



Coping with uncertainty and ambiguity through team collaboration in infrastructure projects

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Abstract

Managing risks and uncertainty are terms that are used interchangeably by project teams. Research on project procurement shows unexpected events in project delivery are often distinguished by these terms. This raises questions concerning how collaboration and coping ability help deal with inherent uncertainty and ambiguity. Using Weick's sense-making process of reflection and re-analysis a novel methodological approach was developed. A project database and contemporary literature was mined using the perspective of Snowden's *Cynefin* ambiguity framework. Two industry sourced examples provided support to the arguments made. The findings suggest that collaboration may lead to reduced people and process ambiguities and where ambiguity is revealed in projects it is often unrecognised, residing in a disordered zone. Observing ambiguity in this way provides a better understanding of ambiguity and advanced coping strategies. Having these perspectives is useful for identifying ambiguity where it may otherwise be missed or subsumed into risk and uncertainty.

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1. Introduction

Much of the focus of research into project procurement and delivery is centred on managing risk; in addition, there is a growing interest in uncertainty management, where the focus of this paper lies. Often the words risk and uncertainty are used together and interchangeably linked into a common concept with risk inferring something negative and uncertainty being concerned with an identified unknown event which could be treated as either negative or positive (Ward and Chapman, 2003). The role of ambiguity is often ignored or forgotten in broader thinking about dealing with risk and uncertainty where the existence of multiple and conflicting interpretations is linked to confusion or a lack of understanding.

The concepts of risk, uncertainty and ambiguity are connected and together they require extensive consideration when faced with unexpected events that disturb successful project delivery (Cicmil et al., 2009). The aspect of ambiguity within dealing with unexpected events is particularly interesting and presents opportunities, offering insights to improve project management practice. This is particularly so when delivering complex projects where unexpected events are the norm (Florice et al., 2011). The role of collaboration, for example between the project owner representative, design and project delivery teams in complex infrastructure projects, has raised ambiguity as a noteworthy source of potential risk and uncertainty (Hagen and Park, 2013). This is because ambiguity is in part a state in which we mistakenly *think* we know something when our assumptions, as the receiver of a communication message (spoken, written or graphical), are at odds with the intended communicator of the message. This misunderstanding can lead to unintended consequences. For example rework caused

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by misunderstanding requirements as specified or inferred in briefing documents or working drawings that lead to significant cost and time escalation (Dalcher, 2012; Love et al., 2000).

Collaborative project procurement and delivery approaches draw all parties closer together into an information and knowledge sharing framework that helps convert many aspects of uncertainty and ambiguity into identifiable, understandable and measureable risks. Naturally all uncertainty and ambiguity cannot be eliminated. However, collaboration intensity, with its associated information and knowledge sharing, varies with project procurement form (Davis, 2008). Additionally, it was observed in Australia that experience with project and program alliancing has resulted in a shift in workplace culture. For example, as part of a study entailing thirteen in-depth interviews with alliance managers Walker and Lloyd-Walker (2011) reported that alliancing principles were positively affecting non-alliance projects and influenced the way that projects were led and managed by those with experience of alliancing. This increased trend of adopting collaborative project delivery principles is tangible in engineering and construction sectors (Ke et al., 2015).

It is suggested that risk, uncertainty and ambiguity are endemic within complex projects. They can be managed more effectively through intimate and open collaboration between the project owner, the design and the project delivery teams than that which would occur in circumstances where they work as separate but coordinated teams that follow linear processes of brief development, design then delivery. This argument forms the

conceptual model identified in Fig. 1 described as the Logic of Collaboration. It is explained as follows;

1. Intimate and genuine collaboration achieved by people working as a single integrated team openly share information and knowledge leading to an environment in which a more complete shared understanding of the project context is possible; leads to,
2. a single integrated project team's complete shared understanding of the project's situation and context leads to an improved ability to cope with uncertainty and ambiguity;
3. this facilitates the application of shared understanding to decision making and thus leads through jointly coordinated action to substantially enhance the effective management of uncertainty and ambiguity.

To summarise project managers are often confronted with situations where 'messy' or 'wicked problems' with no identifiable clear solution. Accordingly, the least harmful or disadvantageous solution must be chosen from a pool of available but unfavourable options (Hancock, 2010; Rittel and Webber, 1973a; Rittel and Webber, 1973b). These situations present significant risks, uncertainty and ambiguity. This leads to two primary research questions that are placed centrally in Fig. 1.

1. How does collaboration between the client, its design and delivery teams, lead to improved coping ability associated with uncertainty and ambiguity?

