conformances >300 reports), lessons learned reports (>500 entries from eight projects with examples identified in Table 4), requests for information (>2000), site diaries (e.g., daily reports from eight projects >5000 records), and issues for construction documentation (e.g., drawings).

We have also conducted 19 in-depth, formal, semi-structured interviews with members of the alliance entity and its subcontractors (Table 3). A copy of the interview protocol we have used in the study is available upon request from the corresponding author. In sum, questions focused on: (1) risk identification and prevention; (2) identifying rework events and describing (e.g., *how*, *why*, *what,* and *when*) they occurred, the consequences, and resolution; (3) continuous improvement and learning initiatives implemented to address errors and rework; and (4) suggestions to better manage errors and rework in projects (e.g., lessons learned and change).

Table 4
Thematic examples of absorptive capacity routines in practice derived from interviews.

Routines in a program of projects (Internal)	Examples	Routines within the alliance entity (External)	Examples
Facilitating variation	*Dialogue with Sub/c*: "Sometimes, we ask [the subcontractors] what rework occurred today and have good discussions around it. These would be small events that don't end up as NCRs [non-conformance reports], but some do. If we continue talking about it, people will think about it. So, we talk and discuss rework and NCRs" (Site Superintendent) *Daily pre-start risk session*: "We have toolbox talks to inform everyone what is going on for the day and discuss potential risks. We now discuss about potential rework risks, near-misses, and that sought of stuff. We bring things out, and everyone learns. Sometimes we discuss how issues were solved" (Project Engineer)	*Engendering best practice*	*Knowledge and practices from other program alliances*: "We are always looking to see what the other alliances are doing and how we can learn from them." *Continuous improvement:* "Our continuous improvement is branded as the 'war on waste. The top three wastes we've identified are transportation, rework, and waiting (Continuous Improvement Manager) *Engagement with universities*: "We're engaged with a number of universities looking at how we can reduce waste as part of our continuous improvement strategy. XXX is looking at how we can utilize the last planner better" (Continuous Improvement Manager) *Incentivization*: "If we develop new technology or innovation that the other alliances adopt, then the XXX we may get a bonus" (Engineering Manager)
Selecting regimes to manage projects	*Investment in technology*: "Our reliance on BIM (building information modeling) allows us to attend to issues [errors and changes] from an interdisciplinary perspective. We notify all affected by a problem." *Resources to share rework knowledge:* "A consultant has been appointed to help us share knowledge about errors and knowledge. He goes to the site, undertakes some workshops, and gets people talking about rework. For him, it's about the conversation" (Continuous Improvement Manager) *New ways to capture rework data*: "NCRs are used to capture our rework, but they are not always reported. So, we tried to capture at its source on-site and during toolboxes and use a new categorization (Continuous Improvement Manager)	*Generating new knowledge and change*	*Requisite imagination:* "Our design includes a risk-based around design rework. We run a risk register and are quite transparent about how we do it. There's quite a methodological way of working through risks. You know what your risk bucket should be as part of the design process, and we can put in defenses to prevent the need for rework. I guess we are guessing in advance the chance of rework" (Design Manager) *Lessons learned*: "You often don't think how a change [due to a mistake] affects the wider team/This was a lesson learned. Now, when a change is needed, it is communicated to the wider team, and we have a weekly meeting where the issue is talked about (Design Manager) *Error management*: "We have an open culture, camaraderie, and joint problem-solving toward errors, but it doesn't extend to subcontractors. I think they have an important role to play, and we should consider their input in the design process" (Construction Manager) *Error management*: "The language we use in this project is collaborative. The culture is nurturing. You know, there's a support network, and there is a sort of selflessness that comes through as a result of the culture. It is enjoyable to be in this culture where you know it's very supportive" (Design Manager)
Sharing knowledge within projects	*Joint problem-solving:* "Any problems [errors] we have or rework are brought up at toolbox meetings, and everyone learns from there – we share our experiences. There is nothing to hide. We talk about it [errors and rework] and move on" (Project Engineer) *Dialogue with Sub/c*: "The daily 2.00 o'clock quality toolbox meeting with the construction team planning helps us identify the next day's work. What materials are coming, and the support is needed? How much traffic control is required? I guess we look ahead to anticipate and prevent rework by looking ahead and sharing our thoughts and experiences [site management team and sub/c] so we can get the best outcome from our planning (No.7). (Quality Manager)	*Sharing knowledge across projects*	*Target outturn cost production*: "Most risk is contingent on doing design rework. Our design includes risk. So, we have an optimistic outlook when we start the design and put the TOC [target outturn cost] together. Our assumption is not to do rework, but then obviously, we have a contingency bucket as things inevitably change, whether through an omission on our part or whether a stakeholder changes their mind. It is through establishing a TOC we can learn and share from previous jobs" (Project Engineer) *Community of practice*: We've begun to informally share experiences with our rework across projects and with sub/c. We've started rolling out a program, a kind of community of practice "(Continuous Improvement Lead)
Reflection, updating, and replicating	*Identifying new practices*: "We have a really good quality team here. We spent quite a lot of time discussing it [quality] and assuring it since our first set of projects. What we build to the best of our ability is built right the first time and has a great quality system. I guess instead of a checklist as previous, we have now become reliant on ITPs [Inspection Test Plan] and the like to get everything right before we before we do it" (Site Superintendent) *New process 5 'whys'*: "We introduced the 5 whys into our non-conformance reporting to better understand why they occurred. There is also a suggestion for learnings" (Quality Manager)	*Learning from and within the supply chain*	*Shared value*: We work with subcontractors to help them develop their systems and capabilities. We try to use local contractors, up-skill them, and even source local materials. You see, if we can help the subcontractors, they will make less mistakes" (Construction Manager) *Monitoring production pressure*: "It's a fast-paced project. There's a lot of pressure coming from a lot of directions. I would say it's certainly more difficult than other projects. Everyone is pulling in the same direction, being on the same team, but it's moving fast. People do feel pretty under the pump. We are always benchmarked against previous performance and the performance of other XXX alliances ….and are continually looking to drive down the cost of design and the alliances. I'm gonna stick to that first [design] solution and not change it again. A couple of areas the alliance is pushing at the moment are adapting, adopting, and inventing. Adapting is adopting something from a previous project and tweaking it to make it work.

