FUTURE FUELS CRC

Learning lessons from procurement failures:

Improving future fuels project outcomes

Produced as part of FFCRC project RP2.3-06
Risk Governance for Procurement in Future Fuels

November 2022

Foreword

David Norman
CEO, Future Fuels CRC

The mission of Future Fuels CRC is to enable Australia's energy sector to adapt its infrastructure to net zero emissions fuels. The opportunities, benefits and urgency of decarbonisation are very real, but we can never lose sight of our number one priority, safety. A key research program for Future Fuels CRC is to develop world-class best practice safety and reliability performance and to reduce the risk of major incidents. Australia's energy sector's safety performance is world leading and we must build on this by looking at our operations every day with fresh eyes and a truly global perspective. These case studies are designed to give teams at every level access to the root causes of major incidents that started at the procurement phase of the project. From the boardroom to onsite toolbox talks, these stories are thorough and easy to use, giving your team the opportunity to build better, safer processes and ways of working. So please do share these stories with your colleagues and discuss how your team can learn lessons of the past for a safer introduction of fuels for the future.

Foreword

E. (Ted) Metcalfe

Independent Consultant and
Industry Advisor to this Research Project

Learning lessons from the mistakes of others

In my career spanning more than forty years as a professional engineer in the oil and gas industry, I have witnessed many examples of unplanned outcomes with procurement processes, and I am confident that this research project will deliver real value for our industry.

Although I joined the oil and gas industry in Canada, for most of my career I have worked all around Australia in the transmission pipeline industry with operating companies, engineering consultancies, construction companies, and finally for many years as an independent consultant. This variety has allowed me to observe procurement transactions from several different perspectives.

That experience, plus a reading hobby driven by a passion for understanding what went wrong with failure of complex engineered systems, has encouraged me to advocate for knowledge transfer through sharing stories, and for assurance of process safety and system integrity in all aspects of the pipeline industry.

Being involved with APGA, the RSC and FFCRC by assisting with research projects that examine the influence of organisational factors on engineering practice and public safety has given me a great opportunity to pursue this advocacy.

We can be justly proud of our record of safety and reliability in Australia, however, because we transmit mostly fossil fuels, our public image is struggling badly in the face of the climate change debate.

To retain the respect of the public we need to change.

Our challenge is to safely and effectively repurpose the pipeline industry by combining the existing fossil fuel transmission assets with innovative new technologies in order to assist the energy transition and decarbonisation effort being led by the FFCRC.

Sadly, some previous attempts to introduce new technology into an existing industry have ended in disaster, including the development of reusable spaceships, supersonic airliners and composite building cladding materials, to name just a few.

In addition, many other well-known failures around the world have resulted at least in part from mistakes made in procurement transactions, and this booklet outlines the details and lessons learned in a number of those events.

We must learn and apply the lessons of such failures. To assist FFCRC members with that learning, this booklet has been produced as the first of a number of outputs from this research project.

We must carefully consider all the risks in our procurement processes, or we risk losing public support, and the Australian gas transmission pipeline system will become a white elephant.

We will only get one chance to achieve this transition to the future fuels economy.

Foreword

Professor Jan Hayes

RMIT University

Plans for decarbonisation of the gas industry and the development of a new future fuels sector will lead to an explosion of project activity in coming years and with it, billions of dollars in procurement of goods and services. These exciting times must be tempered with excellence in supply chain management.

Procurement problems can be catastrophic. Seventy-two residents of the Grenfell Tower in the UK died in 2017 when a small fire in one apartment spread rapidly to the rest of the building as a result of flammable cladding that recently had been installed on the outside of the building. While this terrible event shines a light on procurement issues in the built environment sector, a subsequent review showed that similar potential exists in UK civil construction more broadly. This potential for latent problems in procurement combined with significant new project work to implement plans in the gas sector for future fuels was the motivation for suggesting to the Future Fuels CRC that research on procurement risk governance might be appropriate. This provided the genesis of FFCRC project RP2.3-06, of which this booklet is a part.

Working with the pipeline sector over the past fifteen years has left me in no doubt that engineers love to learn about past failures to improve their own professional practice. With that in mind, we have produced this booklet summarising lessons from past procurement failures. Lessons for the pipeline sector are drawn from procurement failures in sectors such as energy, chemicals and infrastructure based on public domain information.

I would like to acknowledge my co-authors Dr Yen Pham, Dr Rita Zhang and Dr Nader Naderpajouh. Viet Hoang and Erin Mellencamp also provided excellent production support. The project has received important input and support from our industry advisers, particularly Ted Metcalfe. The Institution of Chemical Engineers' recent publication *Learning lessons from major incidents: Improving process safety by sharing experience* was another inspiration in preparing this booklet.

The cases can be shared as a set using the entire publication, but the format is designed so that individual cases can be extracted into a standalone PDF or physically printed across an A3 or A4 page (depending on the length) to allow wider distribution.

Detailed research reports are available to participants on the FFCRC website, and further dissemination materials such as this will become available over coming months.

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Industry Endorsements

Michael Malavazos

Director, Engineering Branch, SA Department for Energy and Mining

As the lead regulator for the South Australian oil and gas and transmission pipeline sectors, one of my key objectives is to maintain a strong regulatory and industry focus on process safety management. As a key element of any PSM framework, root causal analyses have revealed that deficiencies in procurement processes have significantly contributed to many losses of containment incidents. Some specific deficiencies relate to poor supplier workmanship, critical parts and components not meeting design specifications, poor quality assurance and poor vendor management practices, to name a few. This experience is demonstrable proof that an effective procurement risk management system is essential for the safe and reliable delivery of projects. The lessons learnt from the case studies detailed in this booklet can be an invaluable source of information towards the development of such systems, not only for the oil and gas sectors but the impending future fuels sector.

Peter Cox

Vice President, Energy & Chemicals - Australia East & PNG, Worley

As a director of the Future Fuels CRC, past president of APGA and a 30+ year career with Worley bidding and executing oil and gas projects, I have regularly seen procurement teams placing orders purely on the basis of lowest cost without regard to quality and its impact on lifecycle cost. This publication tells the story of some notable failures associated with supply chain issues in an easy to read and really interesting way which is the best way to learn from others without having to learn the hard way. As we transition to a net zero economy, our industry faces a massive challenge to construct and re-purpose energy infrastructure in a compressed timeframe to achieve our climate commitments. The way we have traditionally managed supply chains will not enable us to complete all of this work in time so there is a need for companies to work effectively together in partnership ecosystems rather than in competition to share lessons learnt and technology to build many projects in parallel rather than in series. There is a danger in this environment where teams are too busy that mistakes from the past will be repeated. I hope that the stories in this publication will reinforce the need to work smarter rather than faster and to collaborate and support each other to deliver safe and reliable infrastructure.

Tony Williams

Director, GPA Engineering

As an Engineer and Project Manager for 39 years in the implementation, consulting and delivery of many pipelines and industrial projects across a myriad of industries, I have observed how poor procurement practices can result in poor project outcomes. I have also observed the consequences of these poor practices during insurance claim investigations on behalf of the insurance companies where significant failures have occurred through poor procurement and operational processes and have resulted in serious damage to the clients' bank balance and reputation.

Projects are required to be completed in shorter times frames and much of what we purchase for projects in Australia comes from overseas and this introduces not only pressure on early purchase but a lack of transparency in manufacturing, testing and delivery with high risks to final product quality and suitability before it arrives at the project site to be incorporated into a project.

The high dollar value for procured goods from overseas can also introduce fraudulent practices or substandard manufacturing processes resulting in poor purchased product quality. Procurement requires a vendor to have a strong quality reputation and demonstration of similar experience. The vendor must have quality-assured processes in materials selection, manufacturing, product testing, validation against specification, manual handling and packaging, and method of delivery. Using a risk-based approach enables both the vendor and the buyer to ensure the key risk areas for different processes, materials and equipment have been identified and appropriate controls are in place.

Storytelling through case studies is an important way to ensure the presentation and preservation of many of the key risk areas and enables education to a wide audience with different levels of experience in the purchasing process. Australia and the world currently have a significant number of large-scale traditional projects and new energy projects involving new and less mature organisations and manufacturers. This presents a time of high risk commercially, technically and safely and so I believe the issue of this body of work is very timely and should be a must-read. This approach provides value for the new products, environments (e.g. space) and manufacturing processes that are being developed currently.

Kane Ramsay

President, Enscope

In my 30-plus years in the industry I have witnessed first-hand changing procurement practices often leading to poorer project outcomes. While increased governance has been necessary in response to past shortcomings, too often Project Management has become dis-empowered and Procurement departments have been incentivised to chase “lowest price” at the expense of “best value”.

This FFCRC Research Project has explored the organisational factors, the decision making processes and the contributing causes across a range of Project Failures with the aim of assisting the industry to learn from past mistakes. Facilitating the pipeline industry’s place in a future decarbonised economy will be challenging enough without having to re-learn hard lessons.

I commend the Research Team under Professor Hayes for their contribution to our shared knowledge and encourage all industry participants with involvement in procurement to take the time to read this booklet.

Steve Davies

CEO, Australian Pipelines & Gas Association

In an increasingly complex and challenging operating environment, taking the time to understand the lessons of past failures is both increasingly important and increasingly hard to do. This project intends to make it easier to learn from the past and it is an unqualified success. The information is presented in a highly digestible format and the specific procurement lessons are identified and set out for the reader. With the scale of the decarbonisation task ahead and the fundamental influence the procurement process has over every project, this booklet is essential reading for everyone involved in project delivery in any sector.

Mark Fothergill

General Manager, Infrastructure Engineering, APA

High reliability industries are constantly striving to manage risks. This new study highlights the critical relationships between engineers, procurement specialists and project managers, and deficiencies that can result in significant losses, extensive schedule delays and serious harm. This booklet is an easy read, presenting procurement lessons on 19 case studies. Ask yourself, are you and your staff aware of and managing the 5 top procurement lessons?

Chris F Yoxall

Vice President, North America, ROSEN Group

Having worked for 3 decades in Africa, Australia, Asia and North America, I have seen not only the differences in how procurement has changed over time, however I have also seen differences from a geographical point of view. The role of procurement within the supply chain process becomes extremely crucial today, more so than in the past given market drivers that have never been seen before. The work that FFCRC has undertaken, under the guidance of Professor Jan Hayes and her team has allowed us to benefit from exploring lessons learnt. This booklet is a must read for all in a management capacity.

Sector: Oil Industry

Buncefield Tank Farm Fire

Description

The immediate trigger for the December 2005 catastrophe at the Buncefield oil storage depot in the UK was a large petrol storage tank that overflowed whilst it was being filled from a pipeline. The magnitude of the resultant vapour explosion was much greater than anyone knew was possible. Houses close to the terminal were destroyed, and buildings as far as 8km away had windows broken. Forty-three people received minor injuries (but there were no fatalities). Over 20 large storage tanks on the site were destroyed in the subsequent fire, which burned for five days. There was also significant damage to the adjacent industrial estate and interruption to aviation fuel supplies in the UK. The response involved over 1000 emergency services personnel.

The failure

Hertfordshire Oil Storage Ltd (HOSL) operated part of the Buncefield site. Tank 912 was being filled with unleaded petrol from a pipeline. The tank was overfilled because the tank gauging system was not working and the independent high-level system in place failed to shut off the supply to the tank. Petrol continued to flow from the top of the tank into the surrounding bund, and a large vapour cloud formed. At 6am on Sunday 11 December 2005, the first explosion occurred likely ignited by traffic in a nearby carpark.