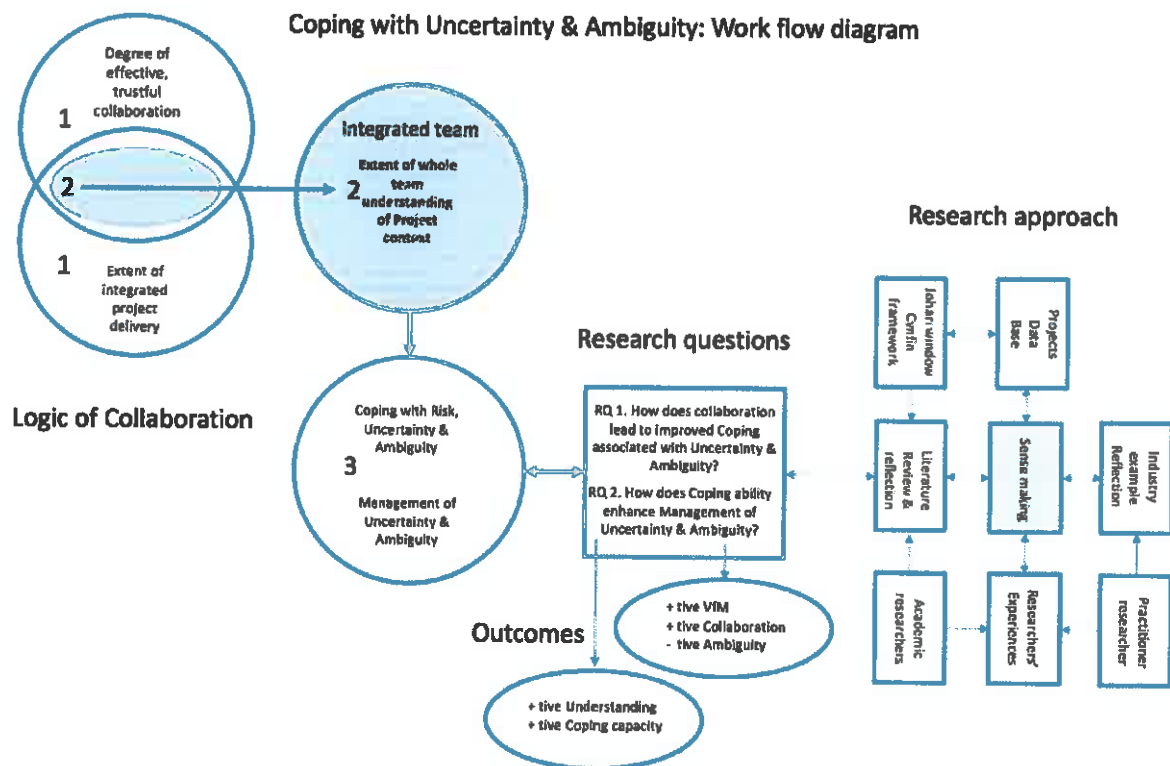


Fig. 1. Coping with uncertainty & ambiguity: work flow diagram.

2. How does coping ability enhance the effective management of uncertainty and ambiguity? Risk, uncertainty, ambiguity and collaboration

Risk appears in literature and project management (PM) guides as a term that embraces uncertainty and ambiguity. However, there are important distinctions to be made that are relevant to collaboration that effectively copes with various forms of risk and uncertainty.

2.1. Risk

Traditional PM thinking has centred on risk management as being a core PM competence that includes the “process of risk management planning, identification, analysis, response planning, and controlling risk on a project” (PMI, 2013, p309). The Project Management Institute (PMI) Body of Knowledge (PMBOK®) identifies risk as an uncertain event that is interpreted by individuals as a potential risk, threatening planned delivery. Individuals have degrees of risk appetite associated with potential risk and consequences; it sets a level a threshold point at which a perceived risk moves from being acceptable to be unacceptable (PMI, 2013, p311). This appetite governs a likely risk response, including; identification, what an analysis indicates and a potential outcome arising from any action. Several well regarded texts provide detailed advice on the risk management process (for example Infrastructure Australia, 2012; Ward and Chapman, 2003) and many authors have written extensively on risk (Kwak and Stoddard, 2004; Sanchez et al., 2009; Williams, 1995). In addition there is a standard that provides guidance for this process (British Standards Institute, 2000; Caravel, 2013). Finally, PMBOK® suggests a range of tools (PMI, 2013, Chapter 11).

2.2. Uncertainty

Risk is usually spoken about in conjunction with uncertainty and often with an unspoken acknowledgement of ambiguity. This infers uncertainty as being partially temporal. Temporal assumptions about uncertainty in PM terms are generally constrained to the project delivery lifecycle, although many risk management strategies may be to simply avoid problems occurring during a project life cycle (PLC). Uncertainty has also been discussed in terms of difficulty in developing a probability profile of an event happening within the project's time frame or in developing an assessment of its likely impact (British Standards Institute, 2000; Caravel, 2013). Cleden (2009) devotes a book to the subject and raises awareness that uncertainty potentially offers opportunities and categorises uncertainty into uncertainty about information, understanding, tempo and complexity level.

Taking a ‘Johari window’ perspective Cleden (2009) characterised uncertainty in terms of a four-quadrant knowledge-centric matrix of known knowns, known unknowns, unknown knowns and unknown unknowns (please visualise a rectangular window opening divided into 4 equal panes as the quadrants, or for more details on this concept refer to Luft and Ingham, 1955). Adapting a Johari Window/Cynefin Framework four quadrant concept from Cleden (2009, p13) Walker and Lloyd-Walker

(2011) build on Snowden's idea from a PM perspective and show a relationship with team collaboration in managing projects. The principal concept about uncertainty is whether a situation being faced is ordered, unordered or disordered (Kurtz and Snowden, 2003; Snowden and Boone, 2007).

Known knowns are predictable events with adequate data available. Quadrant one represents a highly ordered simple situation where the required response is to sense the uncertainty, categorise the unknown risk using routine frameworks, templates and guidelines to evaluate the potential impact and to formalise a response.

Known unknowns have ambiguous outcomes, but there is an understanding about what should be considered and relevant contingency actions. Quadrant two presents a somewhat ordered but complicated situation in which uncertainty relates to parts of the situation. Uncertainties that are not known can be identified by specialists and experts. The project delivery teams can readily identify expert knowledge and cope with the risk or uncertainty. Doing this requires analysis and collaboration.