(*continued on next page*)

Table 4 (*continued*)

Routines in a program of projects (Internal)	Examples	Routines within the alliance entity (External)	Examples
			And inventing is where we have to come up with something innovative" (Design Manager)
Adapting to new situations	"We've had a really, really long and successful relationship with [the contractor], and that stems back 10 or 12 years. Our workforce is ramping up as we have continued work. Working with [the alliance] has helped out business. It's quality and safety issues of its procedures and that sort of thing. So, we've been learning and improving systems' (Subcontractor)	*Understanding success (i.e., what works) and failure (i.e., what does not work)*	*Understanding*: "We're trying to understand the causes of rework so we can better predict them going forward. We've developed a new rework classification to help us move forward" (Continuous Improvement Lead)
Facilitating psychological safety	*Being able to speak up about errors*: "I spend 90% of my time maintaining culture. We have the open conversations [with the alliance]. We can speak openly and be frank about errors and rework so they don't happen" (Subcontractor)	*Transferring knowledge externally*	*Desorptive capacity*: This construct has emerged by the client benchmarking each alliance's innovations and providing an incentive to transfer knowledge to other alliances and the wider industry. This was an issue discussed during our meetings with the continuous improvement team (Informal discussion)

3.4. Analysis

As research examining absorptive capacity in alliancing is limited (Love et al., 2016), we take a purely qualitative and nuanced account of our data by delving deeper into that collated to understand better how this dynamic capability is enhanced from error-making and rework. Thus, we adopt thematic analysis to identify patterns in meaning across our data. Typically, inductive analysis is used in cases where no previous studies have dealt with the phenomenon, so categories are coded from the data (Hsieh and Shannon, 2005). However, in our case, based on the research of Lewin et al. (2011), Walker and Lloyd-Walker (2020), and Love et al. (2023a), we have established a framework for how absorptive capacity is practiced and enacted in a program alliance. The routines identified in Table 1 and Fig. 2 guide our thematic analysis (Berg and Lune, 2012). A summary of our research process is presented in Fig. 3.

4. Research findings

As we have identified, the alliance entity is responsible for delivering a program of projects; it also can be viewed as being contractually separated from its projects. The PAA only applies to four organizations that provide engineering and management expertise, information, and knowledge to subcontractors who construct an asset. Moreover, the alliance deals with other program alliances and the external environment to derive generated knowledge, which is then applied and adapted to its projects. Thus, we analyzed our documentary sources and interview data and reflected on the meetings with the continuous improvement team to produce the thematic maps of learning practices used to handle the alliance's errors and rework, identified in Figs. 4 and 5. Examples of quotes and extracts from the lessons learned register to support our observations are presented in Tables 3 and 4 The conceptualization of absorptive capacity presented in Fig. 2 provided the basis to conduct the analysis and delve deeper to unearth new dynamics within a program alliance and its projects.

We would like to point out that learning routines identified as themes are interdependent and often overlap. Indeed, the boundaries of the identified learning routines are blurred, so our thematic maps are somewhat arbitrary. However, the thematic maps present the nuances and intricacies of absorptive capacity at various levels in a program alliance environment.

4.1. Program of projects

Our conceptualization of absorptive capacity in Fig. 2 for the 'program of projects' included four learning routines, also present in this case. However, two additional routines were identified (in red in Fig. 4) as contributors to establishing absorptive capacity: (1) *facilitating psychological safety* whereby people can speak 'openly' and share their knowledge of errors and assimilate it within a given context without fear of reprimand; and (2) *adapting to new situations*, where subcontractors became curious and willing learners as they were provided continuity of work and became committed to collaborating with the program alliance. Moreover, the subcontractors were able to effectively adapt and respond to error situations in ways that maximized their ability to resolve them quickly to mitigate their impact on a project's performance.

The routines we uncover operating within a project and its supply chain align with our conceptualization, but the context differs. The *management of adaptive tensions* was embedded in the work practices, and people are open to learning and facilitating continuous improvement. While intra-project benchmarking was undertaken, it was used as a guide to establish the Target Outturn Cost (TOC), scheduling, and managing safety. There was a drive and desire to do better with each project delivered, but this could occur by *reflecting, updating, and replicating* knowledge and best practices. A case in point was the introduction of the '5 Whys' as an amendment to non-conformance reporting to help site management better understand why quality standards were not being adhered to in projects (Table 4).

While there was an importance placed on understanding 'what went wrong' (i.e., why rework occurred), the equal emphasis focused on learning from 'what went right'. For example, in-ground services to support power for a rail line were installed over several kilometers without any errors and rework. In a nutshell, the conditions contributing to completing the services route were enacting the Last Planner System® (LPS) (e.g., Touchplan), legitimizing communicative action, and embracing requisite imagination. Thus, the practice of understanding and learning from success has enabled the alliance's site management teams to build resilience to production pressure.

Notably, several site-based employees of the alliance had been involved with the delivery of BWPA. They had experience working in a collaborative environment and drew upon their knowledge derived from BPWA to address and manage the risk of error-making and their treatment. So, in the case of our *facilitating variation* routine, the project engineer representing the alliance's contractor introduced the potential for rework into its pre-start meeting and encouraged subcontractors to 'openly' engage in dialogue about issues they thought were relevant.

Additionally, the site superintendent sought to actively engage in daily conversation with the subcontractors, asking about problems they encountered and explicitly encouraging them to report and discuss any rework they had endured (Table 4). The ensuing dialogue focused on exchanging perspectives and exploring how future rework events could be mitigated. For example, while inspecting works, the site superintendent and quality manager would ask subcontractors about problems they encountered and how they resolved the issue. The aim here was to learn about 'how' such work could be captured better and used as a basis for learning in the future.

The embedded collaborative mindset underpinning the alliance was also extended, though informally, to supply its supply chain, particularly subcontractors. An open office whereby subcontractors can drop in, have informal discussions about issues, and directly interact with the alliance's contractor enables the free exchange of knowledge and bolsters the collaboration effort. *Knowledge sharing within projects* resides with the alliance's contractors, who have proactively treated errors and rework. A coach, an independent consultant specializing in error management who had been involved with BWPA and led its charge on rework, was employed to support subcontractors in developing their learning capacity. Workshops were regularly undertaken on-site with subcontractors to coach them about sharing errors and identifying circumstances where rework went unreported. While the coaching process aimed to stimulate joint problem-solving and dialogue, there was also a drive to empower subcontractors to propose solutions to combat error-making.