The Buncefield fire highlights procurement issues with the tank level instrumentation where the operation of a key safety device was compromised by poor design and lack of communication along the supply chain.

The independent high-level switch

The high-level switch that failed to protect the tank had been supplied by a company called TAV Engineering in July 2004. The switch design allowed for some functionality to be routinely tested, but the design also meant that it was easy for the switch to be left in a non-functioning state after such tests had been performed. A padlock was used to lock a lever into the 'operational' position. During testing, the padlock was removed to allow the test lever to be moved. Then the padlock was reinstated to ensure that the test lever did not interfere with operation of the switch. Without the padlock in place, there was no guarantee that the switch was functional. This is not a good design for a safety-critical instrument. TAV was aware that the switch would be used in a safety-critical application, but they chose not to modify the design. The switch was replacing a model that did not include this padlock design.

The switch was part of an overall tank instrumentation package designed by Motherwell Control Systems. Motherwell engineers did not understand the criticality of the lever position or the padlock and saw it only as an anti-tampering device. TAV did not tell them and they did not ask, despite the safety-critical nature of the switch. The subsequent investigation criticised Motherwell's actions as follows:

- *'The process for ascertaining and then specifying the requirements of switches they supplied and/or installed was not adequate.*
- *They did not obtain the necessary data from the manufacturer and it follows that they did not provide such data to their customers.*
- *They did not understand the vulnerabilities of the switch or the function of the padlock.*
- *There was a reliance on TAV, which was not justified given the lack of information provided and the critical role that Motherwell had in installing safety-critical equipment.'* (COMAH, 2011, pg 14)

HOSL was also criticised for failing to provide sufficient oversight of the ordering, installation and testing procedures. The switch was tested periodically, but operational personnel were not aware that the padlock needed to be in place in order to hold the test lever in the correct position for the device to perform its safety-critical function. The Competent Authority for Control of Major Accident Hazards (COMAH) also criticised aspects of the contractual relationship between HOSL and Motherwell, saying:

'Where contractors are engaged to carry out work upon which the safety of many and much depends, something more rigorous than the evident casual relationship with Motherwell was called for:

- *There should have been a formal contract in place clarifying the expectations inherent in safety-critical work.*
- *There should have been an effective system of reporting and recording all significant faults and their resolution. This system should have been understood and implemented by both contractual partners.*
- *Reliable and up-to-date specifications of what was in place and what was required should have been provided.*
- *Critically, in respect of the replacement of the IHLS switches in 2004, there should have been a formal "management of change" process. This typically would have included an engineering assessment of the benefits and disadvantages of any such change, and a consideration of what changes in procedures (e.g., in testing) would be necessary as a result.'* (COMAH, 2011, pg 20)

Procurement lessons to be learned

1. Responsibilities for safety-critical equipment must be formally specified.
2. Vendor data on key items is critical.
3. Effective management of change is important when procuring replacement items.
4. Clear specifications for safety-critical equipment must be mandatory.

More information

COMAH. (2011). *Buncefield: Why did it happen? The underlying causes of the explosion and fire at the Buncefield oil storage depot, Hemel Hempstead, Hertfordshire on 11 December 2005.*

Hayes, J., & Maslen, S. (2018). Buncefield stories: organizational learning and remembering for disaster prevention. In R. Gephart, C. Chet Miller, & K. S. Helgesson (Eds.), *The Routledge Companion to Risk, Crisis and Emergency Management Routledge.*

Sector: Chemical industry

Hawaii Fireworks Disposal Explosion and Fire

Description

On 8 April 2011, an explosion and fire resulting in the deaths of five workers occurred at a magazine that stored explosive materials. The workers were employed by Donaldson Enterprises, Inc. (DEI). They had been disassembling fireworks for disposal. The process they followed involved disassembling each firework into its component parts and accumulating the components, including explosive components. They were doing this work outdoors. Just prior to the incident, it started to rain, so the materials and various metal and plastic objects were moved inside the entrance to the magazine, where explosive materials were stored. In these dangerous conditions, the entire load exploded simultaneously.

Contractor selection and supervision

DEI is a small firm whose primary business is storing unexploded ordnance on behalf of the US government. In early 2010, they were awarded a government contract to dispose of fireworks seized by customs officials in Hawaii. DEI was awarded the contract because at the time, they were already storing the seized fireworks, and their bid was assessed as the best overall value for money. DEI had no prior experience in fireworks disposal, but this was not known to government procurement personnel, nor was it uncovered during the procurement process.

Before disposing of the initial batch of fireworks in the first half of 2010, DEI had produced a risk assessment and a procedure for the disposal activity, both of which were submitted to the relevant government agency. No one at the agency had the technical skills to evaluate the quality of the work done, and no feedback was provided. Due to minor operational problems with the disposal, the procedure was modified on several occasions and each time submitted to the government agency with no feedback received. The risk assessment was never updated and did not consider hazards associated with disassembly that occurred at the time of the incident.

Procurement lessons to be learned

1. Contractor selection criteria must take into account technical experience when complex hazardous tasks are involved.
2. Responsibilities must be clearly defined through the supply chain, and those responsible must be competent.
3. Change management processes must consider any impacts on the performance of hazardous tasks.

More information

CSB. (2013). *Investigation report: Donaldson enterprises, inc. Fireworks disposal explosion and fire*. 8 April 2011. U.S. Chemical Safety and Hazard Investigation Board. https://www.csb.gov/donaldson-enterprises-inc-fatal-fireworks-disassembly-explosion-and-fire/

> ***Contract for hazardous work awarded to contractor with no specific experience***

Sector: Chemical industry

Explosion at Shell Moerdijk Petro-chemical Plant

Description

On 3 June 2014, an unexpected chemical reaction took place in a reactor vessel in the propylene oxide-styrene monomer plant. The system became overpressured, and the reactor exploded. The explosion sent large debris up to 250m and smaller items up to 800m; it was heard 20km away. Two operators were nearby and were injured by the blast wave and burning catalyst pellets. Smoke from the ensuing fire covered adjacent local residential areas and triggered local crisis management arrangements. Subsequent studies showed no offsite smoke impact on health in the local area.

Catalyst purchasing

The reactor system was being put back in service after maintenance at the time of the incident. In accordance with well established procedures, ethylbenzene was being used to heat the reactor contents. Tests conducted in 1977 when the original system was designed had shown that heating the catalyst bed in this way did not cause any unexpected reactions. This finding was assumed to hold through subsequent decades despite changes to the system including, critically, a change to the catalyst type used in the reactor.

A new catalyst was selected for use in 1999 that was less safe in use with ethylbenzene, although this was not recognised at the time. In 2011, the catalyst manufacturer changed its production process, which resulted in new chromium impurities being introduced into the catalyst. This information was included in safety information sheets provided to Shell after 2011 but was not specifically highlighted. These two factors combined meant that the catalyst was safe to use in normal operations, but a runaway reaction was possible when the catalyst was exposed to hot ethylbenzene.

Procurement lessons to be learned

1. Management of change processes must cover all routinely supplied items and include changes initiated by suppliers.

More information

Dutch Safety Board. (2015). *Explosions MSPO2 Shell Moerdijk*. https://www.onderzoeksraad.nl/en/page/3438/explosions-mspo2-shell-moerdijk

Leveson, N. (2017). *CAST Analysis of the Shell Moerdijk Accident*. http://sunnyday.mit.edu/shell-moerdijk-cast.pdf

> ***Management of change fails to consider supplier-initiated change***

Sector: Infrastructure

Channel Tunnel

Description

The Channel Tunnel, completed in 1994, was the largest private sector infrastructure project of the twentieth century. It comprised two 7.6m diameter rail tunnels and a 4.8m diameter service tunnel running approximately 50km beneath the Straits of Dover, plus all associated infrastructure and rolling stock. While the competition to build the tunnel was sponsored and initially organised by the French and UK governments, the project was built with no government guarantees – financing was left to the market.

The project was 19 months late and cost more than double the original estimate, which led to major questions about the financial viability of the tunnel throughout the 1990s. The project was a technological success but a financial failure whereby each passenger who uses the service is heavily subsidised by the private investors who financed the project.

The initial project structure

The British and French governments set up a competition to build, own and operate a fixed channel link. The four submitted tenders included proposals for various kinds of bridges and tunnels. Tender evaluation was done on the basis of financial and technical viability. The successful consortium of banks and construction companies was chosen with no consideration of their competence in ongoing operation of major infrastructure despite that being part of the scope. The winning consortium proposed a project to design, build, equip and commission the tunnel system over 4½ years to May 1993 at a cost of £4.87 billion. Ultimately the cost blew out to over £10 billion.

The winning consortium established an entity called Eurotunnel to raise the finance for the project and a construction company called Trans-Manche Link (TML) which contracted with Eurotunnel to design, build and commission the system. It is now accepted that a more comprehensive planning stage and establishment of a clearer ongoing owner for the infrastructure would have avoided many of the later problems. The technical director of Eurotunnel from 1985 to 1991 later described this method of managing the overall project setup as *'like releasing a mouse at a Christmas party – the reactions of all those affected are unpredictable and uncoordinated, and everybody believes that he knows what the end result will be'* (Kirkland, 1995, pg 5).

Lack of a 'client'

The intent was that over the duration of the project, Eurotunnel could transform from a financing agency of the contractors into an owner and eventually operator of the Tunnel. As such, Eurotunnel took over immediate responsibility for project management of design and construction, and ultimate responsibility of tunnel operations for the next 55 years. By this time, TML was well underway, and they had no interest in supporting anything other than a weak client to oversee them.

As the project proceeded, several major areas of disagreement arose. A key point of dispute related to finding the best balance between capital and operating costs. Since TML was responsible for capital cost and Eurotunnel was responsible for operating costs, the interests of the parties diverged significantly. In a contracting environment that also favoured a fast-track approach of simultaneous design and construction, conflict was inevitable.

> ***Largest private infrastructure project***
>
> ***19 months late, price doubled***
>
> ***Lack of planning at every stage***

A consequence of the structure of the project was the poor handling of the interface with the Intergovernmental Commission (IGC), the project's impartial regulatory and safety watchdog. IGC required major design changes on safety grounds as the project proceeded. Many of them were imposed after supplier contracts had been signed. TML made a series of claims against Eurotunnel, who in turn made several claims against IGC.

Another problem was that the whole project benefit was contingent upon construction of high-speed land links to complete the transport route between Paris and London, which the French government did but the UK did not for some time. This broader work to embed the Tunnel in a full operating system was another client responsibility that was done poorly in the initial stages because of the way that Eurotunnel came into existence.

The winning consortium included five French firms and five British firms, leading to a necessarily multinational, multilingual workforce. Nearly 13,000 people worked directly on the construction of the tunnels (more than 100 million working hours). In the early stages of the work, there were effectively two separate projects operating at two different sites on either side of the Channel. This arrangement compounded communications problems and lack of trust.

Dispute resolution

The banking consortium had a major influence on the contracting strategy and rolled everything into one contract with various ways of compensating for different aspects of the work. Separate contracts with requirements driven by the technical needs of the purchase (such as uncertainty/risk and expertise) would have led to easier project management and a more cost-effective outcome. A single contract made for an uncompetitive and adversarial relationship. This culminated as a highly adversarial relationship between the client organisation and the primary construction company and a 'winners and losers' mentality. Dispute resolution processes were triggered continually.