Unknown knowns represent untapped knowledge and infer that they can be identified with effort and coped with. Quadrant three represents unordered complex situations and uncertainties in which the interactions, dynamic and intertwining nature of uncertainty surrounding the situation are difficult to fathom. The lack of order and apparent logic drives a need to probe rather than sense what may happen. Often what needs to be known may be available somewhere within the project team and so it is important to aim for cross-team collaboration. Probing, rapid assessment and response are vital and so this situation necessitates even closer collaboration than Quadrant two.

Cleden also labelled uncertainty as unknown unknowns, suggesting that they are events that are hidden and unpredictable. Quadrant four represents a highly unordered situation and levels of uncertainty. No order or pattern can be discerned and modelling or long term planning is useless because of the highly dynamic and evolving interaction between parts of the situation being faced. The only way to deal with this uncertainty is to have a clear and strong sense of the desired end point and to manoeuvre and incrementally respond with rapid assessment and recalibration of planned action.

Viewing uncertainty through this knowledge-as-action perspective requires embracing uncertainty and dynamically dealing with it. It clearly illustrates the need for intimate and genuine collaboration between all parties and teams that have critical knowledge to offer about the nature of potential disruptions to reconstituting order. The focus is often on interfaces and interdependencies.

At the intersection of the four quadrants (rectangular window) is a disordered zone where most people find themselves when faced with uncertainty and ambiguity. They are in a state of being disordered because they are unsure if the situation they face is ordered or unordered. Kurtz and Snowden (2003) argues that people generally have a predisposition or habitual response when faced with uncertainty as illustrated in the Cynefin Framework (Kurtz and Snowden, 2003). For example, people who are more bureaucratically inclined might try to force a command and control response reverting to what they have learned to be ‘best

practice'. This can prove disastrous if they are facing a complex uncertain risk event. In complicated situations of uncertainty better practice may be far more effective than trying to force a best-practice approach because there may be many viable solutions that are difficult to rapidly evaluate. Consequently a satisficing approach may be most appropriate (Kurtz and Snowden, 2003).

2.3. Ambiguity

Ambiguity may be considered from several perspectives (Pich et al., 2002). The ambiguity most readily associated with situational uncertainty is when a 'messy' situation is difficult to identify and evaluate. In these situations, using the term 'uncertainty and ambiguity' accurately illustrates the problem. The nature of uncertainty sometimes suggests one thing when viewed from one perspective, but the same situation may even suggest interpretation of an entirely opposite thing when viewed from an alternative perspective. It is tricky to interpret the meaning and impact of a situational signal about a particular uncertainty.

A second and often neglected form of ambiguity is found when people facing uncertainty jump to conclusions based on invalid assumptions about the situation from a people and process interpretation of what they perceive as occurring. People *think* that they are facing a known known (personal communication or process interpretation) when in fact they are facing a mis-known known. This may occur because the communication signal is unclear, but they fail to realise it or that they impose bias (based on their disordered state) founded on their interpretation of the signal.

2.4. Collaboration

A number of empirical studies have demonstrated the value of intimate high-level inter-team collaboration. Cohen (2010) undertook six case studies in the USA on Integrated Project Delivery (IPD) projects that demonstrated higher levels of cost and time certainty through improved knowledge and information sharing within a highly collaborative cross-team workplace environment. Also revealed were a set of characteristics that facilitated and enabled superior performance through collaboration (Cohen, 2010), (Aapaoja et al., 2013). Similar findings are reported in complex project delivery in New Zealand and Australia (Ibrahim et al., 2013). In Australia, Davis (2006) interviewed fifty seven alliancing subject matter experts, Walker and Lloyd-Walker (2015) interviewed fifty alliancing subject matter experts that resulted in the development of models and a taxonomy that places collaboration as pivotal in building trust for effective information and knowledge sharing. These studies collectively support point one introduced in the opening section of the paper.

The second point of the logic of collaboration relates to shared understanding of context and assumptions. These are made by teams leading enhanced collaboration and improved coping with uncertainty and ambiguity. They can be illustrated by case studies, for example, Cicmil and Marshall (2005) argue "... in an

unpredictable world where the outcomes of an action cannot be known in advance, managing should be seen as a process of continually rearranging the paradoxes of organizational life through a different type of leadership."

In their study of a complex public sector project they viewed interactions through a particular ontological and epistemological lens to understand how parties viewed and sensed the emergence of uncertainty, requiring the need to negotiate meaning and action. From an ontological perspective they found the world-view position taken by their case study participants showed that respondents believed they were interacting within a single purpose team. Actions and motivations were united in delivering the project effectively. They accepted the inter-play of influence that various teams had at different times, contingent on their contribution of knowledge and information. They did not see things from an isolated A, B, and C perspective but as an integrated 'one team' comprising teams A–C inclusive. They were naturally reconfiguring their 'truth' about the situation they faced as and when new information or uncertain events interposed.

Additionally, Cicmil and Marshall observed that the epistemological stance held by project participants was that the 'truth' of the situation they faced evolved and that unanticipated and uncertain events were naturally part of the co-construction of the reality they faced (2005, p533). In other words, they believed that 'facts' (plans and documents) were not stable or 'a given' and were represented by plans and documents that were naturally established through the power and influence hierarchy of team status, whether it is owner, designer or contractor. This way of making sense of perceived reality as it unfolds is termed as *ontology of becoming* rather than *ontology of being* Koskinen (2010, 2012). The status quo for teams taking this action-learning world-view is that uncertainty and ambiguity are a natural part of the evolution of learning and that the way to cope is through embracing uncertainty and ambiguity and using the knowledge resources of all participants as and when they contribute. This form of project team interaction presents a stark difference to the traditional construction/ management leadership approach that is dominated by hierarchy and professional status.

