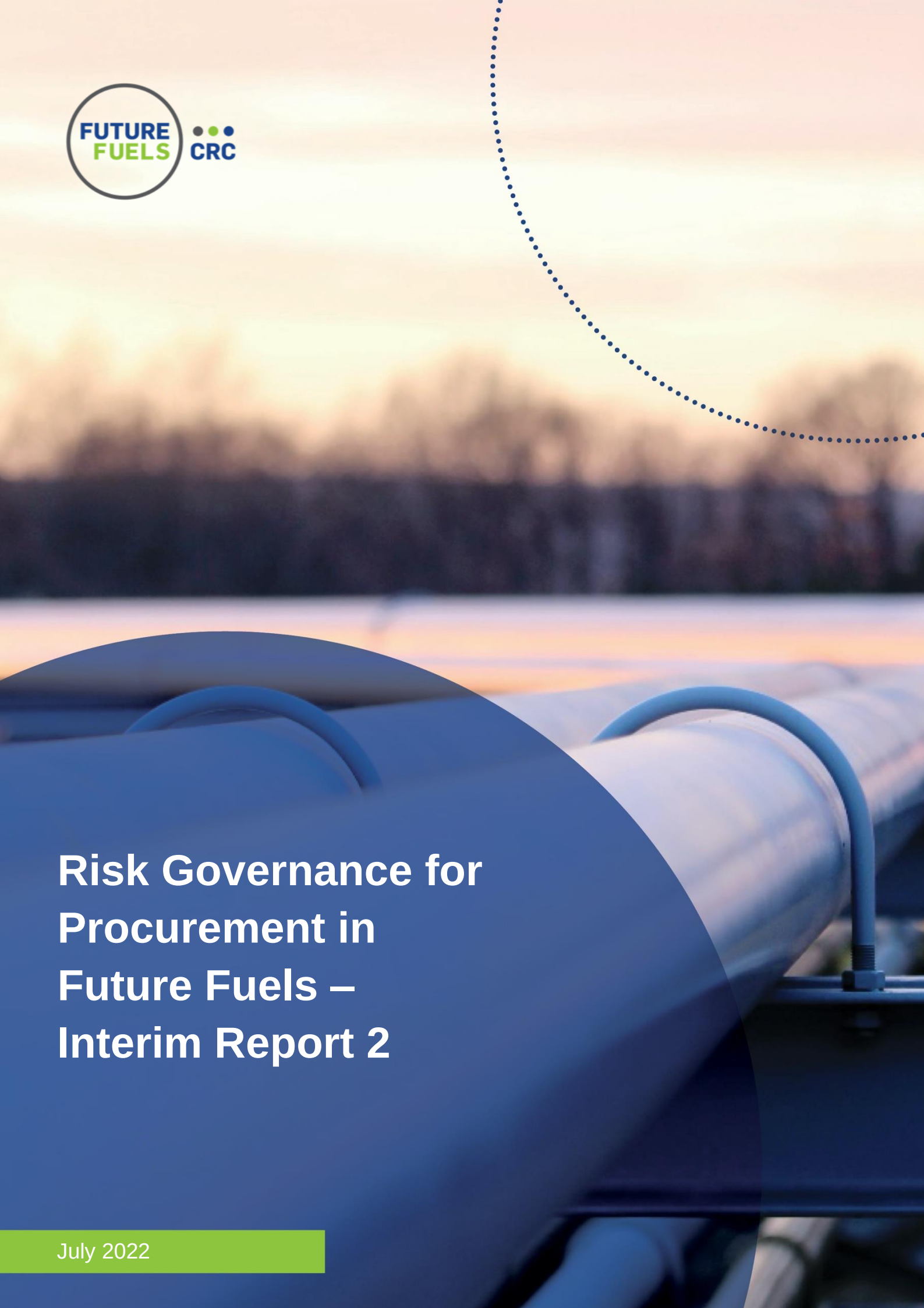

Risk Governance for Procurement in Future Fuels – Interim Report 2

July 2022

Project number: RP2.3-06

Risk Governance for Procurement in Future Fuels

Authors:

Dr Yen Pham
Professor Jan Hayes
Dr Rita Zhang
Dr Nader Naderpajouh
Professor Ron Wakefield

Project team:

Ted Metcalfe (Independent consultant)
John Piper (JP&A)
Soheil Taherian (OSD)
Medhi Fardi (APA)
Damian Petz (Jemena)
Andrew Pearce (Woodside)
Kane Ramsay (Enscope)
Sean Armitage (Momentum Engineering)
Sobhi Khoury (Spiecapag / HDI Lucas)
Mark McLeod (Nacap)
Jack Greenwood (SA DEM)
Raimond Sils (Beach Energy)

Australian Government
Department of Industry, Science, Energy and Resources

Business Cooperative Research Centres Program

This work is funded by the Future Fuels CRC, supported through the Australian Government's Cooperative Research Centres Program. We gratefully acknowledge the cash and in-kind support from all our research, government and industry participants.

Important Disclaimer

Future Fuels CRC advises that the information contained in this report comprises statements based on research. Future Fuels CRC makes no warranty, express or implied, for the accuracy, completeness or usefulness of such information or represents that its use would not infringe privately owned rights, including any parties' intellectual property rights. To the extent permitted by law, Future Fuels CRC (including its employees and Participants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this report (in part or in whole) and any information or material contained in it.

© Copyright 2022 Future Fuels CRC. All Rights Reserved

Acknowledgement

This work is funded by the Future Fuels CRC, supported through the Australian Government's Cooperative Research Centres Program. The cash and in-kind support from the industry participants is gratefully acknowledged.

We also acknowledge and thank interview participants for sharing their experiences and expertise.

Project information	
Project number	RP2.3-06
Project title	Risk Governance for Procurement in Future Fuels
Research Program	Research Program 2 – Social Acceptance, Public Safety and Security of Supply
Milestone Report Number	Interim report 2
Description	This interim report covers the fieldwork phase of the project. It details analysis results of interview data from industry stakeholders and new perspectives that provide the basis for the next phase of the project – developing a risk governance framework to support procurement in a future fuels environment
Research Provider	RMIT University
Project Leader and Team	Jan Hayes, Rita Zhang, Yen Pham, Ron Wakefield, Priyanka Erasmus (all RMIT), Nader Naderpajouh (University of Sydney)
Industry Proponent and Advisor Team	Ted Metcalfe (Independent consultant) John Piper (JP&A) Soheil Taherian (OSD) Medhi Fardi (APA) Damian Petz (Jemena) Andrew Pearce (Woodside) Kane Ramsay (Enscope) Sean Armitage (Momentum Engineering) Sobhi Khoury (Spiecapag / HDI Lucas) Mark McLeod (Nacap) Jack Greenwood (SA DEM) Raimond Sils (Beach Energy)
Related Commonwealth Schedule	This project is part of output RP2.3 but does not correspond to any existing milestone
Project start/completion date	19 July 2021 – 19 December 2022
Access	**Open** – available publicly to all parties outside the CRC
Approved by	Ted Metcalfe
Date of approval	1 July 2022

Table of contents

Summary of report

Procurement failures in the infrastructure and engineering industry, including the energy sector, are not uncommon and very costly. While procurement risk has generally been well managed in the gas sector, there is still room for improvement as failures of goods and services procurement through ineffective supply chain risk management in transition to the future fuels space could impact the development of the emerging industry. Research into effective mitigation of such threats is warranted to ensure that societal expectations for public safety are met and that the reputation of both organisations and new technologies are enhanced.

This project aims to develop an understanding of practices that can be implemented to improve risk governance in the gas pipeline sector. Such understanding will encourage the diligent and established application of risk mitigation measures in the procurement practices implemented for future fuels infrastructure and technology development.

In the first phase of the project, a review was conducted of academic, grey, government and industry literature on procurement risks and associated failures of engineering and infrastructure projects. Based on the literature, four categories of risk were identified:

- supply chain coordination and management process
- supplier
- external environment
- trust and cooperation.

Nineteen examples of procurement failure were identified and reviewed for common lessons learned. Finally, documented procurement practices and guidance on best practices in procurement risk governance were also highlighted. Details are in the first interim report published on the FFCRC website in March 2022.

In this second interim report, current procurement practices as well as the associated risks and risk management strategies in the gas pipeline sector deriving from interviews with industry stakeholders are described and summarised, specifically:

Procurement risks and procurement practices in the gas pipeline sector

A wide range of risks have been reported by interviewees and grouped into four categories informed by the literature described in the first report. There is no difference in procurement risk main themes between the gas pipeline sector and the future fuels environment, while the context discussed under themes have different nuances. Interviewees also suggested good practices for procurement risk management (Table 1).

Table 1. Procurement risks and procurement practices in the gas pipeline sector

Risk category	Main risk	Good practice
Supply chain coordination and management	Inadequate planning	• Treat planning itself as a necessary task and allow time in the schedule to do it properly. • Pay attention to all three factors in the golden triangle of cost, quality, and schedule. In particular, be honest and realistic about timeframes from the beginning. • Identify long lead items and manage them carefully, acknowledging that markets, and so availability can change. • Build in time for cross-functional reviews such as constructability reviews. They are a good investment of time as they reduce problems later. • Assign responsibility for risks to those best placed to manage them.

Risk category	Main risk	Good practice
	Specification issues	• Reduce complexity in specifications as much as possible. Do not include irrelevant material that makes specifications difficult to follow and obscures key information. • Include a description of what you are trying to achieve with the specified goods/equipment so that experienced suppliers can use their expertise to provide advice on whether what has been specified will be fit for purpose. • Do you need a bespoke specification in a given application or will a standard specification be sufficient? • Ensure sufficient engineering expertise is involved in specifying what is required.
	Poor contractor/supplier selection	• Adopt a pre-qualification system in place to ensure that only those capable of providing a technically acceptable solution are invited to provide a commercial tender. This reduces the temptation to select a low-cost solution that is ultimately not technically acceptable. • In addition to cost and technical feasibility, consider experience, track record, local representation, health and safety record and anti-slavery practices for the supplier and all sub-suppliers when selecting a preferred supplier. • Draw on industry experience (not just company experience) when selecting suppliers.
	Contracting issues	• Establish mutually beneficial contractual arrangements with well-defined terms and conditions at both functional and technical levels. • Be realistic and explicit about equipment lead times with consideration to the long delivery time for equipment purchased from overseas. • Improve the transparency in the contracting process with adequate risk assessment and allocation among all parties at the beginning. • Pay attention to the dispute resolution/avoidance provisions in contractual terms and conditions to avoid disputes when conflicts occur.
	Logistics issues	• Ensure logistics is taken into account in comparing tenders including requirements for packing, transportation and storage of goods and equipment to prevent damage. • Detail responsibilities for the condition of goods in all contracts including testing requirements linked to custody transfer to ensure that responsibility for repair can be simply identified if damage occurs. • Monitoring and active quality management across logistics interfaces is critical for early detection of problems. • Make a mindful choice about who should be responsible for logistics and assign responsibility for risks to those best placed to manage them.

Risk category	Main risk	Good practice
	Manufacturing QA/QC failures	• Start planning for a quality output from the prequalification stage and apply QA/QC thinking to the whole supply chain from specification through to installation on site. • Ensure QA/QC is comprehensively addressed in contracts and specifications to avoid costly scope changes. Criticality evaluation is important, acknowledging where uncertainty is high. • When assessing criticality, be sure to consider the need for overseas manufacturers to comply with Australian standards. • Ensure that the project team knows quality is everyone's responsibility. • QA is not scalable based on order size – small orders might need more QA because they may be less important to the supplier and so more prone to problems. • Resourcing for good, independent quality inspectors available to visit remote and international locations can be difficult. Start planning early. • Field hydrotesting can be logistically complex and resourcing difficult. Again, start planning early.
	Experience/expertise issues	• Improve the experience of the project operation/management team in providing appropriate procurement decisions with consideration of high-quality goods/services and of the whole project costs. • Make sure to have people with relevant expertise (i.e., engineers) involved in the whole project cycle. • Encourage knowledge and lesson sharing across the sector through industry forums or conferences. • Recruit engineering consultants for support but make sure the right expertise is acquired.
	Communication issues	• Make sure all parties are well informed and updated on requirements and expectations and the ability to address them. • Early and frequently engage suppliers/contractors to understand their capabilities to fulfill requirements and be informed of any issues. • Ensure that early, accurate, and all potentially relevant information is passed on to the right party. • Encourage practitioners to raise concerns when in doubt before taking action.
Suppliers	Manufacturing problems	• The QA/QC system might fail at manufacturing. Reputational suppliers with good customer service are likely to recover and rectify manufacturing problems more quickly. • Early engage and allocate sufficient time with local manufacturers to make sure requirements are well understood. For big projects, having the engineer responsible for the specification to be at the factory is crucial to ensure compliance and resolve issues if they arise.
	Non-compliance	
	Forged certificates/counterfeit materials	
	Supplier experience and expertise issues	
	Market burst	

Risk category	Main risk	Good practice
	Inadequate prequalification process	• Take additional checks in the QA/QC process when possible to prevent counterfeit/fraudulent issues. Make sure third-party inspectors are actually independent of the vendors. • Acquire overseas expertise for equipment packages in the absence of in-house expertise. • Subcontractors should also be subject to the prequalification process to make sure they are qualified for the job.
External environment	Shipping disruptions due to Covid-19 pandemic	• Allocate sufficient time in the project schedule and communicate with manufacturers to diversify shipping options.
Trust and cooperation	Trust/relationship issues	• Ensure necessary procedures including QA/QC and auditing are applied with all suppliers despite any existing relationships. • Communicate with suppliers/contractors in a clear, open and transparent way about risk sharing to build a trusting relationship. • Early engage with manufacturers at the senior level to increase priority before purchasing in order to reduce delay risks. • Ensure efficient and frequent communication between key parties is maintained. Having technical and procurement teams work alongside and provide relevant support to achieve best project outcomes.
	Internal relationships	
	Cultural issues	
	Cross-sector cooperation	

Further details are given in Section 3.1.

Procurement risks and procurement practices in the gas pipeline sector

Moving to the future fuels environment, research participants indicated several challenges. Their opinions and experience regarding procurement risks in future fuels are summarised using the same general risk categories as in the gas pipeline sector. Specifically, key challenges suggested by interviewees are:

- Complexities of knowledge management, including learning from other industries and inclusion of current research outputs into practice.
- Upskilling the workforce given uncertainties associated with policy and technology development.
- Planning for the uncertainties and addressing the complexities that are created as a result of the new configuration in the supply chain.
- Development of new standards and regulations and their congruencies with practice at the international level.
- The need to focus on mitigating risks rather than transferring, as contractors may not be able to handle them and will use other strategies and contingencies that increase project resource needs and costs.

Further details are given in Section 3.2.

New perspectives towards a risk governance framework

Interviewees have given many insights into the ways in which procurement can fail and what practices might be adopted to prevent such failures. The previous interim report addressed past procurement failures and their causes. This section addresses new perspectives that will be used in the next phase of the work to develop a new risk governance framework to support procurement to be undertaken in a future fuels environment.

Five new perspectives (uncertainty, interface management, resilience, temporality and high reliability networks) have been identified that we expect to be useful in determining an appropriate risk governance framework for future fuels that builds on the industry's procurement successes, takes into account past procurement failures and addresses the unique circumstances posed by future fuels.

Guiding questions to review the interview data and incidents analyses are shown in Table 2 below.

Table 2. New perspectives and guiding questions for further analysis

Perspective	Guiding questions for further analysis
Uncertainty	• What types of epistemic uncertainty contribute to the risk of procurement failure according to the past incidents and the interview data? What types of knowledge are not being acted upon and why? • In what ways does a future fuels procurement environment make such uncertainties more relevant to project success and failure? • How might uncertainty in procurement for future fuels be reduced?
Interface management	• At what interfaces is the risk of procurement failure identified in past incidents and the interview data? Who are the interface participants? What are the interface issues that contribute to the risk of procurement failure? • What are the key interfaces that need management attention in the future fuels environment? What do successful interface interactions look like? • What should be done to achieve successful interface interactions and reduce procurement risks for future fuels?
Supply chain resilience	• Do interviewees describe procurement failures that can be linked to a lack of supply chain resilience? • Can the cases of procurement failures be linked to a lack of supply chain resilience? • If so, how might system resilience be increased so as to better manage the potential for procurement problems in the context of future fuels?
Temporality	• How is temporality in procurement experienced by decision makers? • What meaning is given to past and current events that could impact procurement outcomes? How are these events brought into play in making procurement decisions now for the best outcomes in the future? • How do different actors experience the pace of activity? Does this have implications for procurement risk? • Are there risk management implications from the episodic nature of procurement? If so, what and how are they best mitigated? • How could processes linked to temporality be improved in order to gain better procurement outcomes?
High reliability networks	• To what extent do supply chain participants see themselves as part of an integrated network? • How do the various actors across the procurement chain conceptualize ‘never events’ and how to avoid them? To what extent do the actors agree? • To what extent do the other likely properties of high reliability networks exist in current energy sector procurement? • Are there ways reliability could be enhanced, particularly in the context of future fuels?

Further details are given in Section 4.

Drawing from the good practices and new perspectives to reduce risks associated with the procurement process in the gas industry, the final stage of the project is to focus on the risk governance framework to improve procurement outcomes in a future fuels environment.

1 Introduction

Failures of materials, equipment or services through ineffective supply chain risk management represent a threat to the successful development of the emerging hydrogen and biogas future fuels industry. In addition to the potential for major cost and schedule blowouts, failures on any early project in this new industry could cause significant reputation damage and so adversely impact the development of the entire sector. Research into effective mitigation of such threats is warranted to ensure that societal expectations for public safety are met and that the reputation of both organisations and new technologies are enhanced.

Despite the cruciality of procurement procedures and supply chain management in the successful execution of infrastructure projects, there have been many examples of procurement failures leading to unplanned adverse outcomes. The gas industry has not been immune from such incidents although specifics are often not readily available to share due to commercial/legal issues.

With these factors in mind, research questions addressed by this project are:

- Why have past significant procurement failures in the gas industry and elsewhere occurred? What can be learned from them?
- What are the risks associated with the procurement process in the gas industry and what risk governance practices can be used to prevent the recurrence of procurement failures in the context of future fuels?
- What does a robust procurement risk governance framework look like in a future fuels environment?

The project involves four main tasks:

1. Literature review
2. Study current procurement practices
3. Develop a risk governance framework
4. Develop risk mitigation recommendations

In the first task of the project, a review of academic, grey, government and industry literature on procurement risks and associated failures of engineering and infrastructure projects was conducted. These include identification and analysis of risks on the supply chain coordination and management process and the supply side, risks from the external environment, and risks related to behaviour and cooperation. Lessons learned from procurement failures in engineering and infrastructure incidents were discussed. Finally, documented procurement practices and guidance on best practices in procurement risk governance were also highlighted. Details are in the first interim report published on the FFCRC website in March 2022.

The focus of the project has been shifted to Task 2 with commencement of fieldwork with key stakeholders across the entire supply chain for procurement of both goods and services in a project environment and in operations. In this second report, an analysis of field data on current gas pipeline sector procurement practices as well as the associated risks and risk management strategies has been provided. The aim is to gather stakeholder experiences in procurement of both goods and services and also their views on procurement risk management and how it will change in the context of future fuels. This is followed by a review of new perspectives that may be useful in development of a risk governance framework in the context of future fuels, including uncertainty, interface management, resilience, temporality and high reliability networks.

The overall outcome of the project will be an understanding of the practices that can be implemented to improve risk governance in the gas pipeline sector. Such understanding will encourage the diligent and established application of risk mitigation measures in the procurement practices implemented for future fuels infrastructure and technology development.

2 Fieldwork methods

The target population for the interviews includes professionals involved in procurement across the energy sector from gas pipeline owners/operators to suppliers, consultants, specialist contractors and regulators. The purpose of the interviews is to build an understanding of existing gas pipeline sector procurement practices and the associated risks and risk management practices. This includes experience in cases where the procurement of either goods or services has gone according to plan as well as cases where the plans were not met.

Interview participants were recruited in three ways:

- By direct invitation through emails to pipeline stakeholders known to the project research team and industry advisers as a result of a decade of previous research with this group,
- Through newsletters and announcements in appropriate meetings by FFCRC, and
- Through circulation of the invitation email to their connections by people who have received it from the research team (snowballing).

One hundred and four invitations were issued by the research team directly. From those invitations, sixty-two responses were received. Fifty-six interviews were undertaken by video calls (since the project was undertaken during the COVID-19 pandemic with travel and face to face meeting restrictions in place). Interviewee demographic information is shown in Table 3.

Table 3. Interviewee demographic details

		Number of interviewees	Proportion of interviewees[1]
Gender			
Male		54	96%
Female		2	4%
Group			
Owner/operator contracts personnel	O/O CONT	1	2%
Owner/operator purchasing personnel	O/O PUR	2	4%
Owner/operator engineering specialist	O/O ENG	7	13%
Owner/operator quality personnel	O/O QUAL	1	2%
Owner/operator warehouse and logistics personnel	O/O WARE	1	2%
Owner/operator construction manager	O/O CONST	1	2%
Owner/operator system safety specialist	O/O SAFE	3	5%
Equipment/material/logistics supplier	SUPP	14	25%
Engineering consultant	ENG CONSULT	18	32%
Construction contractor	CONST CONT	4	7%
Third party certification/quality specialist	QUAL SP	1	2%
Lawyer	LAW	1	2%
Regulator	REG	2	4%

[1] Percentages may not add up to 100% due to rounding.

Professional experience			
10 - < 20 years		15	27%
20 - < 30 years		17	30%
30 years or more		24	43%
Total		**56**	**100%**

Interviews were conducted in a semi-structured approach with the conversation significantly driven by the responses of the interviewees. Conversations were tailored based on the profession of each group and guided by the following main questions:

1. We are interested in hearing from you about cases where procurement of goods and/or services has gone well and where it has not gone according to plan. Have you been involved in cases where procurement has contributed to a project not going according to plan?

   Or

   What should your clients do to get the best service from you? (In case the interviewee is a supplier)

2. Let's take one and can you tell us what happened?
   a. Were there issues with the supplier? If so, what?
   b. Were there issues in supply chain coordination and management? If so, what?
   c. Were there any contributors from the external environment to the failure? If so, what?
   d. Were there issues regarding behaviour and cooperation? If so, what?
   e. What were the consequences?
   f. What controls were in place that should have prevented this from happening?
   g. In your view, why didn't they work in this case?
   h. What could have been done differently?
   i. Is any of this available in a documented form (incident report, lessons learned)?
3. Have you been involved in procurement cases where the risks were significant and yet things still went according to plan?
4. What are the key differences between this case and the others you have spoken about so far?
5. What systems, procedures, practices etc contributed most to the project being successful?
6. Do you think procurement risk is generally well managed in this sector? What are the key strengths and weaknesses in your experience?
7. How do you think procurement risk management play out in the context of future fuels?
8. How do you think procurement risk management in the sector could be improved?

Interviews were recorded with permission based on the Ethics approval and transcribed for analysis.

Ethics approval for the project was obtained from RMIT's Design and Social Context College Human Ethics Advisory Network on 19 October 2021.[2]

The study was regarded as 'low risk' because participants were not placed at any foreseeable risk. The only personal information collected about individual participants was their names, organisational roles and contact details. The primary focus for data collection from the interviews was the experiences and perceptions of individuals on procurement risk management in the gas pipeline sector.

All interview recordings and transcripts were de-identified and assigned a project code so that they cannot be attributed to specific individuals. All interview data has been treated as confidential. No interview data has been discussed or published, or will be, which could identify an individual participant. Industry partners of the FFCRC do not know the identity of individual participants although in some cases they may be able to guess given the relatively small pool of individuals within the sector.

[2] RMIT University Human Research Ethics Committee Project No. 2021-24714-15802 approved 19 October 2021.

3 Analysis of field data

Recordings of interviews were professionally transcribed and then coded in NVivo. An inductive approach was used to develop themes about procurement risks.

These themes were then grouped into four groups informed by the literature described in Section 3.1 of the first interim report. The results are shown in Table 4. It should be noted that several interviewees are closely involved with future fuels aspects of the pipeline industry. There is no difference in procurement risk main themes between the gas pipeline sector and the future fuels environment, while the context discussed under themes have different nuances.

Table 4. Common themes on the pipeline sector procurement risks drawn from interviews

Risk category	Risk source	Interview theme on risk
Supply chain coordination and management	Planning & forecasting	Inadequate planning
	Scope & baseline specification	Problems with specifications (e.g., incomplete specs, bespoke specs)
	Supply chain configuration	Poor contractor/supplier selection
	Contracting strategy	Risk transfer rather than risk sharing Contract disputes
	Logistics	Problems with logistics (e.g., damages in transit, delays to delivery)
	Quality assurance/Quality control	Manufacturing QA/QC failures
	Risk management	Inadequate safety management processes
	Experience & expertise	Inadequate operational and project management experience & expertise
	Communication	Inadequate communication
Suppliers	Performance & operations	Manufacturing problems Non-compliance
	Supplier behaviour	Forged certificates/counterfeit materials
	Supplier experience & expertise	Skilled resource shortage
	Supplier environment & market	Market burst
	Sub-suppliers	Inadequate prequalification processes
External environment	Law & regulations	Uncertain timeframe for environmental approval and land access
	Standards & codes	Differences in standards
	Economic	Foreign exchange rate Price uncertainty
	Political & governmental	Unpredictable trade behaviour
	Natural events	Shipping and travel disruptions due to Covid-19 pandemic
Trust and cooperation	Trust issues	Trust/relationships issues between clients and suppliers
	Organizational and cultural issues	International relationships Cultural issues Cross-sector cooperation

Details of each of the interview themes are provided in the following sections organised according to the overarching risk category.

3.1 Procurement in the gas pipeline sector

3.1.1 Supply chain coordination and management

According to our interviewees, effective supply chain coordination and management in procurement is achieved by good planning, clear specifications, choosing the right contractor/supplier, setting up the right type of contractual relationships, paying attention to logistics, risk management and QA/QC. Experience and expertise, and communication are other overarching themes.

Many of these functions are about setting up and then managing a series of organisational interfaces. Attention to interface management is crucial as 'the amount of coordination that went into managing all interfaces' (ENG CONSULT 1) is why some projects work particularly well. Other projects may be less successful because 'people either just weren't aware of the interface or didn't maybe quite think about the criticality of that particular interface.' (ENG CONSULT 1). For example, 'material handling and transportation, it's obvious once it happens, but if you didn't know it happens, it isn't quite so obvious', and that is something 'that you might not have thought about before' (ENG CONSULT 1). Procurement involves many interfaces but the key to effective management is to clearly define individual responsibilities in order 'to hit everyone's strong point' (ENG CONSULT 1).

Monitoring interfaces is a good way to anticipate developing issues. As another interviewee explained, 'as project managers and project engineers, it's very much dealing with interfaces between design, between packaged equipment, construction contractors, obviously getting things commissioned at the end of the day, owners' objectives, etc.' but 'I guess we would see that as being project management, don't believe what people tell you … till you've checked it yourself or someone that you trust has checked it' (O/O ENG 2). Another interviewee believed that a good procurement professional is actually an interface manager as their role is not limited to 'identifying the material and equipment but also can actually problems solve some of the issues' (ENG CONSULT 14). Given the global nature of procurement, things can go wrong even if responsibilities are defined. Active management is required as this interviewee explains: 'And the reason it went wrong was because even if you had identified all stakeholders involved and their decisions and set the boundaries… it was just too disparate. There was not enough control over what it is that the client ultimately wanted, and how it was that they were going to get it… That's a procurement horror story in the sense that – not that it was mismanaged, but it was undermanaged' (LAW 1).

Another interviewee thought the liability linked to custody transfer is one of the biggest issues in the industry because 'sometimes it's not that easy to actually work out where it went wrong… We use epoxy coatings. So, was it the person who prepared the pipe, the person who applied the coating, was it the coating itself to blame? So, then you get into these three/four-way disputes and everyone's blaming everyone else' (SUPP 8). Supply chain coordination and management is also significantly an exercise in managing uncertainty.

The following sections provide further details about interviewee's views on why procurement fails and how such failures can be prevented.