Both TML and Eurotunnel were restructured several times and made claims against each other as the project proceeded, which led to initiation of the formal dispute resolution clauses in the main contract. Dispute resolution was driven by each party seeking to minimise its financial liability.

Procurement lessons to be learned

1. Ensure sufficient upfront effort on projects to define a clear scope and tender evaluation process.
2. Contractors must have demonstrated competence in all activities they are expected to undertake. If appropriate contractors cannot be found, the scope of work may need to be divided into smaller packages.
3. A strong owner is needed to ensure that the purpose of the project remains the key priority throughout.
4. Early engagement with regulators is critical so that requirements and a time frame for key reviews and approvals are established.
5. Project structures must foster relationships with existing operations so that interfaces are well-managed, or project benefits may not be realisable.
6. Project risk management processes must be grounded in management of the engineering risks to project outcomes, and responsibility for residual risk must be shared.
7. Projects that involve team members of different nationalities working in different countries likely induce risks resulting from differences in legal systems, culture and tradition, disciplines, languages, ways of working and many others. Careful consideration must be given to such issues in the conceptual stages of the project and throughout project execution. A focus on effective communication must be prioritised and maintained to address cultural matters.
8. For complex projects, 'partnering' style contracts are preferred to align goals and share risk and reward.

More information

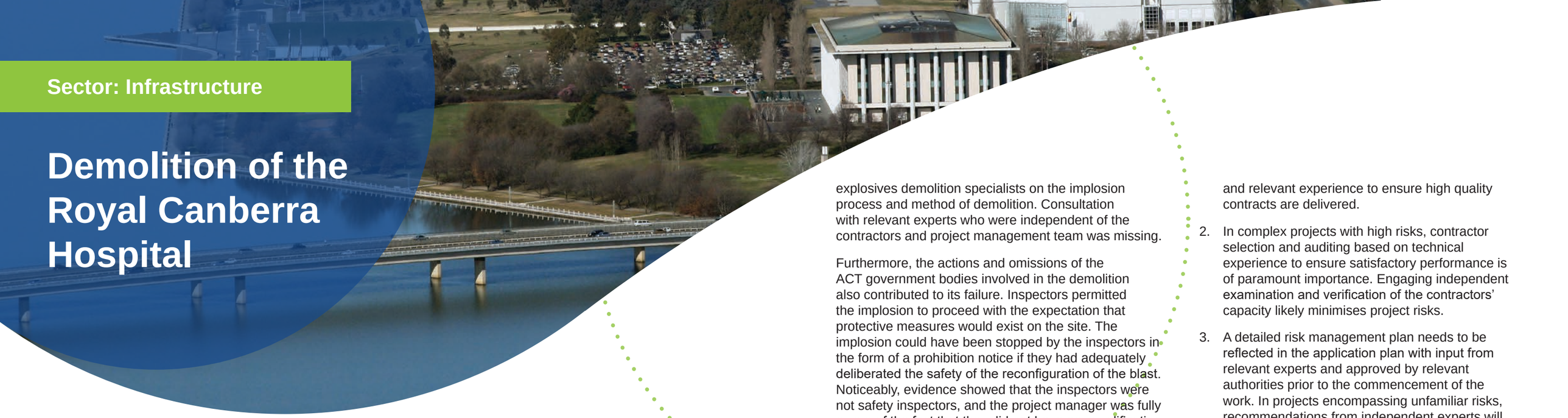
Flyvbjerg, B. (2014). What You Should Know About Megaprojects and Why: An Overview. *Project Management Journal, 45*(2), 6-19.

Genus, A. (1997). Unstructuring Incompetence: Problems of Contracting, Trust and the Development of the Channel Tunnel. *Technology Analysis and Strategic Management, 9*(4), 419-436.

Kirkland, C. J. (1995). The Channel Tunnel - Lessons Learned. *Tunnelling and Underground Space Technology*, *10*(1), 5-6.

Shani, W. (1993). Channel Tunnel hingsight. *TunnelTalk, Feb 1993*, 1-4.

Stannard, C. J. (1990). Managing a Mega-project - The Channel Tunnel. *Long Range Planning, 23*(5), 49-62.



Sector: Infrastructure

Demolition of the Royal Canberra Hospital

Description

On 13 July 1997, thousands of people gathered beside Lake Burley Griffin to watch the demolition by implosion of the old buildings of the Royal Canberra Hospital on Acton Peninsula. The event had been promoted as a public spectacle. When the demolition was triggered, a fragment was expelled from one of the corner columns of the main tower block, instantly killing Katie Bender, a young spectator 430m away in the crowd. The inquest report following the accident detailed factors contributing to the cause of death, which included the incorrect use of explosives, insufficient site preparation, the failure to obtain advice or consultation from experts, and inadequate protective measures and testing.

The cause of failure

The inquest report described the implosion project as a systemic failure with those involved failing to adequately comply with the standards and codes of practice as well as the requirements of contracts. While implosion, if carried out properly, is as safe as conventional methods of demolition, it is the use of this method by incompetent and inexperienced personnel that led to the death of a member of the public.

The responsibility for the safe conduct of the implosion project fell to the contractors and to those who employed and supervised them. The project director and manager were inadequately skilled in overseeing the task undertaken by the contractor and subcontractor. Their lack of competence led to inadequacies in assessing the quality of the tenders, the implosion method and the suitability of the contractors. This enabled final decisions to be made months prior to the finalisation of the tender process without any critical examination or consultation of the demolition proposal, which should have been carried out in a project of this kind.

Both the contractor and subcontractor were not sufficiently competent for a highly dangerous task, which resulted in failures in employing a correct methodology of implosion. These included using an excessive amount and a wrong type of explosives. Another factor was the failure to follow appropriate safety procedures, particularly protective measures on the site. The contractor also made incorrect cuts following the engineer's negligent approval and placed explosives on the incorrect side of the building's steel columns, which caused the blast to be directed at the spectators.

Another factor that contributed to the accident was a lack of supervision on the site by the engineer to ensure compliance with the approved method of cutting columns. The project also failed to obtain expert advice from experienced structural engineers and independent explosives demolition specialists on the implosion process and method of demolition. Consultation with relevant experts who were independent of the contractors and project management team was missing.

> ***Incorrect use of explosives***
>
> ***Insufficient safety measures***
>
> ***Inadequate contractor selection in a high-risk project***

Furthermore, the actions and omissions of the ACT government bodies involved in the demolition also contributed to its failure. Inspectors permitted the implosion to proceed with the expectation that protective measures would exist on the site. The implosion could have been stopped by the inspectors in the form of a prohibition notice if they had adequately deliberated the safety of the reconfiguration of the blast. Noticeably, evidence showed that the inspectors were not safety inspectors, and the project manager was fully aware of the fact that they did not have any qualification or expertise relevant to the demolition process.

However, while the inquest report concluded that the inspectors *'failed to meet the standards… reasonably expected by a competent WorkCover inspector'*, it acknowledged that they did not contribute or have any direct connection to Katie's death. The roles and responsibilities of inspectors were not to double check the credentials and experience of the contractors selected or to act as a safety officer to those on the site as required by law.

Another government failing was the absence of consultation with relevant regulatory authorities and inappropriate decisions to promote the implosion as a public event that engaged thousands of spectators in a high-risk environment. This indicates a lack of adequate consideration of public safety and awareness of significant risks inherent in the implosion project.

Procurement lessons to be learned

1. The contracting, tender and selection processes need to be led by those with appropriate expertise and relevant experience to ensure high quality contracts are delivered.
2. In complex projects with high risks, contractor selection and auditing based on technical experience to ensure satisfactory performance is of paramount importance. Engaging independent examination and verification of the contractors' capacity likely minimises project risks.
3. A detailed risk management plan needs to be reflected in the application plan with input from relevant experts and approved by relevant authorities prior to the commencement of the work. In projects encompassing unfamiliar risks, recommendations from independent experts will give rise to the overall interests of both the public and general work safety.
4. A quality assurance system needs to be active at all stages in high-risk projects to ensure safe project implementation throughout their life cycle.

More information

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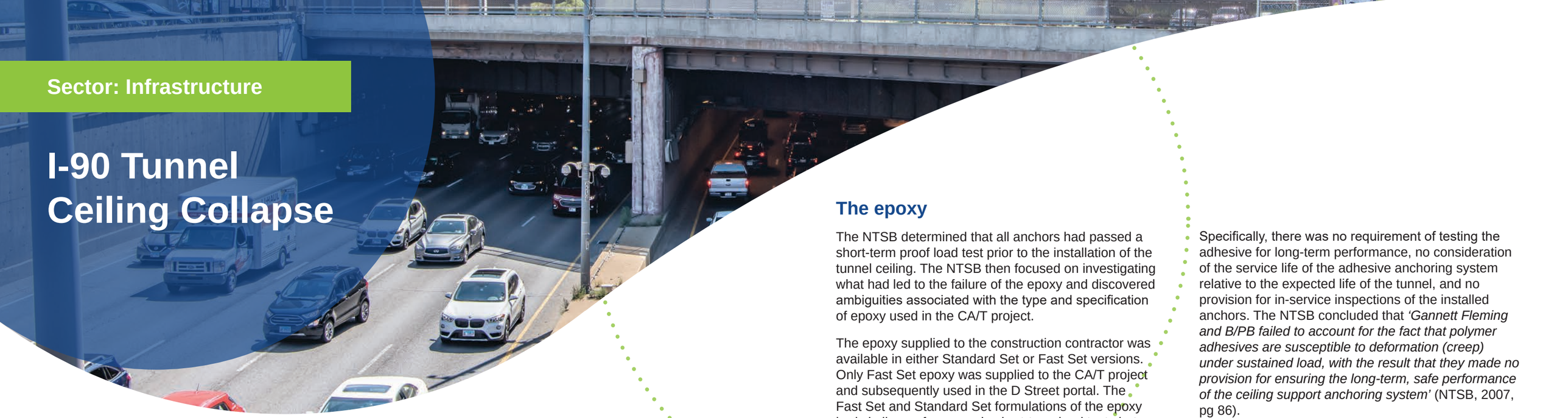
Madden, S. (1999). *Inquest findings, comments and recommendations into the death of Katie Bender on Sunday, 13th July 1997 on the Demolition of the Royal Canberra Hospital Acton Peninsula, ACT.* ACT Magistrates Court. https://courts.act.gov.au/__data/assets/pdf_file/0017/1008080/Katie-Bender-redacted.pdf

Sector: Infrastructure

I-90 Tunnel Ceiling Collapse



Description

The Interstate 90 (I-90) Connector Tunnel was constructed as part of the Central Artery/Tunnel (CA/T) project in Boston, which was also known as the Big Dig. This was one of the most costly and complex infrastructure projects in the USA with a final cost in excess of US$14 billion at completion in 2006. It was managed by Bechtel/Parsons Brinckerhoff (B/PB), a joint venture between two major engineering firms.

The incident

A section of approximately 2,600 feet of the cut-and-cover tunnel known as the D Street portal was opened to traffic in December 2000. On 10 July 2006, when a car was approaching the portal, a section of the tunnel's suspended concrete ceiling detached from the roof. About 26 tons of concrete and suspended components fell onto the car and the roadway. The driver of the car had minor injuries, but the passenger was fatally injured.