In past research studies and in practice reasons cited for 'good project' outcomes included good risk management (McDermott et al., 2013). Over the years research respondents have articulated 'good risk management' but they have struggled with explaining cross-team collaboration. It is suggested that examples of cross team collaboration include, 'passing the baton of influence' and 'shaping views' about uncertainty and clarifying ambiguity through meaningful dialogue and shared perception. In the discussion that follows the research approach this is elaborated upon.

3. Research approach

Having earlier identified two research questions it was established that a 'sense making approach' would be the most suitable methodology to facilitate a rigorous outcome (Weick et al., 2005). In addition, an ontological perspective was used to frame several case studies. A team comprising academic researchers experienced in collaborative forms of project delivery,

together with industry representatives from practice, were brought together. Reference to Fig. 1 (Methodology component) places sense making central to the research approach. In order to explain the phenomenon existing theories relating to risk, uncertainty ambiguity and the nature of collaboration were reviewed and reflected upon. A Project Data Base of collaborative forms of project delivery was mined and significant examples were sourced that included, a longitudinal study of a museum alliance project (Hauck et al., 2004; Walker and Hampson, 2003), a study of relationship based contracting from Davis (2006), research into advanced project management collaboration skills (Lloyd-Walker and Walker, 2011) and a study into collaborative forms of project delivery (Walker and Lloyd-Walker, 2015). A project management perspective of the Cynefin framework built understanding and connections between the Project Data Base and extant literature. This combination of theory, reflection upon empirical studies and practice provided ideal narrative to support sense-making as recommended by Weick (2001) (Weick et al., 2005).

The practitioner team drew upon extensive IPD alliance experience to illustrate target outturn cost/ time development for projects and contingency budget development. This experience exemplified the way in which the client, design team and contractor collaborate at the front-end of projects. This provided a focus on risk and uncertainty assessment and in particular provided deep insights into the nature of ambiguity. These illustrations were utilised as powerful examples in the discussion section that follows.

4. Discussion

This section of the paper is divided into four sections, each section is an example that progresses an insight into the two questions posed in the introduction. The sections illustrate specifically how the collaborative development of a contingency budget has the ability to contain risk. How collaboration may be built upon through the development of TOC and revealed specific characteristics that enabled a shared team understanding via collaboration. Finally, details are presented identifying collaboration's ability to enhance coping with uncertainty and ambiguity.

4.1. Containment of risk and uncertainty

Project delivery estimates include a contingency (cost and time) component to account for anticipated risk and uncertainty (Ranasinghe, 1994). They often represent a 'best guess' for both known and identified anticipated risk potential outcomes and unknown uncertain and ambiguous potential outcomes (Baccarini, 1998). Known knowns are most easily accounted for as risk items, however the unknown represents uncertainty. A portion of this uncertainty is known with 'yet-to-be determined decisions' so these can be referred to as known-unknowns in Quadrant Two or 'unknown-knowns' in Quadrant Three. Sources of ambiguity represent a particular component of 'unknown-knowns' and also 'unknown unknowns' (Quadrant Four) due to people and/or process misunderstanding or situational misunderstanding.

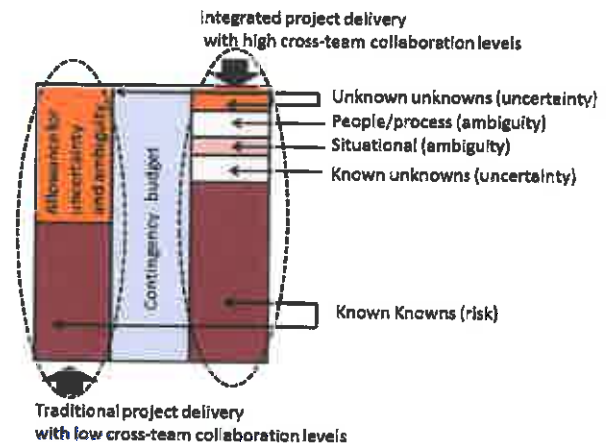


Fig. 2. Uncertainty and ambiguity within the contingency budget development.

Fig. 2 illustrates how a contingency budget may be composed and how the ambiguity component is shown as a significant part of uncertainty that should be considered. There may not be any specific acknowledgement or allowance made for situational, people/process ambiguity in traditional project delivery (design, bid, build) due to its fragmented nature. However, some allowance may be made in a general sense by taking an informed 'guess' and notionally loading in uncertainty and ambiguity into a course grained 'unknown unknowns' allocation. The left hand column illustrates a non-scaled conceptual situation showing these unknown unknowns as substantial as may be the case in complex projects. Project bidders frame their contingency budget (cost and time) within this context. This is based upon known and evaluated risks together with an allowance for general uncertainty that cannot be identified as a known unknown relating to, for example, unresolved tender documentation and communication ambiguity. There is always a proportion of both uncertainty and ambiguity that project bidders will allow for, based on experience and expert judgement contingent on their state of unknowingness and their assessment of potential ambiguity.