Planning and forecasting

Inadequate planning

Many interviewees described problems associated with tight or unrealistic timeframes that arise due to inadequate planning at the start of projects. One interviewee believed that 'the attitude comes from not having a realistic view of what the project and the schedule should be for a project – that's where a lot of projects go off the rails right from the start. And when clients award jobs to people, when they really have no chance of being successful, there's going to be a problem down the track.' (ENG CONSULT 11). In another example on a renewables project, 'not enough money was spent in the FEED [front-end engineering design] phase' (O/O ENG 2) contributed to the project failing.

An interviewee in the supplier group described 'I've seen three projects in the past two years… where procurement difficulties arose as contractors had their award dragged out by the principal', so 'the contractor

can't give us his order as the principal won't give him his contract… because their environmental approval doesn't happen as quickly as they predict… but the completion date never gets moved' (SUPP 1).

An interviewee who used to work as a contractor spoke about a project that 'failed on many levels' because 'the client had to either achieve a financial close by a certain date, or the project wouldn't go ahead' (O/O ENG 2). In this case, inadequate time spent on the planning phase, specifically on FEED 'in fully understanding that the project would need' (O/O ENG 2) led to a lack of a well-defined procurement process including risk assessment and cost estimation.

Rushed project execution results in corners being cut and activities that are best done sequentially being done in parallel. As one interviewee gave an example, 'designers are told to just get on with the design, constructors are told to get on with construction… and they didn't wait for the vendor data… because we're late' (ENG CONSULT 3) while it should have been the case that 'the vendor has to send as-built design information for the designers to do the final tweaks to the design' (ENG CONSULT 3). Another interviewee shared his thoughts about final vendor data not being available and how they attempted to mitigate that risk, 'we may have to rework, we may have some changes, etc. To mitigate that risk, we can order some extra materials' but 'you as a client need to be prepared to make those decisions and suffer the schedule risk' (ENG CONSULT 11).

Other consequences of inadequate planning include equipment being not fit for purpose, schedule being delayed and more money getting spent to fix problems or to meet short timeframes. As one interviewee explained, 'poor project planning leading to rushing into buying materials and not enough time to spend on the specifications' (ENG CONSULT 7) can result in poor specifications. In some cases, inadequate planning might lead to safety and quality control procedures being ignored to get work done more quickly so as to meet schedules. One interviewee gave an example about a gas pipeline project where 'we'd dig up a defect area and find a rock the size of a kitchen table laying on top of the pipe. They just threw it in the ground to meet that schedule' (ENG CONSULT 3). In this case, poor construction practices under time pressure damaged the pipeline leading to more work later to repair the problem that was created. Another interviewee described major consequences of poor planning in a renewable project, 'we weren't anywhere near objective enough in how those risk assessments were valued' and 'the project has three years late and counting' (O/O ENG 2) which led to formal disputes between the client and the contractor and a loss in tens of millions on the contractor side.

The overall conclusion from the interview data is that poor procurement planning can create compressed timeframes which can lead in turn to poor work practices as suppliers and contractors try to stick to contracted deadlines. The consequences may be felt later in the project or even in the operational phase of the constructed facilities.

Good practices for planning

While poor planning is a problem, many interviewees spoke about what makes for better planning. In project planning, there is a need to ensure a realistic estimate for setting project timeframes at the beginning, considering time and costs taken for 'project definition' to understand 'what the project would need' (O/O ENG 2) and for required procedures including environmental approval and land access.

Understanding the consequences of poor planning, some participants shared that their organisations were upfront about timelines and pointed out that planning decisions need to address competing demands of time, cost and quality. As one interviewee in the supplier group explained, 'we're always very explicit in our offers about what the realistic timeframes are, and we're not shy in saying that, so that we set a realistic expectation provided at the start… and the people we deal with in a procurement sense… know the ropes, and roughly know what can be done, what can't be done' (SUPP 1). Sometimes it can be costly to meet a tight timeline, as this interviewee further commented, 'we always put the options forward, as to how you can meet a compressed timeframe' from the client, 'but it always involves more costs' (SUPP 1).

As other interviewees expressed their thoughts, 'I think in the golden triangle of cost, quality and schedule, it's very hard to satisfy all three, but quality and schedule, often for the clients, are paramount drivers because it has to work and it has to work on time' (ENG CONSULT 6), and 'If you can have a good balance between the cost and the quality, then everything goes well. But if you pay more attention to the cost and less attention to quality or ability of that manufacturer, it doesn't' (ENG CONSULT 7). Whenever any of the three corners of the triangle 'go out of balance, disaster follows very close behind' (QUAL SP 1). A good practice is that it should not be

‘acknowledged that one of those factors is important above another’ because ‘the supplier will take full advantage of this. So, if you tell them we’re really keen on quality and delivery, watch the price double. If you tell them you’re keen on delivery and we’re holding the price, watch the quality have a problem, and so on’ (QUAL SP 1).

One interviewee talked about the importance of constructability workshops. ‘On some very large projects, I spent upfront with the procurement and engineering, did a lot of constructability workshops and it makes a big difference because by doing that you're supporting the engineering to provide the procurement packages to procurement. Sequencing and sizing make a big difference because when you look at it as a constructability, you want to understand how you can handle that material in the field… You involve the designers, engineers, the procurement team and it’s usually led by the construction team. By doing that you're able to really reduce any failures in the process’ (CONST CONT 1). Another important factor in project planning is to identify ‘long lead items early on in the project’ and ‘be reasonable with the timeframe of manufacturing of the items and applying risk factors in the schedule’, then ‘plan for appropriate design’ so ‘you can develop good specifications.’ (ENG CONSULT 7). Often the more experienced, the ‘better positioned and better resourced’ clients have better planning processes while those who are often the smaller companies and ‘don’t purchase the equipment on a regular basis… maybe a little less experienced with it’ and end up with a lack of consideration about the transportation time for long lead items, particularly from overseas (SUPP 5).

At the time of writing a scope during the project design stage, it is necessary to estimate the appropriate lead time by investigating the current market as ‘there are lead times for different times’ (O/O ENG 3). One interviewee suggested pre-identification and pre-procuring long lead items as a good strategy to reduce lead-time and delivery risks. ‘In a pipeline project, it’s typically the line pipe… That obviously addressed or helped address the procurement risk - lead-time impact to project for the line pipe’ (ENG CONSULT 12). The interviewee then further explained the strategy, ‘a lot of large companies that I deal with have their preordained or preapproved suppliers and providers… The relationships can assist the lead time. They’ve pre-agreed unit costs or pricing and pre-agreed data sheets and specs’ (ENG CONSULT 12).

But there are potential risks associated with buying long lead items early. Procurement on long-lead items may commence when the design is 85% complete or less. In this case, the final details ‘can actually be substantial changes to the way things have to actually be fabricated’ and ‘a designer and project manager don’t necessarily understand that’ (SUPP 13). Not only do design modifications impact fabrication but they also create ‘a battle between commercial people over what’s a reasonable cost, which in itself is a costly exercise’ and battles with the supplier and fabricator and time and money spent ‘arguing over the details of who’s right to charge what’ (SUPP 13).

Another interviewee explained a successful ECI project where the owner took on a high risk long-lead item because the ‘tender process’s going to take up all that time that whoever the successful contractor needs to engage with’ the suppliers (O/O PUR 2). In the interviewee’s view, it’s a good idea that the owner takes on the long-lead item rather than leaving it with the successful contractor to get the process started much earlier. ‘By the time they go through the tender phase, the evaluation, approvals, award, and then – and we, as contractors, we can’t spend money until we’ve got a signed agreement’ (O/O PUR 2).

In summary, key strategies for good planning in relation to procurement suggested by interviewees are:

- Treat planning itself as a necessary task and allow time in the schedule to do it properly.
- Pay attention to all three factors in the golden triangle of cost, quality, and schedule. In particular, be honest and realistic about timeframes from the beginning.
- Identify long lead items and manage them carefully, acknowledging that markets, and so availability, can change.
- Build in time for cross functional reviews such as constructability reviews. They are a good investment of time as they reduce problems later.
- Assign responsibility for risks to those best placed to manage them.

Scope and baseline specification

Problems with specifications

One common problem identified by interviewees is that projects start without a clear and detailed understanding of the required scope. In some cases, incomplete specifications are distributed, which causes significant problems throughout the later stages of the project (QUAL SP 1).

Uncertainties about the scope can take several forms. The first issue raised by multiple interviewees was technical errors in specifications meaning that what was specified was not fit for the purpose the user has in mind. An interviewee explained a situation where 'the client didn't appreciate the differences between spiral wound pipe and seamless pipe or operating and construction of main gas pipelines' (ENG CONSULT 3) that ended up with inappropriate pipe being specified and supplied. The same interviewee then gave another example about different definitions of a defect in the line pipe coating from the project contractor and the coating firm. Such inconsistency between parties in defining technical specifications resulted in conflicts in project delivery. In this case, one party delayed finishing their work for about three months (ENG CONSULT 3).

Another example given is about design changes that were not adequately considered when finalising the specifications. In this case, the required pipeline design factor was increased from 0.72 to 0.8, meaning less steel required for the same diameter. However, 'something which got overlooked was increased in design factors led to an increase in hydrotest pressures' which 'increases the expansion in the steel pipe at the time of the hydrotest.' This was not properly considered before the change in design and resulted in 'cracking in the epoxy products.' (SUPP 1).

Another interviewee described a case where there was a lot of debate about whether a pipe was compliant with the appropriate specification or not. 'There was this defect occurring through quite a number of the bits of pipe and it's quite interesting that the pipe could be compliant, but when you welded two bits of the pipe together, the feature being near the weld would then make the weld non-compliant, which meant you needed to then cut it out. So, you could have a compliant pipe which you couldn't weld together and have a compliant weld' (ENG CONSULT 1). A better written specification would not have created this problem.

From some suppliers' viewpoint, technical problems can sometimes be anticipated if the specification clearly defines what the end objective of the product or service is. This makes it easier for suppliers to draw on their expertise to provide an appropriate solution. As one interviewee said, 'to make it easier on us, to be able to identify what pre-engineered solution or solution they need, they need to give us a good heads up or a good understanding of what's their end goal, what are they trying to achieve, so we can give them the right product to fit the requirement – the right solution' (SUPP 6).

As another interviewee put it, it's critical for clients to communicate what they need because 'sometimes we have clients specify things and they don't even know what they need', and this would be effective through open conversation between the client and supplier (SUPP 7).

While important details in specifications are sometimes missing or incorrect, specifications tend to be very long and detailed documents. This can make it very difficult for suppliers to find important details. A lot of suppliers are overseas where 'English isn't their first language, so having them receive a 40-page specification for a job that's only worth a couple of hundred thousand dollars is a real problem because you really have to wonder whether they actually take the time to read the customer specification or not' (SUPP 13). Minimising the specs to 'get to the point of what you really need' will be beneficial (SUPP 7) as 'there's a lot of complexity in the way the Australian industry writes specifications that makes it difficult for international suppliers to actually understand what it is' (SUPP 13).

Incorporating voluminous and sometimes irrelevant requirements in specifications can also lead to perverse problems with selection of the successful tenderer. Not having clear specifications might lead to the risk of selecting a tenderer 'who doesn't really understand what the purchaser wants or needs but is seen by the procurement people as offering a more compliant offer. Whereas the people that do actually understand what the specification is asking for are looked on less favourably' because they 'have a very long list of deviations' (SUPP 13).

In the view of suppliers, these problems occur because of 'the end users not employing a lot of their own engineers and developing in-house expertise and having a lot of it driven by consultants' (SUPP 13). Another interviewee called this 'word processor engineering' where consultants duplicate specifications from previous projects and charge clients for that service (SUPP 7). Other reasons for overly long and complex specifications might be consultants trying to inflate their work scope. 'The more documentation they produce the more they get paid' (SUPP7). Alternatively, long specifications can sometimes be a result of an overly conservative approach as this interviewee explains: 'On the client's side, maybe they've seen some things that are challenges with past equipment that they may be trying to implement new requirements in order to avoid some of the past mistakes that they've made' (SUPP 7).

As another interviewee explained, the big contributor to the issue is that companies are 'under significant cost and time pressure' hence 'there's a lot of cut and paste engineering that happens' (SUPP 13). But rushing the production of specifications can mean that unnecessary requirements are added where a better solution might be to purchase 'the basic package where they can keep their cost down might be a way to keep the overall project cost down as well' (SUPP 7).

The final issue with specifications in the view of some interviewees is the widespread use of bespoke specifications in the Australian energy sector. When talking about specifications, interviewees emphasised the importance of having a design that is easy to understand. It's a challenge when overseas fabricators are imposed by bespoke standards while they are often only familiar with a certain series of international or common industry standards. As one interviewee gave an example, 'The technical specification was very bespoke, therefore difficult to implement by a fabricator who was used to common industry standards' and 'from the start there was lots of work on clarifying requirements, for example, around the fabrication of the exotic pipework, of which there was a lot in this skid, did not really get conveyed appropriately to the fabricator' (REG 1). In the end, the whole process had major impacts on project schedule and resources, even though the products could meet the requirements.

The overall conclusion from the interview data is that problems with specifications take the form of technical errors and/or over complexity driven by conservatism and a lack of consideration of what makes specifications simplest for suppliers to understand. In other cases, specifications fail to leverage suppliers' expertise. The consequences may be increased costs for both supplier and purchaser and ultimately supply of goods or equipment that is not fit for purpose.

Good practices for specifications

Interviewees had many suggestions for how specifications can be improved.

One supplier suggested better communication via a process where the client and supplier can sit to run through the documentation on specifications because sometimes 'it is probably not relevant where you could easily do something over a short document compared to… 50 to 100 specifications on a project' which is time-consuming for suppliers to go through and 'costly for clients to get consultancy companies to put them together' (SUPP 7).

Reducing use of bespoke specifications was seen as a way to simplify processes. The suggestion is to not fall 'into the trap of trying to bespoke everything' as it will 'incorporate your vendor's errors into it, because you've asking them to make something they've never made before' (O/O ENG 1). The preferred way forward is to standardise specifications so that there are 'standardized industrial solutions to be procured, which the supply chain is used to delivering to' (ENG CONSULT 3). Similarly, from a contractor's point of view, 'alignment as much as possible to Australian standards for technical specs and if there's any deviations to that for a reason…bringing it up and changing it as much as they can within that would help' (CONST CONT 3).

Not all procurement occurs in a project environment. Specification problems can equally arise when procuring complex goods and services in an operational environment. Another interviewee gave us some examples where a product was not fit for service. Specifically, the wrong type of glass reinforced epoxy was specified for the facility operating temperature (SUPP 2). These failures were repeated because the product 'wasn't fit for the temperature that it was operating at, so it was going soft' (SUPP 2). The lines failed during hydrotest but 'if someone hadn't hydrotested them properly and put them into service, then you could have had a catastrophic failure'. Consequences of that include 'environmental damage that's done from all that leaking' and a major cost blowout (SUPP 2). Clearly, 'if the product's not fit for service, it should never ever be purchased for that service' (SUPP 2). In some cases, there are potential safety consequences. 'You're dealing with hydrocarbon service and

you're potentially putting someone's life in danger by putting something in that is not fit for service, and that's the reality of it. If you get a leak and it somehow gets a spark, it can create an explosion if it's gas' (SUPP 2). Ultimately, it's important that 'the engineers need to be the people that set the specifications, so they know what their operating envelope is. You need to be able to determine that a product that is selected for that operating envelope is fit for service' (SUPP 2).

In summary, key strategies for improved specifications suggested by interviewees are:

- Reduce complexity in specifications as much as possible. Do not include irrelevant material that makes specifications difficult to follow and obscures key information.
- Include a description of what you are trying to achieve with the specified goods/equipment so that experienced suppliers can use their expertise to provide advice on whether what has been specified will be fit for purpose.
- Do you need a bespoke specification in a given application or will a standard specification be sufficient?
- Ensure sufficient engineering expertise is involved in specifying what is required.

Supply chain configuration

Poor contractor/supplier selection processes

Inadequate systems and practices for selection of contractors sometimes result in poor outcomes with significant economic consequences. The main issue described by interviewees was choosing suppliers only based on price rather than the quality of goods or services they can offer or their track records. One interviewee described a project where the client decided to choose a supplier who was not technically qualified for the job at hand but had provided a low-bid offer. As a result, 'two years later they spent millions of dollars to totally replace' the entire product (ENG CONSULT 3).

The interviewee mentioned a similar issue in another project where 'they drilled the price down in the beginning because their own estimators weren't good enough to understand all the costs associated with construction' (ENG CONSULT 3). Consequences of that include awarding the tender to those who offer the best price but that does not necessarily come with good quality of service. The interviewee further described the problem with a contractor who won the bid, 'client was left with no information about the job, and the job wasn't finished' as the contractor was 'cutting things out of the design' and 'walked off the job' after failing in communicating with the client (ENG CONSULT 3).

This interviewee was not alone in seeing problems with the technical capability of some owners in evaluating tenders. However, 'sometimes we feel the due diligence is not done well enough on the operator's side, so they don't actually understand the technology, or they don't validate specifications or track record or this sort of things sufficiently to be able to compare apples for apples in terms of proposals. They think it's apples for apples, but it's quite often a pear versus an apple' (SUPP 11).

Another interviewee explained the importance of suppliers themselves doing due diligence on what the operating company is asking for to ensure that it will perform the required function. As he explained, 'so the due diligence and the preparation is seen significantly, and we see a lot of success with that approach, and it's mainly driven by the consequence of not getting it right because of operational impact' (SUPP 10). It's also important to use a collaborative problem-solving approach to provide a service that will fix complex problems. 'It could be even on terms of they may have asked for something, and after doing that up front due diligence you may end up actually offering something that was not quite what was asked for… there are quite a few stakeholders… if you could get them working in a collaborative environment…' (SUPP 10).

Another interviewee explained the consequences of a project where procurement has been effectively driven by the decision of choosing a contractor based on their marginal cost difference rather than their technical capability over others. 'There were people involved in the organisation… they either didn't want to speak up against cost, they were the ones who ended up having to manage this crappy contract but for whatever reason… organisationally it suddenly was better to go along with the low-cost scenario' (ENG CONSULT 4). The interviewee then described major consequences: 'The equipment hadn't been used for years. It all broke down.

They didn't have the right skilled foreman, etc. The machinery wasn't up to it. The job got spread out badly. Lots of trench and right away was open. It rained like mad. There were huge damages. There were EPA [Environmental Protection Authority] breaches and the thing finished four months late and it was just the absolute false economy… I could not fathom that they'd even prequalified at the same level let alone just the idea that someone who wasn't operating and hadn't really operated for four years was just going to be able to snap their fingers, pull a top-notch team together, have all of the underlying systems, management plans and things like that that were conditions of contract and then start rapidly and really make the most of that pre-wet season window. Just unbelievable!' (ENG CONSULT 4).

Many interviewees talked about how suppliers from overseas have been selected due to lower costs of their products. This preference has impacted local production. As one interviewee explained, 'We lost our pipe coating industry here and why? Common denominator: lower cost' (ENG CONSULT 2). As another interviewee had personal experience of a similar issue in a project where pipelines were chosen from overseas instead of purchasing from Australian experienced supplier, 'line pipe comes in diameter and tonnes, … the tonne rate may have been more attractive for the overseas pipe … but it costs a lot in terms of the relationship between the buyers and the projects … you've got to support the local guys who've kept this industry alive for 40 years. You can't just let it all go overseas' (ENG CONSULT 3).

Lower costs don't necessarily come with good quality. In fact, extra expenses might incur during project execution due to poor quality products. As one interviewee described: 'There is a pipeline in Australia… where there were so many defects that it costs them $5 million before they got the pipe out of the yard… and that was purely because it was bought out of a Chinese mill, again, poor quality' (ENG CONSULT 2). As another interviewee pointed out, 'knowing that the cost of the component that I was purchasing would pale into insignificance in comparison with the consequence of a failure' (ENG CONSULT 5).

There have been also cases where customers purchased equipment from third-party vendors which could be 20-30% cheaper than the general market but 'these engines are meant to last 30,000 operating hours. So you're talking four and a half or five years. Within 12 months they might fail because it's not built to the same quality… They realised they should have spent more money upfront and actually gone with the people that they know and trust and they've got the backing to support the product that they need. So whilst they might save a dollar today, it's going to cost them twice as much in the long run' (SUPP 6).

Another similar story is a decision to buy 'a standard material fitting that didn't meet the engineer's requirements' because of lower prices' (SUPP 3). In this case, specialised material requirements from engineering were ignored to save cost. Although the hot tap fittings passed the ultrasonically test, 'it was high porosity… and gas leaked out through the steel… They had fittings that came out that were warped that had ripples. So they hadn't been rolled properly and these have been welded on to the pipe and then they've had to buy another lot of fittings' (SUPP 3).

The small cost that the company could save at the early stage eventually led to cost blowouts and potential safety issues if not detected. 'The $10,000 they save in construction costs maintenance a $1 million to cut out… $10,000 here and there on projects that are multimillion dollar projects just for the sake of saving' (SUPP 3). Not only the material did not meet the manufacturing requirements but also the factory acceptance testing. 'They would have had to have been forgery – forged certificates because they're saying that they've met our testing requirements' (SUPP 3).

Another issue related to low-price products is that the actual cost might not be low. As one interviewee explained about a decision to buy a fibreglass pipe from overseas instead of in Australia based on cost differences, 'the construction price was actually double because there's twice the number of joints, and the risk of leakage was double because every single joint has a propensity to leak' (ENG CONSULT 10). In this case, the pipe was more expensive because of a lack of shipping containers during Covid-19 and then damages in transit.

Selecting suppliers should be based on their ability to produce high-quality products with appropriate delivery schedules and prices. One interviewee commented that 'there is a price to be paying for good quality… and if you get the right quality delivered on time into your project, and you don't have quality issues in construction time, it can save you millions' (ENG CONSULT 2). Costs should not be the only priority, especially for products where safety is crucial, as one interviewee's suggestion, 'if I'm looking at boiler tubing, I wouldn't go to anyone else

except the Japanese and the Germans because they produce the quality tubing steel on time and for the right price. It's not cheap but… it survives in boiler tubes and they're very dangerous, obviously' (ENG CONSULT 2).

Many interviewees spoken about the importance of having good contractor/supplier selection processes in place in order to avoid these types of problems.

Good practices for contractor/supplier selection

Interviewees talked about effective practices to select the most appropriate contractors. The focus is on ensuring the technical competence of all contractors or suppliers who are invited to submit a commercial tender. Those without adequate competence are not invited to tender so there is no temptation to choose an option that will not be fit for purpose, just because the price is low.

Best practice starts with prequalification that includes interviews, an expression of interest and site inspection where relevant and possible. After shortlisting, tender documents are issued and parties involved in the project meet to discuss tender responses. As one interviewee further explained, 'there were assessment criteria, we told them exactly how we would assess it' (ENG CONSULT 2). Apart from price, the assessment criteria comprised 'quality, experience, equipment, etc.' (ENG CONSULT 2). As another interviewee described the tender evaluation system in his company, criteria rating 'is usually facilitated between procurement and engineering' as technical parts of the tender, independent of the price' (O/O ENG 5). Individual review has been conducted before a calibration session between team members, which results in the final decision (O/O ENG 5).

The experience and capabilities of the manufacturer or supplier and the ability to communicate well with them are especially important when 'you're deviating from your typical practices' (ENG CONSULT 7). For example, this has happened in the supply of line pipe from overseas. As one interviewee explained, 'when it comes to coating, we use Australian standards for coating of pipes, but… all the coating is done overseas. When you select a coating plan, firstly ask them "Are you familiar with these standards? Do you have any issue?" Sometimes these questions don't get asked at the beginning and the project gets in problem and then the manufacturer didn't do it properly' (ENG CONSULT 7).

Other good practices for contractor/supplier selection that were mentioned include engaging suppliers and contractors that are 'well-established' and have 'a very strong local presence' (O/O ENG 1) and those with 'previous experience' (ENG CONSULT 18), 'good track records' (SUPP 1), integrity (ENG CONSULT 18) and good customer service to back up when things go wrong (ENG CONSULT 1, ENG CONSULT 7). One interviewee said 'we wouldn't take on people with particularly a poor health and safety record… Those subcontractors or service providers that do become preferred, we've moulded and educated them into our culture of health and safety' (O/O PUR 2). Interviewees also mentioned modern slavery as a consideration in the prequalification process. It is important to know 'who are the providers or the suppliers we are considering approaching' (ENG CONSULT 14) and 'to confirm anti-slavery or not' during the due diligence check (O/O ENG 4). All of these factors can be addressed in prequalification.

Another interviewee talked about the importance of local agents, 'even though the majority of the equipment came from overseas, the local representatives were actually thoroughly knowledgeable and plugging into their overseas supply chains, had delivered other projects of similar type'… They 'weren't just salespeople' but 'almost worked as agents to facilitate what the customer or the client was asking for and provide us with honest feedback', thus 'choosing the agent was a major factor in not having any avoidable or silly disputes. And being able to resolve a lot of issues at no cost to anybody, because you could reach a reasonable compromise' (O/O ENG 1).

Another type of agent is those who are based in Australia and can 'demonstrate what process they have undergone to ensure the factories and the industries overseas are good factories' (O/O ENG 3). In such cases, the liability and insurance are with these national agents as they are to undertake the quality assessment process (O/O ENG 3). These agents can also help with small orders when companies are unable to purchase at random times, for example, 'a small amount of pipes in a big cargo ship' as the agent can sometimes combine orders from multiple companies (O/O ENG 3).

While having local agents for overseas manufacturers is useful, it sometimes creates problems in prequalification requirements if local offices are required to meet all the same requirements as the physical manufacturing site. One interviewee talked about the difficulty to meet the requirements of the prequalification process when his

company acts as a representative for an overseas manufacturer. ‘Our customer doesn’t want the risk of choosing a product or choosing a company to deal with. They want to put it on to a third-party so the third-party gets in between… The problem is if it was between our manufacturer and this third-party, it would be quite easy because they’re the ones with all their ISO, all of their anti-bribery, corruption, or all of the documentation and approvals… We’re a representative for them so we don’t have that level of ISO… We’re not a manufacturer so us applying for that is irrelevant but they don’t have that flexibility in their system to allow to go’ (SUPP 3).

Finally, prequalification schemes can benefit everyone in the industry, even if come companies are too small to be able to implement such complex administrative systems for themselves. As another interviewee further explained, ‘the pipeline industry is a very small community. People know each other’ so you can select specific manufacturers based on the past experience of colleagues in your network with them, including ‘record inspection in place when the items are being manufactured’ (ENG CONSULT 7). Similarly, lists of material providers, contractors, design service providers have also been used in some companies (O/O ENG 3).

Prequalification needs to be a dynamic process to take changing circumstances into account. As part of prequalification, revisiting supplier lists that companies have been using is also important as ‘the vendors themselves are dynamic’ as the result of changes in ‘their personnel, quality processes, their subcontractors and where they source material’ (ENG CONSULT 13). It is therefore important ‘to have a regular update of the prequalification process’ and ‘open to assessing new suppliers and new service providers’ because projects are ‘either cost-driven or schedule-driven’ so competitiveness might be a key driver (ENG CONSULT 13).

One interviewee shared a lesson about applying a multi-supplier selection strategy which gives companies more flexibility to continue their operation when things go wrong (O/O PUR 1). This is useful especially when dealing with suppliers who supply rare materials and have some levels of power (O/O PUR 1). Some suppliers become ‘demanding a lot to have money paid up front’ and ‘payment terms against delivery and guarantees are difficult to negotiate. Suppliers are starting to have a little bit more leverage’ (CONST CONT 1).

In summary, key strategies for good contractor/supplier selection suggested by interviewees are:

- Adopt a pre-qualification system in place to ensure that only those capable of providing a technically acceptable solution are invited to provide a commercial tender. This reduces the temptation to select a low-cost solution that is ultimately not technically acceptable.
- In addition to cost and technical feasibility, consider experience, track record, local representation, health and safety record and anti-slavery practices for the supplier and all sub-suppliers when selecting a preferred supplier.
- Draw on industry experience (not just company experience) when selecting suppliers.

Interface management

Once the right contractors/suppliers are chosen, successful procurement then requires good management of all various organisational interfaces created.