The D Street portal ceiling was installed by a contractor, Modern Continental Construction Company. The ceiling consisted of concrete panels and a supporting steel framework suspended from the tunnel roof by stainless steel anchors installed in place with epoxy adhesive. An investigation into the incident by the National Transportation Safety Board (NTSB) found that all 20 anchors attaching a main ceiling support beam to the tunnel roof pulled out and fell onto the roadway. Among the remaining 634 adhesive anchors, 161 had measurable displacement, i.e., showed evidence that they steadily pulled out of the roof under the sustained tension load.

Decisions to use the adhesive anchors

Gannett Fleming, the design consultant, originally proposed to use undercut anchors in this part of the tunnel. However, this design was rejected by B/PB because they had had problems with this type of anchor on another project with different project characteristics. Gannett Fleming continued exploring alternatives but suggested that undercut anchors would still be the best choice for this application. Once again, B/PB was not convinced, and Gannett Fleming ultimately followed their direction to use adhesive anchors. While this adhesive anchoring method was not necessarily inappropriate, it was unusual in this application, and neither Gannet Fleming nor B/PB took account of the long-term performance of the anchors. This was an issue since polymer adhesives were known to deform under sustained loads.

> ***Tunnel ceiling collapsed***
>
> ***Adhesive anchors failed***
>
> ***Wrong epoxy formulation***

The epoxy

The NTSB determined that all anchors had passed a short-term proof load test prior to the installation of the tunnel ceiling. The NTSB then focused on investigating what had led to the failure of the epoxy and discovered ambiguities associated with the type and specification of epoxy used in the CA/T project.

The epoxy supplied to the construction contractor was available in either Standard Set or Fast Set versions. Only Fast Set epoxy was supplied to the CA/T project and subsequently used in the D Street portal. The Fast Set and Standard Set formulations of the epoxy had similar performance in short-term load tests but dramatically different performance under long-term loads. Specifically, the Fast Set epoxy displayed significant displacement (creep) when subject to constant loading. The NTSB concluded that *'the source of the anchor displacement that was found in the D Street portal tunnels and that precipitated the ceiling collapse was the poor creep resistance of the … Fast Set epoxy used to install the anchors'* (NTSB, 2007, pg 90).

The question is how the construction contractor chose to use an epoxy formulation that did not fit the purpose of the application. The NTSB found no evidence that the construction contractor was provided with a choice or made a conscious decision to use one epoxy formulation over another. When the construction contractor purchased the adhesive anchoring system, the Fast Set epoxy formulation was the only one offered by the supplier. The NTSB discovered that the Fast Set epoxy had previously been tested for creep performance and failed to meet the performance standard on multiple occasions, and thus it was recommended for short-term application only. However, the supplier's product documentation did not indicate any difference in long-term performance between the two formulations. In summary, there is evidence that the supplier knew that their product was not suitable in the specific application for which they provided it, and this was not communicated to the construction contractor.

Lack of expertise

The incident also suggests a failure of expertise by both Gannett Fleming and B/PB when it comes to understanding possible failure modes of the anchoring system. The designers should have considered that all polymers are likely to deform under sustained load, and yet there were no relevant specifications in the contract to address the long-term properties of the adhesive.

Specifically, there was no requirement of testing the adhesive for long-term performance, no consideration of the service life of the adhesive anchoring system relative to the expected life of the tunnel, and no provision for in-service inspections of the installed anchors. The NTSB concluded that *'Gannett Fleming and B/PB failed to account for the fact that polymer adhesives are susceptible to deformation (creep) under sustained load, with the result that they made no provision for ensuring the long-term, safe performance of the ceiling support anchoring system'* (NTSB, 2007, pg 86).

Procurement lessons to be learned

1. Contextual differences should be considered when using past experiences in decision making. Decision makers should defer to professionals with domain knowledge and skills in a new project context.
2. Training and continuing professional development are necessary for designers and other practitioners to update their knowledge as well as keep up with new developments and new products emerging in the industry.
3. Product certification processes should seek evidence to verify information.

More information

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Sector: Infrastructure

Berlin Brandenburg Airport Construction Project

Description

Berlin Brandenburg Airport (BER) finally opened on 31 October 2020 after 29 years in the making with nine years of delays and more than double the initial estimated construction costs. Almost everything that could go wrong with this largest airport construction project in Europe went wrong, which made the project a high-profile failure that has continued to damage the reputation of all actors involved.

Major causes of failures documented in parliamentary hearings and investigations into this megaproject have so far included flaws in governance structure, deficiencies in project planning and failures in construction and interface management.

History in the making

In May 1991, several months after the unification of Germany, the Berlin Brandenburg Airport holding company was founded for construction planning for a new airport in Germany's capital. The planning process started shortly afterward in early 1992. After several disputes, it took the company almost nine years to approve a tentative plan in late 2000 to open the airport in 2007. However, this milestone and a number of further milestones established after that were unable to be achieved.

In 2003, the BER board decided to take over the planning and construction process, terminate the entire privatisation process previously approved and take the project forward under public sponsorship. In 2006, following disputes with residents and major issues over flawed construction cost calculations, physical work finally began after 15 years of planning. However, the opening dates continued to be postponed owing to a series of technical difficulties.

Lack of a general contractor

From 2003 to 2005, when three governments decided to change BER to a public project, they hired an experienced project manager from the private sector and Planungsgemeinschaft Flughafen Berlin Brandenburg International (pg bbi) which was a joint venture of architects as the general planner. While the roles of pg bbi were to undertake the design planning and review and to supervise the detailed design and construction performance, the project failed to appoint a general contractor. This led to a series of major problems later as the responsibility for the detailed design remained with Flughafen Berlin Brandenburg GmbH (FBB), the developer of the project. FBB took the advice to divide the construction of the passenger terminal into 35 lots with the same number of tenders, which was a key contributor to the construction delays. Instead of overseeing one general contractor and contracting out construction and interface risks, FBB was in charge of interface management with 35 contractors as well as all associated risks.

> ***High-profile project failure with bad planning***
>
> ***29 years in the making***
>
> ***Budget blowout***

Deficiencies in governance and management

The project also experienced deficiencies in governance structure and expertise at the management level. As of 2013, most of the supervisory board members of FBB were politicians. A lack of construction expertise and experience on the supervisory board resulted in ineffective governance. There was no project steering team and no mechanisms to monitor the management team. In addition, independent assurance by external parties was also absent from most of the project. Throughout the project, transparency was missing with parliaments and the public being uninformed.

Expertise and experience were not only missing at the management level but also of major concern at the design and construction levels. Media reports revealed that the chief planner and designer of the fire safety system was a technical draftsman who later admitted his lack of engineering qualifications.

Constant design change requests

As the project suffered major delays, FBB put effort into meeting a new targeted completion date in late 2011. Many different equipment and materials tenders proceeded before the detailed design was completed. The parallel design and construction processes led to significant interruptions in the construction due to mistakes or late delivery of design documents and constant design change requests. FBB also ambitiously decided to redesign the terminal building to be able to handle the new A-380 Airbus plane. Later, it became clear that A-380 would not use the BER airport in the future, but this design change necessitated significant changes in the smoke extraction system, which further undermined its functionality.

Bad planning also resulted in hundreds of other issues being spawned in a chaotic rush to completion prior to the intended opening date in 2012. Significant disruptions occurred as a result of planning errors and construction faults and ultimately caused an inevitable cost blowout and timetable delays.

The financing in the BER project lacked transparency throughout the project. Neither the supervisory board nor the parliaments had provided a financing plan for the project completion. By late 2012, expenditures for the airport amounted to €4.3 billion (almost twice the original construction estimates) and by 2015, the total costs reached €5.4 billion. Additional needs for financial support to cover current costs and repair consequences continue.

Procurement lessons to be learned

1. In large-scale complex projects like airport construction, relevant expertise and experience are requisite at both management and execution levels.
2. If fragmentation of construction contracts is necessary to obtain specialist expertise, ensure that there is a construction management arrangement in place to manage interfaces and associated risks.
3. Beware of optimism bias in setting project delivery milestones. Ensure schedules reflect feasible delivery plans not simply externally imposed preferences or requirements.
4. Independent assurance from external parties is indispensable to detect flaws in project planning and performance.
5. A strong project owner is needed to ensure that the purpose of the project remains the key priority throughout.

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Sector: Infrastructure

The CBD and South East Light Rail Project

Description

Despite billions allocated to public transport infrastructure projects by the government, New South Wales (NSW) has a long list of failed public transport projects, from trains and trams to ferries. The construction of the Central Business District and South East Light Rail (CSELR) project has been characterised by a series of problems, including significant delays, higher costs with lower benefits than the approved business case and a lawsuit against the NSW Government.

The CSELR project had an initial estimated capital cost of AU$1.6 billion and a scope including a 12-kilometre route with 19 stops. Transport for NSW (TfNSW) started developing a strategic plan in 2011 and procuring major construction contracts in 2013. In late 2014, the Public-Private Partnership (PPP) contract was signed with major modifications due to scope changes, which led to an increase in the capital cost budget to AU$2.1 billion. In 2015, ALTRAC Light Rail took responsibility for operating and maintaining the light rail services as part of a PPP agreement. Major construction started in late 2015 and was expected to be completed in 2018 with services operating in early 2019. However, the service was only launched in late 2019 due to significant project delays.

Planning and procurement

The 2016 Auditor-General's performance audit report identified major problems around the way TfNSW managed the project in the period 2011-2014, including tight timeframes, an inadequate business case and poor governance in the planning stage. A dedicated project team was missing, and the distinction between commissioning, assurance and delivery roles was unclear. The project design and scope of work were not finalised prior to the start of the tendering process and the letting of the main PPP contracts. Consequently, bid prices increased and ongoing additional costs have been incurred. Capital costs were optimistically underestimated while benefits were lower than assumed in the business case due to increases in travel time assumptions deriving from changes in project scope.

Negotiations with contractors continued over design and scope changes, leading to increased project complexity due to major contract modifications. The contract structure meant there was little pressure on the contractor to offer the best value prices for new or revised elements.

The performance audit report also noted inaccurate and untimely information released by TfNSW, which minimised the transparency and accountability of the project. These included incorrect estimates of costs in the business case which had been covered as 'huge wins' offered by the preferred bidder. Further, TfNSW also did not timely disclose information on the reduced benefit-to-cost ratio of the project to the public, which was later acknowledged as an oversight.

A number of unresolved issues that increased the project risks and decreased value for money included: outstanding third-party agreements that affected the design and scope of works; planning consent conditions; and early works contract scope, duration and status for handover to the contractor. The pre-tender assurance review did not adequately address the risk of interface management of two main contracts and the potential risks of overlaps between the early works contractor package and the main works PPP package.

> ***Inadequate business case, poor governance***
>
> ***Dispute and settlement of AU$576 million***
>
> ***Major delays and impacts on community***

Contractual modifications and dispute

The project suffered from significant delays and budget blowouts, and there have also been unresolved claims for contractual modifications and undetermined penalties for delays. The relationship between TfNSW and Acciona, one of the design-and-construct contractors of the project, deteriorated with a legal dispute arising between the parties over costs incurred due to design modifications. In 2018, Acciona commenced legal action against the NSW Government, further delaying construction work. Of the 31 zones along the CSELR route, work started late in 17 zones. In 2019, parties reached a settlement package with the government paying up to AU$576 million over the duration of the extended PPP term.

Project impacts

A large number of complaints were received about excessive noise, dust and vibration caused by construction work along the light rail route, specifically night works. Community angst, distress and frustration were heightened by the project delays.

