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# Competencies that lead to high performance as a project engineer in a management consulting engineering company

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## ABSTRACT

### CONTEXT

Over the last century there has been increasing application of projects and project management techniques as foundations for business operations. In engineering industries, this has resulted in the emergence of project engineering as an area of specialisation, and there is a need to understand what this encompasses in the context of Western Australian engineering practices in the mining industry.

### PURPOSE

This study aims to contribute to the body of research focusing on engineers and the mining industry. The main objective is to establish broad competencies required to achieve high performance as a project engineer. As a priority, it aims to improve overall understanding of the role of engineers, specifically project engineers, in project completion.

### METHODOLOGY

A Critical Incident Technique (CIT) methodology was used for the interview and analysis. CIT is a cognitive task analysis (CTA) method described by Flanagan (1954) to diagnose key actions or requirements that make the difference between success and failure in the performance of a task in five key steps: objectives, plans and specifications, collecting the data, analysing the data, and interpreting and reporting.

### OUTCOMES

The key competency areas discovered were 1: Expertise, 2: People management and interpersonal skills, 3: Actions and approach to work. The overall objectives of project engineers as described by the participants fell into either of two categories: to support the project manager, or to facilitate the delivery of a project on-budget, on-schedule and in accordance with the contract.

### CONCLUSIONS

The project engineer is a hybrid of technical expert and project manager, where technical expertise is broad rather than specialised. The key discovery made in this work is that a high performing project engineer also cultivates an approach to work that is based around continuous learning. The engineer must extend their expertise beyond technical outputs and focus on project tasks and roles. This research has implications for engineering education relating to the need to develop alternative skillsets (for example, leadership, people management and linking interdisciplinary tasks) alongside traditional engineering competencies.

### KEYWORDS

project engineer, critical incident technique, competencies

# Introduction

## Projects and Industry

In the early 1990s the term 'projectification' was coined by researchers to describe the increasing trend of organisations executing their work in project-style solutions (Kujala, Artto, Aaltonen & Turkulainen, 2010). Kujala et. al. described this as 'a trend towards servitised offerings and life-cycle solutions' (2010). This project-oriented business model developed in part because of globalisation of economies and an increased trend towards outsourcing (Kujala et. al., 2010). For example, a mining organisation will generally outsource the design, procurement and construction of its processing plant to a contracting engineering consultant. The contractor may be responsible for the delivery of engineering, procurement and construction (EPC) services that constitute the project that they are contracted to complete (Walker, 2015). A management consulting engineering firm is one that specialises in providing engineering services to deliver these 'projectified' bodies of work.

The Western Australian Government reported $27.2 billion AU of major resource projects similar to this being under construction in the month of March 2020 (Williams, 2020). The mining and construction sectors produced $120.7 billion AU in Western Australia (WA) in the 2018-19 financial year, accounting for 42% of WA's gross state product (GSP) (Williams, 2020). These figures reflect the size of the industries that rely heavily on organisations with project-based business models, and therefore rely on project engineers.

This research focuses on the role of project engineers in a management consulting engineering organisation (referred to henceforth as Company X) that delivers Engineering Procurement and Construction (EPC) and Engineering, Procurement and Construction Management (EPCM) services for minerals processing plants. The organisation exemplifies an approach to work encapsulation and execution in projects that is typical in WA's engineering industries including minerals, infrastructure and oil and gas (Walker, 2015).

## Project Engineers

The current understanding of project engineers in Australia is lacking because the role is relatively new to the industries (compared to the technical engineer or project manager) and differs sufficiently from other types of engineer that many pieces of existing research cannot be assumed to be accurate (Hodgson, Paton & Cicmil, 2011). This leaves room for valuable discoveries related to how project engineers operate and how developing certain skills or competencies (through engineering education or otherwise) can positively impact performances in this role. As a result of the positive link between high-performing project engineers and delivery of on-time, on-budget and in-scope projects (Miles, 2013), this potential for advancement can have significant impacts on an organisation's capacity to execute projects successfully, particularly in the realm of engineering management consulting.

Over the last century there has been increasing application of projects and project management techniques as foundations for business operations (Hodgson et al., 2011). Across engineering industries, this has resulted in the emergence of project engineering as an area of specialisation, and there is a need to understand what this encompasses.

The image of a project engineer built by current literature is of an engineer with broad but shallow technical knowledge who bridges the gap between technical and project management specialisations. Miles (2013) described the project engineer as the person who 'controls the critical links needed to create the project deliverables'. Tremblay, Wils & Proulx (2002) explain that a project engineer specialises by broadening their technical skills rather than focusing on a single sector.