One major issue with interfaces is that there might be different sets of personnel involved in different phases of projects. Specifically, at the procurement phase, there are procurement specialists and engineers who are involved in specification preparation and/or contracting but then at the execution phase, there are project management people and ‘perhaps a different set of engineers. The engineers onsite tend to be more involved rather than the initial design engineers’ (SUPP 13). That is potentially a source of problems, ‘having that change of personnel or not having the continuity of personnel through the project means that agreements and knowledge of what is actually expected and what’s being proposed and agreed and background information to how something was arrived at as a negotiated outcome gets lost, and that then potentially causes problems down the track… because a lot of the time, when you’re negotiating things at the procurement stage, you develop an understanding with the people that you negotiate the required outcomes with, but then by the time it comes to the project execution phase, those people are no longer involved and it’s someone else who’s looking at the specification or contract and interpreting it in a way that’s not necessarily the way that you had understood and agreed with the procurement people’ (SUPP 13).

Having a lot of interfaces means that a good project management structure is required, making it 'day-to-day mentality as opposed to a project mentality' operations (ENG CONSULT 2) to ensure that the responsibility for the 'golden thread' is always maintained (i.e., making sure what is specified at the beginning is what is delivered with every stage being checked). It is important to 'have one facilitation point that executes a particular package' (ENG CONSULT 14) and 'carefully check everything to make sure… what we wanted… is in good condition' (ENG CONSULT 3) because it is problematic to have many contact points dealing with many interfaces (ENG CONSULT 14). 'Having one facilitation point on either side (of procurement) will ensure 'there is one avenue of information and communication going through' (ENG CONSULT 14). Interface management also involves developing contingency plans to manage and mitigate risks (ENG CONSULT 14).

Contracting strategy

Many interviewees spoke at length about the pros and cons of various contracting strategies. This shared experience is almost all in the context of major projects and procuring a complex collection of services and goods by an owner in order to achieve project outcomes.

Good practice in contracting, in any forms, includes a sound and clear contract with well-defined requirements at both the functional level and/or at the technical level. A sound contract should be 'mutually beneficial, not one party trying to control the other' and not 'really bespoke with every operator having their own variants and their own lawyers wanting to tweak things and set themselves up to advantage' (REG 1).

Realistic lead time is emphasized as suppliers tend to be explicit about that in contracting arrangements based on their experience and understanding of 'what's happening at the manufacturers' to avoid contractual disputes (SUPP 1). It seems to be not a priority for many clients in Australia to consider the delivery time for equipment purchased from oversea suppliers, which can be an issue given the long transport time (SUPP 5).

Views on various contracting strategies including problems and best practices are detailed below.

EPC (also known as EPCI)

In a contracting strategy commonly known as EPC (or sometimes EPCI), the owner seeks to let a single contract for the entire project (i.e., engineering, procurement, construction and installation). The primary contractor would typically be a firm whose primary focus is construction and they would then build a consortium or set up subcontracts with other parties to provide engineering (i.e., design) and procurement services. EPC contracts are also typically lump sum (i.e., a fixed price is agreed for a fixed scope with a process to account for variations). All activities related to procurement of goods and equipment including writing specifications, selecting and managing suppliers, dealing with logistics, etc are ultimately the responsibility of the primary contractor.

EPC was seen by an interviewee as a good model when 'what you're doing is very routine', paving the way for a very clear contract with well-defined requirements at a functional level (O/O QUAL 1). Another interviewee expressed similar views indicating that EPC would work well 'where there is a well-defined requirements and little execution risk' (ENG CONSULT 3). Yet another interviewee thought that EPC has some clear advantages: 'there's a lot to be said for giving the responsibility to a single entity… for managing all. But it will depend on how good that contractor is' (O/O QUAL 1). This last quote hints at some of the risks associated with EPC contracting that other interviewees described.

As one interviewee told us, this contracting model 'has been popular with bankers and lawyers', not 'with experienced project managers' (ENG CONSULT 3). The reason is that 'on linear projects like pipelines where execution risks are greater, EPC is a much bigger gamble' (ENG CONSULT 3). In this kind of contracting arrangement, as the owner's engineers are not involved in the procurement process, they might not be aware of procurement issues when things go wrong. As one interviewee told us about problems around hydrotest failures in an EPC style project where their firm, as an owner's engineer, was not directly involved in the procurement process but 'suffered the consequences of some issues' (O/O ENG 1).

The experience of both the operator and the primary contractor is critical. Firstly, the operator must have sufficient experience to be able to specify exactly what is required and to select a contractor with the right skills and experience to successfully execute the work. An interviewee described a project where a pipeline 'was clearly a very poor fit for purpose, a 400 km pipeline with no intermediate peaking capability … It was an EPC contract' (ENG CONSULT 5). The pipeline was designed 'by an engineering house for a power company' who

was ‘inexperience and lack of operational input’ and ‘there was no owner sitting over top of it’ (ENG CONSULT 5). Secondly, the primary contractor’s experience is critical because under this model, the owner has little oversight. One interviewee believed that EPC, which ‘basically is almost the main method of contracting now’, is flawed, as ‘the management of lower tier suppliers and subcontractors very much fits under the main contractor’s remit’. This can be a significant risk because ‘we don’t have massive visibility on those subcontractors, and… you’re relying on the main contractor to provide that oversight’ and ‘it does come down to the quality of the EPCI contractor’s people, and… if you’ve got an inexperienced team, an EPCI can be a nightmare because you’re supposed to be sitting there hands back and letting them get on with it’ (O/O ENG 7).Sometimes the problem isn’t a matter of a lack of experience but rather the structure of the contract itself incentivising people to cut corners. Another interviewee observed that ‘as has happened on every one of these EPC projects, it’s in the interests of the contractor to direct the engineer working for him as an EPC subcontractor to cut corners, save money, substitute materials’ (ENG CONSULT 3), which was consistent with some of the others’ experience, ‘contractors try to take more money because they can hide it in the EPC structure’ (ENG CONSULT 2).

Another interviewee had ideas about how to prevent this. He was of the view that the operator has to have ‘enough visibility and transparency in what the contractor is doing but without overly interfering in their business’ and ‘sociological aspects’ of ‘project management organisation’ in the contracting model, including ‘behaviours and relationships’ can’t be underestimated (O/O QUAL 1). ’The relationship between the operator and the head contractor’ and ‘the nature of the head contractor’ (O/O QUAL 1) have a significant influence on project outcomes.

EPCM

When an EPCM strategy is used, one contract is tendered for engineering (i.e., design), procurement and construction management services and a separate contract is tendered for construction. This used to be a common contracting strategy but is now less used. Some projects still adopt this where uncertainty is high.

In EPCM, as the engineers work directly for the client and help them subcontract construction services, the client will have a greater influence on the engineering. As such, this kind of contracting arrangement allows the engineers to effectively have a higher degree of power and represent the owner’s interest rather than having ‘things being driven by the construction contractor’ (ENG CONSULT 3). One interviewee told us that ‘for some recent hydrogen production and gas blending facilities, for one client, we were doing more EPCM’ (ENG CONSULT 6).

Risk transfer rather than risk sharing

Many interviewees described problems associated with stakeholders trying to transfer risk onto others rather than sharing or mitigating it. Risk transfer is ‘the most common attitude among lawyers who are the ones who most commonly advise management on which contracting strategy to use; it handballs the risk to somebody else’ (ENG CONSULT 3). The interviewee further explained when common contracting strategies switched from EPCM to EPC, people attempted to transfer risk to other parties, which ‘has resulted in a lot of unnecessary disputes’ (ENG CONSULT 3).

An interviewee who worked as an engineer consultant agreed that contracting arrangements where risks can be passed onto the construction contractor are the best way to achieve the lowest-risk outcome for the client/owner. However, ‘that’s not favoured by the constructors because your constructors actually sell machine hours and manhours. That's their business model. The more manhours they can build into the project, into their costing and more machine hours or hire rates, that's where they make their margin’ (ENG CONSULT 5).

An interviewee from the supplier group explained the consequences of risks being pushed downstream through the supply chain, where the people at the bottom don’t sign the contract with such terms and conditions. Often the head contractor should ‘push all the risks down and the risk should be at a level where it’s best able to be managed’ (SUPP 14). But in many cases, the risk was pushed right down to the suppliers, for example the steel companies and the pipe or turbine producers, where they have to carry 10-year design warries. ‘And you just can't get that out of a steel company’ (SUPP 14).

Many contracts just ‘don’t protect anyone. It pushes the risk down to where it’s, one, can't be managed and, two, by and large most companies, if it were to go wrong, don't have the wherewithal financially to pay out’ (SUPP 14). The risk then ‘bounces back quite heavily back up the chain. So, it’s a false belief that they're absolving

themselves of risk. All they're doing is they won't know about it until it's too late'. According to the interviewee, this is a significant issue particularly with big renewable projects, including wind farms and gas hubs. The driver of this is because companies are 'not accruing any risk on their balance sheet' so 'they go in at low margin and try and make it on variation. So, they're trying to protect their margin' (SUPP 14).

It is important to try to have the best party manage the risk, as one interviewee explained. 'If the risk is about the specification and the product selection for the process, all that needs to sit with the engineering company. If it's about... the handling or the coating of the material, that needs to sit with the manufacturer. And then once it comes down to the installation and the construction of the pipeline, risks around the site conditions… those sorts of things need to be managed by the construction contractor' (O/O CONT 1). More importantly, 'it's very unlikely that only one part of the supply chain can mitigate total risk. So, it should be a more collegiate view to mitigating risk' (SUPP 14).

For land access, whether it is farmland or industrial land, there might have been issues with cultural heritage and with Aboriginal communities, which requires negotiation with the landowners. This kind of risk would be with the asset owner. The ways to manage the risk is to arrange public and private meetings with relevant stakeholders and try to keep the start date flexible because that depends on the land access agreement in place and the extension of time that can be negotiated with the construction contractor (O/O CONT 1).

Early Contractor Involvement (ECI)

As the name suggests, Early Contractor Involvement is a contracting strategy that involves selecting the successful contractor earlier than the case under an EPC arrangement and drawing on the contractor's expertise in completing the concept design. In this way, the contractor and owner jointly establish the basis on which a firm contract price can be agreed. Once a price is agreed, procurement activities proceed essentially as described under an EPC arrangement.

Many interviewees mentioned successful projects with ECI where they were delivered early and within budget. In this kind of project, a lot of effort was given into the process of allocating risks and costing them out under the negotiation between different parties. As one interviewee described, 'having sold some of the risks which was best allocated between the principal and contractor' and 'the quality, at the end of the day, was exemplary' (ENG CONSULT 2). The advantage of this contracting scheme is that it's very clear about each party being responsible for the risks allocated to them as 'in an ECI process, it's totally open book because you see how they've priced the risk' and 'the risk money was included in the price' (ENG CONSULT 2). This helps with mitigating conflicts in defining the responsibility when things go wrong, such as damages in transit.

It's also beneficial 'when you don't have all the information that you need in order to be able to manage the risk… We would use an ECI contract to have the contractor start working in parallel with some of the engineering, so that we can identify issues and get them built into the design with the input of the construction contractor, and… it helps us manage the risk. If we identify a problem, we can say to a construction contractor, "You know about that now, what's the price to deal with it." They tell us the price… We get a fixed price without having to build in extra contingency' (O/O CONT 1).

It takes time for the whole risk assessment process at the beginning where 'you get the right people in the room' (ENG CONSULT 2) to identify and assign all the risks, estimate related costs and make 'informed decisions on the selection of concept' (REG 1). However, 'it's just paid hand over fist because' in case 'there is an argument as to who's responsible' (ENG CONSULT 2).

One interviewee said 'it's rare that you move straight into an ECI phase, there's usually a competitive phase to a certain level of design that precedes that, and they will make a choice and work with their preferred contractor. And yes, at the end of that you come up with – there're a few different models, but usually it's called a risk-adjusted price. So you might settle on the known knowns and the unknown knowns, so that would all – those unknowns would sit in a risk pool that could be shared' (O/O PUR 2).

Another interviewee described a successful project with a client who is very mature but has never done an ECI before in Australia. 'They were very sensitive to it' and 'it was a highly complex project' but they 'realised the value of going through the ECI process and developed a team and we worked on it for two years and developed a scope, had risk strategies, undertook geotechnical testing, and engaged with stakeholders, and went through our procurement strategy. So it was very much an open book in terms of how we went to work like we were one

team' (CONST CONT 2). The interviewee then further commented 'It was just a very well-planned project and the client was that mature in that they understood that the subcontractor needed to make enough money and margin… So in terms of successes, it was all things procurement and integration of teams and landowner discussions, all of those things made that probably the most successful project that I've been on… The client was very well aware that it's a relationship, they want to get it done within a certain budget, and they were mature enough to set a reasonable budget' (CONST CONT 2).

From a contractor's experience, a lot of ECI contracts have been successful. 'With the oil and gas space, and it'd probably work well with overhead transmission lines and things like that' (CONST CONT 3). ECI enables to 'work through a lot of the constructability type issues' and if they can be sorted during an ECI phase, 'when you go to execute and convert that to a construction contract, your risk profile is well known' (CONST CONT 3). As ECI allows parties to understand 'a full joint risk assessment… it reduces the amount of variations and changes after that contract's been awarded' (CONST CONT 3).

From a supplier's perspective, ECI works well for clients to draw the expertise from the supplier to ensure risks are well managed from the beginning. Specifically, it helps them to write the appropriate specifications including putting the right standards for overseas manufacturers, particularly when 'Australian contractors or Australian engineers tend to use Australian standards for steel that doesn't necessarily work' overseas (SUPP 14). Further, it helps clients to understand freight issues, particularly the timing around freight (SUPP 14).

Other interviewees expressed different experiences with ECI. Although ECI allows to detect things that would go wrong in risk assessment and mitigation workshops, blind optimism might occur when parties don't want to 'talk about what might go wrong' (ENG CONSULT 3). Another interviewee indicated that 'it's not black and white' to deal with penalties for things for which no party has responsibility or control (ENG CONSULT 5). This interviewee described how difficult it can be to get risk management and incentives aligned using one project as an example where 'there was a very high rate of weld failure' but the contractor was not incentivised to stop the welding and sort it out 'because the welds are failing through cracking. If the contractor stopped the welding, he would have been hit with a schedule penalty, so it was up to the principal to stop the welding and it was only done after 70 km of weld was done and that was to avoid being pinged for not meeting his schedule' (ENG CONSULT 5). This was clearly a problem, but the contract arrangement encouraged parties to keep going rather than stop and resolve a problem that was not of their making.

Another interviewee thought 'in the offshore industry… sometimes there's a risk of getting (the contractor) involved too early, because they're not particularly good at the real conceptual design, because the conceptual design, certainly in offshore, is more around operational requirements… so there's a risk that you load them up with too much responsibility' (O/O ENG 7). The interviewee then explained with an example of a recent project where 'we've probably entrusted them to do that too much and they haven't done it well because it's not in their core skill set. Also, they still don't have operator experience, so we're after a good project outcome in terms of cost and schedule, but only if we get a good result in the operational phase… Design a pipeline, that should be pretty straightforward, but design the whole system and that interface with… process engineering – there're topsides as well because we have an interface between subsidy and topsides. If you get too involved in that too early, it's a problem for them' (O/O ENG 7).

There would be another issue that the companies that are given the award to the ECI don't do enough work during the ECI phase. 'They want to put their attention onto the real project. They generally put younger, less experienced resources into the ECI, so you might not get the quality of documents that you want or the quality of knowledge that you want' (O/O CONT 1). One way to manage this is 'to be very clear in what the deliverables are for the ECI… and you need to work closely with the contractor during the ECI process so that you can respond quickly if you can see they're not doing it the way you want. And if it's possible, I'd recommend that you share offices during an ECI' (O/O CONT 1). This will help to strengthen not only the relationship but the level of trust through frequent communication between parties, and thus 'you can react quicker and hopefully resolve the problem before it takes too long or becomes too difficult to resolve' (O/O CONT 1).

From one contractor's point of view, it will take 'a high level of trust between the two organisations' under an ECI contract, 'because - not that it's a blank cheque, but usually it's of a target cost. You come up with a target cost together, but as issues come up… it can ratchet up as you discover risk… However, there is less commercial conflict' (CONST CONT 4). A lump sum is sometimes easier because it will protect the contractor with 'clarifications, qualifications' and 'you hold the risk, you manage it, it's very clear what's changed commercially,

and you just put in notice and you claim that… it's all in our lap' while in an ECI, 'there's a lot of work to manage it properly to make it effective' (CONST CONT 4).

From one supplier's experience, ECI hasn't 'worked well probably in the last seven or eight years. And that's not because the model was flawed, it's because the whole contracting landscape has become far more adversarial in that time. Back 20, 25 years ago, if there was an issue around deliveries or timeframes. it used to be quite commonplace to sit down… find a way forward to create the least damage to all parties concerned. That's not the case anymore. Very adversarial now'. Some companies realise that although ECI is very good for them, 'it just adds cost and complexity to the project' (SUPP 14).

Relationship contracting

The underlying principle of relationship contracting is that the parties establish an agreement on the premise of a collective responsibility for delivering best for project outcomes and acceptance of the various types of risk by the alliance member best able to manage them, thus reducing their likely impacts. The team works collaboratively to deliver the project objectives in a "no blame" environment underpinned by pain share/gain share.

Without establishing common goals, contractors and suppliers can logically act in ways that are to their benefit and not the benefit of the project. An interviewee explained a contracting strategy where there was 'a super low price (that is) too good to refuse' that suppliers 'from countries that had not been traditional suppliers to the transmission pipeline industry' offered. 'So they would bid in to meet the minimum specification as defined, and then they would try to add value to the whole contract to exercise – to tap into the variations provisions in the contract and basically to convince them to build a better product… And then the contractor's strategy appeared to be to try to down spec, to trim and to cut in order to make a profit from that low price. So rather than trying to add value into the project, they tried to find ways of delivering the project that really scrimped and cut corners and that was the strategy to get in with a super low price too good to refuse, and then down design the thing wherever they could'. This is the problem behind 'specific design issues and aspects of construction that needed a lot of rework after materials were on the ground and in the ground' (ENG CONSULT 18).

Many interviewees emphasized the benefits of relationship contracting, indicating a more common transition from traditional forms to this kind of contractual arrangements. Specifically, many companies moved onto that from the old EPC arrangements where construction contractors have high levels of control. Further, relationship contracting is favoured as it reduces the possibility of 'a contract ended in dispute because there was not sufficient clarity between the parties at the time they signed the contract' (ENG CONSULT 3).

One interviewee believed such a collaborative contracting approach is 'more sensible and probably the only way to go' as 'you may get a hard dollar contract, but it's how you arrive at that hard dollar contract' (ENG CONSULT 15). It is also important to get the contractor involved early 'because if you've designed it and then you just put it in the market, it just becomes a lowest-price auction otherwise. So the collaborative approach – and it doesn't have to be an ECI; it can be other ways of doing it. It can be a negotiated design and construct. There are a number of ways to set these things up' (ENG CONSULT 15).

The relationships between key parties determine the transactions. As one interviewee explained an example of a lump sum fixed price contract for a pipeline that was delivered wholly by a contractor. 'The engineering contractor for them, or sub-contractor, didn't have a lump sum and fixed price to them. So fundamentally the transaction between the contractor and the client was on one basis, but the one between the contractor and their subcontract wasn't. When the price went up, they can't get passed on to the client. 'If there's no relationship, or if the relationship isn't as good as what it's thought to be, then the transaction will be severely affected if the transaction itself isn't able to withstand the relationship manoeuvres' (LAW 1).

From a contractor's point of view, a collaborative approach is crucial, particularly with a limited number of subcontractors working in the industry (CONST CONT 3). Even though it's the responsibility of the subcontractor, when things go wrong, it's important to help them out, 'bring them along and not push all that risk onto them', because 'at the end of the day, the costs that we might recover from a subcontractor is nothing compared to the costs that we would otherwise incur because our jobs not progressing' (CONST CONT 3).

From some suppliers' perspectives, alliance agreements are beneficial, because they are a tool to help reduce time and costs owing to pre-agreed terms and conditions, 'which could take months to negotiate on a competitive process… On the aftermarket side, that makes things a lot easier, because there's more transaction from an

aftermarket side as compared to new equipment, so that really helps smooth the business transactions' (SUPP 7). Further, suppliers can become an extension of the client's team, 'and this is where you can have conversations with them to figure out exactly what they're trying to achieve and how to meet their requirements, and you can look then at how to optimise their solutions a lot better because you can spend a bit more time looking at that and formulating a solution with long-term benefits that will help reduce their overall lifecycle costs' (SUPP 7). The cons of alliance contracting are 'complacency. People forget what's in them. People forget they're there, especially on the customer side. Sometimes they don't always identify the efficiencies or understand the efficiencies of having that alliance agreement' (SUPP 6).

Contract disputes

Interviewees described examples of causes of contract disputes which include 'not sufficient clarity between the parties at the time they signed the contract' (ENG CONSULT 3). One interviewee believed the nature of disputes is the same, 'it's usually poor drawings or poor documentation, inadequate scope of work, going out too early, difficult clients and difficult contractors, underbidding' (ENG CONSULT 15). There are also 'a whole range of other things which have manifested over the years… that provide the basis of disputes', including logistics of the supply chain such as 'custody damage to the pipe, damage to the coating' and delays in deliveries (ENG CONSULT 15).

Disputes result from conflicts between parties with consequences impacting timeframes, costs, and reputation. As one interviewee talked about his experience, 'I reckon that there are only two reasons for dispute in construction projects. The first one is poorly made and kept records. And then the other one is bad feelings between the parties' (LAW 1). In some cases, 'the consequences of disputes are that a broader set of stakeholders get affected every single time', depending on which party is responsible for the costs (LAW 1).

If there is a dispute resolution provision when making the transaction, a relationship between parties isn't necessary. 'But often what happens is people don't look at the dispute resolution, or avoidance provisions in particular when they're drafting up their contractual forms' so when 'the relationship's falling apart', there will be no chance for dispute resolution process (LAW 1).

Good practices for contracting

In summary, key strategies for good contracting strategy suggested by interviewees are:

- Establish mutually beneficial contractual arrangements with well-defined terms and conditions at both functional and technical levels.
- Be realistic and explicit about equipment lead times with consideration to the long delivery time for equipment purchased from overseas.
- Improve the transparency in the contracting process with adequate risk assessment and allocation among all parties at the beginning.
- Pay attention to the dispute resolution/avoidance provisions in contractual terms and conditions to avoid disputes when conflicts occur.

Logistics

Problems with logistics

Given the global nature of procurement in the energy sector, the logistics of moving equipment and materials from the place of manufacture ultimately to site is a significant issue. The main issues are damage to items in transit and delays to delivery.

Logistics is sometimes not sufficiently considered in comparing procurement options and making the wrong choice can have a significant adverse outcome. As one interviewee described of a case where a purchase was made overseas because it seemed to be the cheaper option, 'It costs more to remediate the pipe than the pipe cost. If they'd listened to the advice and bought 20-meter lengths from an Australian manufacturer, they wouldn't be in the pickle that they're currently in' (ENG CONSULT 10). Sometimes 'there was no coordination with the

shipments from overseas', as one interviewee explained what happened in a project where 'it all just got really messy' (ENG CONSULT 3). As another interviewee described the failure of interface management with pipelines purchased from a mill in one country and coated in another country. The fact that there were many interfaces in different countries might result in the pipes having flaws during transit then being 'checked by someone that wasn't necessarily part of the design team… and it was just purely visual' and ignored by the coating team as it's not their problem (LAW 1). The problem is not because the people involved 'were bad people or anything like that. But because that's just what happens sometimes... By the time that the pipe actually arrived in the field, not only is it non-conforming, but it's damaged (LAW 1).

Other interviewees told us of several cases where the line pipe purchased from overseas was damaged in transit because it was not handled properly or 'didn't have adequate weather protection or just got lost' (ENG CONSULT 3). Shipping can be a problem for line pipe, 'sitting on the back of the boat, salt water's crept into the end of things and then when it's been installed, things didn't work' and 'a glass-reinforced pipe - you can bruise it where you can't actually see the defect on the outside and sometimes it can actually take some time for the defect to develop, so it's not quite like steel where if it passes a hydrotest it should be good… It also essentially relaxes under load, like when you load it up, it actually will distribute the forces through the fibres and the defects can eventuate over time' (ENG CONSULT 1).

Rail transport of pipe has another set of issues. As one interviewee explained, 'we had a lot of transport issues with large diameter, thin wall pipe with just ovality. You'd put it on a train, you'd get some static electricity built up just with the vibration, if they don't brace it correctly it just starts to oval on you' (CONST CONT 4). Another catastrophic failure occurred when 'the line pipe was all transported by rail, and they just had all these weld cracks open up because of the vibrations on the trains and how it was packed. And then… because that's obviously a time dependent mechanism, years later then there's just failure after failure after failure' (CONST CONT 4). A lesson learned from the failure with the pipe transporting by train is 'to make sure that those protocols, whether it's to the updated standard for transporting pipe by rail or the specification that we develop… are implemented'. Another practice is to do special checks. 'If we're receiving pipe that has been shipped by rail, we'll actually NDT [non-destructive testing] the seams and just make sure that… those cracks haven't opened up because of how they've actually transported it' (CONST CONT 4).

One interviewee mentioned problems related to poor packing and weather protection for materials and equipment which led to the need for repair and replacement. As the interviewee explained further, 'moisture is one of the worst things getting into finely machined equipment' (ENG CONSULT 3). Another interviewee made a similar point saying that sometimes the goods aren't 'packed correctly and sufficiently to keep them safe during the transport. And on occasions, the timber crates have deteriorated or haven't been strong enough during the lifting operation and has resulted in damage to the goods' (SUPP 5). Some practices given by interviewees about handling pipes include 'put a plank of wood in between the two' pipes and 'require wood to be scalloped out to increase the contact area between the pipe and the actual bollard, just to try to distribute the load and any sort of fatigue or rubbing or friction damage' (ENG CONSULT 1) while about engines, an interviewee talked about making 'a cocoon for the engine to sit in' and 'recording the acceleration all the time' and with thresholds, 'the vibration that the engine will receive' can be controlled (ENG CONSULT 8). With the High Build Epoxy, testing up front on the batches of the product is useful to manage coating material issues (CONST CONT 4).

The next issue is appropriate storage. Many weathering issues happened with the line pipes coating where they are 'just been sitting too long' under the sun or in a tropical environment. For example, with the High Build Epoxy, 'there's a lot of water uptake into the coatings' and companies have to 'pay the price for that depending on what type of field joint coatings is going on that' (CONST CONT 4). Another similar story is a line pipe was fabricated and coated 'two years before the job began. So all that line pipe was sitting port side, so it was getting salt spray, it wasn't preserved very well at the ends… Then it starts creeping in against the toe of the coating and that just creeps, creeps, and just rust starts forming underneath and it just starts eating in on the coating itself' (CONST CONT 4). Consequences of that are 'a massive amount of work' to 'strip the outer jacket… and then blast back and re-prep everything' for more than 1000 km of pipes, 'it's called triple random pipe which is 18 joint lengths so you're talking thousands of lengths' (CONST CONT 4). In this case, the construction contractor had to re-prep 'something that's damaged, and then… accept all future liabilities around that to a certain extent for a certain period of time afterwards' for the pipe that was sitting 'wharf side for so long in the salt kind of environment… it was so weathered' (CONST CONT 4).

Many of these issues arise because of problems with ill-defined responsibilities regarding the chain of custody and liability, particularly related to damages during transport because 'there wasn't much clarity around the custody transfer, handover and transportation', 'it's a bit hard to specify things along the way' and 'put any KPIs [Key Performance Indicators] in place to manage it' (ENG CONSULT 1). As one interviewee described such problems with line pipe, where 'you do not have the time to inspect the coating fully, both internally and externally depending on how it's coated, and it goes straight into the stockpile. And these are 24-hour operations, so you can't have a guy standing in the pipe inspecting pipe at night, it's dangerous, it's too quick' (ENG CONSULT 10). As another interviewee explained about the degradation of the pipe in transport, 'it becomes a lot more grey about who is ultimately responsible for it just due to the change in custody ownership', whether it should be the responsibility of the supplier, the transporter, the vendor who 'didn't give any detail but a certain protection needed to be taken', or the contractor 'who joined the two bits together' and 'should have noticed the degradation where they could cut the damage bits off' (ENG CONSULT 1).