Despite the fact that there are systems in place to capture non-conformance, they only capture a fraction of the rework that occurs in their projects. However, such additional data is located in different locations and varying formats within the alliance's project information systems, rendering it difficult to quantify and understand the impact of rework on operational performance. Aware of this problem, the continuous improvement team allocated funding and resourcing to its projects to develop a new system to capture rework (*internal selection regime*).

We identified this problem in our previous work and are working with the alliance to develop a knowledge-based engineering system to capture rework and predict its risks (Matthews et al., 2022a, 2023). Additionally, other universities have been working with the alliance to look at ways to improve learning and knowledge dissemination. For example, one project commissioned by the continuous improvement team examined how the LPS could be better utilized to promote dialogue between construction team members and identify problems in advance.

4.2. Alliance entity

Regarding the 'alliance entity,' two additional themes emerged during our interviews. The first was *transferring knowledge externally*, referred to as *desorptive capacity*. This additional dynamic capability enables the safe transfer of knowledge from the program alliance to the other four alliances (Bravo et al., 2020). As the alliances are benchmarked against each other and are incentivized to transfer the developed best practices and innovations, a degree of desorptive capacity fit exists. Determining the extent of the alliance's desorptive capacity fit with the other four alliances is outside the remit of our research. Nevertheless, it would be worth examining whether 'programs of alliances' vary in their levels of desoprtive capacity (i.e., more or less than each other).

The second theme identified was *understanding success (i.e., what works) and failure (i.e., what does not)*. In this case, the alliance focused on understanding 'what worked' and 'what did not' in varying situations. The alliance was aware of the impact of workplace demands and constraints on people's performance. Thus, it encouraged its team members to anticipate errors, enabling them to understand, embrace, and adapt to the environment within which they occur. In this instance, people acknowledge that errors happen – an innate feature of an error management culture – drawing on prevailing learning routines to anticipate and prevent rework risks and recover from events that manifest. Thus, people adopt a preparedness mindset, which complements requisite imagination (Fig. 5). However, requisite imagination extends beyond predicting risks to consider uncertainty where we need to accommodate future scenarios that could transpire.

The alliance aimed to deliver its projects by *engendering best practices* and 'learning through' (i.e., how to handle) errors to enact continuous improvement. For example, the rail network operator suggested that all alliances record their non-conformances in a standardized format to improve knowledge-sharing between alliances. As each alliance recorded them in different ways and reported them to the operator, it was impossible to compare them and derive knowledge that could be shared for benchmarking purposes. A copy of the proposed improvement submission can be seen in Fig. 6. Notably, we can see here how the operator learned from the experiences of BWPA as they recognized the relationship between rework and safety incidents. Non-conformance reporting to the operator is now standardized, contributing to each alliance's ability to establish its desorptive capacity.

Engaging with stakeholders is critical for the alliance. However, at the beginning of the project, stakeholder management was its Achilles heel. Lines of communication had not been established early enough when projects were being designed. As a result, changes in the design often needed to be made, which sometimes negatively impacted downstream construction activities (e.g., delays, productivity, and rework). In Table 5, we provide extracts from the lessons learned register from the alliance entity during its formative years. The alliance actively engages with its stakeholders at all levels, but this remains a complex process to manage due to often competing and conflicting demands.

Creating *new knowledge and change* aligns with the PAA with a pain-gain share incentive regime providing the footing for collaboration, meeting the KRAs, and stimulating innovation. Adopting a single-team mentality does not automatically materialize in an alliance – it takes time to establish. Understanding how a change impacts the wider team is seldom realized in a traditional procurement setting as the 'over the wall' principle applies (Table 3). Within an alliance, however, emphasis is placed on communicating with all parties so they can address its consequences and learn together – natural features of an error management culture.

Our previous studies have examined the culture of the alliance, which we found to be aligned with error management (Matthews et al., 2022b; Love et al., 2022b). This finding is reinforced by examples of comments obtained from interviewing representatives from the alliance entity presented in Table 4. Terms such as open culture, joint problem solving, camaraderie, and selflessness identified by interviewees are the epitome of alliancing practice and an error management culture. While it has taken seven years or so to establish the alliance's collaborative culture, some people are reluctant to 'speak up,' and there remains a belief that the 'blame game' still exists. For example, a design manager stated, "there is certainly an element of being blamed [design changes/errors] in some teams more than others. So, I think people try to keep quiet".

Establishing a truly 'no blame' environment is a purist's sense of alliancing – it cannot be realized. However, it should be something that all organizations should strive to achieve. This pursuit to ensure people can freely speak up without fear of reprimand contributes to the effective development and implementation of learning routines and, naturally, an alliance's absorptive capacity.

The alliance entity *shares knowledge across its projects* in several ways, such as inter-project benchmarking and forming communities of practice to exchange experiences and insights into dealing with issues such as rework and safety (Fig. 5). The development of a project's TOC is an area that is highly dependent on the sharing of knowledge as it draws on previously completed projects. It holds that the more information available, such as the '*as*-builts' from previous projects, site surveys, and specifications, the more equipped the alliance entity can estimate the TOC. Put simply, information from previous projects acts as a reference design. The alliance is subjected to considerable production pressure and resource constraints, which, during its formative years, impacted its ability to delineate between interfaces and share information. This issue has been resolved as additional people have been employed, but production pressure remains ongoing.