Another issue raised by residents was the physical damage caused to their properties as a direct result of construction work and the process for claiming remediation. The Committee's report also emphasised financial losses and the significant impacts of the project on the physical and mental well-being of business owners who struggled since the start of construction with some having closed down.

Procurement lessons to be learned

1. Project planning and procurement must follow an adequate framework and processes with justified timeframes and scope and sufficient assessment of costs and benefits to ensure the maximised value for money.
2. In complex projects, governance structures need to be well set up in the planning stage with clearly defined roles and responsibilities of all parties involved.
3. Beware of 'optimism bias' with underestimated costs and overestimated benefits in large infrastructure projects. Project cost and benefit estimates should be based on good evidence and benchmarked against similar projects.
4. Strong governance for procurement of large capital projects calls for independent review, a detailed probity framework and extensive due diligence processes. Any potential perceived conflict of interest needs to be recognised and addressed to maintain confidence in procurement.

More information

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Sector: Infrastructure

New South Wales Public Transport Failures

> *Ferries cannot pass under some bridges*
>
> *Ferries cannot operate after sunset*
>
> *Repair work required, major delays*

NSW trains too wide for tunnels

Transport for New South Wales (NSW) let a major contract (AU$2.3 billion) for new rolling stock for the regional rail network to a South Korean manufacturer. Part way through the procurement process, it became clear that the trains were wider than the existing rolling stock, and so the normal safety clearance between the trains and some tunnels would be breached. In some cases, the trains are literally too wide to fit in tunnels in the existing system.

A key design specification for railway rolling stock is the cross-sectional dimensions of carriages, which are set to maintain what is known as the 'kinematic envelope', i.e., the clearance all around the carriage that allows for the rocking of vehicles and variations as carriages tilt when passing around bends in the line. The clearance is required to ensure a safe margin between rolling stock and fixed parts of the network such as tunnels and platforms. In the NSW regional network, eight older tunnels west of Katoomba are slightly smaller in diameter than the rest of the network and require a smaller-sized carriage if the kinematic envelope is to be maintained.

Previous designs of rail carriages and locomotives have all accommodated the old tunnels, but specification and risk assessment for procurement of the newest trains did not adequately take into consideration the different fixed facilities that the trains would encounter, and so the specified kinematic envelope cannot be maintained in all cases.

The problems are to be fixed by a combination of relaxing safety standards and modifying fixed facilities. This will add two years to the current project, but the cost has not been released. As of early 2022, the new trains are not yet operational.

Sydney ferries too high for bridges

River Class ferries operated on Sydney Harbour have been criticised for similar sized-related problems. These new fleets of ferries built in Indonesia are too high to fit under some of the bridges on the Parramatta River. Passengers on the upper deck would have to move to the lower deck as the vessels pass low bridges.

In September 2017, Transport for NSW called for expressions of interest from ferry builders for new vessels for the Parramatta River route, but the purchase was shelved because the bids were too high. In 2019, the project went ahead and upon being awarded the contract, Transdev Sydney Ferries placed an order for 10 new ferries to be constructed in Indonesia.

> *Trains too wide for old tunnels*
>
> *Modifications on fixed facilities required*
>
> *Budget blowout, two-year delay*

In August 2020, solid asbestos was found in gaskets on four out of the 10 new ferries during testing in Newcastle. The new ferries are also unsuitable for several specific operating regimes. The first new fleets which entered service in October 2021, more than a year later than scheduled, can only operate during the daytime until a design flaw in the glass is fixed to reduce glare in the wheelhouse at night. The existing fleet, the Emerald Class ferries, would continue to be used until the River Class vessels can operate safely in the dark. However, the Emerald Class ferries are not able to dock at their usual wharf at Manly in very low tides. Options are being considered for a new gangway, and the ferry operator, Transdev, stated that about 5% of the services were affected.

In January 2022, more than 40 defects were found across all of the new vessels, which are undergoing major rectification work so they can operate in the dark.

No public domain information has yet been released as to why these problems have arisen, so it is not clear at this stage whether the failures in risk management are primarily in specifications or whether the new ferries were correctly specified and yet not delivered by the supplier. Various stakeholders are demanding an inquiry so more information may become available.

Procurement lessons to be learned

1. The specification for the new trains and ferries did not adequately consider variations in operational requirements across the networks, so expensive modifications are required. Specifications must take into account all necessary variations in operating requirements.
2. Further lessons could be drawn if/when more details are released of why the procurement systems have failed.

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Sector: Aerospace

Loss of Space Shuttle Challenger

Description

When Challenger mission 51L finally launched on 28 January 1986, the vehicle exploded after only 73 seconds and killed the crew of seven astronauts. The loss resulted from failure of o-ring seals in a joint on the solid rocket motor that allowed hot gases to escape, which impinged on the fuel tank, caused structural failure and then led to the shuttle breaking apart. The o-rings themselves failed due to the cold weather on the morning of the launch, but the safety of the design of the joints that required these seals and the impact of weather on the o-ring performance had been the subject of discussion within the project team for some time.

The loss of Challenger highlights procurement issues with the shuttle components and with the relationship between Morton Thiokol (MT), the contractor responsible for the solid rocket boosters, and National Aeronautical Space Administration (NASA).

The decision to launch

NASA had in place a formal process to decide whether it was safe to go ahead with each mission. The Flight Readiness Review was a four-stage process starting with contractors formally certifying in writing the flight readiness of the elements for which they were responsible. Approvals trickled up through the system to a conference of senior NASA representatives who made the final decision to go ahead.

Solid Rocket motor o-rings were defined as a 'criticality 1' feature because failure could cause loss of life or loss of the shuttle. The reliability of the o-rings was therefore critical and yet the operating history of the space shuttle program indicated that o-rings were sometimes being eroded. Of particular concern to some MT engineers was the apparent correlation between low temperature and o-ring erosion. Following observed damage to o-rings in other low temperature launches, this issue had been raised on multiple occasions, but the formal advice was waived by a NASA middle manager, and the concerns were never communicated to higher levels of management.

Regarding launch approval for flight 51-L specifically, weather forecasts suggested that the launch temperature on 28 January would be well below the experience base of the operating data. MT engineers raised specific concerns regarding the integrity of the o-rings given the very cold temperature forecast for the morning of the launch. They presented this data to NASA engineers on the evening before the launch with a recommendation not to launch. NASA disputed the analysis done by the MT engineers and famously demanded that the MT manager present *'take off his engineering hat and put on his management hat'*. Under further pressure from NASA, he gave MT's approval for the launch to proceed. Only MT's final signoff on the readiness of the solid rocket motors for launch trickled up through the system.

> ***Space shuttle and 7 astronauts lost***
>
> ***History of technical problems***
>
> ***Each launch was 'Russian Roulette'***

Procurement of the solid rocket motor

Going back even further into the history of the shuttle design reveals earlier procurement issues linked to contractor selection, experience and expertise and quality assurance. The initial tender evaluation placed MT last in terms of design capability, but NASA noted that their jointed casing design would lead to the lowest costs, so MT were chosen as the successful tenderer.

The innovative jointed design was problematic from the beginning and exhibited problems during the test and certification stage. Performance issues with the o-rings were known by NASA from 1977 with some NASA engineers expressing the view at that time that the design itself was unsafe and the joints requiring o-rings should be eliminated or redesigned. Despite this, the design was accepted for flight in 1980. Once in operation, persistent o-ring problems were seen with six consecutive launch constraint wavers issued prior to the 51-L mission.

The Rogers Commission also noted that reductions in NASA's safety, reliability and quality assurance workforce had seriously limited capacity in these areas and further that the remaining personnel had been placed under the supervision of those whose activities they were supposed to check. As a result, the o-ring problems were not communicated to management until after the fatal flight.

Procurement lessons to be learned

1. Ensure chosen suppliers have sufficient technical skills for the job at hand. If in doubt, put additional oversight in place.
2. Ensure integrity and performance tests mimic operational conditions as far as possible.
3. Act on quality assurance and quality control test results. In the end, it is better to make hard decisions when testing indicates problems rather than continue and hope for the best.
4. Encourage technical experts to speak up and to ensure that concerns are treated seriously.
5. Link evidence of risk management failures to high-level decision making. Project risk management linked to real world evidence of failures is important.
6. Incentivise contractors to report problems rather than hide them.
7. Provide sufficient skilled people for safety and quality assurance, and give them sufficient authority for their voices to be heard at decision making levels of the organisation.

More information

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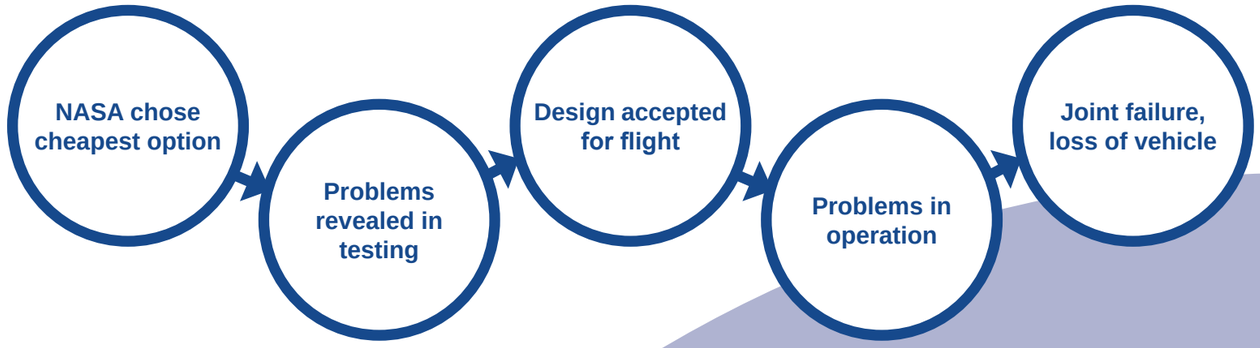
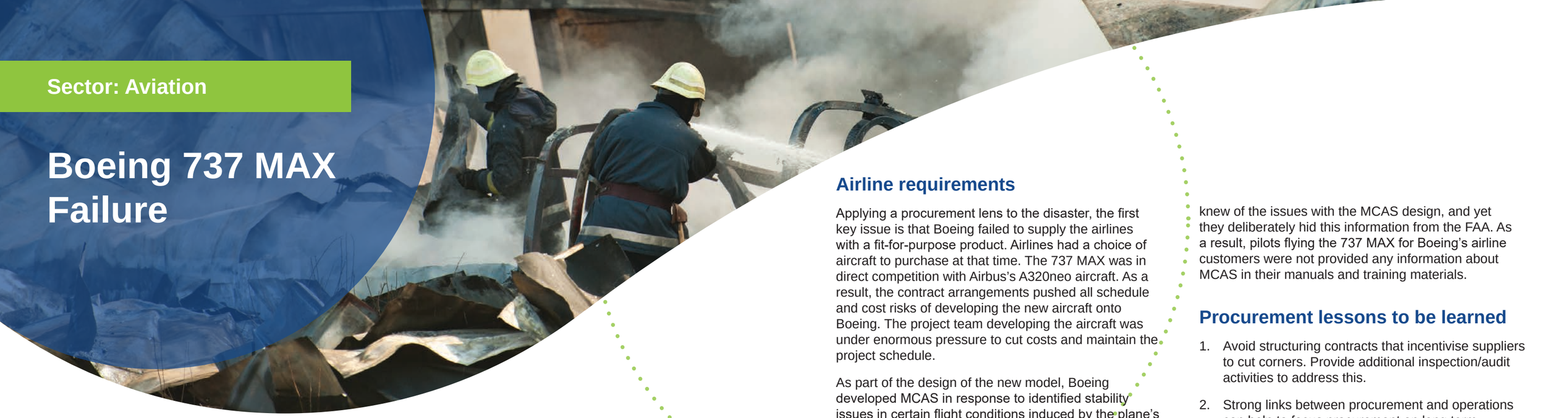


Sector: Aviation

Boeing 737 MAX Failure



Description

The design of Boeing's 737 MAX aircraft was the 4th generation of 737 aircraft and was based on the previous model (737 Next Generation). On 8 March 2017, the Federal Aviation Administration (FAA) granted an amended certificate to Boeing for the new design, and the first aircraft went into service two months later. On 29 October 2018, an Indonesian domestic flight operated by Lion Air crashed after pilots advised air traffic control that the aircraft was experiencing flight control, altitude and air speed issues. 189 people were killed. 157 people died on 10 March 2019 when another aircraft crashed in Ethiopia after experiencing similar control problems. After the second accident, the problems were traced to Boeing's new aircraft - the 737 MAX.