Fig. 2 also illustrates a contrasting situation for the variety of relational or integrated project delivery (IPD) forms in the right hand column. In an IPD context, client, design and project delivery team engage in intimate and open collaboration. This allows greater access to each of the parties' rich perspective of the nature of various uncertain aspects that emerge. Thus for IPD forms situational ambiguity is reduced. Effective collaboration can enhance perspective-taking that may reduce potential people/process ambiguity. Perspective-taking skills reduce the tendency for stereotyping, prejudice and restrictive thinking and also enhance open dialogue, consideration of other's validity of opinion and increase the likelihood of creative thinking (Alam et al., 2010; Parker et al., 2008). Consequently, the known known risk is greater for IPD than more traditional project delivery forms because collaboration has reduced some of the uncertainty. There will always be some known unknown uncertainty because even with intense collaboration some aspects will remain unknown. Additionally, there will inevitably remain some element of situational as well as people and process ambiguity that will need to be allowed for in the TOC development. However, IPD approaches permit the

extent of unknown-unknowns to be reduced because intense knowledge sharing across the client, design and contractor teams uncover prospective uncertainties and identify and resolve much of the potential ambiguity.

Unknown unknown uncertainties and ambiguities may be more effectively dealt with through more general collaborative behaviours between the project owner, design team and delivery team. Often the misunderstood potential people/process unknown unknowns can easily be neglected unless there is open and genuine collaboration to allow effective communication between parties. Open and genuine collaboration is more likely to occur in an integrated IDP 'one team' context.

4.2. Establishing collaboration—developing a target outturn cost (TOC) estimate

Collaboration is central to the development of a realistic and rigorous TOC. Research survey participants interviewed across several research studies indicated IPD was characterised by deep levels of collaboration (Lloyd-Walker et al., 2014). They assert that this resulted in increased clarity of scope, better understanding of emergent potential difficulties, greater appreciation of roles and contributions made by all parties and general reductions in uncertainty that is normally 'covered' by blanket contingency in traditional projects. Perspective taking emerged as a central competence that supported effective collaboration.

Perspective taking requires appreciating the motivations, value proposition and constraints faced by others. This leads to a reduction in the impact of information and knowledge asymmetry in two ways. First, high levels of perspective taking, enhanced appreciation and valuing a likely contribution that others can make to understanding issues and complex problems. This encourages those with information and knowledge to feel valued enough to offer access to that resource. Second, an appreciative team member who welcomes input from others prepares themselves to consider information and knowledge that would otherwise be discarded or not considered. This opens up discussions and helps to reduce uncertainty associated with known unknowns as illustrated in Quadrant Two. It also leads to clarification of what might otherwise be misconstrued and identified for unanticipated possibilities through open-exchange with others. This clarification can lead to reduction in ambiguity.

Power imbalance is also reduced through collegiality and collaborative behaviours. Power asymmetry is closely linked with information and knowledge asymmetry and high levels of perspective taking enhanced appreciation. Alliance behaviours result in team members respecting the value of knowledge over positional status and this encourages a more open workplace culture.

Team collaboration provides an environment for far greater understanding of project constraints and possibilities than would occur in traditional project delivery. The impact of having the client representative being able to input information and knowledge relating to project context, its anticipated scope and other client-side information cannot be overstated. Similarly having the design team and project delivery team collaborating on a pragmatic solution also helps to reduce the levels of uncertainty and ambiguity because proposed solution options can be more intelligently examined and discussed. This reduces uncertainty and contingency allocations that would otherwise be allocated. Some of the contingency illustrated in Fig. 2 would be reduced through this process to contribute towards reducing the TOC, but also innovation, improvement ideas and other positive opportunities may emerge from this process of collaboration and joint exploration of options and possibilities. Significant rework reductions may also accrue because all team members gain a deeper understanding of the project, its complexities and nuances (Love et al., 2015).

Fig. 3 is a conceptual development derived from an ontological perspective of direct experience whilst acting on behalf of alliance teams developing TOCs. Generally, estimates are based on various assumptions about the expected cost/time and may be represented by a likelihood curve that cost/time would be 'x'.

The left hand side of Fig. 3 represents the 'normal situation' development of a TOC for traditional project delivery. It illustrates the notional P50 or 50% chance that the cost or time would be 'x'. In assessing a realistic contingency figure a 80% cost curve point is heuristically considered as reasonable based on the Parito principal (Imai, 1986; Raftery, 1994). The 80% confidence of estimate point on that curve would be higher than the 50% point at $x + y$ dollars for cost or months for project delivery duration. At the right hand side of Fig. 3 the same project is illustrated but estimated under conditions of intense and effective collaboration. Noteworthy, the curve is far less spread between the 50% probability and 80% probability points where the value at the 80% point is lower due to greater collaboration leading to increased

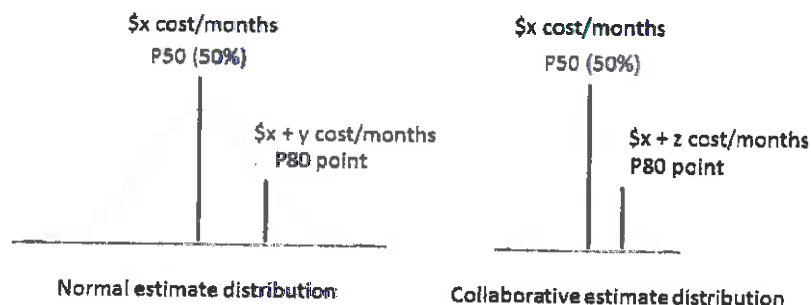


Fig. 3. Illustration of the TOC cost/time development.

joint understanding and resolution of uncertainty and potential ambiguity. A normal curve is illustrated but in actuality the curve may look skewed further to the right due to a greater level of the ‘unknown’ in traditional estimates become ‘known’. Accordingly, the curve reflects greater confidence in the estimate. The additional clarity and use of broader perspectives allow much ‘tighter’ and more confident estimation of cost or time. Narrowing the TOC figure between the 50% and 80% level provides greater certainty to the anticipated actual outturn cost and that may have a significant impact on team behaviour in delivering projects. Narrowing that spread in TOC estimate also may be due to the client more accurately explaining the project's business case. A significant advantage of a narrow spread between the 50% and 80% TOC points can result in the Actual outturn cost (AOC) being more likely to be achieved. Successful cost/time delivery places all parties in a more confident, lower blame-ready mode to undertake the project so that disputes and defensive routines are less likely to be deployed by project teams against each other. It is also easier to develop a more effective incentive based on more confident TOC figures.