The alliance entity recognizes the value of *learning from and with its supply chain,* and that collaboration with all stakeholders is critical to its success, with the design coordinator stating, "we work really hard to

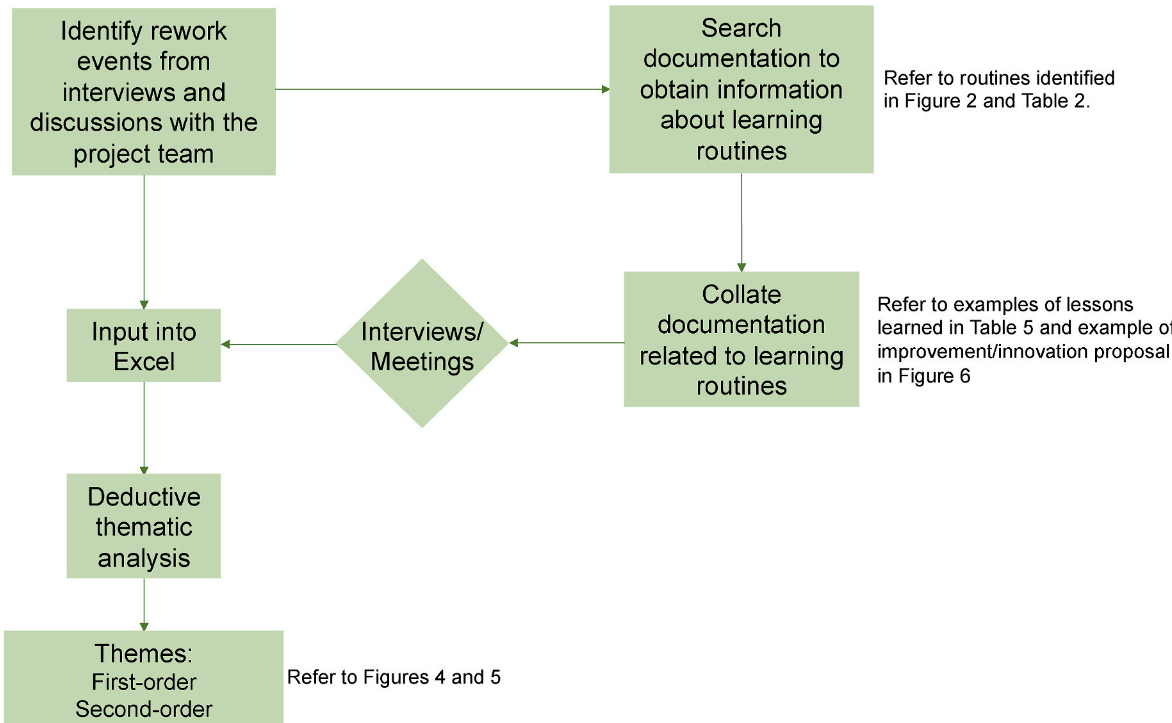


Fig. 3. A summary of the research process.

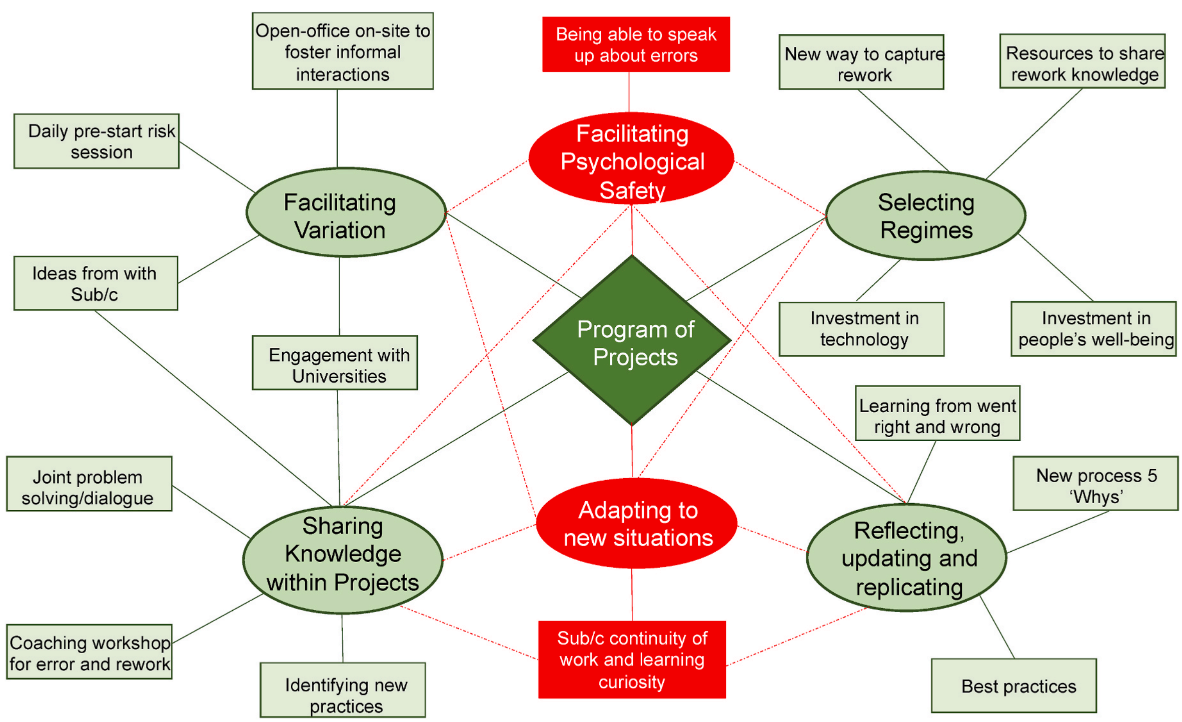


Fig. 4. Thematic map for 'program of projects' learning routines.

liaise with our stakeholders. Without their input, we wouldn't get things done on time. It's been a slog, but we're trying and learning as we go". Indeed, learning is an innate feature of the alliance, with the continuous improvement manager stating that they "aspire to be a learning organization" and improve local subcontractors' and suppliers' capacity and capability. The alliance has fostered learning routines through a shared value approach by enhancing local organizations' competitiveness and improving social and environmental conditions in the area where projects were being delivered.