Another point that can make the handover become problematic is the customs and payment of duty or tax when the equipment arrives in Australia, which 'sometimes people don't appreciate… or anticipate… Taxation and duty on arrival for Australia, it's fairly straightforward, but customs assess it at the time of import'. In some cases, 'you get advised that it should be duty free' but then you still have to pay or 'when goods arrive, depending on where they've come from, they may need additional treatment once an inspector views it, which can add significant costs and especially if it's large, oversized machinery or things like that, it's hard to move to a position that it can be treated. Otherwise, have to treat on the wharf, which is all extra costs at the end of the day' (SUPP 5).

Successful logistics is critical for successful procurement. Interviewees have described problems with transport, packing and storage of goods which are exacerbated when logistics are not considered sufficiently in supplier selection and/or custody transfer and liability for damage is not clearly defined. There can also be practical difficulties related to customs clearances, duty payments and arrival inspections.

Good practices for logistics management

Most of the practices suggested by interviewees for good practice in logistics for procurement relate to custody transfer arrangements.

A model on custody transfer of line pipe that was shared by one interviewee is to have an agreement where a sample of pipe is taken and put in transit with a very deep inspection being conducted 'prior to handover, which might be in the stockpile' (ENG CONSULT 10). As the interviewee explained, 'On a basis of ratio, so many ends might be dented, so many scratched might be on the coating, we'll categorise them whether they need to be the superficial scratched on the coating, whether they're shallow and require minor repair, or deep and require high level repair. Generally, the contractor will do the repair for the client, but at some later stage, otherwise you'd be double handling all the pipes. So, you have a side agreement that takes quite a bit of time to negotiate but generally the pipe in the stockpile will be $25 a joint. Five percent will require minor damage costing, $25, and so on and so forth. So, based on sampling, you will agree with the clients on what repairs need to be made' (ENG CONSULT 10).

The other way of dealing with custody transfer problems is to have a client's inspector, for example, 'for six months, checking each pipe' when it's 'get off loaded' to identify 'who caused the damage? Was that inherent from the shipping, prior to custody transfer, or was it you guys loading out?'. This model is often more expensive than 'to do a sample and come to an agreement' (ENG CONSULT 10). There are plenty of other models around custody transfer with different agreements that can 'tailor for each individual project' and the responsibility of parties can be 'worked out in the contract' (ENG CONSULT 10).

Apart from clear responsibilities, 'a defined point of handover' should be considered in the contract terms given all the transitions between different points of handover such as ports and road transport networks (SUPP 5). For example, 'if you get some smaller parts… of equipment, it may be better for delivery direct to site or a port or an airport. If it's a remote site, the overseas supplier is probably not an expert on local carriers… so it may be better for them to stop their responsibility when it hits the Australian port. And then we get local experts involved to get it the last leg' (SUPP 5).

It is crucial that a good contracting strategy needs to be carefully considered to effectively manage risks such as custody transfer problems from the manufacturer to the construction contractor. For example, one interviewee

told us about an example where there were problems around a sub-sea installation with a lot of pieces and interfaces. As the interviewee explained, ‘there was this period between these pieces being on ship and being on the dock’ where the company was responsible, ‘just managing the risk around that was a complication… the contracting model shouldn’t have had’ us ‘in that custodial position’ (O/O QUAL 1).

Another interviewee pointed out that ‘the whole chain of custody, particularly around Covid life is a big issue’ and ‘if you think that your QA [Quality Assurance], your procurement or your contract is going to save you from a myriad of things you’re wrong’, therefore ‘if you can give the whole risk to one party and you only have to inspect the delivered product once at the stockpile certainly makes a lot of sense’ (ENG CONSULT 4). Based on his observations, trust plays a significant role, because of ‘the impacts of a perception of slight overpayment for a good or service versus all the other protective measure costs and there’s still the poor outcomes’ (ENG CONSULT 4).

A practice related to custody transfer is ‘to specify exactly when the custody of the pipe changes from the manufacturer to the contractor and they will inspect the pipe at that point in time (O/O CONT 1). A lot of quality problems happened around the ends of the pipe. ‘The pipe is usually bevelled to a specific specification so that when you weld it, it joins together easily. If those ends are damaged and they need to be prepared… again we do an inspection before the pipe is transferred from the manufacturer to the construction contractor, so if it’s been damaged by the transportation process, then the pipe supplier will repair that damage’ (O/O CONT 1). Before the pipe is delivered, ‘if there’s any damage, then the pipeline manufacturing company would be responsible for repairing that’ (O/O CONT 1).

As another interviewee (CONST CONT 4) explained his company approach which includes an inspection and test plan developed for custody transfer of line pipe and induction bends. ‘Now we have these pretty in-depth programs based on what type of product is being delivered on what type of inspections we do at custody transfer. So even though it’s time consuming, no matter what job it is… we holiday inspect every single joint’ (CONST CONT 4). Similarly, another interviewee explained his company’s approach, ‘we quite often engage marine surveyors, whether it’s loading on or off a vessel, to do a full inspection and take photos and report on it. And that way, we’ve got a record of if there is any damage or where did it occur and that’s our handover at the point of delivery’ (SUPP 5).

There are various views on the merits of responsibility for logistics lying with different parties. On interviewee prefers an approach of ‘having one logistics provider that can manage the whole logistics for the project rather than having all the different suppliers managing the logistics to the project site’ (ENG CONSULT 14). There are potential savings and coordination, ‘particularly if you've got a remote project. You can have common coordinated warehouse areas, and laydown yards, and load in, load out, and management of import duties and all sorts of things there’ (ENG CONSULT 13). This will help to minimize the risk of multiple logistics interfaces. A different approach used is ‘to engage the supplier to bring the material from the manufacturer to the wharf – beyond the wharf, to our site. These are usually done with agents. The agent will coordinate the manufacturing with the mill, pipe mill, and they will coordinate the delivery to site, which will include shipping from the country and transporting it by road or rail or whatever, specifically to our site’ (O/O CONT 1).

From a supplier’s viewpoint, it is best to ‘carry out with our customers, a custody transfer inspection at the point of handover’ and ‘any damage that’s noted on the coating, on the pipe or anything like that, we’ll repair onsite as part of that handover process’ (SUPP 13). For goods coming from overseas, ‘We’ve got a third-party inspector looking at the goods at the port before they load it on’ while if the custody transfer points take place in Australia, ‘which it does for most of our high-pressure gas pipeline work that’s got coatings on it… which are prone to damage, we do that with the client… We take every pipe off the track, we roll it across a set of racks, we visually inspect 100% of the pipe. We holiday test, jeep test 10% of those pipes. If there’s any repairs required, we quarantine them then and there, and we’ve got people to fix that coating (SUPP 14).

However, ‘the amount of diligence that customers put into that is very variable’, as some customers ‘have a very defined process that we have to go through for inspecting goods for them to receive into their stockpile, whereas other customers will just not have any process at all’ (SUPP 13) because it is ‘really expensive’ (SUPP 14).

In summary, key strategies for good logistics management suggested by interviewees are:

- Ensure logistics is taken into account in comparing tenders including requirements for packing, transportation and storage of goods and equipment to prevent damage.
- Detail responsibilities for the condition of goods in all contracts including testing requirements linked to custody transfer to ensure that responsibility for repair can be simply identified if damage occurs.
- Monitoring and active quality management across logistics interfaces is critical for early detection of problems.
- Make a mindful choice about who should be responsible for logistics and assign responsibility for risks to those best placed to manage them.

Quality assurance/quality control (QA/QC)

Manufacturing QA/QC failures

Purchaser's quality assurance systems targeting the manufacturer's activities are designed to detect problems with the quality of procured goods close to source so they can be fixed with the smallest cost and schedule impacts. Some interviewees described cases where QA/QC systems failed, particularly if there are many interfaces involved. As one interviewee explained about a project in which some valves were manufactured in Europe but the coating was completed in India, 'there was a breakdown in the QA, where it wasn't appropriately coated or there was no QA of that coating and it was sent back to [Europe]. And before they got ready to ship them back to Australia, they realised all this coating was fundamentally cracked, so they had to send it then back to India. And then from India they had to then send them to Australia to try and save some timing' (REG 1). The repair work caused significant project delays but the potential consequences could have included leaks to atmosphere if the valves had been installed without the problem being identified.

Another example of QA/QC failure is wellheads that 'were manufactured with sub-quality gaskets' because 'there was a lack of QA in the supply chain to ensure that all components of these wellheads satisfied the relevant standard for that particular company' (REG 1). Consequences were not only extra costs involved because of the need for shutdown and repair, but also the safety aspects due to potential leakage.

Another interviewee told us about technical issues of a project which happened during commissioning because the equipment 'was left to degrade somewhat for five years' and somehow there was an assumption that 'the inspection had taken place' and then during 'the last commissioning inspection, there were problems found' (ENG CONSULT 6). Although 'that was really largely due to the sequencing and the hiatus in the project', a lack of inspection led to problems to be found at a very late stage (ENG CONSULT 6).

Another similar example is the damaged coating of a pipe submerged in deep-water. Incorrectly coated pipe at the project stage has led to costly repairs many years later. 'We've had to design a special system to try and fix that coating to make sure we don't have top of line corrosion, so again that was not picked up as it probably should have been in the project phase, and 10 years down the track, it's bitten us… It precipitated a lot of remedial actions which of course down the track is expensive, and as I say much easier fixed during the project phase' (O/O ENG 7).

One story we heard is a failure regarding forged third-party certification. The line pipe was coated overseas and passed through all third-party inspection, specifically the monitoring of the production coating process; however, 'it later turned out those were all forged'. Consequences of that are 'two kilometres of coating stripped off and then recoated here [Australia]. So obviously it was ultimately the company itself bore that, so it was out of our pocket' (CONST CONT 4). In this case, even though the company tried 'to do all the right things with these third-party inspectors in China... it was never quite clear because we didn't have any investigative capacity in China, so what we surmised is that they were in on the scam essentially even though they were certified by… whoever it happened to be… all these different third-party certification firms' (CONST CONT 4).

Also, to ensure the quality of the selection process, careful consideration of 'inspection points you put and which aspects and documentation that you want to review' is necessary as sometimes 'inspection and expediting companies become more aligned to the actual manufacturer. They're working on a regular basis, and their loyalties tend to lie with the manufacturer rather than the owner or the engineer that is buying the materials' (ENG CONSULT 13). There are many issues originating from the suppliers and third-party inspectors 'You can't trust

certain manufacturers… You definitely trust some parties more than others… And the whole inspection regime' in some countries 'is compromised with brown bags… The big lesson learned is with certain jurisdictions, you need to take a different risk profile on approaching' (CONST CONT 4).

Overall, problems with manufacturing QA/QC as recounted by interviewees relate to lack of visibility of the entire supply chain to the purchaser which can mean that inspection requirements are not appropriate. The physical and organisational distance between overseas sub-suppliers and the final users of equipment mean that there are multiple interfaces and multiple possible points of failure. It also means that interests are not generally aligned. Good practices for manufacturing QA/QC attempt to address these weaknesses.

Good practices for manufacturing QA/QC

A particular lesson to be learned from the above examples is that the QA systems need to be applied through the whole supply chain, from manufacturers down to all sub-suppliers. In the first two cases of QA/QC failure described above, the purchaser had no visibility of sub-suppliers and yet it was failure sub-supplier systems that cased the goods to be unfit for service in both cases.

Part of the application of QA thinking to the entire supply chain is the suggestion that the 'prequalification process incorporates a site inspection, (ENG CONSULT 2), particularly for materials purchased overseas. The whole QA/QC process including onsite inspection is then designed to ensure that the specifications are correctly understood, the supplier of equipment is competent, the products comply with Australian standards, and the logistics and transport mechanisms are suitable for the task employed (ENG CONSULT 2, ENG CONSULT 7). As one interviewee put it in a case where the Duplex materials were specified correctly but a site inspection in the overseas mill was missing, leading to contamination-related issues due to improper packing only being found out at the later stage, and consequently huge costs (ENG CONSULT 2).

In another example, sending 'an Australian experienced team in the Chinese mill… to go through the pipe making process' was a success story about having quality products (ENG CONSULT 10). The big lesson is that 'inspection is not worth the paper it's printed on… If you don't inspect it correctly yourself or someone you can totally 100% rely on, then it's not worth doing' (ENG CONSULT 17) and it has to always 'have good inspection and supervisor testing at factory stage before delivery' (CONST CONT 1).

Another issue we heard from interviewees is related to small orders, for example, in response to the need of maintaining a network. When purchasing small orders, there might be a 'trade-off between the price and the quality' and 'it's very hard to even get a big mill to look at an order like that' (O/O ENG 5). In such cases, the quality process is often not of paramount importance and inspection procedures are often skipped as 'we really struggled to find somewhere that would make that pipe especially for us' (O/O ENG 5) and in such cases projects may suffer from major quality issues. This means that small orders may require proportionally more inspections. To avoid consequences such as pipes being unable to be welded, QA/QC procedures including third-party inspection are necessary. 'An open tender for inspection panels' is a solution in response to applying more QA in place to reduce such risks of specific orders.

It is also important to develop a detailed inspection plan to 'ensure compliance' (CONST CONT 3) and revisit those plans to check if they are thorough enough, 'because the inspector is only going to test what you want him to' (O/O PUR 1). With purchasing small orders, especially when things are being rushed, there are often some inherent risks and QA procedures are likely to be skipped, which might result in further delays and extra costs when problems occur.

When procuring a service, it's important to put the right controls and supervision on that service provided by the supplier. 'Because if you don't, they can end up charging you for a lot of things that you shouldn't be charged for, and they can change things around in such a way that will obviously benefit them and not the project. So that's one thing that's very important is to make sure to put proper supervision on them' (CONST CONT 1).

Another interviewee gave us an example of a carbon steel gasket being installed in the subsea hub for the flow line connection rather than a stainless-steel gasket, and in just over 10 years it just corroded away and created a loss of containment. This cost the company 'a lot of money to fix the initial problem, and then also to make sure that it wasn't systemic through other trees' (O/O ENG 7). A lesson learned that he raised is that 'a quality guy working on a project can't be responsible for checking absolutely everything that's done, it's got to be a mindset for everyone working on the project' (O/O ENG 7).

Interviewees also talked about criticality evaluation being the driver for the level of QA/QC attention required. Criticality evaluation should be risk-based but it is 'getting more difficult' due to Covid-related travel restrictions and 'our reliance on these tier one contractors more and more' (O/O ENG 7). This means uncertainty has increased. 'For major procurement items, we would look at the criticality of it… We'd normally send our own people over for critical factory acceptance testing' (O/O ENG 7). However, 'when we go out now to EPCI contractors… that criticality evaluation is probably not as useful because you're wrapping everything up into one package' (O/O ENG 7). During Covid, 'we've been playing around a little bit with the virtual surveillance, which is having a local representative over there with the goggles on' (O/O ENG 7). Other companies also use local representatives with major oversea suppliers that they've got good relationships with (SUPP 6). One key point about inspectors is that 'if you're bringing in an inspector that doesn't know the equipment, that can create more problems than you want. It's best to use someone that is independent and that understands the equipment' (SUPP 7).

An interviewee talked about challenges related to the availability of inspectors. 'There's different companies have different expectations or compliance as in individual certification as far as onsite is concerned. So, for example, competing asset owners, site readiness or construction readiness is ok for one lot, whereas for another lot, it's not good enough and they've got to do more dig-ups experience or something like that in order to be out in the field. So, trying to roster them and resource them to transition from one to the other is a challenge when you're dealing with very short lead times on projects' (SUPP 9).

Another interviewee was surprised at how many clients do not audit major suppliers at a more frequent basis as part of the operation of the business; usually the audits only take place as part of the QA/QC process within projects (SUPP 10). Based on his experience, regular auditing is best practice. 'It doesn't have to be annual, it could be every second year – whatever that frequency is… We audit them – not with compliance in mind, but actually with how well are we doing, what are the indicators we're striving for, and how are we working against those metrics as a good practice? And it's not so I can have a certificate on my wall if something went wrong, and I can say, "We audited them and the audit was fine," it really was with a best practice in mind' rather than being 'triggered by unwanted events… And it's interesting what you get to find in these audits – the gaps, the observations that you find, and they allow you to deal with them and close those gaps, and it's in our interest that those a dealt with because it's a risk to our business' (SUPP 10).

Another interviewee thought most companies have little experience with independent quality inspection. 'One of the big things that goes wrong is that they hire a quality inspector in some places, but that inspector actually used to work for that company that they're inspecting… We have to have an expat inspection lead, because otherwise it's just pointless' (QUAL SP 1). Another big issue in some overseas locations is that inspectors 'have lived in that town all their lives so they have to be incredibly tactful if they find something wrong. And it doesn't work. So, you often find that there is a poor risk process that's aimed around inspection… And remember, inspection is expensive' (QUAL SP 1).

Problems arise with equipment and goods purchases from many international locations. Sometimes goods are not poor quality per se but fail to meet Australian standard requirements because manufacturers are used to complying with different sets of requirements. This is a long-standing issue as one interviewee told us: 'the mistakes that were made previously were still being made today' (ENG CONSULT 16). Specifically, products purchased overseas must be replaced because of the different certification systems, causing major project delays and extra costs. This has been compounded because of Covid, 'we could not send our people over to do the factory acceptance testing and do a review of equipment as it was being built… Now that I've learned that you can't do that easily via remote control, we would get an independent party in America to actually review that process… What we would require from the independent auditor and hazardous area expert is actually to do a full audit on those components that relate to that hazardous area requirement' (ENG CONSULT 16).

Field hydrostatic testing

Quality assurance continues in the field during construction. Various test types are possible but most interviewees spoke about hydrotesting. Hydrotesting is designed to find construction defects in pipelines before they are put into the service but it is also the last line of defence for manufacturing defects. In some cases, a failed hydrotest identifies manufacturing problems that have not been detected earlier in the supply chain.

One interviewee described an example, ‘the pipe would have passed a mill hydrotest at their end’ but ‘something in the manufacturing process went wrong’ (ENG CONSULT 1) and manufacturers failed to detect the problems. Another example is about a pipe that failed the hydrotest in a local workshop which turned out to be from ‘a stockpile of rejected pipe failing some of the NDT that happened before hydrotest in the mill’ (O/O ENG 1) but somehow ended up being delivered.

Another similar case is the pipeline failing the hydrotest at the site, which ‘ended up being quite a messy case because you’ve already built the pipeline’ and resulted in ‘a lengthy dispute with the pipeline company’ and eventually ‘a fairly large settlement’ (O/O CONT 1). In this case, the hydrotest at the mill couldn’t detect the small defect inside the wall of the pipe, because ‘the pipe comes off the production line, goes into a tank and passes a very quick, literally seconds hydro test. It’s just really to find major issues’ only (O/O CONT 1).

When the pipes failed the hydrotest at commissioning, one assumption that was made is that ‘there might’ve been a power failure or a cut in the power supply during the production process, just for seconds, just enough to create a small defect and the pipe keeps moving on’ and it’s just hard for the mill to do differently. ‘It’s just a risk that we manage through the contract to try to keep them responsible until that test is done’ (O/O CONT 1).

The financial consequences can be significant when manufacturing problems can only get picked up at the end of construction and it’s ‘tricky to go and change something that’s 140 km long once it’s in the ground’ (ENG CONSULT 1). Hydrotest failures are quite rare however, ‘when you're producing over 1200 kilometres of line pipe in that pipeline, to only have two critical defects in that length is actually probably not a bad result’, and to some extent, ‘you do rely on, and… expect hydrostatic test failures with such large volumes of pipe’ (O/O ENG 1).

In many cases, ‘a small failure in the pipeline is very hard to find, especially if it’s a very long pipeline’ (O/O CONT 1) and the failure is just something that can’t be done differently but it’s ‘a risk that we manage through the contract to try to keep them (manufacturers) responsible until the (last) test is done… When we draft a contract with a supplier, we will pay them several milestones along the way, but the last milestone would be contingent on them passing that hydrotest. They don’t get that last payment until we’ve finished all those tests’ (O/O CONT 1).

The logistics around conducting major tests at remote construction sites can be significant. A service provider who covers both non-destructive testing (NDT) and hydrostatic testing expected ‘ample notice’ from the clients, particularly because the constructors and/or people who run large-scale projects often only ‘think of the NDT testing’ whereas ‘the hydrostatic testing is far more involved and far more difficult to put together on these big projects than the NDT’. Therefore, it needs to be prepared properly. ‘It is a logistical nightmare in some cases… Generally, it’s forgotten about by the constructor or the client until the last minute. So, that effectively then puts an enormous amount of pressure on us as the service end of it’ (SUPP 12). Based on the interviewee’s experience, ‘we’ve found over 30 years that there’s not enough information handed out upfront, and it really is crucial stuff’ (SUPP 12).

Another point the interviewee made is that not only upfront but also correct and timely information is required from the client, as that effectively affects how the service could be provided and met requirements. In many cases, there seemed to be internal disconnects as inconsistent information was given from different people within the same organisation at different time, causing a lot of problems. ‘I think a single point, when clients are requesting these jobs, you’ll have your commercial people you’re dealing with, but from a technical point of view, you want to be dealing with one or two technical people. But you only want to answer it once. You don’t want to be answering it five times’ (SUPP 12).

In summary, key strategies for good quality assurance in relation to procurement suggested by interviewees are:

- Start planning for a quality output from the prequalification stage and apply QA/QC thinking to the whole supply chain from specification through to installation on site.
- Ensure QA/QC is comprehensively addressed in contracts and specifications to avoid costly scope changes. Criticality evaluation is important, acknowledging where uncertainty is high.
- When assessing criticality, be sure to consider the need for overseas manufacturers to comply with Australian standards.
- Ensure that the project team knows quality is everyone’s responsibility.

- QA is not scalable based on order size – small orders might need more QA because they may be less important to the supplier and so more prone to problems.
- Resourcing for good, independent quality inspectors available to visit remote and international locations can be difficult. Start planning early.
- Field hydrotesting can be logistically complex and resourcing difficult. Again, start planning early.

Risk management

In a way, all procurement processes are about risk management but organisations have specific review processes related to risk that provide an overview of and check on all the activities that aim to prevent failures.

Safety management processes

Interviewees in the system safety specialist group reported that there is a weak connection between safety management studies (SMS) and procurement risks. AS 2885.6 lists material defect, design defect and construction defect as possible threats to pipeline integrity but these are typically not addressed in detail in an SMS. Safety management processes are focused mostly on causes of physical damage to the pipelines rather than considering that procurement might actually be a threat to the pipeline.

From the project perspective, SMS is likely one more layer of governance in the handover rather than identifying problems at the early stages to avoid schedule delays or extra costs in fixing them. As one interviewee explained, 'we would risk assess if we didn't do anything what could happen – it could be a pinhole in 10 years' time or whatever – and then we'd put controls in place, and then we'd make sure that it was appropriately managed, so those controls would come out of the risk assessment... Where are we going to have those things like daily reporting on-site, and inspection in the coating supplier's factories and things like this? You wouldn't normally do that, except that you know that there's a historical problem (O/O SAFE 1).

As another interviewee explained, 'when you're getting a large pipe order, you obviously can't be there to check what they're doing all the time, so you are relying on the fact that the manufacturer is capable… It sort of goes down to being confident in who you're choosing… ultimately what we would handle to the operations would be the [master deliverable register], so your records, your manuals, what's it about, how you maintain it, how to operate it… Obviously, if there's something that's wrong with the item, we would normally pick it up during commissioning, so if there's an issue with the line pipe then that's why you do your hydrotest, which picks up issues with that. Anything that we handover to operations is something that's been successfully commissioned and safe to operate' (O/O SAFE 2).

And another interviewee said, 'in terms of in the broad context of pipeline safety management, it's a different process or a different forum or a different way that you've got to deal with it. Rather than just do a relatively high-level Mickey Mouse discussion in the workshops. So, all I do is at least say, "Have you got a plan? Give me the documentation to say you've got it in place, so then I can reference it in the report". But that's as far as it goes. At least there's some sort of traceability, so that people can refer back and say this is how they handle their general process of design materials, construction, all that' (O/O SAFE 3).

In operational SMS, procurement problems in operations, for example, replacing items that are not fit for purpose, are not covered. 'It would just come up about emergencies and spares and things like that, for that sort of thing. But, no, is probably the honest answer there' (O/O SAFE 3).

Experience and expertise

A cross cutting theme in the interview data is that many interviewees expressed their concerns about the experience and expertise of practitioners involved in project execution. This includes the competency of both project operators and suppliers and includes issues with both management professionals and engineers or 'from the top to the bottom of the supply chain' (REG 1).

Sometimes technical skills are adequate, but project management is poor. As one interviewee explained, 'Sometimes we don't have adequate project managers… You need the engineering team to be able to demand

of the supplier that they provide Gantt charts and production plans and so forth, and you need in the supplier's side to be able to produce those things… And that causes utter chaos' (QUAL SP 1).

In some cases, 'the operational competence is lacking' (ENG CONSULT 2), leading to incorrect procurement decisions. On the operator's side, problems occurred when the wrong products have been procured because 'the competency of the procurement logistics group is not really aligned with the technical people that are actually responsible for' ensuring meeting standards (REG 1). Examples we heard include a lack of a strong contract written by the commercial department, specifically, an inadequate warranty clause in regard to a provision for dealing with pipelines that leak on hydrostatic tests (QUAL SP 1). Or a specification that fails to cite the right gasket standard (REG 1).

As another interviewee emphasized a lesson learned, 'there was the management procurement team needs to be mature enough… to not go buying materials that on the face value are cheap but are expensive to produce', and 'in procurement you've got to look at the whole project cost, you don't go out and get a specification that might be compliant but then not look at the construction costs of that particular specification' (ENG CONSULT 10).

Another lesson we heard is to have people with relevant expertise be responsible through the whole cycle, particularly an engineer 'responsible from cradle to grave to make sure that that material is supplied' as the procurement person might look at the specification while the engineer 'will understand what it's for and how it works' and point out 'issues to procurement in the prefabrication, the fabrication, and the delivery stage, making sure the whole thing's covered' (ENG CONSULT 10).

One interviewee suggested that 'first and foremost is admitting what you don't know' and then 'pay someone else as a trusted advisor to help with the project or the description or the performance requirement of the product together' to have 'a quite defined requirement and get a proper procurement outcome from it' (ENG CONSULT 4). Another suggestion is to 'have an open dialogue with suppliers' which might 'take an element of risk' rather than 'pay someone else to fill in your knowledge gap' (ENG CONSULT 4).

From one interviewee's suggestion, pooling experience across the sector is beneficial. Specifically, 'if a big company or a recognised company… has approved any pipe type, we have come through any engineering forums or conferences or seminars or industry and we look at it and… we build on the engineering and knowledge from those people' (O/O ENG 3). An example of this is a forum in Victoria where some companies meet once a quarter and discuss different issues around new products, including their potential value in the market, costs, testing, regulation, etc. (O/O ENG 3). This is a comprehensive approach, 'developing economies of skills rather than having three companies improving three products independently' (O/O ENG 3).

Sometimes the problems originate from poor performance on the part of suppliers but can be tracked to selection of the wrong supplier. Another interviewee described his experience with such cases: 'We think a brand-new pipe should be fit-for-purpose, but unfortunately some pipes aren't… At the end of the day, we've got a pipeline that's not fit-for-purpose, and the only ones winning out of that are lawyers' (REG 2). Based on his auditing experience, some of the companies' decisions 'are purely dollar based' which resulted in products not lasting long. 'They didn't either design their equipment right, so they either didn't get the right expertise up-front, the right consultants or whatever '(REG 2).

Issues with experience and expertise can also arise with engineering consultants. As one interviewee explained about a pipeline with an acoustically induced vibration problem that the mechanical engineers didn't realise at the time of the design, as 'there wasn't enough engineering experience all around', 'the contracting strategy (i.e., EPC) allowed them to do it', and 'we failed to audit the design against the project requirements at the completion of design' (ENG CONSULT 3). Another interviewee described another case with the pipeline design being 'very poor fit for purpose' as it was 'designed by an engineering house for a power company with very little input from operating experience' (ENG CONSULT 5). In both cases, the contract model was EPC but the problems were not just about the designers not having the right experience to follow the specification requirements but also the failing of the people who undertake the auditing process. These examples also raise concerns about the trust

relationship between the contractor and the owner that might have been missing as the contractor could cover such problems for as long as possible. This is further discussed in the “Trust and cooperation” section.