The main advantage of a collaborative approach being adopted to develop a TOC is that the contingency allocation for risk and uncertainty is substantially reduced from that experienced in transactional traditional project delivery forms. Client, design and construction team members share knowledge and thus jointly better understanding a project's technical and other needs. When skilled client, design and delivery team entities collaborate as a single integrated team they provide a knowledge space. Understanding the complex interplay of systems and events that impact and drive the project's trajectory is created in this space. This results in a greater understanding of the inter-connectedness of the project's constituent parts. Consequently, the contingency budget is reduced and the estimate of known costs is increased, it reveals what would remain unknown and unknowable in a traditional procurement approach. Previously unknowns become better known and accounted for, notably the remaining contingency requirement is reduced. A lower contingency is partially offset by additional collaborative costs for the integrated team to gain a better understanding of the project's context. Teams are then better prepared due to dissemination of deep project knowledge to manage the project's design and delivery. Moreover, the spread of estimate of cost and time is reduced forcing the profile of distribution from a flatter shaped distribution curve to a more peaked one.

Evidence indicates that intimate collaboration between the client, design team and project delivery team provides the real potential of more accurate estimates of time and cost as well as being able to ‘walk through’ the issues surrounding a project to enable the scope and requirements to be more effectively enunciated and understood by all parties. This deeper joint understanding has a significant impact on uncertainty and ambiguity levels.

4.3. High level collaboration

An emerging picture about what drives collaboration within an integrated construction/project delivery context becomes

apparent from the theory and practice reported. Several key constituent elements of high level collaboration requirements stand out. These are summarised below.

Analysis of data from Walker and Lloyd-Walker (2015) revealed specific characteristics that enabled a shared team understanding via collaboration throughout the delivery of alliance projects. Subsequently these characteristics, displayed in Table 1, enhanced the project teams' ability to better cope with uncertainty and ambiguity.

Based on empirical research findings, it is concluded that effective identification of ‘the unknown’ is possible through effective collaboration that was evident in the efficient application of IPD. Situational ambiguity can be minimised. This can occur through improved shared understanding of the project context and situation gained through team members' effectively sharing their perspective and absorbing information and knowledge. These skills help them understand the perspective of others. Similarly, people and process ambiguity can be reduced when all team members better understand what each other mean as communicated through text, images, documents and discussion. This is based on distributed leadership where power and information asymmetries are minimised and in which there is an environment of collaborative working in a healthy workplace as reported by Walker and Lloyd-Walker (2015).

In summary, collaboration enables the project owner and design and delivery teams to better understand each other's perspective *through* jointly solving problems and overcoming difficulties and coping with unanticipated events. In this way it is argued that the advantage of risk and uncertainty within the workplace environment discussed above actually helps to build trust and respect between teams as well as individuals. Having an environment in which perspectives are shared helps to reduce ambiguity because as the various teams collaborate, communicating and discussing issues, they unearth potential misunderstanding and erroneous assumptions. This process helps them to build shared mental models.

4.4. Collaboration's ability to enhance coping with uncertainty and ambiguity?

IPD forms vary in intensity of integration between client, design and contractor teams. Examples were found in the USA, see (Cohen, 2010; NASF, C., APPA, AGC and AIA, 2010). Other forms of collaboration that adopt a similar form in the UK were described by (Brady and Davies, 2010; Gil, 2009). Others involved intense forms of partnering found in Nordic countries (Constructing Excellence, 2012; Department of Health, 2012). Project and program alliancing presented another IPD form evident in Australia and New Zealand (Jacobsson, 2011; Jacobsson and Roth, 2014), the Netherlands (Crevani et al., 2010; Davis and Love, 2011; Walker and Lloyd-Walker, 2014) and Finland (Laan et al., 2011). A European concept of competitive dialogue (CD) is a recent adaptation (Lahdenperä, 2012). To a lesser extent than IPD forms, collaboration is set between the design and project delivery teams in public private partnerships (PPPs) (Hoezen et al., 2010; Plantinga and Dorée, 2016; Voordijk et al., 2013). However, there has been a

Table 1
Characteristics of enhanced coping with uncertainty and ambiguity.