Our findings have provided insights into the learning routines in a

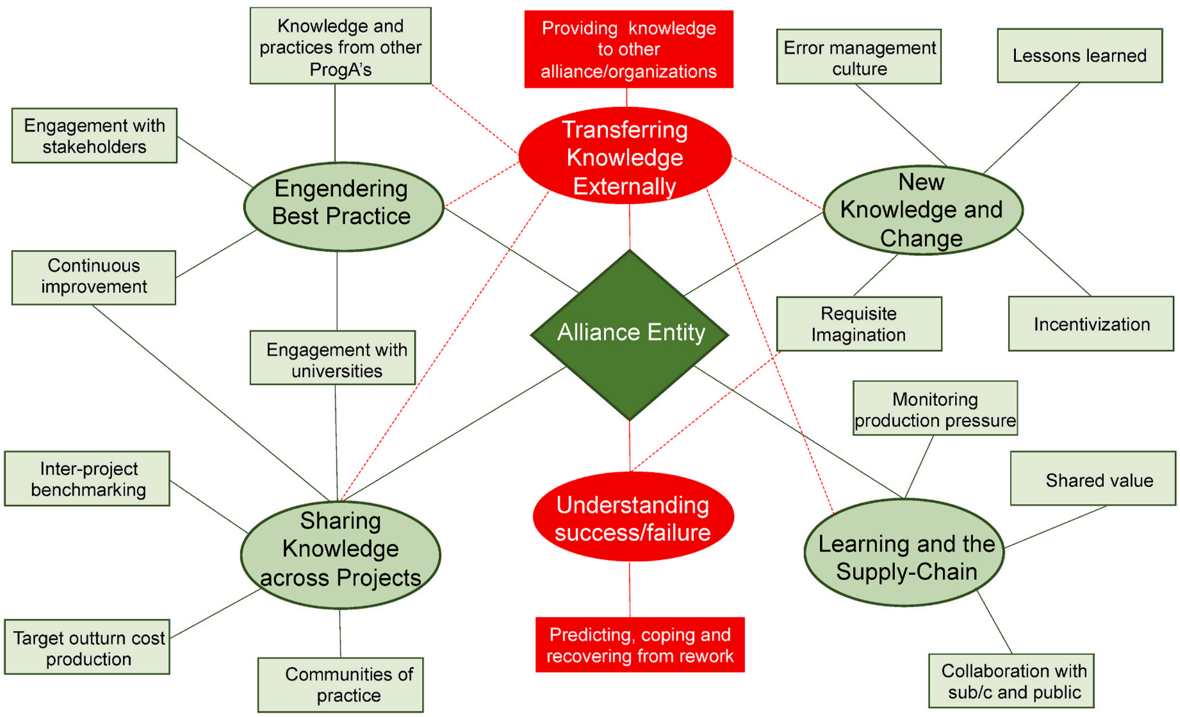
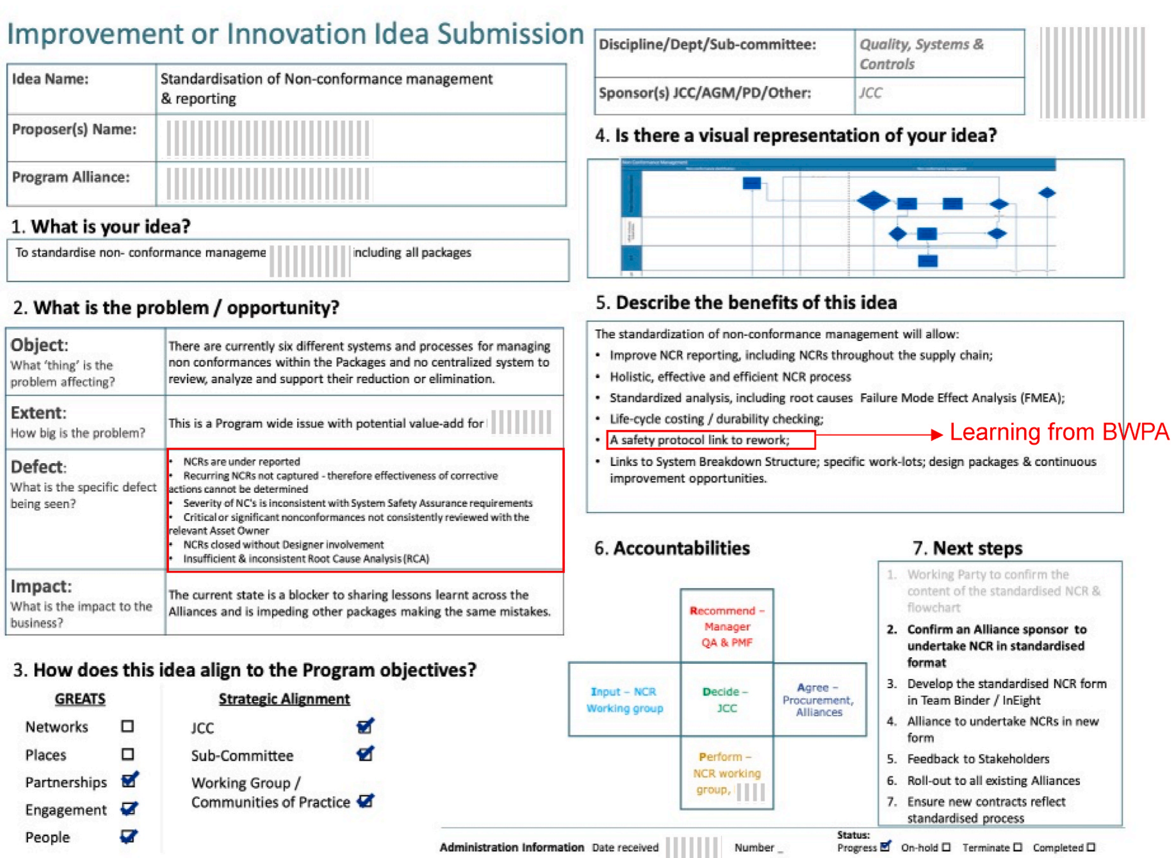


Fig. 5. Thematic map for the 'alliance entity' learning routines.



Improvement or Innovation Idea Submission

Idea Name:	Standardisation of Non-conformance management & reporting
Proposer(s) Name:	
Program Alliance:	

Discipline/Dept/Sub-committee:	Quality, Systems & Controls
Sponsor(s) JCC/AGM/PD/Other:	JCC

1. What is your idea?

To standardise non- conformance manageme … including all packages

2. What is the problem / opportunity?

Object: What 'thing' is the problem affecting?	There are currently six different systems and processes for managing non conformances within the Packages and no centralized system to review, analyze and support their reduction or elimination.
Extent: How big is the problem?	This is a Program wide issue with potential value-add for
Defect: What is the specific defect being seen?	• NCRs are under reported • Recurring NCRs not captured - therefore effectiveness of corrective actions cannot be determined • Severity of NC's is inconsistent with System Safety Assurance requirements • Critical or significant nonconformances not consistently reviewed with the relevant Asset Owner • NCRs closed without Designer involvement • Insufficient & inconsistent Root Cause Analysis (RCA)
Impact: What is the impact to the business?	The current state is a blocker to sharing lessons learnt across the Alliances and is impeding other packages making the same mistakes.