Good practices related to experience/expertise

In summary, key messages related to experience/expertise suggested by interviewees are:

- Improve the experience of the project operation/management team in providing appropriate procurement decisions with consideration of high-quality goods/services and of the whole project costs.
- Make sure to have people with relevant expertise (i.e., engineers) involved in the whole project cycle.
- Encourage knowledge and lesson sharing across the sector through industry forums or conferences.
- Recruit engineering consultants for support but make sure the right expertise is acquired.

Communication

Another cross-cutting theme from the interviewees linked to supply chain coordination and management is communication. Some interviewees mentioned communication-related issues, indicating that they can contribute to procurement failures. In many cases, ‘lack of scope definition, lack of understanding of risk, lack of awareness of the things that are likely to cause problems, at tendering and tender review stage, prior to awarding a PO [purchase order]’ (ENG CONSULT 11) as a result of inadequate communication causing problems down the track.

As one interviewee gave an example about a project that was delayed, ‘procurement was already done in the past… but the client had to procure the services of the supplier to assist with the installation… and new instrumentation’, there were some issues with engaging the supplier and communicating with the client. Specifically, the lack of communication of the budget and expectations about quality and schedule led to a mismatch in project priorities and thus ‘significant over budget from the client’s perspectives (ENG CONSULT 6).

Communication is a key to procurement success. Communication of requirements, as one interviewee explained, ‘whether it is for a piece of equipment or a contract, and diligent review and that sort of tender review process’, needs to make sure ‘that the tender completely understands the requirements and have completely addressed the requirements’ (ENG CONSULT 11).

Communication plays a crucial part in risk sharing as it helps clients to better ‘understand the risk and understand who’s in the best position to manage that risk’… ‘find things upfront, get everything out in the open and work together to get through it’ (ENG CONSULT 11).

As one interviewee suggested, when selecting the manufacturer or supplier, it’s important to not only understand their capabilities but also to communicate well with them, especially ‘why you’re deviating from your typical practices’ (ENG CONSULT 7). A typical example is the use of Australian standards for manufacturing which has not been aware of by many overseas suppliers. It’s important to ask questions at the beginning and then proceed to proper initial negotiations and evaluation to fully understand what the manufacturer can offer (ENG CONSULT 7). As another interviewee suggested, it’s also very important to get ‘the suppliers to actually understand what the standards said, what was in it, and to contribute, and that’s a huge dimension thing’ (ENG CONSULT 2).

One interviewee said it happened quite frequently that information was not passed down to the construction because of the failure in the communication process (CONST CONT 1). ‘What happens is in order to fast track a job, sometimes they start placing orders early on earlier versions of the design… As the design progresses, sometimes you have some changes in the design. That does not get translated down in a timely way… It was already manufactured and shipped off the earlier revision… So managing of revisions, and especially on such large projects, you’d have to manage the revisions with your manufacturer and with your contractor on site, the constructor’ (CONST CONT 1).

Another interviewee also agreed that ‘one of the biggest issues that we have is trying to get all the correct information’ and ‘in some cases, you just have to say based on the assumption that this is what it’s going to be, this is how we’ve designed it. We’ve designed it on these assumptions’ (SUPP 8). It’s also difficult to get

information from other authorities because ‘When they were all government enterprises, we tended to sort of cooperate a little bit with each other. And now that they’re all privatised, they’re reluctant to often share information with you’ (SUPP 8).

From the supplier’s point of view, it is very important to ‘have clearly defined requirements from engineering’ and the related risk ‘can be mitigated by having early enough communication with design. And making sure that the designers have a thorough review of what is being offered by the supplier’ (CONST CONT 1). Sometimes, ‘it’s a little bit difficult because with our specialised area there’s not a general understanding with people with corrosion protection and cathodic protection. So, there’s probably maybe some education required by pipeline project managers. Especially new project managers, a little bit better understanding of what the attributes of a good coating, what the requirements are… Would probably then help that we’re all on the same page’ (SUPP 8).

Another major problem is a lack of communication within the organisation, specifically ‘between the engineering team, the procurement team and the project team’ (O/O CONST 1). One interviewee talked about a case with a technical issue with equipment related to hot water meters that was picked up as part of the QA process on the operator side but was not detected by the suppliers. In this case, someone acknowledged the issue, but the inventory warehouse team continued to purchase meters because internal communication failed. As the interviewee described the case, ‘we heard about this, but no one told us to stop purchasing. And secondly, the contract that was arranged and what was executed was that we had to buy a minimum of 20,000 in the first year’ and ‘from their perspective, they were doing what they were told to do’ (O/O PUR 1). Although no alarming failure rates in the field have been seen, overall, ‘the time, effort, warehouse, etc. – it cost us in the end’ (O/O PUR 1).

Another interviewee gave us an example about a long lead item purchased overseas that suffered from time blowout due to Covid-induced lockdown, potentially delaying their project. In this case, the project was delivered on time and on budget with ‘only a small price increase’ because the warehouse specialist was on the frontline of flagging potential issues with the procurement team to source other suppliers, despite ‘a really reactive space’ that they had to work in. As the interviewee explained, ‘we’re in that front phase of receiving the reservation and request and making sure that we’ve got the inventory in the warehouse, or if it’s on order requirements, it’s coming in with those lead times and those clear communications. Procurement does that strategic sourcing for us to set us up to ensure that we have those contracts or suppliers all lined up and ready to go’ (O/O WARE 1).

Clear communication and regular engagement between different teams are important to ensure efficient procurement. The good practice for communication is to have ‘everyone in the room… and involved in the conversation’ and make sure to have regular meetings internally and with suppliers to make sure everything is on track and issues are captured before they become significant problems (O/O CONST 1).

Good practices for communication

In summary, key strategies for good communication suggested by interviewees are:

- Make sure all parties are well informed and updated on requirements and expectations and the ability to address them.
- Early and frequently engage suppliers/contractors to understand their capabilities to fulfil requirements and be informed of any issues.
- Ensure that early, accurate, and all potentially relevant information is passed on to the right party.
- Encourage practitioners to raise concerns when in doubt before taking actions.

3.1.2 Suppliers

Supplier performance and operation

Manufacturing problems

Section 2.1 discussed quality assurance testing put in place by the purchaser, but manufacturers also have in house QA/QC systems to detect issues in their own operations. Interviewees gave us examples of cases where the manufacturer’s QA/QC system was either missing or not adequate to detect the problems before delivery. In

one example, the pipe purchased from overseas had two hydrotest failures related to the long seam weld at commissioning which was then fixed by representatives coming from the mill (O/O ENG 1). In another example, the thread GRE [glass reinforced epoxy] pipe 'is essentially threaded together… but something in the manufacturing process went wrong… and the thread didn't stick to the pipe, such that you could basically wipe the pipe and the thread would wipe off' (ENG CONSULT 1). The pipe was delivered to site in this unusable state.

In these cases, the pipes failed the hydrotest, but the suppliers recovered by sending representatives over to do good customer service. Noted that 'all the right terms and conditions' were in place (ENG CONSULT 1) to reduce financial and schedule impacts on the projects. A lesson that can be learned is that reputational suppliers likely respond quickly when things go wrong as they have good customer service.

Regarding GRE pipelines, an interviewee shared the way his company approached the industry, 'we were providing products that were API certified, so API is American Petroleum Institute, and they have developed specifications for materials for hydrocarbon service' so 'we've never had to do a warranty job ever' (SUPP 2). The interviewee then explained that 'the manufacturing regime is very specific, so everything, as far as raw materials, goes through the process of manufacturing and each part of the raw material process is ticked off, and then they construct the product and then it goes through a testing regime… The manufacturer can't change anything in that process, it can't change the resin system, they can't change where the glass comes from, it's got to be the same glass from the same manufacturer or the accreditation for the product is invalid' (SUPP 2).

In another example, the interviewee described a project failing where gas processing equipment from European suppliers did not operate during commissioning, which cost all parties significantly more time to rectify issues (ENG CONSULT 6). In this case, 'it was very clear that the package had not undergone the factory acceptance testing' and final inspection by the vendor, probably due to 'some chaos in their workshop in the procurement process' created by the Covid-19 pandemic.

Non-compliance

Sometimes equipment is manufactured according to the manufacturer's intent, but they have misinterpreted the purchaser's specification and so supply non-compliant goods or equipment. An interviewee told us a story about valves that were ordered from overseas and were found to be non-compliant when they arrived on site. Prior to manufacturing, a kick-off meeting was organized locally to make sure the supplier understood the specification. 'Although the purchase specification was correct, the manufacture was incorrect' because it wasn't 'transcribed properly across'. So, a lesson learned is that 'if it's a big project', apart from a kick-off meeting, the engineer 'who quite often writes the specification' needs to be there, 'for the period inspection to make sure that everything is right throughout the whole process' (ENG CONSULT 10). The interviewee then emphasized, 'it's important to spend extra money to get, at least, one or two of the actuators… in the factory, then you know they fit', and 'if they don't fit then they can modify them while they're in the factory before they're shipped' (ENG CONSULT 10).

In another example, liquids were discovered in the pipeline during the operational phase because 'the designers not having the right experience' and 'there was no owner's engineer sitting over the top of it because they were working for a power company' (ENG CONSULT 5). As the interviewee explained about this non-compliance issue, 'under Queensland legislation, it is a requirement to intelligently pig your pipeline - I think it might have been after 10 years or whatever - but they were up against then not complying with the regulations if they didn't get this intelligent pig through by a given time' (ENG CONSULT 5).

Supplier behaviour

Forged certificates/counterfeit materials

Many interviewees described cases where forged certificates and falsified materials and equipment were found. Even with reputable agents providing the interface with the operator, there are still risks of products that are 'not been milled to your specifications' and sometimes 'you just don't have the opportunity to put the QA in place at the mill to watch it being milled and tested' (O/O ENG 1). Examples of risks include certificates supplied from the vendor through the agent were fabricated or forged or fraudulent, materials purchased from overseas through a known Australian agent were falsified and counterfeit quality issues in equipment.

As a result, not only the procurement process had to be repeated but also the schedule and costs of projects were significantly impacted. As one interviewee described the elbows purchased from overseas that had

fraudulent certificates, ‘we had a look at them, and they were just dangerous, they hadn’t even been hydrotested, they couldn’t have been hydrotested because they would have blown up, and everything was out of specification’ (ENG CONSULT 10).

Another interviewee told us about the issue of inspectors, ‘a lot of the large companies… who are supposed to be independent are actually not independent, they’re bribed by the factories to turn a blind eye so, again, you’ve got to be very careful in some of these countries’ (ENG CONSULT 10).

Lessons to be learned include taking additional processes including additional checks and steps early in the procurement processes to find issues and it is case-by-case driven decisions (O/O ENG 2). For example, positive material identification at the source is one of the solutions to prevent the issue from occurring again but that takes time and costs money (O/O ENG 2). Another lesson is to send a representative from the purchaser side to the factory of manufacture for inspection ‘even if you get all information from suppliers’ (ENG CONSULT 6).

Interviewees emphasized the importance of relationships with suppliers where they don’t have trouble sending representatives over for additional checks (ENG CONSULT 10) and conforming tests to the relevant standards (SUPP 1). For new suppliers, ‘you’ve got to prequalify companies that you know can give you quality products. So, you have to, initially, take price out of the scheme altogether for companies that you do not have a relationship with, or you check the market, they haven’t either produced before, so you get a sense that they’re going to be fraudulent’ (ENG CONSULT 10).

Supplier experience and expertise

Several issues related to experience and expertise on the supplier side were raised during interviews. One of the common issues is skilled resource shortage, particularly in remote areas. As one interviewee explained, ‘there's only a certain number of people that are willing to go into the middle of nowhere for three weeks at a time with the skillset able to do this work, are willing to do it for x amount of dollars. It doesn't matter who you pick, it will be the same people doing the actual fieldwork regardless of who you go with’ (ENG CONSULT 1).

As another interviewee thought, ‘having capable people in the contractors is really, really important, and it’s difficult because in the oil and gas industry having young people go into that industry and certainly the old guys – my vintage – who are going out, there is a real gap… I think it’s the people thing that’s probably the number one issue in terms of performance for contractors, absolutely’ (O/O ENG 7). A part of the problem is that young people ‘don’t want to work for a hydrocarbon company’ (O/O ENG 7).

Another issue is a lack of experienced materials and equipment agents who ‘would carry a reasonably strong internal engineering and/or quality resource’ because ‘the industry's become so competitive that those agents just can't afford to carry those people and be competitive against their peers’ (O/O ENG 2).

One interviewee mentioned an example of good supply chain management where suppliers have ‘an in-house materials management system that collects information on every piece of stuff that’s ordered’. Specifically, ‘there’s the right inspection steps all along the way’ to check ‘where it’s coming from, how it’s got to be packaged, and where it’s got to go to’ and ‘there is software out there that purports to do stuff like that, but you need the experience to go with it to make it work’ (ENG CONSULT 3).

Another example of good practices is reshoring which is a solution for the issue of not having the in-house expertise with equipment purchased from overseas. As the interviewee explained, ‘the gas turbine engine that was built in Norway… they will send a Norwegian guy… here to do his work’, which results in ‘massive cost savings’ (ENG CONSULT 8).

Supplier environment and market

Market burst

In some cases, suppliers are unable to meet the demand ‘when the market is tight, and for some reason, it’s boom or bust’ and ‘supply chains are so long’ (O/O QUAL 1). This is one of the risks down the supply chain that requires attention. In one story that we heard, an overseas experienced designer/fabricator was chosen but then outsourced the fabrication and assembly to somewhere else to shorten the lead time because they encountered schedule impacts and were unable to meet the client’s schedule. As the interviewee described, ‘a good solution

to recover schedule turned out to be a disaster… because the subcontractor had not been subject to robust prequalification or evaluation… and the cultures of the two companies were very diverse… and the behaviours from the start of that subcontract were not good… It had about a three-month impact on the schedule of the project' (O/O QUAL 1). In such cases, it's very hard to have 'good technical and quality capability assessment' of the subcontractors and apply 'the quality control plans' that had been set up for the existing contractors.

Another similar example we heard is when 'there's a lull in the market, the providers don't keep assets in the country… a lot of the equipment, or the expertise, personnel… a lot of that leaves Australia' (O/O PUR 2). The interviewee explained 'it's just something that we have to work with, there's no real solution because it's our way of going to work. So when it heats up, the supply is really tight. And trying to solve that with – you can't get the client to take that on, it's part of our methodology and costing' (O/O PUR 2). The interviewee also believed that the only way to solve the problem is an ECI phase which gives the contractor time to engage with resources, hire equipment, specialist personnel, etc. but 'then it becomes a more complex contractual model and a lot of clients don't like that because they feel they don't get the best value for money' (O/O PUR 2).

Sub-supplier problems

Manufactured goods are provided by suppliers who in turn hire many sub-suppliers to provide raw materials or specialist components. Procurement risks arise within the chain of sub-suppliers.

Inadequate prequalification process

Several interviewees emphasized the importance of having contractual terms and conditions to be applied to sub-suppliers. Contractors go through the prequalification bid evaluation but their designers or fabricators who are subcontractors to them might not be subject to robust prequalification or evaluation, which created a range of issues. As one interviewee described, 'all the way through the fabrication we had numerous weld failures and rejections, because welders had not been qualified. And that caused lots of delays' (O/O QUAL 1).

Other sub-supplier problems

An interviewee told us about problems with sub-suppliers, particularly steel makers who are subcontractors to the pipe manufacturers and did not traditionally deal with project owners or contractors. As a result of their large production of steel, 'it's just a matter that they are doing a small job which is difficult, and really don't want your scrutiny. And it's very difficult to gain their attention and deal with anything that's a bit unusual, like Australian standards' (QUAL SP 1).

One of the issues that can make projects go wrong is weldability, or long pipelines 'don't carry that much gas by world standards. So they're relatively small diameters. They're made by the least robust pipe making process, which is high frequency welding. And until the paradigm now shifts with hydrogen, we're looking for the highest possible utilisation, and therefore the lowest cost in a pipeline. So, we're pushing the technical envelope out' (QUAL SP 1).

Good practices for supplier issues

In summary, key strategies to minimize risks on the supplier's side suggested by interviewees are:

- The QA/QC system might fail at manufacturing. Reputational suppliers with good customer service are likely to recover and rectify manufacturing problems more quickly.
- Early engage and allocate sufficient time with local manufacturers to make sure requirements are well understood. For big projects, having the engineer responsible for the specification to be at the factory is crucial to ensure compliance and resolve issues if they arise.
- Take additional checks in the QA/QC process when possible to prevent counterfeit/fraudulent issues. Make sure third-party inspectors are actually independent from the vendors.
- Acquire overseas expertise for equipment packages in the absence of in-house expertise.

- Subcontractors should also be subject to the prequalification process to make sure they are qualified for the job.

3.1.3 External environment

There are a range of risks related to external environment factors that are beyond the control of both the purchaser and suppliers. For example, there is often 'a lot of volatility in raw materials. Iron ore prices, those sorts of things can also be an external factor that's difficult to manage' (O/O CONT 1). Not only the increase in raw material price but also 'the knock-on effects of the cost here in Australia to manufacture, labour, rents, all those other things are going up' (O/O WARE 1).

One of the common issues that interviewees mentioned is shipping disruptions due to natural events such as the Covid-19 pandemic. As one interviewee described, 'it's just about impossible to get things on ships and when you do get them on ships, it's impossible to tell when they're going to arrive. And even our suppliers can't tell us when it's going to arrive' because of 'the changing notions of quarantine in different countries' (O/O ENG 1). 'We tried to get that shorter lead time' on material but 'we're having trouble supplying or sourcing the raw materials… and there're less aeroplanes flying and boats shipping around the world that we can get onto' (SUPP 6).

Prior to Covid-19, there might be freight schedule problems (SUPP 1), for example, a monopoly on shipping that impacted schedules (ENG CONSULT 2), but often 'it was more predictable' (O/O ENG 1) and reflected in the lead time and price (SUPP 1). And 'the problem was less with the shipping company and more with the manufacturer' (O/O CONT 1). Covid-19 is causing raw material delays, labour shortages and price increases, making global supply chains a mess and uncertain. 'In the past we would have looked to procure an item that would have taken six weeks from overseas and now you're looking at 20 weeks and you don't get that 14 weeks back in a project' (O/O CONST 1). 'One of our larger engines, to freight it, say air freight – it used to be around the $80,000. You're up around $250,000 to freight that same engine today during COVID' (SUPP 6).

Apart from 'putting in enough time in your schedule', another strategy to minimize shipping-related risks during pandemic is to work with the vendors to try to 'get different shipping avenues if we were looking to get something out of the country and then also looking at how we separate personnel to mitigate our chances of reducing personnel to COVID-19 or close contacts' (O/O CONST 1).

One interviewee talked about the supply issue for products for epoxy coatings due to huge storms in the US. 'That caused a lot of factories to close down, and they were already being impacted a little bit by COVID… They were basically naming their price and people just had to pay it because it was just a real slow down because of factories being offline because of power outages or damage' (CONST CONT 3).

Another problem is the unpredictable trade behaviour which is more of a political/governmental issue. For example, some countries might impose import duties on materials coming from other countries to boost their own production industry of a particular material, increasing the price of the material (O/O ENG 1). As a consequence of political events, international shipping might also be delayed for months (CONST CONT 2), impacting project schedules.

In terms of regulatory risks, one external factor that should be considered is the timeframe taken to get the environmental approval owing to changes in 'activists and changing investing sentiment to support oil and gas projects' (O/O ENG 2). This will take longer than it used to because of 'community concern with hydrocarbon-based projects' (O/O ENG 2).

Regarding land access, 'sometimes the government might support a major project… They might give the project a particular status that enables you to move faster through the approval process, but they won't assist you with negotiating with landowners... Sometimes it can be as disruptive as having to actually change the route of the pipe around a particular landowner if you can't get agreement' (O/O CONT 1).

Changes in legislation might also impact procurement. As one interviewee gave an example regarding a new withholding tax applied in Papua New Guinea, 'which is against the double tax agreement that Australia and Papua New Guinea have signed. And that's caused all sorts of confusion' (ENG CONSULT 13).

Interviewees also talked about one of the drivers of 'designing a good and reliable infrastructure' (SUPP 4) which linked to a change in laws on accelerated depreciation of assets. 'Instead of writing a pipeline off over three to five years, they had to write it off over the design life of the pipe. So these companies instead of being able to do their depreciation on this asset in a few years, and then get their money and start building some more assets, now build it as cheap as possible for the 40-year design and basically as soon as it's commissioned they go back and start doing maintenance because the maintenance– it would be depreciated' (SUPP 3).

One interviewee believed 'resource constraint is probably one of the greatest external factors' and the other is policy decisions, specifically industrial policy, which depends on the government (O/O ENG 6). A lack of industrial policy 'creates huge uncertainty in relation to what technology is going to be chosen, and what technology is not going to be chosen' (O/O ENG 6).

Standards and codes are another important risk source. Many interviewees talked about challenges regarding standards that they face on a regular basis, specifically the inconsistency between Australian and international standards. As one interviewee explained, 'when it comes to oil and gas pipelines, Australia is not a big market for that. And especially if you are ordering a small quantity of pipes and equipment… you may not encourage them to comply with all your Australian standards that you identify, because they have a much bigger order' from other countries (ENG CONSULT 7).

Another issue related to standards has been reflected in the previous section when we discussed interviewees' thoughts about bespoke specifications. Again, to deal with the issue, there is 'a need to standardise the specifications internally', or 'reduce the need for bespoking' to reduce costs without compromising safety (REG 1). In one of successful stories, an interviewee explained that apart from 'having a very mature relationship with the key suppliers… to have a good understanding of capability… a lot of work has been done internationally on collaboration and standardisation on' the equipment. Things worked very well because 'you have pre-agreed specifications, which are standardised by the equipment supplier' (O/O QUAL 1).

The foreign exchange rate is one of the economic risks that was mentioned. It's likely that the price and exchange of materials purchased from overseas will fluctuate during the job and the question of who wears this can be a major problem as 'neither the client nor the contractor has any influence over the price' (ENG CONSULT 3). Depending on how the contract is set up and whether the project or the shipping is delayed, 'that's a bit of a risk… and can vary' (SUPP 5). This problem should be 'part of risk sharing' to be included in a proper contracting strategy (ENG CONSULT 3).

An interviewee talked about a threat related to the oligopolistic market or monopolistic market where one big service contractor 'undercut the small contractor and wiped them off completely' to get the job that would 'have an impact on quality somehow' of the service provided (O/O ENG 3).

Another interviewee mentioned price uncertainty, 'what I find is very recently procurement of steel, steel products, cabling products, one is certainty around pricing and price movements have been considerable… So you're putting in a price now for a job that might happen mid-next year, trying to get certainty around that. And if the client's not willing to take on any risk for steel pricing - it's about futures markets and trying to figure out where the price is going to go. The global supply chain is very stretched at the moment and it's very unclear to me the risks in terms of shipping, in terms of steel pricing, in terms of getting scrap steel for the manufacture of steel, where that's heading because there's so many different factors or inputs that are influencing that market' (CONST CONT 2).

Another issue linked to COVID-19 is the availability of certain items that are outsourced. As one interviewee explained, 'we do have most of it done internally, but still dependent on some third party externally, so we have seen some general impacts of availability' (SUPP 10). Companies might make assumptions that they are always available but when resources are no longer available… 'even before Covid, that's always been: Do you know where you stand? where you have components or parts being produced externally?' (SUPP 10).

A strategy to manage this risk is to 'try and do as much of it in-house as we can. Where we can't, it really is through an audit process and the audits certainly have a quality compliance requirement, but we do try and get a good understanding of the risk provided to us based on their business… Software for us is a good example, we typically deal with all the software external companies that are niche and of high competence, but those are

probably the highest risk to be acquired by a larger software company that may embed them, and all of a sudden, your risk is now in the hands of someone else' (SUPP 10).

In summary, there are a range of risks originating from the external environment that are beyond any firm's control. The most common issue mentioned by interviewees is shipping and travel disruptions particularly exacerbated by the Covid-19 pandemic, which has resulted in material delays, labour shortage and price increase, significantly impacting project schedules. Several strategies suggested to minimize this risk and its consequences include allocating sufficient time in project schedule and communicate with manufacturers to diversify shipping options. Other issues that were mentioned include changes in legislation, time taken for environmental/land approval procedures, differences in standards, foreign exchange rate and price uncertainty. Interviewees reported no further specific strategy to minimize external environmental risks. Given that those external factors are out of the individual supply chain or firm's control, it is necessary to be well informed of those risks and focus on mitigation strategies on a case-by-case basis depending on each individual project.

3.1.4 Trust and cooperation

Trust issues

The issue of trust and relationships with suppliers is as crucial as the services and goods that they could provide. Even with a good relationship, necessary procedures cannot be skipped, as there have been always risks of not taking them. As one interviewee described a story where pipes had never been tested in the mill and the certificates supplied were forged, 'there's really no way of working out exactly who had done that. I think we trusted our supplier, so we suspected it happened at the mill end' (O/O ENG 1). As another interviewee suggested 'the lesson learned there was don't trust shipping agents even if you give them a specification; you've got to keep on them all the time' when 'the shipping agent tore up the specification and got a ship that was out of insurance' and 'the ship broke down… it was an absolute disaster… As a consequence of it being late, we weren't able to finish the pipeline within the dry… and had to go back in the wet season' (ENG CONSULT 10).

Trusting relationship does not mean that QA/QC procedures (ENG CONSULT 2) including independent audit (ENG CONSULT 3) on any suppliers that 'you get with partnering' (O/O ENG 2) are not required. However, it means to try to not 'tie the supplier up in knots and punish him if he's late' and set up terms and conditions that are only beneficial for one party (ENG CONSULT 10). Some interviewee expressed their thoughts about trust, for example, 'my trust was always to follow certain brands' with a reputation (ENG CONSULT 5). In most cases, good relationships will result in the easy interpretation of the requirement, and collaboration to identify and address risks early (REG 1). In other cases, good suppliers will suggest clients what would be best to suit their needs (ENG CONSULT 3).

Regarding interests between different parties, 'the good risk-sharing is going to only occur when you've got open trusting relationships, and there's a recognition of a common goal between the participating parties' and 'if you've got competing interests, then you don't have trust' (O/O ENG 2). Communication including open dialogue plays an important role in building the trusting relationship between parties. In some cases, it can be complicated when different actors are involved. As one interviewee described, 'we're really being given the responsibility from a principal to lead commissioning, but we're not paying for the equipment or services ourselves' so 'the vendor is supplying, they just will not follow our instruction… The vendors can be pretty dismissive of that and – unless it's coming from the principal, they don't really want to be answering to a consultant' (ENG CONSULT 6).

As another interviewee shared the experience with building trust with suppliers, the first thing is to 'try to distribute the work evenly with the contractors' and then 'sit down with them and do the risk assessment at the award of the contracts and all those diligences that these are the threats, or these are not the threats... That gives you also a good level of confidence that if something goes wrong, who is responsible then legal binding' (O/O ENG 3).

From a supplier's perspective, 'building rapport and trust with customers and vice versa, to make sure you can honestly and openly talk to each other, understand each other's needs… means everything... It's a two-way street… but being the supplier, we have to put in more of an effort than the purchaser or the customer' (SUPP 6).

A good strategy to mitigate delay risks is to have the commitment at senior levels of the company that is manufacturing the goods before placing the order to 'get a bit more priority if they've got conflicting priorities'

(ENG CONSULT 13). As one interviewee described a project where ‘everyone was struggling with a solution… and that was sorted out at a CEO level’ for coating issues, as the contractor had preferred suppliers, ‘and that’s built on reputation to supply’, the relationship between parties played an important part. Eventually, ‘all that product that was condemned was replaced free of charge. The client was part of those discussions because obviously it was their end product’ (O/O PUR 2).