Characteristic	Description	Comment
Substantial colocation	Physically placing team members in a location in which they have common workspace/ integrated virtual space as well as share documents and information. It also related to hierarchal integration mechanisms that facilitated interaction and collaboration	Two positive attributes of colocation may be observed. First, physical colocation allows people to easily meet by chance or design, to discuss issues. A form of 'mental' colocation means that there is low power distance between team members so they feel free to honestly exchange ideas and respect that other perspectives can be both valid and valuable.
An integrated risk mitigation strategy	Enabling and promoting a cross-team (client, design and contractor) conversation about risk, uncertainty and ambiguity so that wider perspectives were accessed. It also features integration of risk management/risk mitigation systems	The workplace culture is noticeably flat with traditional hierarchical lines being blurred to reduce information and power asymmetries. Each participant is respected for the knowledge, skills, attributes and experience contribution being made and these build trust amongst team members. The governance structure supports openness, transparency and commitment to a best-for-project focus by all team participants. This is reinforced by several factors; the alliance form of contract, the painshare and gainshare arrangements, an explicit focus on joint understanding of objectives and action to be taken and performance being based on project outcomes rather than individual team outcomes. This binds the teams into a 'sink-or-swim' together attitude that promotes finding solutions to problems as they arise that are focused on a best-for-project outcome. It is in everyone's interest to achieve a successful project outcome rather than an individual team optimised outcome.
Behavioural characteristics and normative practice that:	Features the need for an <i>authentic leadership</i> as described in Lloyd-Walker and Walker (2011) in which mutual respect and perspective taking ability together with demonstrated evidence aligning action with rhetoric about group values; Enhance a <i>trust-control balance</i> to shape levels of autonomy and recognised various forms of trust building and maintenance; Reinforce transparency through <i>open-book</i> auditing and access processes; Establishes a <i>common best-for-project mindset and culture</i> that provided a compelling vision that aligned people's goals and encouraged a challenge of the status quo to strive for excellence; Establishes a <i>no-blame culture</i> that allows people to feel safe to express concerns, share ideas and be innovative	These behavioural characteristics help lower power and information asymmetries. Authentic leadership provides the leadership support for all the trust building, acceptance of accountability, allows genuine discussion about differences of opinion or views, mistakes or misunderstanding and facilitates an ambience in which concerns can be thoroughly discussed and addressed.
Processes, routines and means that support the above behaviours is reinforced by:	Consensus decision making that results in full support facilitated through a no-litigation agreement; An incentivisation scheme of gain and pain sharing to reward and encourage effective management of risks and deliver on the specified key results areas; Mutual dependency and accountability between parties to reinforce the importance of a 'one team' integrated project delivery unit	People solve problems. Finding ways for people to communicate and interact creatively lies at the core of effective coping with unforeseen problems. Common shared communication systems such as building information modelling and groupware information communication technology support exchange of information. However, it takes people interacting and co-creating knowledge to use information and knowledge to plan and act to overcome difficulties as well as to enable smooth planning and execution. The form of flat and authentic leadership identified by Lloyd-Walker and Walker (2011, p81) helps to unleash creativity and innovation. They found that the workplace culture particularly exemplified by a no-blame culture permit the safety needed to openly admit error when unintended consequences become apparent. The workplace culture needs to be focused on supporting learning and experimentation when faced with unexpected events to overcome problems. Numerous scholars (Baiden et al., 2003 ; Drejer, 2008 ; Koolwijk, 2010 ; Walker et al., 2014) argue from their analysis of nine exemplar projects that team practises that support integration of teams and collaboration deliver superior project outcomes.

documented case of a project alliance being established with a large PPP project ([Azim et al., 2010](#)). Design and construct forms of project delivery also consist of collaboration through a design and contractor joint entity managing the design and delivery phases of projects based upon a client brief ([Jacobsson and Walker, 2013](#)).

Drawing upon past relevant research studies insights are presented into IPD's ability to enhance a project team's capacity and ability to cope with risk, uncertainty and ambiguity. Presented in [Table 2](#) are salient examples of respondent quotes from several studies that help explain *how* their collaboration enhanced coping with uncertainty and ambiguity. The quotes