The 737 MAX aircraft contained a new feature compared to previous models. The Manoeuvring Characteristics Augmentation System (MCAS) had the ability to trigger flight control movements independently of pilot action and could place the aircraft into a dangerous nose-down position. Inputs to the MCAS system came from the angle of attack (AOA) sensors externally mounted on either side of the aircraft fuselage. In both accident cases, faulty data from an AOA sensor triggered the MCAS system to incorrectly force the nose of the aircraft down. Pilots repeatedly struggled to regain control of the aircraft but were unsuccessful. In the Lion Air case, a similar incident had occurred with the same aircraft on the previous day, but the flight crew came up with an innovative method to control the aircraft (removing electrical power from the flight control that was incorrectly activated by MCAS), and the flight landed safely. The sensor problem was noted in the aircraft log, but the aircraft response and the innovative way around the problem were not recorded.

Boeing is effectively a supplier of complex, high-tech equipment to airlines with third-party certification of the design of the equipment carried out by the FAA on behalf of the airlines. In that framing of events, the accidents can be seen as procurement failure where a key supplier failed to deliver a fit-for-purpose product to the airlines. After the accidents, Boeing agreed to pay over US$2.5 billion composed of a criminal penalty (i.e., fine), compensation to Boeing's airline customers and the cost of establishing a victims' beneficiaries fund linked to the two crashes mentioned above. Boeing's chief test pilot at the time of the aircraft development and certification was indicted for fraud, effectively for lying to the FAA, in October 2021. A Texas jury recently found him to be not guilty. No one else has been criminally charged as a result of these failures.

> ***Boeing receives $2.5 billion penalty after two airline crashes in 2018***

Airline requirements

Applying a procurement lens to the disaster, the first key issue is that Boeing failed to supply the airlines with a fit-for-purpose product. Airlines had a choice of aircraft to purchase at that time. The 737 MAX was in direct competition with Airbus's A320neo aircraft. As a result, the contract arrangements pushed all schedule and cost risks of developing the new aircraft onto Boeing. The project team developing the aircraft was under enormous pressure to cut costs and maintain the project schedule.

As part of the design of the new model, Boeing developed MCAS in response to identified stability issues in certain flight conditions induced by the plane's new, larger engines. Despite the system's critical role in assurance of in-flight stability, it was not declared a safety-critical system. The system also operated on a single input (an AOA sensor) which contravened Boeing's safety philosophy. Despite pilots not being told that the system operated in this way, Boeing assumed that pilots could quickly compensate for any potential malfunction.

Furthermore, AOA sensors are not new, and previous 737 models had an alarm to indicate if AOA sensor readings disagreed (i.e., if one sensor is faulty). This alarm was also part of the certified 737 MAX design, but in fact it was not functional in the 737 MAX aircraft delivered to airlines, which made it even more difficult for pilots to determine the nature of the problem if the MCAS activated incorrectly.

In summary, the malfunction of one of two AOA sensors changed from something that would trigger an alert to something that would not trigger an alert but would threaten flight stability in completely unexpected ways.

FAA certification

Boeing is a US-based multinational corporation that designs, manufactures and sells commercial airplanes to airlines worldwide. When an airline buys new aircraft, they are custom manufactured, but the basic airworthiness of the design of the aircraft is not checked by each purchasing airline. Aircraft designs and operational requirements are certified.

Linked to certification is the level of pilot training required for the new aircraft. This is critical to the schedule as Boeing's airline customers were permitted to fly the 737 MAX only after training requirements were approved by the FAA. Boeing technical pilots were responsible for providing the relevant information to the FAA. The investigation found that these individuals knew of the issues with the MCAS design, and yet they deliberately hid this information from the FAA. As a result, pilots flying the 737 MAX for Boeing's airline customers were not provided any information about MCAS in their manuals and training materials.

Procurement lessons to be learned

1. Avoid structuring contracts that incentivise suppliers to cut corners. Provide additional inspection/audit activities to address this.
2. Strong links between procurement and operations can help to focus procurement on long term production and safety requirements.
3. Not everyone in business always behaves ethically. Important information should be independently verified.

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Sector: ICT-based transport

The Myki Ticketing System

Description

In 2002, the development of a smartcard public transport ticketing system (Myki) was planned to replace Melbourne's aging Metcard system, which would expire in 2007. An initial budget of almost AU$1 billion was approved in 2005 for the Myki project. However, this ICT-based project experienced significant technical challenges, major delays and cost overruns and became the subject of public controversy.

Implementation of Myki

The time taken for the Myki system design and implementation more than quadrupled from the original plan of two years to nine years. This resulted in substantial additional costs of approximately $550 million, an increase of more than 55% in the original budget of the project.

Unusually in the design of similar systems, Myki combined both metropolitan and regional areas and covered a wide range of functions as well as a complex range of ticketing fares. Following its rollout, the Myki system encountered many operational issues, including slow card reader response times, intermittent technical failures and inaccurate data regarding patronage measurement. Among more than 5,000 complaints from public transport users about Myki performance between 2010 and 2014, overcharging was the most common issue followed by refunds and reimbursements.

Cause of failure and procurement issues

Reviews of the Myki implementation identified significant issues with the governance structure and contractual arrangements. The roles and responsibilities of key governance agencies were poorly defined, which resulted in difficulties in determining which agency had overall accountability for the project and what different aspects of the project each agency was responsible for.

The project also experienced major issues associated with the initial contractual arrangements that undermined its viability. Specifically, the original Myki contractual agreement was too large, complex and hard to manage with over 13,000 pages, 40 schedules, 370 separate documents and 3,000 outcomes.

> ***Poor governance and planning***
>
> ***Complex contractual arrangements***
>
> ***Optimism bias about delivery schedules***
>
> ***Major delays, cost overruns***

Furthermore, despite the volume of material produced, the initial specification was poor which led to more than 350 changes to the original specification during the development process. The procurement strategy included an outcomes-based specification through an open architecture approach that resulted in difficulties in determining whether certain functional performance requirements were within or outside the contract's scope. This led to misunderstandings and ambiguities of the requirements and consequently disputes with the contractor about costs and priorities.

The review in 2014 also revealed that the contract did not include the flexibility to address contractor underperformance such as suspension or exit of the contract. The contractor had to manage outstanding build issues in parallel with the commencement of operations, which compromised their capacity to meet agreed milestones and ultimately the project's delivery. As a result of insufficient understanding of the risks associated with ICT projects, a fixed tender approach was chosen, which was not an appropriate procurement approach for such a risky ICT-enabled project as Myki.

Since the expiration of the former Metcard was fixed as 2007, the Myki initial contract set an overly ambitious timeframe for implementation of two years. This unrealistic delivery timeline led to the contractor consistently failing to meet milestones and subsequently resulted in major contractual amendments. The underestimation of the project complexity resulted in further cost overruns due to the need to keep the Metcard system operating in tandem with Myki for an extended period.

Reviews in 2011 and 2012 also highlighted the issue associated with relevant expertise required to manage ICT-enabled projects that are deemed to be high risk in terms of cost and time overruns. Inadequate ICT capability and capacity within commissioning agencies contributed to poor project management.

Procurement lessons to be learned

1. Governance structures need to be well established during planning with clearly defined roles and responsibilities of all parties involved.
2. Investing time to engage all relevant parties at the beginning of contractual development is crucial to ensure all contract requirements are clarified.
3. Learning experiences, including appropriate benchmarking against similar projects implemented in other jurisdictions, are essential to gain assurance about the project feasibility.
4. Project planning, including implementation and delivery schedules, must be developed based on good grounds not on deadlines of the existing contract.
5. Project managers are required to have relevant experience and expertise to manage procurement. In the absence of this, external advisors should be employed to assist with oversight of project technical aspects.

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Sector: Maritime

HMAS Westralia Ship Fire

Description

The HMAS Westralia ship had undergone six weeks' maintenance prior to sailing on 5 May 1998. Members of the ship's company, the Fleet Intermediate Maintenance Authority and the primary contractor, ADI Limited, were responsible for the maintenance work. This included fitting new flexible fuel hoses to the main engines by a subcontractor under ADI's direction.

On 5 May 1998, one and a half hours after departure from Fleet Base West, a huge fuel leak was found near cylinder 9 of the port main engine with fuel spraying under pressure like a garden hose. The port main engine was immediately shut down, and some fire-fighting equipment was set up as a precautionary measure.

About five minutes after the fuel leak started, a fire broke out in the main machinery area. It quickly intensified and destroyed electrical cables on the deckhead above the main engines. Thick black smoke and extreme heat built up rapidly and made the atmosphere in the room inadequate to support life. It took two hours to extinguish the fire. Despite the firefighting efforts, including external support, the crew was unable to save everyone who was in the machinery space when the fire started. Four young sailors died as a result of carbon monoxide poisoning from smoke inhalation. It was the worst naval disaster in Australia in 34 years since the Melbourne-Voyager collision in 1964.

The cause of the fire

The report of the Royal Australian Navy (RAN)'s Board of Inquiry into the incident concluded that the fire *'was caused by diesel fuel from a burst flexible hose spraying onto a hot engine component and then igniting'*. The new flexible fuel hoses had replaced the original rigid pipes. Testing of the failed hose and other newly installed hoses clearly confirmed that the steel braiding wires had failed due to fatigue after less than 40 hours of operation. The source of the fatigue loading on the flexible fuel lines was most likely the action of the injector pump, which causes pressure pulses in the supply and return lines of the low-pressure fuel system. The presence of these pulses was well known. However, no relevant experts were consulted during the redesign.

Procurement failure

The inquiry report concluded that the new flexible fuel hoses *'were not properly designed and were unfit for the intended purpose'*. Furthermore, the proper processes to implement the configuration change for fitting the flexible fuel hoses were bypassed, mainly due to *'ignorance and incompetence'* of key personnel within RAN and ADI Limited. Specifically, the intended arrangements were not approved by the appropriate authorities and did not comply with Lloyd's Register of Shipping requirements. Even though the hoses could withstand the expected static system pressure, the arrangements were not properly engineered, and the design did not consider dynamic loads.

> ***Ship machinery space fire***
>
> ***Design error***
>
> ***Four fatalities***

Although the key organisations involved in the flexible fuel hose fitting were all accredited to a quality standard, evidence showed that the quality assurance systems were either inadequate or inadequately executed to prevent the provision of a non-conforming product. A lack of rigour by both external and internal quality auditing personnel was likely part of the problem.