3. How does this idea align to the Program objectives?

GREATS		Strategic Alignment	
Networks	☐	JCC	☑
Places	☐	Sub-Committee	☑
Partnerships	☑	Working Group / Communities of Practice	☑
Engagement	☑		
People	☑		

4. Is there a visual representation of your idea?

5. Describe the benefits of this idea

The standardization of non-conformance management will allow:
- Improve NCR reporting, including NCRs throughout the supply chain;
- Holistic, effective and efficient NCR process
- Standardized analysis, including root causes Failure Mode Effect Analysis (FMEA);
- Life-cycle costing / durability checking;
- A safety protocol link to rework; → Learning from BWPA
- Links to System Breakdown Structure; specific work-lots; design packages & continuous improvement opportunities.

6. Accountabilities

Recommend – Manager QA & PMF
Input – NCR Working group
Decide – JCC
Agree – Procurement, Alliances
Perform – NCR working group,

7. Next steps

1. Working Party to confirm the content of the standardised NCR & flowchart
2. **Confirm an Alliance sponsor to undertake NCR in standardised format**
3. Develop the standardised NCR form in Team Binder / InEight
4. Alliance to undertake NCRs in new form
5. Feedback to Stakeholders
6. Roll-out to all existing Alliances
7. Ensure new contracts reflect standardised process

Administration Information Date received Number Status: Progress ☑ On-hold ☐ Terminate ☐ Completed ☐

Fig. 6. Example of an improvement or innovation idea proposal.

Table 5
Examples 'extracted' from the lessons learned register.

Subject	Situation	Recommendation and Comment	Follow-up Action
TOC Production Process	The TOC was aggressive [i.e., due to production pressure], requiring our own design to progress to preliminary design (PD) or concept design with no proper reference design or project specification within a 9-week time frame. As such, receiving 'as-built' and survey information The works were disproportionally distributed across the drafters/modelers. As such, the civil 3D modeler was inundated with requests from the design and delivery team. Over-reliance on a single person resulted in a bottleneck and delayed providing information to the team to prepare the TOC. Also, when the individual was away for personal reasons (e.g., sick), this posed problems	Even during the business case, as-built drawings, existing surveys, and any other relevant information should be sought to allow the team to commence with all information; that is, a reference design from previous projects. When resourcing the design team drafters and modelers, the delineation between interfacing disciplines must be made clear (i.e., what one team outputs to another and what the other team needs to do with this information). Based on this, the work distribution must be assessed to ensure that specific members are not overloaded. This needs to be established at the start of the project. The process for obtaining cut and fill quantities out of a model needs to be refined. Furthermore, consideration needs to be given to splitting so more than one modeler works on it at a time or if there are other ways to reduce the load on the individual (e.g., two no. Modelers working on the roster on one model?). More resources are required. Additional rail modeler. Note that 12D [terrain, surveying, and civil engineering modeling software] is used in Australia only; however, few are available. So, it may be worth considering other more commonly used packages (e.g., Bentley Rail Track, In-Roads, Civil 3D).	Implement for future TOC. Implement for future TOC
Stakeholder Engagement	Slow response from stakeholders or comments difficult to predict/close out. The design coordinator is overwhelmed with the effort required to regularly chase due and overdue stakeholder comments and chase closeout comments for design leads. Discussions with XXX and the 'rail operator' took place too late in the piece causing late change and delay to Issue-For-Construction (IFC) of design packages	Benefits have been seen from early stakeholder engagement in the design process. Taking the stakeholder through the design process from the initial design stages reduces shock comments. Extra resources are required for stakeholder/reviewer monitoring/coordinating. Engage stakeholders earlier in the piece to seek agreement on maintenance responsibilities	Actively engage stakeholders at all levels No follow-up actions Monitor engagement with XXX and the rail operator earlier to ensure changes do not arise
Collaboration with Sub/c	Contractor involvement and their knowledge of the piling design led to suggestions that are being considered by the engineering team The engineering team needs to go out to the site and speak with the sub/c about issues. They should also work from the site office and encourage other members of the team out there to build and strengthen relationships out there with the sub/c and suppliers.	Early contractor involvement will be implemented to drive value further and mitigate rework. –	Ensure improvements are implemented in future packages
Requisite Imagination	XXX had the delivery team in the office to provide input into the design and plan works before starting on-site	This enabled the different groups across the alliance to get better acquainted and share knowledge, and now that the team is on-site, communication is flowing better.	No follow-up action
Monitoring Production Pressure	XXX requires additional resourcing constraints due to ongoing schedule pressure. Due to the current status of construction, this takes priority – there is a need to prioritize resources. If not, XXX is left to make do and still try and meet the accelerated deadlines.	Attempt to predict/control the resourcing across all packages - those finishing, starting, at construction. Alternatively, adapt package programs to suit this demand.	No follow-up action

program alliance, which have contributed to developing its absorptive capacity. We next discuss the theoretical and practical implications of these findings.

5. Discussion

Learning from errors and having to mitigate rework has helped the program alliance develop and implement its learning routines and absorptive capacity. However, it has taken several years to develop a culture that supports the identification, assimilation, transformation, and use of knowledge derived from errors and rework from the alliance's projects and those from other alliances. Infrastructure mega-projects procured using conventional procurement strategies will seldom, if ever, be able to develop and acquire the benefits of absorptive capacity needed to contain and reduce errors. Such project delivery strategies are by no means relational and thus cannot support the effective implementation of learning routines. We suggest from the evidence that the alliance had a high absorptive capacity, though this is primarily attributable to the length of its operation. Learning routines are operational in the alliance entity and its program of projects, which have been enriched and developed due to managing errors and rework. As the learning routines within the alliance entity are more observable than those played out within projects, they are more likely to be imitated and adopted by other alliances and organizations in the broader construction industry.