The interviewee also emphasized trust issues with both manufacturers and subcontractors. ‘When it comes to horizontal directional drilling, NDT, hydrotesting, all the really critical subs, we have close to preferred. They still have to provide – they still go through a competitive, but they get marks for previous performance, and that trust factor that when things do go wrong, that they’ll stand by you’. Also, when implementing difficult tasks in remote areas, trustworthiness is important and that relies on past performance because it shows responsiveness when things go wrong. The selection of suppliers should not be solely based on the lowest price but on their past performance. ‘Trust is huge because you’re out in the desert, you’ve got – you’re just reliant on everybody who’s out there’ (O/O PUR 2).

Another point we heard is related to the internal systems of suppliers. ‘Everybody is trying very hard to produce the best outcome. But often they’re trying in the face of their own internal systems, which don’t support them’. (QUAL SP 1). There are layers of things in each supplier or sub-supplier’s internal systems to which the needs of the client might not fit, so ‘it’s pretty important to actually get all that buy-in from the people and give the ammunition to all of the players in your supply chain, so that they can impose on their system, what would be otherwise seen as unreasonable constraints’ (QUAL SP 1).

One interviewee believed ‘there’s a very low level of trust between companies in the construction industry, so... if you can do something that improves that level of trust with the people’ and ‘if you can build contracts that encourage’ the ‘collaboration between the engineer, the owner and the construction contractor… you’ll get a better outcome than having a string of adversarial contracts where people are trying to manage their risk or get out of managing the risks. It’s really about understanding where the risk lies, who’s best to manage it and managing it in a total project perspective, as opposed to an individual contract perspective’ (O/O CONT 1).

Organizational and cultural issues

Internal relationships

There has been a range of issues in associated with internal relationships within the owner or operating companies as we heard stories about conflicts between key parties, particularly the technical and commercial departments.

As one interviewee explained with an example of a technical specification being left out of the purchase order, which caused delays. ‘One of the big issues, or the issue that emerges periodically is, simply the interactions, the internal interactions around, in the owner’s area, they can be very strong, or we like to be strong technically. Sometimes you don’t get the same level of focus commercially… you can get an issue where there’re internal disconnects in the process’ (QUAL SP 1).

There should be efficient communication between the three key parties within an organisation, ‘the technical people or the requisitioner clearly specifying what they need, the buyer or the contracts or procurement people, and the quality, safety, environment people (O/O QUAL 1).

Recommended practices include having procurement as an enabling service within the organization to ‘support the technical outcome and the equipment to work’ instead of a governing factor (O/O ENG 1). Engineering gets support from procurement to get the contractors and also supports procurement ‘with the technical evaluation and the requirements in the scope of work for them to go and do their job’ (O/O ENG 3). In addition, ‘the important point here with procurement is that you surround it with the other disciplines that are necessary to make the end product the most efficient and effective outcome’ (ENG CONSULT 2) because ‘you centralise stuff - it’s a single point of failure, and you can’t do that unless you have full competency in your procurement team’ (ENG CONSULT 2).

Another point that was suggested is to have ‘procurement actually part of the project and reporting into the project rather than procurement being a side function over in the broader organisation’ and ‘engineering and procurement, they’re inextricably linked’ (ENG CONSULT 2).

However, there has been a tendency in recent years to centralize procurement to have 'the focus on transactional role' and 'look after the purchase orders and budgets, cost savings and how to get the best KPIs" while 'when it comes to a project procurement function, it's all more about the execution and how to do best for the project, the schedule, and the cost' (ENG CONSULT 14). This dynamic is changing within organisations, 'when the industry is not very busy, the procurement/contracts people within the customer organisations have a lot more power and are able to make decisions. Whereas, once the industry gets quite busy, it goes back to the project people, and they tend to have the greater amount of power to deliver that' (ENG CONSULT 13).

One interviewee told us about such centralised department within his company, called e-procurement department, where they look after the surplus at the end of projects which is beneficial for the company. Buying 'internally at a discounted price and you help the other project, you help the company, and you get a lower price for yourself' and 'this centralised department also had the responsibility to make framework agreements with the suppliers to get better deals in bulk for the company', especially when there are '10 to 12 projects running at the same time, each in the value of excess of 200 to 400 million dollars' (CONST CONT 1).

Cultural issues

In some cases, the decisions for procurement originate from a culture of keeping costs down and that culture has been embedded not only in the procurement department but at the top leader levels. As one interviewee explained 'the culture of the top-down leadership… they might be under the pressure to keep certain costs down so they're running an arrogance or they're running that aim' (SUPP 4). Procurement personnel therefore also has a pressure to save money for the company, 'there's an air of arrogance around them and it's like I'm the gatekeeper of this property or – you will do everything I say and you'll do it for the absolute cheapest price' (SUPP 3).

Cross-sector cooperation

When it comes to general risk controls, one interviewee talked about his experience with the purchasing power tool over all businesses that has been applied in Canada and the States. For example, there are annual procurement fairs where key vendors are invited. There is a joint committee with members from different companies to purchase a large number of pipes together instead of small orders based on a common spec that they develop. 'They have that purchasing power and then they could go to the market and… make sure that what they were receiving was fit for purpose and met everyone's requirements. So there's a level of cooperation that's required there between independent private businesses, but the benefit was very clear for what they're achieving… That takes a bit of momentum with industry to form' (CONST CONT 4).

Good practices for trust and cooperation issues

In summary, key strategies to minimize risks related to trust and relationships suggested by interviewees are:

- Ensure necessary procedures including QA/QC and auditing are applied with all suppliers despite any existing relationships.
- Communicate with suppliers/contractors in a clear, open and transparent way about risk sharing to build a trusting relationship.
- Early engage with manufacturers at the senior level to increase priority prior to purchase in order to reduce delay risks.
- Ensure efficient and frequent communication between key parties is maintained. Having technical and procurement teams work alongside and provide relevant support to achieve project outcomes.

3.1.5 Summary of procurement risks in the gas pipeline sector

Procurement risks and procurement good practices and in the gas pipeline sector informed by industry stakeholders are summarised in Table 5. A wide range of risks have been reported by interviewees with the five most commonly occurring in interviews identified as: (1) inadequate planning, (2) problems with specifications, (3) poor contractor/supplier selection processes, (4) logistics issues (e.g., damages in transit, delays to delivery

and custody transfer) and (5) manufacturing QA/QC failures. These all originate from the supply chain coordination and management process rather than from the supplier's side. Another issue from the external environment that was frequently mentioned is shipping and travel disruptions as a result of the Covid-19 pandemic, which has significantly impacted global supply chains.

Table 5. Procurement risks and procurement practices in the gas pipeline sector

Risk category	Main risk	Good practice
Supply chain coordination and management	Inadequate planning	• Treat planning itself as a necessary task and allow time in the schedule to do it properly. • Pay attention to all three factors in the golden triangle of cost, quality, and schedule. In particular, be honest and realistic about timeframes from the beginning. • Identify long lead items and manage them carefully, acknowledging that markets, and so availability can change. • Build in time for cross-functional reviews such as constructability reviews. They are a good investment of time as they reduce problems later. • Assign responsibility for risks to those best placed to manage them.
	Specification issues	• Reduce complexity in specifications as much as possible. Do not include irrelevant material that makes specifications difficult to follow and obscures key information. • Include a description of what you are trying to achieve with the specified goods/equipment so that experienced suppliers can use their expertise to provide advice on whether what has been specified will be fit for purpose. • Do you need a bespoke specification in a given application or will a standard specification be sufficient? • Ensure sufficient engineering expertise is involved in specifying what is required.
	Poor contractor/supplier selection	• Adopt a pre-qualification system in place to ensure that only those capable of providing a technically acceptable solution are invited to provide a commercial tender. This reduces the temptation to select a low-cost solution that is ultimately not technically acceptable. • In addition to cost and technical feasibility, consider experience, track record, local representation, health and safety record and anti-slavery practices for the supplier and all sub-suppliers when selecting a preferred supplier. • Draw on industry experience (not just company experience) when selecting suppliers.

Risk category	Main risk	Good practice
	Contracting issues	• Establish mutually beneficial contractual arrangements with well-defined terms and conditions at both functional and technical levels. • Be realistic and explicit about equipment lead times with consideration to the long delivery time for equipment purchased from overseas. • Improve the transparency in the contracting process with adequate risk assessment and allocation among all parties at the beginning. • Pay attention to the dispute resolution/avoidance provisions in contractual terms and conditions to avoid disputes when conflicts occur.
	Logistics issues	• Ensure logistics is taken into account in comparing tenders including requirements for packing, transportation and storage of goods and equipment to prevent damage. • Detail responsibilities for the condition of goods in all contracts including testing requirements linked to custody transfer to ensure that responsibility for repair can be simply identified if damage occurs. • Monitoring and active quality management across logistics interfaces is critical for early detection of problems. • Make a mindful choice about who should be responsible for logistics and assign responsibility for risks to those best placed to manage them.
	Manufacturing QA/QC failures	• Start planning for a quality output from the prequalification stage and apply QA/QC thinking to the whole supply chain from specification through to installation on site. • Ensure QA/QC is comprehensively addressed in contracts and specifications to avoid costly scope changes. Criticality evaluation is important, acknowledging where uncertainty is high. • When assessing criticality, be sure to consider the need for overseas manufacturers to comply with Australian standards. • Ensure that the project team knows quality is everyone's responsibility. • QA is not scalable based on order size – small orders might need more QA because they may be less important to the supplier and so more prone to problems. • Resourcing for good, independent quality inspectors available to visit remote and international locations can be difficult. Start planning early. • Field hydrotesting can be logistically complex and resourcing difficult. Again, start planning early.

Risk category	Main risk	Good practice
	Experience/expertise issues	• Improve the experience of the project operation/management team in providing appropriate procurement decisions with consideration of high-quality goods/services and of the whole project costs. • Make sure to have people with relevant expertise (i.e., engineers) involved in the whole project cycle. • Encourage knowledge and lesson sharing across the sector through industry forums or conferences. • Recruit engineering consultants for support but make sure the right expertise is acquired.
	Communication issues	• Make sure all parties are well informed and updated on requirements and expectations and the ability to address them. • Early and frequently engage suppliers/contractors to understand their capabilities to fulfill requirements and be informed of any issues. • Ensure that early, accurate, and all potentially relevant information is passed on to the right party. • Encourage practitioners to raise concerns when in doubt before taking action.
Suppliers	Manufacturing problems	• The QA/QC system might fail at manufacturing. Reputational suppliers with good customer service are likely to recover and rectify manufacturing problems more quickly. • Early engage and allocate sufficient time with local manufacturers to make sure requirements are well understood. For big projects, having the engineer responsible for the specification to be at the factory is crucial to ensure compliance and resolve issues if they arise. • Take additional checks in the QA/QC process when possible to prevent counterfeit/fraudulent issues. Make sure third-party inspectors are actually independent of the vendors. • Acquire overseas expertise for equipment packages in the absence of in-house expertise. • Subcontractors should also be subject to the prequalification process to make sure they are qualified for the job.
	Non-compliance	
	Forged certificates/counterfeit materials	
	Supplier experience and expertise issues	
	Market burst	
	Inadequate prequalification process	
External environment	Shipping disruptions due to Covid-19 pandemic	• Allocate sufficient time in the project schedule and communicate with manufacturers to diversify shipping options.
Trust and cooperation	Trust/relationship issues	• Ensure necessary procedures including QA/QC and auditing are applied with all suppliers despite any existing relationships. • Communicate with suppliers/contractors in a clear, open and transparent way about risk sharing to build a trusting relationship. • Early engage with manufacturers at the senior level to increase priority before purchasing in order to reduce delay risks. • Ensure efficient and frequent communication between key parties is maintained. Having technical and procurement teams work alongside and provide relevant support to achieve best project outcomes.
	Internal relationships	
	Cultural issues	
	Cross-sector cooperation	

3.2 Procurement in a future fuels environment

The previous section has summarised interviewees' general experience in procurement. Most interviewees indicated that procurement risk has been well managed in the pipeline sector. There have been cases where things have not been gone according to plan; however, generally the risk management processes are fit for purpose in controlling risk. Some specified that this is the result of 'lessons learned from bad procurement exercises' (O/O ENG 1) that have happened in the past.

We now turn to what they had to say about procurement in the context of future fuels projects. A small number of interviewees had direct experience of working on a future fuels project. Others had experience working on other kinds of renewable energy project. For many, their views are extrapolated from what they have seen regarding procurement trends in the Australian energy sector in recent decades and their knowledge (which was generally high) of plans to develop a substantial new hydrogen sector.

Several interviewees indicated that the industry would likely encounter the same procurement risks as they have seen in the past when developing of the hydrogen sector. As one interviewee expressed, 'I don't think there'd be much of a difference, as long as the knowledge base that's making the decisions is informed enough to select the correct technologies for that use' (SUPP 4). Others were of the view that the uncertainties linked to the development of new technologies need special consideration. Much of what follows links to uncertainty and lack of knowledge. Overall, this should drive the chosen procurement strategies. Thinking many need to shift as one interviewee described 'clients adopting a process like they would for an oil and gas project, where they'll want to pass most of the risk down to the contractor, is not appropriate right now for hydrogen projects. All that's going to do is ultimately add cost, because contractors have no choice but to include very large contingencies, because they're being asked to take risk potentially on project risk aspects that they don't understand and cannot control' (O/O ENG 2).

Interviewees' opinions and experience regarding procurement risk in future fuels are detailed below using the same general risk categories as above.

3.2.1 Supply chain coordination and management

Planning

Planning for project work in the hydrogen environment is even more critical than in base operations. There are several factors that will influence planning according to interviewees.

The first issue is uncertainty in the planning basis regarding end users. One interviewee believed there are still a lot of unknowns, particularly with 'the production side of things' because not many members of the public know about hydrogen appliances and there's a lot of ongoing research, so 'we'll have a lot of problems there… We've got to go back and do a lot of redesigning there' (REG 2).

The next issue is uncertainty in the technical planning basis for new hydrogen production and transport facilities. One of the issues we heard is translation of research outputs into operational facilities. As one interviewee expressed it, 'the research is theoretical… it isn't in or isn't tested in practice… Somebody's going to have to make a decision about whether they trust the research and build the first bespoke hydrogen geometry pipeline. And that'll be a risk' (O/O ENG 1). As another interviewee put it, 'even though they've been researching it for a long time those lessons haven't crept back in down to the constructor, down to the coalface really yet. So it will be interesting to see what problems then eventuate out of that, and then how they manage that. And it really will be about the steel, the welding, everything else will be the same' (CONST CONT 4).

While hydrogen is new to the natural gas sector, it is a familiar material in some other sectors. One of the challenges is to explore and integrate the current knowledge into the hydrogen space because there has been substantial relevant research available. As one interviewee put it, 'hydrogen's not a new fuel… It's produced and used in refineries all over the world, and there are standards and other bits and pieces. But it's a very small part and our challenge is really to try and take what knowledge is there and apply that to the pipeline space in a safe and economically feasible way… There might be an industry that supports that, that we just don't know about. It's really about discovering what's already available and how we can adapt that to our needs. The adapting and the

research that needs to go into that is I think the key to it…. (Some) stuff shouldn't be brand new to us… but it all happens somewhere in the world, for some other purpose.' (O/O ENG 5).

The uncertainty around new technology requirements creates an environment of rapid change which introduces risks of its own. While the experience with biogas development 'is a bit more mature' because 'there're a lot of (biogas) sites around', it will be more complex with hydrogen and 'we've got ongoing training issues and getting people up to speed with those type of things. So when you do procurement… they're still working out what equipment to get because the technology is changing so much. Because everyone's throwing lots of resources into this business right now, so the rules aren't – the equipment's changing. So procurement will be messy' (REG 2).

Another interviewee also thought the skills are not being developed as there isn't certainty and clarity around policy for hydrogen. 'It's all been market-driven, which means no one knows what's going to happen, effectively… Hydrogen is very expensive. We don't want to be an industry leader, but we want to be a fast follower… Most of the companies do that anyway, when you are a follower, you are not a leader, you are not putting as much funds into it and we are not developing the skills, because we don't know… If there is a policy… which drives that agenda that gives some clarity and certainty to the big industries and organisations, then we can decide, yes, this is the path we have to undertake, and that's where we're going to go and we can put the money in' (O/O ENG 3).

There are transition issues related to how to build an experienced workforce too. Moving 'from hydrocarbon to hydrogen', we need to 'put our experienced hydrogen people – not dedicate them to a particular project, but have them pretty much in an advisory role, and trying to mentor and train up someone who may have a heritage of oil and gas type experience. And getting them to have someone there that they can always talk to, to help them in that transition journey over to the hydrogen space, because in reality, that depth of hydrogen experience doesn't exist' (ENG CONSULT 13). It's also important to get 'the supply chain individuals to go into the engineering fields' as 'they have a different way of thinking so really increasing that level of maturity when it comes to supply chain professionals' (ENG CONSULT 14).

There will be a lot of new people involved in the new space of future fuels. However, the level of experience will be different. As one interviewee put it, 'We'll probably see some people coming into the industry with maybe not quite the same experience and maybe not coming up through your engineering consultancies, where you do get a lot of checking and QA… and getting learned along the way before you're in a position to sign off on designs or something similar' (ENG CONSULT 1).

Despite the dynamic environment some interviewees proposed that planning for the longer term is fundamental to success. One example was this interviewee indicated the difficulty associated with the skill transfer between generations. 'From the pipeline of work, we're talking five to ten years sort of spectrum in getting the right people. Because, we've got great maturity in our organisations, but not necessarily it's not flowing down to the next generation. So, really sort of passing the baton in terms of some of the skillsets required is important, as you sort of strategize the future fuels, getting the right brains into moving forward' (ENG CONSULT 14).

One interviewee noted the lead times of some of the equipment may be longer for hydrogen. 'Obviously the higher spec welding consumables, they have longer lead times, they're not off the shelf. Some of the European manufacturers are quoting 12 months for welding electrodes at the moment... So from a procurement point of view, you have to be aware that those things will have a longer lead time, and that quality requirements will be much more stringent. So we need to, in our agreements, make sure that we've written in the requirements for batch testing, batch certificates, packaging, that sort of thing, so that our QA people have got the tools to make sure that they are getting what the project requires' (O/O PUR 2). This will also need to be specifically allowed for in project planning.

Some early projects are already having to address these issues. Another interviewee thought there would be hidden things 'when you go to a new supply route' and 'there's a bit of a different risk profile that sits around'. An example he talked about is a project where 'the likelihood of hydrogen going into the pipeline is pretty high and we simply did a hybrid meld of what was in the ASMI hydrogen pipeline code, and AS2885, and hopefully got it right. But what it does mean is that it applies constraints, which the steelmaker and pipe maker are not used to, which then meant that the company has gone to probably the most competent pipe mill in the world to make the pipe, at some considerable additional cost… that means it'll be the first pipeline that comes out of that mill into Australia in 30 years' (QUAL SP 1).

In summary, planning challenges for procurement linked to future fuels identified by interviewees include:

- Exploring and integrating current research knowledge into practice and developing policy for hydrogen.
- Upskilling the workforce in line with technology requirements in the absence of adequate policy, and expertise transferring from the gas pipeline industry to the hydrogen space.
- Long lead items that require more system-wide planning across the whole supply chain.

Scope and specification

Interviewees raised no new issues related to specifications when it comes to procurement in future fuels. Having said that, standards are a key part of preparing specifications and may interviewees spoke about standards and hydrogen – see section 3.2.3.

Supply chain configuration

The biggest issue in supply chain configuration in a future fuels environment will be finding sufficient skilled suppliers. This applies to all parts of the supply chain from engineering design services to equipment vendors and site installation crew.

One interviewee explained his points regarding a lack of experience of contractors in hydrogen/biogas, 'when we were looking for a contractor… to do all the engineering and technician assembly and installation… we had to engage a credible sort of Australian service provider that could provide us some engineering and technician to be able to do this work and we struggled... It came down to the fact that we had to engage somebody who had high-pressure gas experience, not necessarily hydrogen experience specifically. And that was the deciding factor in being able to engage somebody to do this work. So, they actually learned on the job probably as much as I did, particularly about hydrogen' (ENG CONSULT 16).

As another interviewee explained, 'to prepare a hydrogen facility or a biogas facility, the equipment that's there, we don't really have technology providers in Australia. We're very much reliant on companies from Europe or from China or from America to not only supply that product to Australia but to then also somehow, supply the ongoing maintenance. That's the gap at the moment… There needs to be some more development of ongoing servicing capability for some of these products within Australia, which isn't there at the moment' (O/O CONT 1). This brings an implication for evaluating suppliers, 'what sort of support they can provide longer term in terms of maintenance and ongoing support' in the context of a lack of in-house experience (O/O CONT 1).

This is discussed further below in section 3.2.2.

Contracting strategy

Contracting strategies will need careful consideration for hydrogen projects in the view of interviewees due to the uncertainties linked to the technology and the lack of skilled and experienced suppliers.

One interviewee thought that the industry should look at developing relationships with newer contractors and 'it's just really around the new contracting models as well. It may be the case that we get more involved in completely turnkey projects where we provide a little bit of operational expertise… We might see just more and more of a turnkey-type approach going forward' (O/O ENG 7). In contrast, another interviewee was in favour of early vendor involvement to share the little technical experience and expertise that is available (ENG CONSULT 13).

Another interviewee believed there will be a lot of smaller players including both owners and suppliers who will be vulnerable to the new market of hydrogen because there is 'no sort of understanding of the market and the risk profile' (ENG CONSULT 15). In the solar and wind farm industry, the owners tend to pass all the risk onto the contractor, 'not just construction risk and procurement risk of materials but also… the risk of connection into the grid. And that's taken out one of two contractors, because they've given them risks that they've no control over… It's the connectivity risk. It's their job to organise the setup, a bit like a turnkey arrangement… the solution for that really is to have some sort of regulatory body, but you can't in a free-market economy… You could have some sort of like registration process that could be implemented, but you'd have to get the owners on side to come up with some sort of registration process for that where the contractors are at least recognised or acknowledged to reach a certain standard. But that's a long-term view I would have thought' (ENG CONSULT 15).

The risk and reward arrangements are different for different members of the supply chain. ‘Hydrocarbon is a high risk, but a very high reward, which drives you to invest in things like quality because the consequences of something going wrong are pretty substantial. When you get a low margin manufacturing business you just can’t play around with that stuff – you can’t spend a lot of money because you’re not making much money to start with’ (O/O ENG 7).

Logistics

There were few new issues raised by interviewees regarding logistics and future fuels.

One interviewee pointed out that the hydrogen sector needs special road vehicles but ‘there are some developments where the manufacturers or the OEMs [original equipment manufacturers] of these vehicles don’t comply with Australian road standards, so even though they may be progressing with the development and they will be available in the US and the EU markets at some point, we won’t be able to bring them onto the Australian roads without them reengineering stuff or at least doing some validation engineering’ (SUPP 11). The interviewee then explained ‘It’s more around their conventional engineering of those vehicles, so not so much around the technology is relatively novel and probably fits into that grey area where it’s not properly covered by the standards, but in terms of actually the chassis and the loadings of the vehicles and the engineering associated with that it is, and how they – basic things like width and height and length and these sort of things, and loadings on axels and stuff, that is all covered under Australian regulation’ (SUPP 11). These issues haven’t been sorted out yet because the vehicle suppliers who supply conventional trucks will find Australia a relatively small market compared to the US and EU and ‘it might be difficult for us to get their attention, especially if we want something that’s bespoke’ (SUPP 11).

Otherwise, base business logistics issues apply to future fuels too. The experience with procurement in Covid-19 constrained environment over the last two years is important to be learned with the difficulty of getting equipment and technical support. As one interviewee said, ‘You order something today, and it won’t appear for a long time because of all the shipping issues, and all those other influences that have happened in the other 12 months, or 18 months now’ (REG 2). As another concern, ‘The equipment will get here when it gets here, but that aftersales support, if it’s not procured locally or if there’s not a local agent involved in the procurement cycle’, it will not be available (ENG CONSULT 6).

Quality assurance/quality control

Interviewees raised no new issues related to quality assurance/quality control when it comes to procurement in future fuels.

Risk management

Interviewees raised no new issues related to project risk management processes when it comes to procurement in future fuels.

Expertise and experience

Experience and expertise are a cross cutting theme for procurement in future fuels as described in other sections. The dynamic and uncertain nature of this new industry raise issues of skilled resources at all stages of the supply chain as discussed in sections 3.2.1 (Planning) and 3.2.2.

Communication

Interviewees raised no new issues related to communication when it comes to procurement in future fuels.

In summary, other challenges of supply chain coordination and management for procurement linked to future fuels identified by interviewees include:

- A lack of required skills within the new configuration of the supply chain.

- The need to consider appropriate contracting strategies due to uncertainties linked to new technology and characteristics of new players with different risk profiles.
- Consideration of logistics complexities and revisiting plans that are based on international experience for the Australian context.

3.2.2 Suppliers

Supplier issues were a hot topic for interviewees.

One interviewee believed that the supply chain for hydrogen 'is not really there yet', especially when the equipment that is coming in is often not routinely manufactured but almost crafted individually or bespoke.

Interviewees talked about the difficulties of the small supply chain in the gas sector and how it plays out in the future fuels space. Significant power lies with experienced vendors and so the first challenge is securing their co-operation. As one interviewee said, 'we're speaking to the same people, but just on different projects so the risk is that we understand one supply chain, and not necessarily open it up for competitive tension' (ENG CONSULT 14). There is little understanding of the competitive nature so it's challenging to compare one solution to another (ENG CONSULT 14). And because of the small market, 'you've actually got quite a lot of market sway, because there're so many projects right around the world now looking for that sort of product' (ENG CONSULT 13). As such, 'it's really key to try and get that senior level of commitment to demonstrate to the vendors that this is a real project, and more than likely, this is going to happen' (ENG CONSULT 13). Given the dynamic of relationships with key suppliers who have a fair degree of power, this kind of discussion and negotiation is needed 'prior to a final investment decision', especially in projects with new technology (ENG CONSULT 13). As one interviewee with actual hydrogen project experience described, what happened when equipment failed. He had 'a breakdown and then we have to wait four months before we can get a replacement; it's just ridiculous' (O/O ENG 4).

Similarly, it's challenging for such a novel technology like hydrogen when only a small supply chain is available and the overseas small manufacturing facilities don't 'have a large-scale capacity to meet… the Australian standards' and 'There're a lot of different risks that you would generally associate with your standard oil and gas project… A lot of manufacturing facilities that are procuring this technology and building this technology don't have well-developed supply chains. They don't have varying supply chains, so if one supply chain aspect goes wrong, they can't build up another supporting supply chain and that issue rolls on in terms of long lead items for your main procurement items. So for us, when we're looking at an electrolyser, you're seeing lengthy procurement timelines for items that you want to achieve Australian standards and the complexities to get it into our country' (O/O CONST 1). Similarly, another interviewee talked about the difficulty to get the pipe that can be used for the hydrogen project that his company working on, 'the pipe that's used to transport hydrogen is of a different specification to standard pipe and that is quite difficult to find at the moment in the global system' because 'not many pipe suppliers or pipe manufacturers are producing that quality of pipe' and 'that's one bottleneck that I would see in the future' (O/O CONT 1).

Interviewees also talked about the expertise of the suppliers in the context of future fuels, indicating a lack of capability at the moment to meet requirements on equipment and packages of equipment. As one interviewee said, 'there's probably a narrow range of skills in some of the hydrogen-specific competencies that are going to be needed. Or even just experience that people need to get the trust needed... There's going to be a huge lack of knowledge. The research may be done, the research papers may be published, we might have a code of practice and all of those sorts of things, but there will be no experience at the scale… well beyond the scale of what we've already done, purely on the basis that we've done something' (O/O ENG 1). As another interviewee explained, 'the appliance manufacturers are actually technology-agnostic. They've got no skin in the game. It's only the asset owners that have actually got skin the game here' (ENG CONSULT 5).