The inquiry report also indicated the weakness of the system in place. Not only the lack of knowledge of personnel involved but also the inadequacies associated with training and selection of key personnel failed to guarantee system safety. Key personnel both in RAN and ADI and the main contractor were not adequately trained or qualified for the work they were responsible for. ADI failed to take necessary steps to supply safe and properly engineered products while RAN failed to obtain the shipping approval of the configuration change to maintain the ship's certification. In 2005, ADI was charged and found guilty of breaching the Occupational Health and Safety (Commonwealth Employment) Act 1991 for its failure to properly oversee the work on the ship's engines.

Following the accident, a number of allegations were raised formally and in the media against Australian government agencies, which led to an internal investigation within the Department of Defence and an investigation by the Commonwealth Ombudsman to examine whether Defence had forewarnings of possible safety risks to the ship. The report in 2008 indicated that Defence was not aware of any concerns about the use of non-genuine and sub-standard spare parts in HMAS Westralia. Such concerns were not able to be *'interpreted as any kind of warning of the circumstances'* that contributed to the tragic fire. The questions of who was responsible and who should be held accountable were left unanswered.

Procurement lessons to be learned

1. Ensure management of change processes are followed and all necessary equipment certifications remain valid through any modifications performed.
2. Specifications must include all relevant operations conditions, including dynamic loads.
3. Both contractors and owners' team representatives must have the necessary technical skills to complete the work for which they are responsible.
4. Design quality assurance is important and should be externally audited.

More information

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Sector: Building

Hyatt Regency Walkway Collapse

Description

The walkway collapse at the Hyatt Regency hotel in Kansas City, which resulted in 114 fatalities and more than 200 injuries, was one of the most well-known failures in structural engineering in recent history. The elevated walkways were designed by an architecture firm owned by Jack Gillum, a structural engineer. Somehow a critical change in the design of the walkways that led to the tragic failure made its way through the design, inspection and construction without any control.

On 17 July 1981, a tea dance was held with about 1,500 to 2,000 area residents in the hotel lobby, an innovative space with three walkways suspended from the lobby ceiling. Slightly after 7pm, the upper suspension rods suddenly pulled through their connections. This caused the fourth-floor walkway to lose its support, crush the second-floor walkway and drop to the crowded lobby floor. Hundreds of guests were trapped under 60+ tons of debris.

The cause of failure

Investigation of the collapse confirmed that the two channels transferring the walkway load into the steel rods had deformed, which enabled the nuts and washers of the rods to pull through the connection. The as-built connection was *'grossly inadequate'* and consisted of two steel rods: one connecting the fourth-floor walkway to the ceiling and one supporting the second-floor walkway below. This connection was not built as per the original design, which had only one steel rod with a nut and washer transferring the walkway load into the rod. This ill-considered change doubled the load on the fourth-floor walkway connection and resulted in the collapse.

The original design was drawn by Gillum's firm. The connection detail was left unspecified by the engineers, indicating that the fabricators were to undertake the calculations for the design. The fabricator thought the original design was impractical and suggested using two rods for the connection. The engineer accepted the suggestion after some quick calculations. Both failed to follow up with a formal application for approval. After the fabricator left for another project, a subcontractor took over the remaining work (including the partially completed connections) and used the fabricator's drawings on the assumption they had been formally designed. The drawings were finalised, and the problem was not picked up by the designer. The design was then fabricated and installed. Soon after installation, the channels of connections began to deform. The issue was disregarded during and after the inspection by practitioners involved who had noticed it.

Changes to original design not reviewed

Walkway collapsed

114 casualties and over 200 injuries

This structural failure was clearly induced by organisational issues which allowed a critical change in the original design to be installed without formal approval and checking by a competent engineer. Deformations of the connections were noticed and reported by the owner's inspector, but this was never followed up. Warning signs should have been recognised but were somehow disregarded by professionals involved. Although no criminal charges were filed, the engineering firm's individuals were *'convicted of gross negligence, misconduct and unprofessional conduct in the practice of engineering'* (Brady, 2015, pg 36). The catastrophic failure left immense aftermath, including legal battles around the loss and the trauma that the rescuers suffered during the rescue effort.

Procurement lessons to be learned

1. Any agreed modifications to the original design/ specification must be reviewed and formally approved via a change management system.
2. Verification of designs and modifications by a competent professional with relevant experience is a crucial part of the quality assurance process to evaluate compliance and identify deficiencies. Professionals must work within the limits of their competency.
3. Risks might exist in the risk control process itself where inspection work is not under supervision or control. All professionals involved should be empowered to speak up so that their concerns can be heard and followed up.
4. The responsibilities of all professionals involved must be explicitly defined early in project planning.
5. Explicit allocation of responsibility, along with effective and clear communication, must be maintained throughout the entire project to ensure public safety and the quality of built facilities.
6. Every individual needs to understand how their actions can impact overall outcomes. This can be difficult but is crucial to operating safely in complex environments.

More information

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Sector: Building

Lacrosse Apartment Fire

Description

In the early morning of 25 November 2014, the 23-storey Lacrosse apartment building in La Trobe Street, Docklands, in Melbourne suffered a serious cladding fire. The fire was ignited by a cigarette on a balcony and spread to the building cladding. The damage caused to the building was significant, and the claimed losses exceeded AU$12 million.

The investigation identified that the rapid spread of the fire was caused by the use of non-compliant aluminium composite panels (ACPs) on the building's external walls. The ACP product comprises a core material between aluminium sheets that are glued to form a laminated multi-layered product. The brand of the ACP product used on the Lacrosse building was Alucobest, which had a combustible polyethylene core material.

The cost of fixing the sector-wide problem of flammable cladding is estimated to be between $250 million and $1.6 billion.

Non-compliant use of ACP cladding

The Building Code of Australia (BCA) outlines the requirements for the design and construction of different types of buildings in which the building solutions allowed are either a 'Deemed to Satisfy' solution or an 'Alternative Solution'. Given the use and number of stories, the Lacrosse building is considered a Type A construction under the specification of BCA. The Deemed-to-Satisfy provisions require that external walls of Type A buildings must be non-combustible.

The use of Alucobest ACPs in the Lacrosse building should not have been considered an Alternative Solution. For a material or building system to be used as an Alternative Solution, BCA requires that evidence of suitability should be provided, for example, in the form of a Certificate of Conformity or a Certificate of Accreditation. However, the investigation found that such documents for the Alucobest ACP product were not available, and Alucobest was even not included in the Australian Building Codes Board – Register of CodeMark Certified Products.

Responsibilities of building professionals

The original cladding specified by the architect to be used on the Lacrosse building was named 'Alucobond', which is an accredited product and has a CodeMark Certificate of Conformity from the Australian Building Codes Board. At some point during the construction process, Alucobest was substituted for Alucobond. The two products are similar in appearance and difficult to differentiate by simple visual inspection. However, Alucobest is not certified and does not meet BCA requirements.

> ***Combustible building cladding***
>
> ***Poor management of change***
>
> ***Serious fire and huge damages***

It is not uncommon that product substitution occurs on building sites. Due process is when a contractor or a sub-contractor makes an application to the supervising architect or project manager for changing a specified material. A request for variation is normally sought, and a revision to the building permit is required if the variation is an essential safety measure or method of construction. However, a review of the documentation lodged by the private building surveyor for the Lacrosse building showed that it did not provide sufficient details to determine whether the external wall was designed to be non-combustible or not. The fire engineering design report failed to specify whether the wall was considered non-combustible, and no document proved that the cladding system was approved or accredited. The hearing into the Lacrosse building fire case pointed out that the fire engineers failed to '*recognise the ACPs proposed for use in the Lacrosse tower did not comply with the BCA*' (Victorian Civil and Administrative Tribunal, 2019, pg 7-8).

The hearing of the case found that the architect failed to ensure the ACP sample provided by the contractor was compliant with the architect's design intent. The hearing also identified that the contractor '*breached the warranties of suitability of materials, compliance with the law and fitness for purpose implied into its Design and Construct Contract*' under the Act (Victorian Civil and Administrative Tribunal, 2019, pg 6).

Compliance with the BCA should also have been confirmed by the building surveyor, but the investigation found that the surveyor failed to '*notice and query the incomplete description of the cladding systems'* in the fire engineering report (Victorian Civil and Administrative Tribunal, 2019, pg 7-8).

Procurement lessons to be learned

1. Detailed full plans with complete design information and clear specifications must be reviewed and approved by relevant decision makers to ensure that the plans meet all relevant standards.
2. Effective change management is critical for safety-critical components. Substitution of product or material must be approved by relevant persons to ensure that the substituted product still meets the requirements of specifications and achieves the intended performance.
3. Systems for independent, external certification, such as by building surveyors, must be robust and include regular checks for effectiveness.

More information

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Sector: Building

Grenfell Tower Fire

Description

The 24-storey Grenfell Tower was part of a council housing complex in North Kensington, West London. The tower was managed by the Kensington and Chelsea Tenant Management Organization (KCTMO) established by the local council in 1996. The tower was renovated during 2014 – 2016. The renovation involved installing an insulated rainscreen building cladding system, which consisted of combustible polyisocyanurate foam insulation and aluminum-polyethylene composite material (ACM) separated by a ventilated cavity.

Early in the morning of 14 June 2017, a fire caused by a malfunctioning refrigerator in a fourth-floor flat spread rapidly to the building's external cladding. The incident led to the loss of 72 lives and an additional 71 injuries. It was the deadliest structural fire in the UK since the 1988 Piper Alpha disaster and the worst UK residential fire since the Second World War. The investigation into the Grenfell Tower fire revealed that the combustible material used in the building cladding was the cause of the rapid spread of fire.

Cost-driven behaviours

The contractor who was originally proposed to carry out the renovation was dropped because their quotation was approximately £1.3 million above the allocated budget of £10 million, which resulted in another contractor winning the tender with a significantly cheaper offer of £8.7 million. While Phase 2 of the inquiry into the Grenfell Tower fire continues, doubts about the quality and standards of work of the selected contractor have arisen given their very competitive price of £2.6 million less than the original quotation. It appears that the evaluation and selection of the contractor were primarily cost-driven without adequate consideration of other criteria such as quality and competency.

The plans by the originally proposed contractor included adopting a zinc composite external cladding with a fire-retardant core, which was approved by residents of the tower. However, following the tender awarded to the new contractor, the local council implemented a value engineering initiative with the aim of saving costs. Amendments were made to the contract between KCTMO and the new contractor to cut costs by replacing the proposed zinc cladding with cheaper aluminium panels that contained a polyethylene core that was proven to be more combustible in tests and banned on buildings taller than 12 metres in Germany and the USA at that time.

> ***Combustible building cladding***
>
> ***Deadliest structural fire***
>
> ***72 casualties and 71 injuries***

Testing and certification of the cladding

The Grenfell Tower inquiry revealed compelling evidence that the cladding system failed to comply with the Building Regulations 2010's requirement. Specifically, it not only failed to adequately resist but also actively promoted the spread of fire with regard to the height, use and position of the building. The question is how the non-compliant cladding was approved for use on the Grenfell Tower as well as other tower blocks in England by relevant inspection and regulatory bodies.