The project owner purposefully manufactured and incentivized the dynamic capability of desorptive capacity present within the alliance to engender an environment defined by its best practices. The transference of knowledge from one alliance to another does not develop absorptive capacity *per se*. A program alliance cannot develop its absorptive capacity if it only acquires and assimilates external knowledge, as it needs to transform and exploit it in some way (Zahra and George, 2002). So, if an alliance can transfer and integrate its newly acquired knowledge within the alliance entity and project's learning routines, its absorptive capacity can be enhanced.

While the project owner would like to see the best practices materializing from its program alliances imitated in future infrastructure projects, their effectiveness in mitigating rework may be questioned. The problem is that those unobservable routines used to manage errors become unrealized as their socially enabling mechanisms are often "specific and idiosyncratic" within a project's context (Lewin et al., 2011: 91). Needless to say, the program alliance delivery strategy has augmented its absorptive capacity by learning to contain and reduce the errors that result in the need for rework in its projects. The evolved learning routines are generic and can support an alliance's absorptive capacity.

5.1. Theoretical implications

The theoretical foundation of absorptive capacity is well-established in the mainstream literature (Bravo et al., 2020). However, in the case of infrastructure projects, which are temporary, organizations, it is still evolving as their context can influence how knowledge is acquired, assimilated, transformed, and exploited. Indeed, as a result of a body of work, we know that the interactions between alliance partners in their pursuit of opportunities for innovation through collective exploitation and exploration of knowledge resources can result in positive outcomes (Enkel and Heil, 2014; Brocke and Lippe, 2015; Seo et al., 2022). However, *how* absorptive capacity is generated, specifically from addressing errors and rework within mega infrastructure projects, especially in program alliance settings, has received limited attention. Access to projects and data is difficult to obtain due to issues of commercial confidentiality, primarily as errors and rework are associated with mis-performance (Love et al., 2016; Walker et al., 2023).

In addition to the learning routines identified in our conceptualization of absorptive capacity presented in Fig. 2, we unearth new constructs to help build this dynamic capability in infrastructure projects. Thus, we present our revised model based on absorptive capacity emanating from addressing error and rework in Fig. 7. While our model is generated from the learning routines associated with managing error, it can be applied more broadly and used as a theoretical framing to represent absorptive capacity in program alliances. We also reveal that desorptive capacity is at play in the program alliance, and thus, we suggest that absorptive and desorptive capabilities are complementary. The acquisition and transfer of knowledge between and within the alliance and its counterparts contribute to their learning capability and efforts to mitigate their rework. Enhancing an alliance's in-bound and out-bound knowledge flows amplifies its learning capability. As a result, this can contribute to strong *appropriability* between all the alliances and thus stimulate further investment in continuous improvement, which benefits participating organizations and taxpayers (Aliashagr and Haar, 2021). To our knowledge, the dynamic capability of desorptive capacity has not been identified in alliancing and, more generally, within the procurement of mega infrastructure projects.

Within our revised model in Fig. 7, we show that facilitating psychological safety is critical to enabling dialogue to flourish and knowledge, which may be suppressed without having the freedom to speak up, to be more readily disseminated. Additionally, we see aspects of resilience emerging as an enabler for absorptive capacity through the learning routines of *adapting to new situations* (i.e., adaptiveness) within projects and *understanding success and failure* (i.e., preparedness) in the alliance entity (Jeffcott et al., 2009). Awareness and opacity are other aspects of resilience that can contribute to an alliance's absorptive capacity. Incorporating resilience into an error management culture allows an alliance to understand, embrace, and adapt their projects to changing and complex conditions arising from production pressure and competing stakeholder demands.

Awareness focuses on data acquisition and providing insights regarding the quality of human performance, enabling the current state of defense mechanisms, and identifying problem areas (Jeffcott et al., 2009). In the case of opacity, the program alliance would be aware of its costs, workload, safety, and quality performance and know where effort needs to be invested in ensuring that defenses are not degraded (Jeffcott et al., 2009). Simply put, resilience is about "transforming lessons from past failures into future success by learning how it is that humans bridge gaps and recover from errors [and often in situations before rework is required] (Jeffcott et al., 2009: 257).

Putting in place learning routines to foster resilience helps an alliance adapt to and act on error-making and acquire the knowledge needed to understand better 'why things go right' instead of 'why they go wrong'. Taking this perspective supports an error management culture, which explicitly adopts a proactive approach to error recovery.

While from a theoretical standpoint, psychological safety and resilience are needed to manage errors in projects better (Love et al., 2023a, 2023b), they can also simultaneously strengthen an alliance's absorptive capacity and organizational learning. To this end, learning routines that center on the triumvirate of absorptive capacity, resilience, and psychological safety, underpinned by an alliance's error management culture, provide an overarching framework to combat rework and other forms of waste in infrastructure mega-projects.

5.2. Practical implications

In light of the dynamic capability of desorptive capacity, encouraging and incentivizing alliances to generate and transfer their best practices and knowledge to other alliances orchestrates activities and resources to focus on delivering assets that will provide economic and social value to stakeholders. Nevertheless, through its focus on relational project delivery approaches such as alliancing, the government can shape the infrastructure market in ways that will better enable value to be created, captured, and shared in the future. The knowledge and practices that emerge from delivering the transport mega-project and its collection of program alliances can provide a platform from which management in public and private sectors can learn and mitigate the errors that can cause rework, time and cost overruns, and impact productivity and safety.

Going forward, as part of an infrastructure mega-project delivery strategy and focusing on managing errors and their adverse consequences, we recommend that learning routines are formally designed and embedded into its procedures and processes to help nurture the program's absorptive capacity. Whether infrastructure mega-projects procured under non-relational procurement strategies can harness the benefits of developing an absorptive capacity requires exploration.

6. Conclusion

The need to perform rework due to errors in infrastructure projects is a problem that pervades practice. Error-making is typically viewed negatively, yet it is critical for learning and innovation. The absence of collaboration and genuine commitment to put the project first and do what is best to ensure the delivery of value for money hinders learning and innovation. However, limited knowledge exists about how program alliances can harness their absorptive capacity to learn from errors, mitigate rework, and improve project performance.