Moving from equipment to engineering services, several interviewees predicted that there will be a worldwide resource shortage in the transition to future fuels, especially 'when it comes to procuring skilled services' (ENG CONSULT 1) as everyone 'will all be engaged in the same learning exercise that we will' (O/O ENG 1). Australia is going in the right direction 'in terms of trying to produce our own skill set' (O/O ENG 1) to prepare for future fuels. As one interviewee has seen skill shortage is a real risk but 'we're an early mover and we've built some expertise within and looking to recruit some that can support that as well and grow that expertise' and 'we would hope that given the risk involved, there wouldn't be a lot of offshoring to the lowest common denominator as can

happen in on the mega projects' (ENG CONSULT 6). As another interviewee expressed, 'with hydrogen, so much of this is a new technology, that even if you are looking externally to try and pull that experience in-house, it just doesn't exist' (ENG CONSULT 2) and another confirmed, 'in hydrogen, because it's new, we wouldn't have that in-house experience' (O/O PUR 2).

Another interviewee further pointed out the dynamic nature of the resourcing issue, 'I think we're going to have a fairly significant constraint because of the lack of training because people won't know what's coming so people won't be trained in… the technology that's used… But in so far as what comes next, no technology is going to be sufficiently resourced over the next five years, so there's going to be resource restraint that pervades over the next five years in every industry because nobody can decide which one they're playing' (O/O ENG 6). The interviewee also believed that 'because of the resource constraint, the quality of the resources coming into what is a very hot market, which will be highly remunerated, you are going to find that the quality of resources drops' (O/O ENG 6). But it is just a temporary phenomenon because 'people come from all over the world to fill in the gap, and the quality will increase as high-quality resources come from all over the world (O/O ENG 6).

In summary, supplier issues for procurement linked to future fuels identified by interviewees include:

- Securing cooperation with experienced suppliers who likely have more power in the future fuels space.
- Limitations in capability of equipment suppliers and the potential need for scaling up.
- Resource shortage within service providers.

3.2.3 External environment

Interviewees identified four new external environmental factors linked to procurement risk in a future fuels environment.

Lack of standards

The first issue is that standards are being developed in parallel with technology research and development. There are going to be some unknowns in the new space of future fuels, particularly when there is not much experience. Interviewees indicated a lack of standards in some of the equipment will be a major issue although it is very common that 'standards always follow new technology development' (ENG CONSULT 9). The interviewee also emphasized the maturity of standards and technical development, 'everyone is trying to learn from each project as well as learn from other jurisdictions and how they codify requirements around these types of projects but obviously we're not in a mature phase' (ENG CONSULT 9), so 'certainly people are taking risks in procurement' (ENG CONSULT 11).

Another interviewee believed that 'the first job that comes out, they might be referencing… off-shore standards because the Australian one hasn't caught up yet.' (CONST CONT 4). In regard to standardization, 'ISO standards are being adopted in some of the technology, for example, for electrolysis, but a lot of this technology is somewhat bespoke' (ENG CONSULT 9). The interviewee also emphasized that 'It's hard to standardise that but you can certainly establish some broader requirements around safety and controls and shutdowns potentially or understanding what can go wrong' and 'some of this is failures that may occur in operation will lead to some standards developing… but certainly there's going to be some unknowns that might lead to an incident that then leads to codification of a requirement' (ENG CONSULT 9).

The risk linked to difficulties of overseas suppliers meeting Australian standards was raised again in a future fuels context. One interviewee thought that the key risks 'are really Australian standards compliance and the difficulties in overseas manufacturers complying with a standard that they're not used to or a manufacturing standard that they're not used to. That's simply the largest risk… across all of our projects in future fuels… But the issue we do see is people underestimate the requirements associated with those standards. So we see businesses and manufacturers that are really keen to win a project or win that procurement that they fall way in understanding their complexities of meeting compliance requirements' (O/O CONST 1). One of the control measures is 'to try and make sure that our scope is really clearly defined, so the manufacturer's really clear in what we want' to avoid the situation when a product doesn't meet the scope of work or requirements, potentially cancelling a contract because of delays (O/O CONST 1).

Another interviewee explained the difficulties linked to scale up of manufacturing, ‘The technology was there, but what we're trying to do now is scale it up because we're trying to bring the cost down. And... the supply chain that goes into manufacturing electrolysers that they've been producing today… is very bespoke, and actually highly inefficient. There's not a refined production line, and whereas we're asking for 1-megawatt three years ago, and last year we're asking for 10-megawatt, now we're asking for 20 – 30 – 50-megawatt. So, we're continually pushing the boundaries, so they're not actually able to get that standardisation, because the industry's changing’ (ENG CONSULT 13). One of the methodologies used to mitigate this issue is to bring the vendor into the early stages of the design process, early vendor involvement, so that ‘you don't necessarily have to align with that particular vendor in the next product’ (ENG CONSULT 13).

New industry players

The second external risk factor relates to the risk to the hydrogen sector as a whole presented by new players. Some examples we heard about the challenge for project execution in a future fuels context is the maturity of the operators. One interviewee described the challenge to implement a project where the operating company’s ‘background is in mainly power generation but not with gaseous fuels’ without ‘familiarity with hydrogen technology’ (ENG CONSULT 9). Because of that, there has been a big gap in understanding the requirements for process engineering, safety and control, and ‘some of the particulars of managing gaseous fuels aren’t really managed successfully through the design’. Because of that, ‘the risk in terms of consequence could be an incident that actually occurs during operation, during start up or during commissioning’ (ENG CONSULT 9). In this case, the discussion between parties assisted with closing the gaps in awareness but the project has still suffered from serious delays.

This issue needs to be addressed in order to guarantee the positive reputation of the new emerging future fuels sector. As one interviewee explained the reason, ‘so the number of people out there with expertise in hydrogen is limited, and people have different niche things, so my niche is more pipeline integrity, high pressured transmission pipelines, that sort of thing, but does that qualify me to be involved with electrolysers, production, compression, and everything else? Probably not… The oil and gas industry is good source for hydrogen-related stuff, obviously, but it’s a very different beat, and there’re still risks… in the early days if you have some sort of major incident with hydrogen, then it doesn’t just damage that particular entity that’s involved, it damages a whole industry because it can potentially tarnish everything that everyone’s trying to do’ (SUPP 11).

Another interviewee talked about some pipelines companies who are building facilities to manufacture hydrogen with a lack of process or manufacturing experience, ‘they can handle putting the product into the pipeline or into the network, but that upfront processing part was just completely outside of their experience and expertise’ (ENG CONSULT 16).

One interviewee believed that engineering skills are transferrable but also indicated the challenges with the skill transfer between generations and a drain of skills away from the gas sector. ‘Because once you are in an engineering field, it doesn’t matter whether a chemical engineer, mechanical engineer, civil engineer, electrical engineer, it gives you a bit of a knack to find out the problems and read the standards and get good’ (O/O ENG 3). However, ‘the attractiveness is not there in the oil and gas industry. It is becoming a club of old people like us’ as youngsters are more attracted to wages in other areas (O/O ENG 3).

Regulation

Another external issue raised by interviewees relates to regulatory risks.

The first issue is that in many areas hydrogen projects fall outside the jurisdiction of current natural gas regulations. This creates problems with approvals. Specifically, ‘in a lot of cases, unfortunately, their legislation is written specifically with a gas designated in it – gas to the specification of let’s say 4546 or whatever. And that is a problem because, realistically, they could cover it under their existing legislation because the safety factors involved are pretty much the same’ (ENG CONSULT 16). Hopefully this is a simple matter of regulatory drafting to resolve but in the meantime one regulator described his state’s interim measures: ‘So we’re developing a code of practice ourselves for all the gaps in our legislation that we need to plug to not hinder people developing this space. So there’s a lot of gaps now because there’re no rules, or there’re vague rules’ (REG 2).

There are also issues with updating regulations to cover the most up to date technical requirements. As one interviewee explained with an example, 'There's a lot of research happening at the moment to work out what hydrogen compatible equipment and line pipe… lots of technical requirements are. And there's some risk that the regulators will not necessarily follow the results of the research but will decide to put additional… not evidence-based restrictions on it. And at the moment I'm trying to buy some hydrogen compatible line pipe to put in a project that I'm doing. I am essentially taking a risk that the regulators will not put additional things on top of that that I couldn't predict and therefore the whole thing doesn't work for hydrogen in the future' (O/O ENG 1). As another interviewee put it, 'Some states have less barriers than other states in terms of their legislative framework and how it can adopt hydrogen in various forms' (ENG CONSULT 9).

Regarding the relationship between standards and regulation, one interviewee said 'We're moving along with standards, but there are still some gaps there. And to understand how the standards fit within our regulatory environment, our regulatory system… which is a problem' (ENG CONSULT 16).

Government support

Several interviewees spoke of the need for government support to get the hydrogen industry kick started.

Government support is one of the key issues as 'all of these projects are uncommercial without some form of government support'. For example, with wind farms in Australia, there is not 'government position on renewables and agreed targets and all the rest, it's very much driven by private equity really. They did have the funding through the government but it's without that certainty around the government committing to certain targets' (CONST CONT 2).

One interviewee was of the view that there were risks linked to the eligibility for assistance, even if such a scheme were to be started. There might be a tendency that the government want to proceed with 'something not too risky because all their reputations are attached to it' so 'they want to go with the larger companies' which 'have a different risk profile' compared to smaller companies who are 'coming from an exploration and mining space' (SUPP 11).

One interviewee believed that the government is putting pressure by 'giving out lots of money to people and saying "spend it now" … to develop these projects, so this will add further pressure to deliver projects according to tight schedules (REG 2).

In summary, issues that are rooted in the external environment of procurement linked to future fuels identified by interviewees include:

- A lack of standards that are being developed in parallel with technology development and potential complexity of consistency with international standards.
- Adaptation of new players who has limited experience with hydrogen.
- Gaps in regulations and their interface with standards.
- The need for government support for the kick-off of the hydrogen industry.

3.2.4 Trust and cooperation

Interviewees raised no new issues related to trust and cooperation when it comes to procurement in future fuels.

3.2.5 Summary of procurement risks in a future fuels context

In summary, key challenges in relation to procurement risk governance for future fuels suggested by interviewees are:

- Complexities of knowledge management, including learning from other industries and inclusion of current research outputs into practice.
- Upskilling the workforce given uncertainties associated with policy and technology development.
- Planning for the uncertainties and addressing the complexities that are created as a result of the new configuration in the supply chain.

- Development of new standards and regulations and their congruencies with practice at the international level.
- The need to focus on mitigating risks rather than transferring, as contractors may not be able to handle them and will use other strategies and contingencies that increase project resource needs and costs.

4 New perspectives towards a risk governance framework

Interviewees have given many insights into the ways in which procurement can fail and what practices might be adopted to prevent such failures. The previous interim report addressed past procurement failures and their causes. This section addresses new perspectives that will be used in the next phase of the work to develop a new risk governance framework to support procurement to be undertaken in a future fuels environment.

The five perspectives chosen are uncertainty, interface management, resilience, temporality and high reliability networks. The sections below summarise these fields and set out how they will be applied to address options for risk governance in procurement for future fuels.

4.1 Uncertainty

In the last decade, risk has been redefined with a stronger focus on uncertainty, particularly strength of knowledge regarding the state of hazards. In addition to these theoretical moves, uncertainty arises as a topic of conversation in several of our interviews and lack of knowledge is an emergent theme. This lens may provide useful insights regarding future risk reduction strategies.

4.1.1 Risk and uncertainty

The concept of risk has a long history with the term appearing in written English in the late 17th century. In modern times, it is used in many fields but in a professional/scientific context, Aven (2012) has identified nine different ways in which risk is expressed including expected value, probability of an undesired event, objective uncertainty, potential loss, probability and severity of consequence, and the effect of uncertainty on objectives.

In the more traditionally-based definitions that focus on probability, probability is simply ‘a tool for expressing the assessor’s uncertainty and beliefs about unknown events and quantities’ (Aven, 2018, p. 881). In recent years, scholars have proposed a broadening of thinking regarding risk which has focused thinking on uncertainty (Aven et al., 2011; Renn, 2008; Renn & Klinke, 2012). This work has resulted in the ISO definition change to ‘risk is the effect of uncertainty on objectives’ (ISO, 2009). Aven (2018) summarises recent thinking when he says: ‘Risk is the mental concept that exists when considering an activity in the future (even if this risk is not measured or characterized). It comprises two main features: (i) values at stake, consequences with respect to something that humans value and (ii) uncertainties.’ (Aven, 2018, p. 880).

This perspective on risk is also present in the project management risk literature. PMBOK’s 7th edition states:

> *Risks are an aspect of uncertainty. A risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives. Negative risks are called threats, and positive risks are called opportunities. All projects have risks since they are unique undertakings with varying degrees of uncertainty.(Project Management Institute, 2021)*

Risk and uncertainty are intimately linked in current thinking about risk and how best to manage it.

4.1.2 Defining uncertainty

The Society for Risk Analysis Glossary (SRA, 2018) defines uncertainty as:

- ‘For a person or a group of persons, not knowing the true value of a quantity or the future consequences of an activity
- Imperfect or incomplete information/knowledge about a hypothesis, a quantity, or the occurrence of an event’.

A review of the literature shows various schemes for how to categorise uncertainty. Renn and Klinke (2012) propose five categories of uncertainty:

- Variability refers to the different vulnerability of targets such as the divergence of individual responses to identical stimuli among individual targets within a relevant population such as humans, animals, plants and landscapes.
- Inferential effects relate to systematic and random errors in modelling, including problems of extrapolating or deducing inferences from small statistical samples, animal data or experimental data onto humans or from large doses to small doses etc. These are usually expressed through statistical confidence intervals.
- Indeterminacy results from genuine stochastic relationship between cause and effects, apparently non-causal or non-cyclical random events, or badly understood non-linear chaotic relationships.
- System boundaries allude to uncertainties stemming from restricted models and the need to focus on a limited number of variables and parameters.
- Ignorance means the lack of knowledge about the probability of occurrence of a damaging event and about its possible consequences. vulnerability of targets, stimuli among individual.

They note that the first two categories can be addressed by improving existing knowledge whereas the last three may be able to be characterised but cannot be completely resolved.

Murphy (2012) maintains that different kinds of uncertainty in relation to level of knowledge must be distinguished:

- total ignorance, where there is no good evidence about what the chosen path of development will lead to;
- partial knowledge, … where risk assessors know that there is increased risk without knowing precisely what it will be in terms of impact, timing, location, duration and who will be affected;
- erroneous knowledge, where lay or scientific risk assessors think they know the risks but are eventually proven wrong.

SRA (2018) opt for two kinds of uncertainty, noting that their definition (quoted above) focuses on epistemic uncertainty as opposed to aleatory (stochastic) uncertainty which is variation of quantities in a population of units (commonly represented/described by a probability model).

There is general agreement that aleatory uncertainty refers to variation in large populations and epistemic uncertainty to lack of knowledge about phenomena. Epistemic uncertainty can be reduced, aleatory uncertainty cannot (Aven et al., 2014).

4.1.3 Uncertainty and decision making

Procurement is essentially an exercise in decision making – what should we buy and how? How should logistics be managed? What level of inspection should we require? Are the goods being produced of acceptable quality? In this way, uncertainty becomes a key factor in making the right choice. At one level managing of such uncertainty is about gathering the right data so that decision makers are well informed and decisions are evidence-based (Lindley, 2014). One set of strategies for risk reduction would be to focus on what information is needed to diagnose developing problems and ensuring that such information is made available to decision makers in a timely manner.

That is not the end of the matter. The social sciences know well that having access to information is not the same as knowing and taking action. Another way to think about management of uncertainty in decision making is to consider the literature on failure of foresight. Drawing from the safety literature on disaster prevention, Turner's work is particularly relevant giving insights into why signs of trouble might not be acted upon. During an incubation period, unnoticed evidence accumulates that is at odds with accepted beliefs about hazards and norms for their avoidance (Turner, 1976, 1978; Turner & Pidgeon, 1997). Features of such a period include:

- rigidities of belief and perception
- minimising of emergent danger
- failure to comply with rules
- involvement of non-experts
- information difficulties and noise
- disregard complaints from outsiders

- decoy phenomena (focusing on the wrong thing).

Ensuring that organisations do not fall into these traps may be a useful way of framing some aspects of how to go about reducing uncertainty.

4.1.4 Implications for risk governance in procurement

Guiding questions regarding application of this perspective to management of procurement for future fuels are:

- What types of epistemic uncertainty contribute to the risk of procurement failure according to the past incidents and the interview data? What types of knowledge are not being acted upon and why?
- In what ways does a future fuels procurement environment make such uncertainties more relevant to project success and failure?
- How might uncertainty in procurement for future fuels be reduced?

4.2 Interface management

Procurement involves the coordination and collaboration of processes and activities across a network of organisations and a variety of functions (e.g., design, manufacturing, and logistics) (Tang, 2006), making interfaces between the different organisations and functions a critical element to be considered. Indeed, interface management has been frequently discussed by participants of our interviews as an important factor contributing to procurement success.

4.2.1 Interface management and procurement/supply chain risk

Morris (1983) was one of the first researchers who introduced “interface management” as a project management approach for managing construction and engineering projects. Interface management is considered as an outgrowth of the influences of systems thinking on project management (Morris, 1983). Systems thinking posits that projects should work as effectively regulated organisations, in which objectives are clearly defined, the constant changing nature of project organisations is recognised, and major subsystems and their interfaces are identified and managed (Morris, 1983). Consistent with the perspective of systems thinking, interface management identifies:

- The subsystems to be managed on a project
- The principal subsystem interfaces requiring management attention
- The ways in which interactions at the interfaces should be managed successfully (Morris, 1983).

Interface management has important implications for procurement processes. Successful procurement of goods or services requires the effective management of information, materials, and cash flow throughout a network of organisations, i.e., a supply chain (Tang, 2006). The supply chain network can be effectively viewed as a system which links suppliers and other functional groups, with a dynamic integration of often reasonably independent entities to work together to deliver goods or services (Olson & Swenseth, 2014). Within the supply chain system, interfaces exist between various organisations and functions. Meanwhile, the supply chain system is also influenced by the external environment in which the system operates, generating additional interfaces between the supply chain system and external entities. Failures in the interactions, coordination and communication at the supply chain interfaces are likely to cause procurement failures, highlighting the useful role of interface management in procurement risk mitigation. Interface management is expected to increase the alignment and reduce conflicts between interface participants by facilitating better communication and collaboration (Shokri et al., 2016)

4.2.2 Definition of interface management

Interface was first defined by Wren (1967, p. 71) as “*the contact point between relatively autonomous organisations which are nevertheless interdependent and interacting as they seek to cooperate to achieve some larger system objective*”. Within this inter-organisational system, each organisation is considered as a subsystem, which seeks to pursue their own objectives while simultaneously serving a larger system and its objectives. Three linking processes were identified at the interfaces of the system (Scott, 1961; Wren, 1967):

- Communication – acting as the method by which action is evoked from parts of the system as well as the control and coordination mechanism which links decision centres in the system into a synchronised pattern.
- Balance – acting as an equilibrating mechanism by which different parts of the system are maintained in a harmoniously structured relationship to each other. It helps to ensure the system integrity in the face of changing conditions.
- Decision making – including both decisions to produce and decisions to participate in the system. Decisions can be affected by the motivations of individual subsystems and the conflict between subsystems' interests and the overall system's interests.

Within the engineering and construction projects context, interface management has been defined as the management of communications, responsibilities, and coordination across the boundaries of project parties, phases, or physical entities, which are interdependent (Shokri et al., 2012). The definition highlights two basic elements of an interface, i.e., the boundary and interdependency across the boundary (Chan et al., 2005).

Researchers have proposed various categorisations of interfaces to be managed. In the context of building construction project, Pavitt and Gibb (2003) identified three types of interfaces:

- Physical interfaces, which are the actual, physical connections between two or more building elements or components.
- Contractual interfaces, which are created by work packages with grouped work elements and associated with different specialist contractors.
- Organisational interface, which are the interactions between various parties involved in a construction project.

Morris (1983) differentiated between static and dynamic interfaces in project organisations:

- Static interfaces, which represent relationships between subsystems that are not affected by the way the project develops.
- Dynamic interfaces, which is the pattern of activity interdependencies generated by the way the project develops.

Shokri et al. (2012) further categorised project interfaces at three levels according to the nature of the interfacing groups:

- Inter-project interfaces between different parties directly involved in project planning and execution.
- Intra-project interfaces within the organization of each independent party involved in a project.
- Extra-project interfaces between the project parties and other parties/organisations which are not directly involved in project execution.

Figure 1 illustrates the three levels of project interfaces suggested by Shokri et al. (2012).

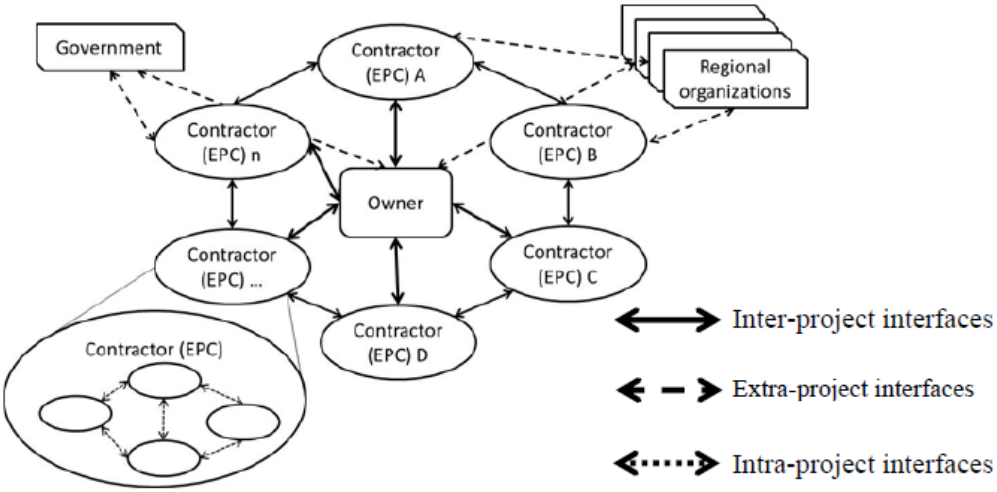

Figure 1. Three levels of project interfaces (Shokri et al., 2012, p. 451)

The structure of three levels of project interfaces is highly relevant to the interview data and will be adapted to analyse key interfaces to be managed to mitigate procurement risks in future fuels.

4.2.3 Interface issues

To mitigate procurement risks through interface management, it is important to first understand what are the major interface aspects that need to be managed. Morris (1983) suggested four principal subsystems at the intra-project level, which can be adapted to reflect key components for interfaces:

- Achieving descried objectives through interface interactions, e.g., delivering goods meeting requirements in terms of technical specifications, time and cost.
- Creating the organisation needed to achieve the objectives, including formal structures, contractual relationships, systems of information flow and control procedures, as well as informal patters of working relationships and communication.
- Minimizing external disruptions from the environment, e.g., obtaining necessary regulatory approvals and dealing with a changing market.
- Providing adequate infrastructure and logistics to accomplish the objectives, e.g., resources, transportation, communication, and utilities.

Various interface issues can occur due to failures in the activities, interactions, and communications among interface participants. Al-Hammad (2000) identified four groups of interface issues among various construction project parties that are likely to lead to poor project performance:

- Financial problems, e.g., delay in progress payment by owner, accuracy of the project cost estimate, and owner's low budget for construction relative to requirements.
- Inadequate contract and specifications, e.g., insufficient working drawing details, insufficient specifications, violating conditions of contract, poorly written contract, and change order.
- Environmental problems, e.g., inaccurate geological data produced, and unfamiliarity with local laws and regulations.
- Other common interface problems, e.g., lack of communication, slowness in decision making, poor planning and scheduling, and lack of skilled labours.

Chen et al. (2008) investigated interface issues in the construction project context from six interrelated perspectives, which provide useful implications for what interface aspects should be managed (Figure 2). The six perspectives include:

- Participants: effective interactions among interface participants are critical in avoiding conflicts. Interface issues in relation to participants include poor communication, coordination, and decision-making as well as participant financial issues.

- Methods/processes: the methods and processes determined for design, construction and manufacturing influence the activities and interactions of interface participants and affect project outcomes. Interface issues resulted from inappropriate methods and processes include inferior design, construction and assembly problems and manufacturing issues.
- Resources: various resources are needed to support interface activities and interactions. Resources related interface issues can be linked to labour, equipment, materials, and information system.
- Documentation: documentation at the interface is important in ensuring that information and requirements are effectively transferred and received. Document related issues at the interface include inadequate specifications & drawings, inadequate contract, delayed permit and shop drawing approval, and change order problems.
- Project management: relevant project management techniques should be applied to coordinate interfaces. Inappropriate project management can lead to issues such as poor planning and scheduling, inappropriate subcontracting, poor risk management, etc.
- Environment: issues can occur at the interface between the project environment and the external environment, such as inclement weather, diverse local regulations, changing building codes and trade union practices, material and labour unavailability, and price changes in the local market.

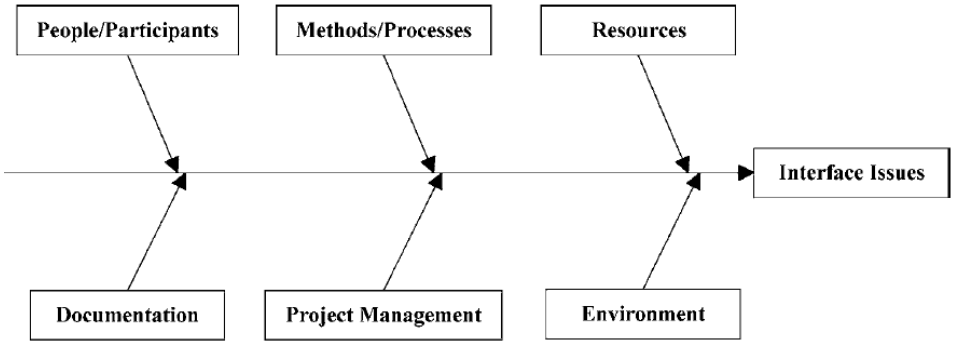

Figure 2. Multi-perspective approach to interface issues (Chen et al., 2008, p. 435)

4.2.4 Implications for risk governance in procurement

Guiding questions regarding application of interface management perspective in managing procurement for future fuels are:

- At what interfaces is the risk of procurement failure identified in past incidents and the interview data? Who are the interface participants? What are the interface issues that contribute to the risk of procurement failure?

- What are the key interfaces that need management attention in the future fuels environment? What do successful interface interactions look like?

- What should be done to achieve successful interface interactions and reduce procurement risks for future fuels?

4.3 Supply chain resilience

The concept of supply chain resilience is used as the third theoretical lens to extend the findings. Generally, this lens is used to go beyond usual practice of ensuring the business as usual and allow consideration of new norms of practice within the future fuels supply chain. The objective of risk mitigation strategies that emerged from the interview data is minimising the likelihood of procurement failures to continue business as usual. Through the lens of supply chain resilience, the industry can also explore alternative mitigation strategies that are related to redirection and adaptation to new scenarios and flexibility within the project plans. In this sense, actions associated with supply chain resilience extend the risk perspective, rather than replacing it. As a result, the mitigation strategies are beyond the alternatives that aim to maintain the current status through risk governance in procurement, and extend to consideration of new normal, or in other words the strategies that promote

"changing in order not to be changed" (Walker, 2020). This lens is specifically important in view of the implication of global grand challenges, including the consequences of Covid-19 pandemic or the move towards future fuels in the supply chain of capital projects in the energy sector.

4.3.1 Definitions

Supply chain resilience is defined as the ability of the supply chain to cope with unexpected disturbances (Carvalho et al., 2012) and to adjust the expected processes within the supply chain prior to, during and following the events (Hollnagel et al., 2006). In this sense, the supply chain may not only maintain the expected procurement practices through risk mitigation strategies, but also explore strategies that allow the supply chain to transform procurement practices in response to changes. Notable characteristics of a resilient supply chain include (Ponis & Koronis, 2012; Ponomarov, 2012):

- Adaptive capability and capacity
- Preparation and proactive strategies
- Response to disturbances
- Connectedness and control within the supply chain network
- Timely recovery to a stable state (not necessarily the existing and planned stable state).