The UK construction industry has witnessed the deregulation and privatisation of building inspection regime. Testing and certification are often commissioned by the manufacturers of products (i.e., self-certified), which is highly problematic because of the inherent conflict of interest. Expert evidence from the inquiry has shown that the current regime for testing the combustibility of materials and cladding systems for high-rise buildings might not be as rigorous or effectively enforced as it is supposed to be. Concerns have also been raised in regard to the reliability of certifications of materials used in high-rise buildings. These issues are still under investigation in Phase 2 of the inquiry into the incident.

Approval and inspection of the cladding

Before construction work commences, full plans or detailed design drawings need to be reviewed and approved by building surveyors to ensure that the plans comply with the requirements of the Building Regulations. In the Grenfell Tower case, despite the fact that the ACM panels did not comply with the Building Regulations in terms of fire resistance, they were still approved by building surveyors from the local council. During the renovation process, surveyors who visited the Grenfell Tower failed to carry out the inspections properly, which resulted in the failure to identify the non-compliant cladding material of the building. This raises concerns about whether the building regulation officers were sufficiently competent; as one investigation noted, there are *'no legislative requirements that set standards of competence or training for building control inspectors'* (Hackitt, 2017, pg 55).

Procurement lessons to be learned

1. The consideration of costs should be balanced with quality and safety requirements and the contractor's technical competency when evaluating tenders.
2. The material or product testing and certifying process should be undertaken by an independent third-party to avoid conflict of interest and to produce reliable information.
3. Auditing mechanisms should be in place to review and monitor the performance of regulation officers to enhance their professional accountability and improve the effectiveness of enforcement.
4. Statutory inspectors should be equipped with adequate skills and clear about their roles and responsibilities, for example through professional development and assessment.

More information

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Sector: Building

Opal Tower Cracking

Description

Opal Tower is a 39-storey residential building located in the Olympic Park suburb of Sydney. The construction of the tower was completed in August 2018, and occupancy commenced soon afterwards. On Christmas Eve 2018, residents of the Opal Tower reported loud banging noises of internal origin that were later found to be associated with cracks in the concrete structural elements. In response, about 3,000 people were immediately evacuated with the help of the police.

Early in 2019, an investigation of the causes of the structural damage to Opal Tower was requested by the NSW Ministry of Planning and Housing. Damage was found to be mainly on hob beams distributing forces between certain columns on levels four and ten of the building. Panels resting on these hob beams and floor plates adjacent to the corresponding columns were also found to be damaged. In the final report, issues with the structural design and construction of the building were declared as the main cause of structural damage.

Non-compliant structural design

Investigations revealed at least two areas of the as-built structure did not comply with the relevant Australian Standard, AS 3600 Concrete Structures, and therefore did not satisfy the requirements of the National Construction Code. These areas coincided with the locations of the most serious damage at levels 4 and 10 of the building. The strength of the damaged hob beams at levels 4 and 10 did not meet the requirements of AS 3600-2009 (the operative version of the code at the time) to withstand the assumed design forces. Moreover, the tie reinforcement for the hob beam was inadequate to resist the significant splitting forces.

The independent investigation into the causes of the incident found that, in order to prevent future incidents of this type, better controls were needed regarding engineering competency and certification of designs.

Construction issues

In addition to inadequate design, several critical safety elements were not constructed in accordance with the design, which further contributed to the structural damage to the building. While full grout coverage was expected between the hob beam and precast panel, only the inner surface of the joint had been grouted during construction, which resulted in eccentric loads and additional bearing and bursting stresses on the hob beams. The cover concrete of the hob beams was also found to be inadequate. An electrical conduit was placed within the cover zone in the vicinity of the hob beam-to-column connection.

Non-compliant design

Severe building cracking

~3,000 residents evacuated

Moreover, the precast panels were constructed thicker than the expected design and were overhanging the interface of the hob beam. The wrong size reinforcing bars were also placed in the horizontal direction of the bottom region of a panel, which resulted in inadequate tensile capacity. No evidence of utilisation of reinforcement crossties was found in the damaged hob beams. Additionally, the strength of the concrete used in the construction of the hob beams was lower than expected.

The mismatch between the constructed building elements and the original design drawings emphasised the inadequacy of the quality assurance and control mechanisms. An example of this fragmented approach and mismatch is the contracting documents and views regarding the design strength of the hob beam concrete on level 4. This indicated deficiencies in documentation and communication of building specifications within the project team.

Procurement lessons to be learned

1. Ensure that all tenderers have sufficient technical knowledge to undertake work for which they are being considered.
2. Rigorous quality assurance and control procedures need to be defined with the involvement of all relevant parties to ensure compliance of the design and construction with the relevant codes and standards.
3. Use integrated documentation and communication procedures that include digital tools to ensure a seamless flow of information to ensure consistency of different project documents and to facilitate automatic detection of non-compliance.

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Sector: Energy generation

South Korean Nuclear Reactor Shutdown

Description

In May 2013, the government of South Korea announced the suspension of operations of two nuclear reactors and extended the shutdown of a third to replace parts that were supplied with fake certificates. At that point, nuclear power plants supplied more than 35% of the electricity needs of the nation. As a result of this shutdown, the Ministry of Trades, Industry and Energy expressed concerns about unprecedented electricity supply shortages during the summer.

Procurement issues

An investigation by the Korea Institute for Nuclear Safety revealed the falsification of 2114 test reports between 2003 and 2012 by material suppliers and equipment manufacturers. Moreover, between 1996 and 2012, 62 equipment qualification documents had been falsified by testing entities. Further investigation of 101 companies revealed extensive illegal activities including bribery, limiting competition in bidding and knowingly accepting parts with fraudulent certificates. As a result, more than one hundred individuals including people from Korea Electric Power Corporation (KEPCO), which is the operator of the nation's nuclear reactors, Korea Hydro and Nuclear Power Corporation (KHNP), parts suppliers and certifiers were indicted.

The shutdown of the two reactors in 2013 was due to concerns over falsified test reports for installed safety-related control cables. These cables were manufactured by a Korean supplier, JS Cable, following KHNP's decision in 2004 to procure safety cables from domestic suppliers for the first time. JS Cable submitted a bid to KEPCO Engineering and Construction (KEPCO E&C), a subsidiary of KEPCO, despite lacking the necessary capabilities to manufacture the cables to the required standards. Saehan TEP, which was chosen by JS Cable to test the cables, outsourced the testing to a Canadian firm called RCM Technologies. This firm reported the results of the testing as unsatisfactory, however, upon the instruction of KHNP to make the results acceptable, KEPCO E&C, JS Cable and Saehan TEP decided to manipulate the test results rather than modify the equipment.

Widespread and systematic supply chain corruption was facilitated by the monopolistic structure of Korea's nuclear power industry as well as close ties between politicians, government, state-owned enterprises and large family-owned conglomerates. The situation was exacerbated by the organisational culture of KEPCO and its subsidiaries, which required conformity, had insufficient and ineffective regulatory infrastructures, and tolerated a generally low standard of personal and corporate ethics. The corruption in the Korean nuclear supply chain first came to light in 2012 after KHNP received information from outside the organisation concerning problems with the supply chain. This observation highlights the ineffectiveness of the internal control mechanisms that were supposed to prevent and identify misbehavior.

> ***Fake certificates in nuclear power plants***
>
> ***Widespread corruption***

Procurement lessons to be learned

1. Regular audit and review of internal control mechanisms, preferably by third-party organisations, and encouraging/protecting whistleblowers to report suspicious and corrupt activities are crucial to minimise corruption.
2. Effective technical prequalification of bidders is needed to ensure all options are technically acceptable.
3. Personal and corporate ethics should be emphasised to reinforce internal mechanisms to avoid corrupt behaviour and resolve issues with conformity, excessive deference to superiors and unwillingness to challenge decisions.

More information

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Sector: Energy generation

Cabin Creek Hydroelectric Plant Fire

Description

On 2 October 2007, a flash fire inside a tunnel that was being recoated with epoxy killed five workers and injured three more. The work was being undertaken at Xcel Energy's hydroelectric plant in a remote mountain location in Colorado. The work location had only a single point of egress, and the initial fire spread rapidly to buckets of solvent and substantial amounts of epoxy stored on location inside the tunnel. The workers who died were trapped and died from smoke inhalation.

The investigation by the US Chemical Safety Board (CSB) found that inadequate contractor selection and oversight contributed to the incident.

Contractor selection and supervision

The workers who died were employed by RPI Coating, Inc. RPI were known by Xcel to have a poor safety record, which should have meant that their tender for the coating work was rejected. Instead, they were awarded the contract based on lowest price despite another contractor being judged best from a technical and quality perspective. As a result of the known safety issues, the RPI contract included a specific clause stating that their safety performance would be closely monitored.

The work proceeded on that basis, but no safety audits of RPI's activities were undertaken. In the weeks prior to the incident, Xcel managers became aware of several significant safety breaches by RPI including one recordable injury. Despite this, no action was taken.

After the incident, the CSB investigation found that the majority of RPI employees working at Cabin Creek had not received adequate formal safety training; effective training on company policies; or site-specific instruction addressing confined space safety, the safe handling of flammable liquids, the hazard of static discharge, emergency response and rescue, and fire prevention.

Procurement lessons to be learned

1. Companies with poor safety records should not be invited to tender.
2. All contractors should be subject to appropriate safety auditing to ensure performance is satisfactory.

More information

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> ***Poor performing contractor chosen***
>
> ***Not closely supervised***
>
> ***Five workers died***

Top Five Procurement Lessons

Improved management of procurement risk has the potential to save money and lives in both the project and operational phases of major infrastructure and industrial facilities. There are valuable lessons to be learned from the past procurement failures across a range of industries and sectors described earlier. The top five lessons for risk governance from past procurement failures are:

Ensure that a selected contractor or supplier has the technical capability to do the work

There are many past cases where projects failed due to errors by a supplier or contractor who should not have been selected to perform work because they did not have the necessary skills and experience. In some cases, owners/operators deliberately chose a cheap but marginally qualified supplier and noted that extra inspection would be required to ensure a good outcome but then failed to perform such inspection/supervision. Falling into this trap can be avoided by pre-qualifying suppliers and contractors, and only inviting bids from groups who are competent to do the work.

Clearly define responsibilities and supervision

Ill-defined responsibilities and lack of effective supervision are a significant causal factor. Interfaces are a known location for errors to arise in organisations, so clear responsibilities for all parties and effective supervision up and down the supply chain are important to ensure any problems are identified early and addressed. This also reduces conflict and misunderstandings. Linked to this is the need for a high level of project team experience and effective project oversight.

Value quality assurance and make it independent

Procurement goes wrong when the work of suppliers and contractors is not independently checked or inspected. Problems can arise due to fraudulent test certificates, etc., but not all testing issues are the result of malicious intent on the part of suppliers. Genuine misunderstandings regarding requirements and/or technical errors occur and are most likely to be identified by a competent, independent inspection focusing on key risk activities. Problems identified must also be acted on in the short-term because making changes is usually more difficult as time goes on.

Embed operational requirements into procurement decision making

Procurement failures occur when operational requirements are not adequately considered in procurement decisions. This can be avoided by the preparation of specifications that ensure the right operational inputs and outputs are included.

Establish common organisational goals

The failure record shows that problems arise when a power balance between client and suppliers/contractors is not achieved, and one side becomes highly dominant. An extremely dominating client does not necessarily get the best outcome, particularly when significant technical expertise resides with the supplier. For complex projects, 'partnering' style contracts are preferred to align goals and share risk and reward.

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