Focusing on a >AU$19 billion transport infrastructure mega-project delivered through five program alliances, we used an illustrative case study approach and a variety of data sources to make sense of how a program alliance developed its absorptive capacity to learn about errors and mitigate rework in its projects. Our analysis revealed that an array of learning routines was used within the program of projects and by the alliance entity to manage errors and rework and stimulate its absorptive capacity. Within the program of projects, learning routines centered around facilitating variation and psychological safety, selecting regimes to manage projects, sharing knowledge within projects and reflecting, updating and replicating, and adapting to new situations. In the alliance entity, engendering best practices, new knowledge, and change, sharing knowledge across projects, learning from and within the supply, transferring knowledge externally (i.e., desorptive capacity), and understanding success and failure, supporting its absorptive capacity.

The learning routines used by the alliance entity and within the program of projects are complementary. However, best practices and knowledge generated at the alliance entity formed the basis for a program alliance's desorptive capacity (e.g., standardization and reuse of design and TOC production). As such, the nuances of practice within projects that manage errors and rework, such as the social interaction and dialogue between site superintendent and subcontractors, are unobserved in the knowledge acquisition process. So, when desorptive capacity is enacted, only part of the alliance's knowledge is transferred. Thus, it is imperative to develop mechanisms to ensure the nuances of

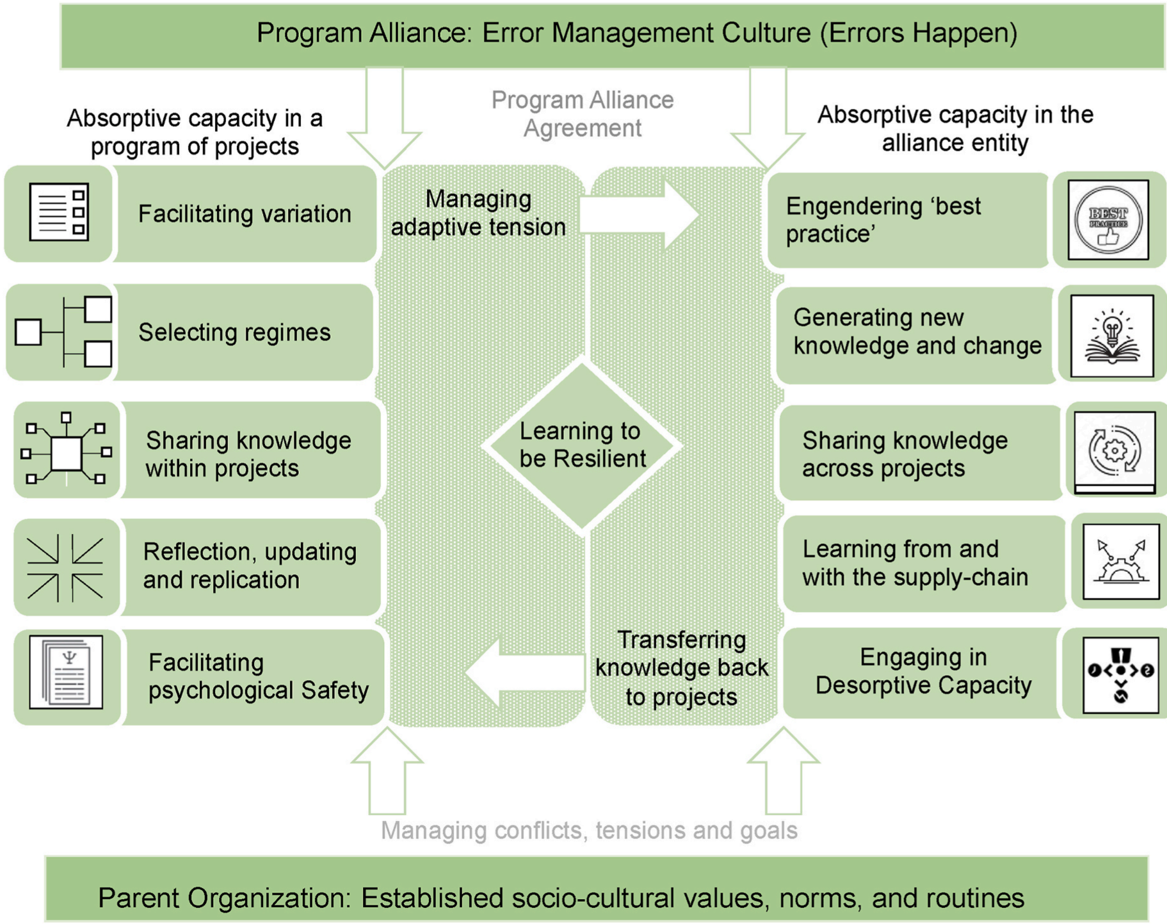


Fig. 7. An absorptive capacity model to learn from error-making and rework.

practice used to manage errors at the coalface of construction are captured and shared.

Formally incorporating subcontractors into the collaboration process of the alliance entity would help improve the capture of error-related knowledge. Perhaps a modified form of a PAA could be extended to subcontractors awarded repeated work across an alliance's projects. If subcontractors like the alliance entity are incentivized, we would see less rework, reduced safety incidents, and improved learning effectiveness and innovation.

To this end, our paper's contribution is twofold: (1) we provide a theoretical framing of absorptive capacity that (mega-project) program alliances can draw upon to manage errors and rework within their projects; and (2) unearth the presence of *desorptive capacity*, which enhances an alliance's ability to transfer knowledge to and leverage knowledge that resides within its network of projects.

A key limitation of this paper is its focus on a single case study. Using a multiple case study design, future research could empirically corroborate our findings. However, the use of program alliancing to deliver infrastructure mega-projects is yet to be considered a mainstream delivery strategy by many governments, so replicating our findings will be challenging. Putting this issue aside, future research should examine how desorptive capacity can benefit the performance of program alliances (and other relational procurement methods) and the effectiveness of their entire supply chains. In the meantime, we hope the knowledge gleaned from the program alliance examined in this paper provides an opportunity for organizations to learn about the treatment of errors and rework in transport infrastructure mega-projects.

CRediT authorship contribution statement

Peter E.D. Love: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Jane Matthews:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Derek H.T. Walker:** Writing – review & editing, Writing – original draft. **Lavagnon A. Ika:** Writing – review & editing, Writing – original draft.

Declaration of competing interest

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

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Data availability

Data will be made available on request.

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