As a result, strategies that are associated with resilient supply chain encourage review of the assumptions at any point and explore if there is a need for new processes and plans. Therefore, mitigation strategies that are driven for supply chain resilience are beyond just the ability to manage risks and include the capacity to respond in an efficient and cost-effective approach based on the contextual changes (Hamel & Valikangas, 2003; Yao & Meurier, 2012). Such strategies and their associated capabilities can be categorised broadly as (Tukamuhabwa et al., 2015):

- Preparation for disruptive events
- Response to disruptive events
- Recovery from disruptive events
- Growth in the face of the disruptive event and gaining competitive advantage in view of potential future disruptive events.

Furthermore, supply chain resilience allows exploration of patterns of flexibility within the risk management process, in contrast to more rigid traditional risk management practices that aim to preserve the status quo by minimising the risk of failure. In this sense, "safe-fail" strategies are also considered that allow the possibility of intentional, designed and controlled failures at smaller scales within the segments of the supply chain to prevent higher level system-wide failures (Park et al., 2013; Wieland & Durach, 2021).

4.3.2 Supply chain resilience and decision making

Pereira et al. (2014) suggested eight issues in procurement functions that impact supply chain resilience, and they include:

- Knowledge management and internal communication,
- Inventory,
- Product flexibility,
- Technology used in the supply chain management,
- Strategic sourcing (supplier base, selection, relationships, developing suppliers),
- Supply chain design and configuration,
- Logistics and transportation, and
- Risk management.

Considering these functions, procurement related decision making can be discussed in view of the four principles of resilience as abilities developed at the system level resilience (assuming a supply chain as a system or a system of systems). These four abilities include the ability to monitor, respond, learn and adapt, and anticipate (Hollnagel et al., 2006). Each of these principles imply certain extension to alternative actions associated with decision making within the procurement risk governance. For example, decisions can include: (i) the ability to

constantly monitor the internal needs of the supply chain, as well as the environment and context of the supply chain, (ii) the ability to respond to the expected and unexpected events within the supply chain, (iii) the ability to learn and establish organisational learning from the experiences as a precedent of adaptivity within the supply chain, and (iv) the ability to anticipate potential events and proactively develop preventive, response and recovery strategies. While these abilities are discussed to some extent in the analysis of the responses of the interviewees for the risk governance framework, the new lens of supply chain resilience can further expand them beyond the actions that only aim to strengthen the supply chain and ensure stability of the procurement practice. Such expansions may consider a transition to an alternative stable state of practice within the supply chain and specifically decision making for future fuels procurement. Examples include the decisions within the companies to adapt, learn, transform and innovate in the face of disruptions, and change the common practices that prepares them for more monumental disruptions (Wieland & Durach, 2021).

To be more specific, the direction of analysis based on the concept of supply chain resilience aims to review the themes emerged from the interviews along with the raw data to provide additional risk mitigation strategies that can be alternatively considered in the future fuels procurement practices. Examples that will be explored from the interview data include potential strategies to target loose type of relationships to reduce vulnerabilities instead of the closely integrated relationships with integration of processes and systems (Wieland & Wallenburg, 2013), which implies the shift of emphasis from integration within the supply chain to communicative and cooperative relationships between the actors. Other examples include resilience by design strategies such as redundancy in supply chain, adaptable raw material capacities, local production and re-allocation, as well as resilience by intervention such as introduction of subsidies (Mahoney et al., 2022). For instance, Panwar et al. (2022) suggested the role of micro supply chains as finite, localised, decentralised and agile models with flexible supplier contracts and relationships that allow “safe-fail” modes in smaller scales to prepare for large scale disruptions. The interview data will be analysed to see how these strategies may differ in the capital project industry within the energy sector to more common prior studies in, for example, commodity markets.

4.3.3 Implications for risk governance in procurement

The development of alternative risk mitigation strategies within future fuels procurement risk governance further emphasises how a supply chain is conceptualised. That is, the aim of this additional research is to shift from supply chain resilience as an engineered and closed system that is aiming for optimal operation, with a focus on speed of recovery, and resistance to disturbances. The alternative view moves thinking towards a socio-ecological approach to supply chain resilience that is aiming for an open view of the organisations and their interactions within the supply chain that allows “safe-fail” and adaptation within the supply chain (Wieland & Durach, 2021). In this sense, the guiding questions regarding application of the supply chain resilience perspective to management of procurement for future fuels include:

- Do interviewees describe procurement failures that can be linked to a lack of supply chain resilience?
- Can the cases of procurement failures be linked to a lack of supply chain resilience?
- If so, how might system resilience be increased so as to better manage the potential for procurement problems in the context of future fuels?

4.4 Temporality

Many interviewees spoke about issues linked to temporality such as schedules and the need for speed. As a result, another developing branch of the organization studies literature that may be useful in developing tools for risk governance in procurement is the work on temporality in organizations i.e., how different organizational actors perceive time and how their actions are influenced by various temporal characteristics.

4.4.1 Time and procurement

Procurement work, particularly in a project environment, has a rhythm driven by time at several levels. Each project has a beginning, middle and end, making the entire experience of work episodic – a process of cycling through a series of well-defined stages regarding what information needs to be produced, by whom and in what sequence. The same applies for procurement of goods and services which is typically subject to strict deadlines. Procurement also draws on experience, linking together the past, present and future in making procurement decisions. Time also represents a scarce resource as procurement activities seek to deliver the required goods

and services in the desired timeframe. Different temporal timescales are another key factor. Successful procurement may be seen as procurement that achieves short term goals of cost, schedule and quality but this hides what is in many ways the most important outcome – robust long term operation of the result of procurement. Different actors along the supply chain have a greater or lesser interest in the long term.

The most recent thinking about time and organisations takes time out of the hands of the external environment and focuses attention on those who work in organisations (Hernes, 2022). Rather than consider what time does to organizations, this type of research investigates how organizational actors express themselves, define themselves, and understand themselves *through* time. It is assumed that 'time emerges from what they do and then shapes them, in turn, as they respond to external events and define their time.' (Hernes, 2022) In this view, organisational actors both experience and create their sense of time. Hernes (2022) further notes that 'few studies address the on-going interplay between the temporally ephemeral and the temporally enduring' meaning that our research will be ground-breaking in applying this perspective to how the ephemeral process of procurement links to the enduring outcomes represented by installed and operating facilities.

4.4.2 The need for speed and its downside

One key part of the temporality research domain that seems to be particularly relevant is the research related to the pace of action in organizations. Placing such a premium on meeting deadlines means that in project organizations, speed is celebrated as 'a synonym of good' (Czarniawska, 2013, pg 11). Despite this, some major projects that have become famous for the meeting deadlines are now equally famous for their mistakes (Grey, 2009).

The formal investigation into the causes of the loss of the space shuttle Columbia and the deaths of seven astronauts on board found that NASA had failed to develop an appropriate leadership culture on safety matters within the space shuttle program and that a management philosophy of 'faster, better, cheaper' was part of the problem (CAIB, 2003). Each shuttle launch was treated as a project in its own right with associated gates and deadlines. Blount et al. (2005) found that temporal uncertainty at NASA over decades had let to an environment in which 'the increasing sense of time pressure and stress compounded those effects [a hard launch deadline] leading employees to filter out information that was not directly relevant to achieving the temporal goal.'(Blount et al., 2005, pg 133) This included safety concerns that might have resulted in a schedule delay. Reflecting on the temporal artifacts in use at NASA before the failed launch, Blount et al found that 'a deadline is a very effective tool for motivating efficiency, emphasizing accountability, and fostering coordination within an organization, but it is not an effective tool for coping with the temporal uncertainty that is inherent to performance in complex systems' (2005, pg 135).

Another example is provided by the Heathrow T5 project. Initially celebrated as a mega project success, in fact the performance of the system once put into operation was a public relations disaster with major flight delays as a result of problems with numerous systems. As Brady and Davies' describe,

> *Throughout the construction phase of the program a huge emphasis had been placed on delivering T5 on schedule. The T5 project headquarters office had clocks counting down from the time T5 was to become operational – originally 4.a.m. 30th March 2008 but which was subsequently brought forward to 4 a.m. 27th March. This deadline was treated as sacrosanct. Thus it became politically impossible to delay the opening even though concerns were raised about the state of operational readiness"* (2010, pg 157).

While these examples reflect on projects overall rather than specifically on procurement, similar issues no doubt exist within the procurement function. There are many other modern organizations where working quickly has become a cultural phenomenon. Grey (2009) maintains that 'the significance of speed in organizations has increased in the recent past' including specifically 'an increasing emphasis on the necessity for ever faster transformations in the workplace.' (pg 31). He calls this the 'fetish of change' (Grey, 2003) noting also that 'there has been an almost unchallenged insistence that rapidity is mandatory for organizational survival' (Grey, 2009, p. 31). It seems organizations have not heeded the warnings of the disasters noted above nor of Lawson's well known paper *In Praise of Slack* that proposes organizations that fail to understand thinking as work and so

eliminate time and resources for thinking and learning in the search for efficiency, are bound to fail (Lawson, 2001).

Accepting that deadlines are important, for organizations involved with hazardous technologies, survival is also contingent upon failure free operation and what is more – failure free operation over an extended period of time. In the two examples discussed above project failure was immediately apparent but in the context of hazardous industries, problems created during the project stage may be latent and only become apparent decades later. One classic example of this is the San Bruno pipeline failure in California in 2010. In this case a natural gas transmission pipeline failed killing eight members of the public. The immediate cause was a faulty weld made in 1956 when the pipeline was installed (Hayes & Hopkins, 2014). This significant construction error had remained undiscovered for more than five decades but ultimately resulted in catastrophe.

4.4.3 Time and high reliability

Another temporal challenge in getting the best in procurement lies in the temporal separation between actions and outcomes. In complex socio technical systems, no single decision results in catastrophe (safety or otherwise). Reality is much more banal with multiple small faults and errors cumulating over an extended period until the system is so fragile that a final error triggers major failure (Reason, 1997). Disasters are classified as such not only because of the damage that they cause in the sense of deaths or major costs but because of the social disruption – the sense that accepted beliefs about the world and its hazards are incorrect (Turner, 1978). They are a powerful surprise.

High reliability researchers have investigated how some organizations manage to escape the complacency that can result from the absence of major failures. Such system reliability is a dynamic non-event that is ‘difficult to specify and visualize’ because ‘there is nothing to pay attention to’ (Sutcliffe, 2011). As Reason explains, ‘it is dynamic because processes remain under control due to compensations by human components. It is a non-event because safe outcomes claim little or no attention. The paradox is rooted in the fact that accidents are salient, while non-events, by definition, are not’ (Reason, 2000, pg 10). The challenge is that constant vigilance is required in the face of no apparent result.

Weick maintains that the key to high reliability is ‘continuous management of fluctuations through restoring interrupted balances. Reliable performance itself is an ongoing activity of balancing significant contradictions’ (2011, pg 25). The question then is how to achieve this in practice. According to Weick, the answer lies in balance between a range of components. ‘[High Reliability Organizations] strive for a balance between components such as principles and experience, anticipation and resilience, input and demand, routine and non-routine, flux and order’ (2011, pg 22). In fact, ‘sustained balance is one way to describe reliable performance’ (2011, pg 23). It can be argued that the issue of temporality and balancing short and long term requirements is an under recognized factor in this list

4.4.4 Implications for risk governance in procurement

Guiding questions regarding application of this perspective to management of procurement for future fuels are:

- How is temporality in procurement experienced by decision makers?
- What meaning is given to past and current events that could impact procurement outcomes? How are these events brought into play in making procurement decisions now for the best outcomes in the future?
- How do different actors experience the pace of activity? Does this have implications for procurement risk?
- Are there risk management implications from the episodic nature of procurement? If so, what and how are they best mitigated?
- How could processes linked to temporality be improved in order to gain better procurement outcomes?

4.5 High reliability networks

High reliability research was mentioned in the preceding section in the context of short and long term goals but this body of research has broader implications for high performance and so is also relevant to best practice in risk governance for future fuels.

4.5.1 High reliability organizations

As described in the previous section, research conducted since the 1990s on high reliability organizations has been influential for organizations that seek high performance, particularly in hazardous industries such as energy. High reliability organizing has been mostly studied through ongoing operations although research attention is increasingly moving to high reliability networks.

4.5.2 Moving to high reliability networks

A small amount of research has made a start in addressing how to apply high reliability concepts in a network of organizations such as in a project environment (see for example Berthod et al., 2017; Berthod et al., 2015).

A recent edited book comprising ten case studies of contracting and system safety identified two common themes when it comes to problematic contracting (Hayes & Tillement, 2022). Firstly, fragmentation narrows focus so that safety outcomes and consequences of choices made are not always visible to all. Further, in many cases, informal practices arise to try to manage boundaries. Some are helpful but others are not designed for system reliability. The cases showed that both inter and intra organisational boundaries can be problematic. Secondly, many of the case studies revealed issues related to temporality, in particular the transient nature of contracted relationships. The cases showed that outsourcing is dynamic in many ways, including outsourcing practices themselves, temporary relationships in project-based organisations, temporary work structures created to deliver outputs and different temporal orientations of different actors.

Across a range of contexts, effective strategies for managing fragmentation and transience included:

- appointing boundary spanners,
- aligning payment structures with desired outcomes,
- alliance-style contracting,
- systems to support interorganisational coordination,
- recognising that long term relationships often exist despite formal structures in place,
- Local contracting to minimise bureaucratic complexity and include performance indicators that encourage the right temporal view to achieve system safety,
- Regular review meetings so that practices can be monitored and adapted if long term goals are threatened.

It can be expected that these factors may equally be relevant to risk governance for procurement in a future fuels environment.

At a recent international workshop on societal safety and networked systems, one of the original high reliability researchers, Emeritus Professor Paul Schulman, put forward the following list of the integrated capacities he sees as likely for resilience and reliable networks of organisations:

- Organisations hold shared objectives, in particular a shared idea of events to be precluded (never events) and their precursors,
- Systems exist for rapid communication across the network of developing issues and more generally for information sharing across the network,
- Organisations in the network have common vulnerability and risk assessment processes and the results are considered collectively,
- Reliability and resilience focussed design strategies are used for hardware and organisations with full consideration of the need for graceful failure,
- Familiarity and trust among personnel across the network are actively encouraged,
- A collective ability is developed to anticipate, model, plan and coordinate for failure,
- A central organisation exists that oversees the network and can anticipate developing problems.

4.5.3 Implications for risk governance in procurement

Guiding questions regarding application of this perspective to risk governance of procurement for future fuels are:

- To what extent do supply chain participants see themselves as part of an integrated network?
- How do the various actors across the procurement chain conceptualize 'never events' and how to avoid them? To what extent do the actors agree?
- To what extent do the other likely properties of high reliability networks exist in current energy sector procurement?
- Are there ways reliability could be enhanced, particularly in the context of future fuels?

4.6 Summary of new perspectives towards a risk governance framework

Five new perspectives (uncertainty, interface management, resilience, temporality and high reliability networks) have been identified that we expect to be useful in determining an appropriate risk governance framework for future fuels that builds on the industry's procurement successes, takes into account past procurement failures and addresses the unique circumstances posed by future fuels.

Guiding questions to review the interview data and incidents analyses are shown in Table 6 below.

Table 6. New perspectives and guiding questions for further analysis

Perspective	Guiding questions for further analysis
Uncertainty	• What types of epistemic uncertainty contribute to the risk of procurement failure according to the past incidents and the interview data? What types of knowledge are not being acted upon and why? • In what ways does a future fuels procurement environment make such uncertainties more relevant to project success and failure? • How might uncertainty in procurement for future fuels be reduced?
Interface management	• At what interfaces is the risk of procurement failure identified in past incidents and the interview data? Who are the interface participants? What are the interface issues that contribute to the risk of procurement failure? • What are the key interfaces that need management attention in the future fuels environment? What do successful interface interactions look like? • What should be done to achieve successful interface interactions and reduce procurement risks for future fuels?
Supply chain resilience	• Do interviewees describe procurement failures that can be linked to a lack of supply chain resilience? • Can the cases of procurement failures be linked to a lack of supply chain resilience? • If so, how might system resilience be increased so as to better manage the potential for procurement problems in the context of future fuels?
Temporality	• How is temporality in procurement experienced by decision makers? • What meaning is given to past and current events that could impact procurement outcomes? How are these events brought into play in making procurement decisions now for the best outcomes in the future? • How do different actors experience the pace of activity? Does this have implications for procurement risk? • Are there risk management implications from the episodic nature of procurement? If so, what and how are they best mitigated? • How could processes linked to temporality be improved in order to gain better procurement outcomes?

High reliability networks	• To what extent do supply chain participants see themselves as part of an integrated network? • How do the various actors across the procurement chain conceptualize ‘never events’ and how to avoid them? To what extent do the actors agree? • To what extent do the other likely properties of high reliability networks exist in current energy sector procurement? • Are there ways reliability could be enhanced, particularly in the context of future fuels?

5 Conclusions

Referring back to the research questions in the introduction, the results of the work to date are summarised below.

- Why have past significant procurement failures in the gas industry and elsewhere occurred? What can be learned from them?

In the first stage of the project, a preliminary taxonomy of procurement risks was constructed based on a literature review and information on past procurement failures that is in the public domain. A wide range of risks have been identified with the two most commonly occurring in the failure cases identified as 1) problems with supply chain configuration (e.g., selecting a supplier who is not suitable) and 2) QA/QC issues (e.g., tests not conducted or not reflecting service conditions). There has been little data on gas sector procurement failures that is readily available to draw on (See Interim Report #1).

- What are the risks associated with the procurement process in the gas industry and what risk governance practices can be used to prevent the recurrence of procurement failures in the context of future fuels?

From the experience of industry professionals interviewed for this stage of the project, the most common issues associated with procurement in the gas industry are (1) inadequate planning, (2) problems with specifications, (3) poor contractor/supplier selection processes, (4) logistics issues (e.g., damages in transit, delays to delivery and custody transfer), and (5) manufacturing QA/QC failures. The current Covid-19 pandemic is also identified as one of the crucial risk factors deriving from the external environment that has caused disruptions in the global supply chains, particularly international shipping.

Interviewees suggested a range of good practices to minimize risks associated with the procurement process in the gas industry (Table 5). Challenges in relation to procurement risk governance in a future fuels environment have also been identified with four issues being highlighted as the most challenging: (1) planning, (2) skill resource, (3) standards and (4) regulation.

- What does a robust procurement risk governance framework look like in a future fuels environment?

This will be developed in later stages of the project.

Most of the work done to date provides input into later stages of the project but this report also addresses new perspectives that will be used in the next phase to develop a new risk governance framework to support procurement in a future fuels environment. These perspectives are uncertainty, interface management, resilience, temporality and high reliability networks.

6 Implications and recommendations for industry

Implications and recommendations for industry will be developed in later stages of the project.

7 Next steps and future works

The initial analysis of the interview data (above) and the past procurement failures (Interim Report #1) have considered procurement failure as an issue of risk. This has been a useful way to gain an understanding of what can go wrong and also some of the reasons why. This stage of the work has also identified five other perspectives (uncertainty, interface management, resilience, temporality and high reliability networks) that may be useful in determining practices to prevent future procurement failures.

Drawing from the good practices and new perspectives to reduce risks associated with the procurement process in the gas industry, the final report which is due in December 2022 will focus on the risk governance framework to improve procurement outcomes in a future fuels environment.

8 References

Al-Hammad, A.-M. (2000). Common interface problems among various construction parties. *Journal of performance of constructed facilities*, *14*(2), 71-74.

Aven, T. (2012). The risk concept—historical and recent development trends. *Reliability Engineering & System Safety*, *99*, 33-44. https://doi.org/10.1016/j.ress.2011.11.006

Aven, T. (2018). An Emerging New Risk Analysis Science: Foundations and Implications. *Risk Analysis*, *38*(5), 876-888. https://doi.org/10.1111/risa.12899

Aven, T., Baraldi, P., Flage, R., & Zio, E. (2014). *Uncertainty in Risk Assessment: The Representation and Treatment of Uncertainties by Probabilistic and Non-Probabilistic Methods*. John Wiley & Sons Ltd.

Aven, T., Renn, O., & Rosa, E. A. (2011). On the ontological status of the concept of risk. *Safety Science*, *49*, 1074-1079.

Berthod, O., Grothe-Hammer, M., Müller-Seitz, G., Raab, J., & Sydow, J. (2017). From High-Reliability Organizations to High Reliability Networks: The Dynamics of Network Governance in the Face of Emergency. *Journal of Public Administration Research And Theory*, *27*(2), 352–371.

Berthod, O., Grothe-Hammer, M., & Sydow, J. (2015). Some Characteristics of High-Reliability Networks. *Journal of Contingencies and Crisis Management*, *23*(1), 24-28. https://doi.org/10.1111/1468-5973.12069

Blount, S., Waller, M. J., & Leroy, S. (2005). Coping with temporal uncertainty: When rigid, ambitious deadlines don't make sense. . In W. H. Starbuck & M. Farjoun (Eds.), *Organization at the limit: Lessons from the Columbia disaster* (pp. 122-139). Blackwell Publishing.

Brady, T., & Davies, A. (2010). From hero to hubris – Reconsidering the project management of Heathrow's Terminal 5. *International Journal of Project Management*, *28*(2), 151–157.

CAIB. (2003). *Report of the Columbia Accident Investigation Board, Volume 1*.

Carvalho, H., Barroso, A. P., Machado, V. H., Azevedo, S., & Cruz-Machado, V. (2012). Supply chain redesign for resilience using simulation. *Computers & Industrial Engineering*, *62*(1), 329-341.

Chan, W. T., Chen, C., Messner, J. I., & Chua, D. K. (2005). Interface management for China's build–operate–transfer projects. *Journal of construction engineering and management*, *131*(6), 645-655.

Chen, Q., Reichard, G., & Beliveau, Y. (2008). Multiperspective approach to exploring comprehensive cause factors for interface issues. *Journal of construction engineering and management*, *134*(6), 432-441.

Czarniawska, B. (2013). Is speed good? *Scandinavian Journal of Management*, *29*, 7-12.

Grey, C. (2003). The fetish of change. *Tamara*, *2*, 1-19.

Grey, C. (2009). Speed. In P. Hancock & A. Spicer (Eds.), *Understanding corporate life* (pp. 27-45). Sage.

Hamel, G., & Valikangas, L. (2003). The Quest for Resilience." Harvard Business Review, September.

Hayes, J., & Hopkins, A. (2014). *Nightmare pipeline failures: Fantasy planning, black swans and integrity management*. CCH.

Hayes, J., & Tillement, S. (Eds.). (2022). *Contracting and Safety: Exploring Outsourcing Practices in High-Hazard Industries*. Springer.

Hernes, T. (2022). *Organization and Time*. Oxford University Press.

Hollnagel, E., Woods, D. D., & Leveson, N. (2006). *Resilience engineering: Concepts and precepts*. Ashgate Publishing, Ltd.

ISO. (2009). *Risk Management—Principles and Guidelines.*

Lawson, M. B. (2001). In praise of slack: Time is of the essence. *The Academy of Management Executive*, *15*(3), 125-135.

Lindley, D. V. (2014). *Understanding Uncertainty*. John Wiley & Sons.

Mahoney, E., Golan, M., Kurth, M., Trump, B. D., & Linkov, I. (2022). Resilience-by-Design and Resilience-by-Intervention in supply chains for remote and indigenous communities. *Nature Communications*, *13*(1), 1-5.

Morris, P. W. (1983). Managing project interfaces–key points for project success. In D. Cleland & W. King (Eds.), *Project management handbook* (pp. 16-55). Van Nostrand.

Murphy, R. (2012). Managing Risk Under Uncertainty. In T. Measham & S. Lockie (Eds.), *Risk and Social Theory in Environmental Management*. CSIRO Publishing.

Olson, D. L., & Swenseth, S. R. (2014). Trade-offs in supply chain system risk mitigation. *Systems Research and Behavioral Science*, *31*(4), 565-579.

Panwar, R., Pinkse, J., & De Marchi, V. (2022). The Future of Global Supply Chains in a Post-COVID-19 World. *California management review*, 00081256211073355.

Park, J., Seager, T. P., Rao, P. S. C., Convertino, M., & Linkov, I. (2013). Integrating risk and resilience approaches to catastrophe management in engineering systems. *Risk Analysis*, *33*(3), 356-367.

Pavitt, T., & Gibb, A. (2003). Interface management within construction: In particular, building façade. *Journal of construction engineering and management*, *129*(1), 8-15.

Pereira, C. R., Christopher, M., & Da Silva, A. L. (2014). Achieving supply chain resilience: the role of procurement. *Supply Chain Management: An International Journal*.

Ponis, S. T., & Koronis, E. (2012). Supply Chain Resilience? Definition of concept and its formative elements. *The Journal of Applied Business Research*, *28*(5), 921-935.

Ponomarov, S. (2012). Antecedents and consequences of supply chain resilience: a dynamic capabilities perspective.

Project Management Institute. (2021). *A Guide to the Project Management Body of Knowledge (PMBOK® Guide) – Seventh Edition*. ProQuest
Reason, J. (1997). *Managing the Risks of Organizational Accidents*. Ashgate.
Reason, J. (2000). Safety paradoxes and safety culture. *Injury Control and Safety Promotion*, *7*(1), 3-14.
Renn, O. (2008). *Risk Governance: Coping with Uncertainty in a Complex World*. Earthscan.
Renn, O., & Klinke, A. (2012). Complexity, Uncertainty and Ambiguity in Inclusive Risk Governance. In T. Measham & S. Lockie (Eds.), *Risk and Social Theory in Environmental Management* (pp. 59-76). CSIRO Publishing.
Scott, W. G. (1961). Organization theory: An overview and an appraisal. *Academy of Management Journal*, *4*(1), 7-26.
Shokri, S., Haas, C. T., G. Haas, R. C., & Lee, S. H. (2016). Interface-management process for managing risks in complex capital projects. *Journal of construction engineering and management*, *142*(2), 04015069.
Shokri, S., Safa, M., Haas, C. T., Haas, R. C., Maloney, K., & MacGillivray, S. (2012). Interface management model for mega capital projects. Construction Research Congress 2012: Construction Challenges in a Flat World,
SRA. (2018). *Society for Risk Analysis Glossary*. https://www.sra.org/wp-content/uploads/2020/04/SRA-Glossary-FINAL.pdf
Sutcliffe, K. M. (2011). High reliability organizations (HROs) *Best Practice & Research Clinical Anaesthesiology*, *25*(2), 133-144.
Tang, C. S. (2006). Perspectives in supply chain risk management. *International Journal of Production Economics*, *103*(2), 451-488. https://doi.org/https://doi.org/10.1016/j.ijpe.2005.12.006
Tukamuhabwa, B. R., Stevenson, M., Busby, J., & Zorzini, M. (2015). Supply chain resilience: definition, review and theoretical foundations for further study. *International Journal of Production Research*, *53*(18), 5592-5623.
Turner, B. A. (1976). The Organizational and Interorganizational Development of Disasters. *Administrative Science Quarterly*, *21*(3), 378-397.
Turner, B. A. (1978). *Man-made disasters*. Wykeham Publications (London) Ltd.
Turner, B. A., & Pidgeon, N. F. (1997). *Man-made Disasters* (Second ed.). Butterworth.
Walker, B. (2020). Resilience: what it is and is not. *Ecology and Society*, *25*(2).
Weick, K. E. (2011). Organizing for Transient Reliability: The Production of Dynamic Non-Events. *Journal of Contingencies and Crisis Management*, *19*(1), 21-27.
Wieland, A., & Durach, C. F. (2021). Two perspectives on supply chain resilience. *Journal of business logistics*, *42*(3), 315-322.
Wieland, A., & Wallenburg, C. M. (2013). The influence of relational competencies on supply chain resilience: a relational view. *International journal of physical distribution & logistics management*.
Wren, D. A. (1967). Interface and interorganizational coordination. *Academy of Management Journal*, *10*(1), 69-81.
Yao, Y., & Meurier, B. (2012). Understanding the supply chain resilience: a Dynamic Capabilities approach.

THIS PAGE SHOULD BE LEFT BLANK

Future Fuels CRC

Enabling the Decarbonisation of Australia's Energy Networks

www.futurefuelscrc.com

info@futurefuelscrc.com

Australian Government
Department of Industry, Science, Energy and Resources

Business Cooperative Research Centres Program