The traditional engineering career pathway begins with a focus on technical engineering. As the engineer advances in their career, they are at some stage confronted with the choice:

continue in their technical specialisation or diverge into a managerial role to become a project manager, taking on control, organisational and supervisory activities (Tremblay et. al., 2002, Hodgson et. al., 2011). The typical project engineer engages in both the technical and managerial sides of engineering from early in their career, yet does not fit neatly into either category.

### Research Question and Contribution

The question guiding this research is:

> *"What knowledge, skills and behaviours lead to high performance in the role of 'Project Engineer' in an engineering management consultancy organisation?*

The research expands understanding of behaviours, skills and knowledge that are important to operating successfully as a project engineer. The organisation under examination is a mid-sized consultancy based in Perth, WA with branches across Australia and the globe.

## Literature Review

### Personal Skills and Competencies for Project Engineers

There is an abundance of research into the competencies, skills and aptitudes that contribute to success as an engineer, but there is also an abundance of terminology associated with the research area. This study does not prioritise between skills, knowledge, behaviours, competencies and other descriptors for actions and abilities that contribute to high performance. This is in order to minimise confusion between terms and represent the data more accurately according to the naturally emerging themes and trends. Male (2010) took a similar approach when investigating generic engineering competencies.

Analysis of the literature reveals some distinct approaches to types of competence or skills analysis in engineers. One approach relates to optimising the professionalism of engineers and does not focus on the disciplinary breakdown of skills. Engineers Australia (EA)'s engineering competencies are broken into three categories: knowledge and skill base, engineering application ability, and professional and personal attributes (EA, 2019). The distinction that EA has made through their use of phrases such as 'Application of…' and 'Professional use of…' describing their competencies is that a competency differs from a skill or knowledge area in its ability to be applied or executed in a practical setting.

Leadership qualities have also been a strong focus for competencies displayed by engineers (Farr, Walesh & Forsyth, 1997; Robledo, Peterson & Mumford, 2011). Farr's team found nine key leadership attributes for engineers as behaviours or skills to exhibit, such as being a good communicator or mastering change (1997). Robledo's team developed a different methodology, which identified the engineer's area of focus to be crucial (2011).

The range of methods and volume of valuable and relevant research that has been discussed here shows the potential for discovering insights into this area.

### Success and High Performance

The objective of this study was to understand the role of project engineers and which factors of their performance contribute most extensively to successful project outcomes. What is the best way to quantify this success? There is a consensus in literature that individual career success leads to organisational success (Shockley, Ureksoy, Rodopman, Poteat & Dullaghan, 2015).

Objective methods that involve directly measurable criteria such as salary or number of promotions have been common (Heslin, 2005) and have been criticised in recent years as being insufficient to fully capture the success of individuals (Shockley et al., 2015).

Alternative measures include the subjective methods, such as job satisfaction and perception of success (Shockley et. al., 2015). Tremblay et. al. (2002) suggest that engineers will tend to perceive high performance according to their own preferred career path. Either technical specialisation or managerial roles is seen as more successful depending on the individual's values.

For the project engineer, it may hold true that their perception of success is linked to their values. There are similarities in the need to balance technical knowledge and managerial capabilities as competing priorities (Hodgson et. al., 2011, Miles, 2013). Company X has a relatively flat hierarchical structure and has standardised bandings for pay, and so the perception of high performance by the participants will be the key measure.

This frame of reference can be established in interviews and analysis. Expertise and high performance can be identified by decision similarity in the group of participants (Kurvers, Herzog, Hertwig, Krause, Moussaid et. al., 2019). Kuvers et. al (2019) state that individuals within an organisation will be consistent with regards to how they perceive each other's expertise, yet this consistency is not necessarily reflective of actual performance. Findings can be calibrated in the interview process by first establishing key objectives of the project engineer role (establishing success through decision similarity), then ascertaining the impact that described competencies had on achieving those objectives (task effectiveness).

# Methodology

## Critical Incident Technique

A Critical Incident Technique (CIT) methodology informed data collection and analysis. CIT is a cognitive task analysis (CTA) method described by Flanagan (1954) to diagnose key actions or requirements that make the difference between success and failure in the performance of a task in five key steps: objectives, plans and specifications, collecting the data, analysing the data, and interpreting and reporting.

The CIT has been used in a diverse range of contexts and industries from organisational psychology to education and healthcare work (Viergever, 2019).  The CIT elucidates key behaviours that people in a given profession should do or not do in order to have the best chance of achieving their goals (Viergever, 2019). Research conducted by O'Connor, O'Dea, Flin & Belton (2008) shows use of CIT to elucidate critical team skills for successful operations in a nuclear plant. This research draws significantly from the research by O'Connor and co-researchers as a good example of successful application of the CIT.