Table 2

Quote reference number: Study source citation and participant identifier in brackets e.g. (IV-10)	Insight and Comment, relevance to Ambiguity and Uncertainty
<i>Quote 1</i> from (IV-10) “75% of the people are in alliances, or have been in alliances so obviously when you put them on another job, that isn't an alliance, they all have that sort of experience, and it just becomes quite natural, regardless of the type of delivery model”	Illustrates how the <i>alliance ethos</i> remains with many of those with alliancing experience and becomes ingrained within the company. In IPD this ethos supports open discussion that <i>enhances clarity</i> of meaning and <i>reduces ambiguity</i> .
<i>Quote 2</i> from (UM-1) “Alliances have been the making of this business; it's really opened up possibilities to work more closely with the clients, work more closely with our consulting partners, and just other members of our industry sector. Before alliancing came along, we all stuck to our little silos and didn't interact...”	Illustrates the perceived benefits of collaboration and the extent to which it is embraced. Working closely with clients with reduced information asymmetry reduces <i>people and process ambiguity</i> . Intimate and close interaction between designer and contractor reduces <i>situational context ambiguity</i> .
<i>Quote 3</i> from (P37) “We do a risk and opportunity workshop, then we would come up with a contingency amount. That contingency we would add to our direct cost estimate...makes up the TOC. Typically, a client would...see is a single line figure at the bottom. But because it was open book, ... they saw how we got to it and they saw the number... their first perception was, this is just your padding...you're inflating the price and that shouldn't be in there. It took months and now, that would never be the thought because ... being part of the delivery (team) ... they suddenly understand exactly what that <i>contingency</i> is for...”	There are two main insights here. First, it explains how the TOC is developed and then how the risk, uncertainty and ambiguity contingency are viewed by the client representative and the design team. It illustrates the deeper insights that all parties to this integrated project delivery approach gain from the collaborative exercise, open-book approach and risk management conversations. Honesty and open-book reduce <i>people and process ambiguity</i> .
<i>Quote 4</i> from (P30) “It's all positive energy... It's about getting the best out of each other and working hard collectively for success and dealing with our problems collectively and it's all on the basis that we don't blame any particular partner; it's <i>us</i> in it together. So it's a really great environment to work in... I've seen some fantastic design and construct contracts go really well, great relationships and at the end (when) the claims start to come in because the bottom line hasn't been realised...things start to really go sour and all that positive energy suddenly gets diverted into negative stuff and the relationships ... start to fall away.”	This illustrates the ambience that IPD forms of organisation exude and reinforce the level of cross-team integration. Intimate collaboration helps people clarify value propositions and expectations. This in turn reduces <i>people and process ambiguity</i> through the collaborating teams' clear alignment of values.
<i>Quote 5</i> from (AH). “We had a major situation in one of the tunnelling (projects)...in the main tunnel where we had some unexpected conditions which would have been classic (adversarial) conditions in a conventional contract and would have resulted in long delays while people argued...who was going to carry the risk. ... We sorted ...methods of overcoming the problem with absolutely no recourse to what it might mean from a contractual point of view... so the delays were minimal and the excess costs were minimal”.	This provides an example of how collaboration between the contractor, designer and client in an alliance form allows a sensible way to resolve potential disputes based on ambiguity in who may be responsible for what in a complex project (<i>people and process ambiguity</i>) as well as providing an example of potential <i>situational ambiguity</i> . The remedy was an IPD approach with a proactive approach.
<i>Quote 6</i> from (BK). “XYZ Corporation had some estimates from ... consultants and they tacked them together to come up with a number (budget) and so the first deliberation after 6 or 8 weeks (was) to agree on the target cost (TOC), so what we did was revisit work that had been done by others and their costings to come up with a number. That was actually a very powerful tool ... because we had to very rapidly come up to speed on all work that had been done by other parties and structure our own estimate and then put on contingency/risk/profit/ overhead and negotiate those with the client. So in that phase, ...all of the hard conversations were held 6 weeks into the project. So the next phase of design and and bring it in under that TOC (was straightforward) as the hard work had already been done, the conversation about what was an acceptable level of contingency, what risk should belong to XYZ and what should belong to the Alliance, what level of profit etc., how do you calculate these things (was done).”	This quote explains the development process of the TOC. We see how client (XYZ) used reference data to develop a feasible TOC. Then once the client, design team and contractor collaborated on the TOC development they were able to better understand risk, uncertainty and ambiguity. By better understanding each other they reduced <i>people and process ambiguity</i> and the wider perspective enhanced understanding of potential <i>situational ambiguity</i> . With improved understanding the contingency allowance was reduced and as illustrated, it allowed squeezing of the range between the 50P to 80P estimate to provide a more realistic TOC that each participant could 'own' as a realistic budget to improve upon during the project delivery phase.

from senior and respected alliance managers/ executives are followed by insights and comments relevant to ambiguity and uncertainty. Quotes 1–3 are from Walker and Lloyd-Walker (2011) study, quote 4 is from the Walker and Lloyd-Walker (2015) study and finally quotes 5–6 come from the Davis (2006) study.

5. Conclusions

Some important concepts concerning uncertainty and ambiguity have been raised. Accordingly an argument that developing effective, intimate and trustful collaboration is a key element to capacity building within the broad project team. Accordingly,

they are able to cope with risk, uncertainty and ambiguity in the project life cycle using an adaptation of the Cynefin framework. Discussion concerning the Cynefin framework highlighted and contextualised the concept of ambiguity in terms of people/ process and situational elements. The level of integration within the team enhances collaboration; this improves the team's understanding of the whole project context. This answers research question one. Aspects of integration enhanced by co-location of teams and communication that enhance a unified team mind-set lead to each team better understanding how their colleagues operate in their various clusters and the processes they follow building on background workplace assumptions. These mechanisms showed how

collaboration improved coping capacity. They were highlighted with the four principal collaboration features explained, following Walker and Lloyd-Walker's (2015) study.

Coping ability is explained with examples taken from practice set out in Table 2. This table explains how collaboration may lead to reduced people and process ambiguities. Collaboration is enhanced by a commitment to common aims and objectives and a common language that develops with workplace culture. Elements such as a no-blame approach, consensus decision making and team structural elements reinforce a best-for-project and sense of teams' mutual dependency upon one another. Fig. 3 and its associated text explains how joint understanding through deep and effective collaboration may 'tighten' the distance between the 50% and 80% estimate of cost and time through better understanding of uncertainty and ambiguity.

This leads to the relevance and contribution offered by this research. It is suggested that the main contribution is to explain *how* collaboration and integrated project delivery approaches enable project teams to better cope with ambiguity and uncertainty. Illustrative quotes from recent studies where project leaders explain strategy and concomitant benefit are provided. Alongside these quotes the interviewees' narrative helps identify how ambiguity was coped with.

Fig. 2 illustrates how a contingency budget may be viewed from a traditional and an integrated project delivery perspective. It shows how uncertainty and ambiguity may be more clearly understood. Observing ambiguity through a people/process and situational lens may provide a better understanding of ambiguity and advance suitable coping strategies.

Central to understanding ambiguity and how it may be coped with in a project management context is the degree and nature of collaboration. Earlier elements of high level collaboration were summarised and in Table 1 it is illustrated how the impact of collaboration in integrated project delivery affects the whole project teams' understanding of the project context.

The authors have identified ambiguity as being viewed through a people/process and situational lens. Having these perspective tools is useful for identifying ambiguity where it may otherwise be missed or subsumed into risk and uncertainty contributes to practice. Also identified is *how* collaboration and team integration enhance understanding by those teams of the project context and through that *how* they better cope with ambiguity. Often practitioners find difficulty in articulating good practice in a way that it can be replicated and this is an innovation diffusion problem that has limited them in their ability to learn from experience.

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