The principle of identifying specific examples that is used in the CIT aligns with the goal of identifying KPIs and objectives for the role of a project engineer. If the participant can first identify the objectives of a project engineer, supplementary questions in CIT style will provide data to conduct evidence-based performance assessment of the behaviours against these KPIs.  Part of the CIT involves establishing categories for behaviours through analysing and processing of data to reveal the critical actions or skills. These categories reveal the various categories of competencies that lead to high performance.

## Interviews

Participants were recruited from a list of project engineers compiled by the managing director of Company X, to ensure relevant expertise. All participants had extensive experience either at Company X or in the field of project engineering.

One-on-one interviews based on the CIT were conducted with 14 participants with significant experience in project engineering. Interviews were conducted in two steps. Step 1 was to clarify to the participants the general aims of the research. This is critical as it allows the participant to exercise their judgement to assess which incidents and examples are most relevant to the goals. Additionally, participants were asked ‘What would you say is the main purpose of a project engineer at company X?’ to establish a general aim.

In Step 2, the interviewer ensured scenarios described by the participant had sufficient detail and relevance to the general aim. This is the unique part of the critical incident technique. It involves the participant first identifying an incident and adding details such as extent of impact on the objective.

A semi-structured interview style was necessary to collect the data, as the project engineers overwhelmingly struggled to identify incidents that fit the categories requested in the questions. Participants tended to rely on generalisations of tasks in order to answer the questions, but were able to give detailed examples and dissections of these. Participants were generally able to strongly link incidents and competencies to the purpose of a project engineer as they described in the earlier questions.  All interviews were recorded, transcribed and de-identified using Otter.ai, then stored securely on a server.

### Analysis

First, transcripts were examined for leading questions and other indicators that data should be removed. Some leading questions were identified and removed in the transcription process. The data were then split into comments describing the role of the project engineer, and comments that described potential competencies. The data relating to competencies were then further divided into categories, resulting in the three key themes.

The findings were compared with the original objective to assess the validity of the themes and identify any divisions of opinion or competing aims, as required by the CIT method (Flanagan, 1954). Analysis of the results produced two groups of thought regarding the objective of a project engineer (described in the results below), with no outliers or other descriptors. The research includes contribution from 14 participants with significant experience in project engineering. Graduates and junior project engineers were excluded.

### Adaptation of CIT

The CIT was an effective approach for investigating the role and competencies of project engineers in this case study, though there were several issues that meant traditional use of the CIT was not adhered to strictly. After conducting a few interviews and consistently struggling to get explicit examples following the script and prompts, the approach was changed marginally. Participants responded much more confidently when prompted to explain the role of a project engineer in more depth, and then asked the incident-focused question immediately based on a comment that had just been made. For example, a statement made about the role of a project engineer; *‘…it’s a key role supporting the project manager in specific areas’* leads easily into an incident when the participant was prompted to describe an example.

The identification of incidents was a good method for producing generalized examples, but participants tended to struggle with identifying ‘critical’ incidents. This made it difficult to establish a scale of importance for the various competencies.

## Findings and Discussion

The goal of this research is not to establish the objectives of a project engineer, rather the competencies related to high performance. However, the objectives were defined in the interviews to assist with determining the relevance of a competency to high performance. Table 1 below summarises the objectives of a project engineer, described by participants.

**Table 1 - The purpose of a project engineer**

| Objective | Description |
|---|---|
| To facilitate the delivery of a project on-budget, on-schedule in accordance with the contract. | Meeting budget, schedule and scope were the primary objectives, safety and quality were secondary but still important. |
| To support the project manager. | Act as support for the project manager in taking responsibility for managing and tracking packages of work as directed. |

Table 2 presents three broad categories that describe the competencies required by project engineers.

**Table 2 - Broad categories of competencies of high performing project engineers**

| Area of Competence | Description |
|---|---|
| Expertise | Broad expertise across technical disciplines focused on tasks, roles and technical output. Deep expertise in construction and site processes and issue identification. |
| People Management and Interpersonal Skills | Manage the flow of information and work between all groups. Interact effectively with others, building relationships and leveraging others' expertise. |
| Actions and Approach to Work | Have strong work ethic and continuous focus on project objectives. Place high value on continuous improvement. |

## Expertise

The 'expertise' competencies reflect the technical elements that project engineers at company X specialise in. Previously there has been lack of clarity in literature regarding what technical expertise a project engineer requires (Miles, 2013, Hodgson et. al., 2011). The findings are consistent with research on technical expertise needed by systems engineers: a broad but shallow understanding of all engineering areas. Our findings build on this premise, indicating more than simply technical knowledge and understanding. The idea of 'broad technical knowledge' is extended to include the need for understanding of the roles of all project stakeholders and also the ability to prioritise and problem-solve within their expertise. This keeps the role of project engineer firmly in the seat of 'engineer' rather than solely 'manager'.

Thirteen of the fourteen participants emphasised the need for expertise in constructability and site operations. Most (eight of 14 participants) explicitly mentioned the importance of experience on site as a field engineer, generally relating it to being critical for early career project engineers. This was explained typically as an experience needed to learn important lessons about the impact of workflow from early in the project on final project delivery and construction. It may also be seen as a critical opportunity to practice and learn the necessity of many of the competencies from category three: *actions and approach to work*.

The area of expertise that was most divisive was the importance of interpreting and understanding contracts and scopes of work. Every participant mentioned either 'scope' or 'contract', but the participant who would be considered as the most expert of the group said the words 'scope' or contract' a total of 73 times in a one-hour interview. Going by number of mentions, the next four candidates, all considered to be top project engineers, mentioned scope or contract an average of 19 times, while the average of the remainder was six mentions. This implies that expert understanding and management of scope of works and contracts is a skill desirable and important for high-performing project engineers, but is either difficult to grasp or not needed at more junior positions in the organisation.

### People Management and Interpersonal Skills

The second category of competencies emphasises the role of project engineer as a people-focused position. These competencies, compared to those from category 1, had equally strong links to the role objectives as described in Table 1. Many of the competencies from this group including relationship building, leadership, interpersonal skills and communication, were mentioned as critical competencies that all acted as tools to effectively manage workflow between stakeholders. The idea of understanding human nature was mentioned mostly by participants at the intermediate level, perhaps reflecting an initial foray into leadership skills, by paying more attention to the team and how to get the best out of their peers rather than performance of basic tasks.

### Actions and Approach to Work

One engineer said:

> *‘There are certain people more suited to the job. I don't think it's something that just anyone can do. I think I've seen that with some of the PEs [project engineers] that have come through, you can identify people and see, he's got the temperament. He's got the hard work, and he's got the ethic. And he's got the practicalness to be successful as PE.’*

This quote reflects the actions and approach to work category, which combined data relating to individual abilities, actions and approaches, and key work tasks. Behaviours and approaches as competencies appear extremely important to the role of project engineer. Notice that this participant does not comment on personality, background or experience, but focuses on the way the hypothetical individual engages with the work and the learning. This is consistent with the way most participants spoke about their role. A project engineer will lean on the experiences of others until they have enough experience themselves, learn continuously, work hard, ask questions and focus on the outcome. These competencies were important at every level of engineering. This brings into question the role that identity, values and self-perception play in the high performance of project engineers.

In terms of work tasks, issue identification was perceived as more important than generating solutions. This may be because the project engineers all saw identifying issues as critical to their role, whereas middle-tier engineers perceive the generation of solutions to be more critical to the project manager.  This contrasts with the view that problem solving “is the core of engineering practice” (Passow & Passow, 2017, p.475).

## Conclusions

The project engineer is a hybrid of technical expert and project manager, where their technical expertise is broad rather than specialised. For those in mining at company X, expertise includes scope of works, contracts, and construction. People management is equally critical to successful outcomes as technical expertise. The high performing project engineer also cultivates an approach to work that is based around continuous learning.

The findings provide a more nuanced understanding of the role of project engineers and reveal key competencies displayed by high performing project engineers, extending work by Hodgson et al. (2010). This has implications for engineering education and practice. The need for development of professional skills in engineering students is indicated, supporting previous research (Male, 2010; Passow & Passow, 2017). This includes the teaching of approaches and attitudes to work. In the context of increased 'projectification' of engineering work, understanding of engineering contracts and project scopes is vital. The need for knowledge of engineering construction is highlighted, supporting the call to extend representation of engineering practice in engineering curricula beyond design (Satnani, Marinelli, Male, & Hassan, 2020). These elements of engineering practice should be embedded in engineering curricula.

The research revealed insights into the objective of a project engineer, being to facilitate project delivery either by managing budget, schedule and scope or by supporting the project manager. This emphasises the need for strong project management skills in the engineering education curriculum, and also raises questions about how engineers are taught to use their technical expertise in a project delivery scenario.

For individual engineers, development of the identified competencies may aid in career development and progression in project engineering. For organisations that employ engineers, understanding of competencies can inform and optimise career management policies and processes.

## Further Work

There are many opportunities for further research.

**Expand the Search:** Using this research as a foundation, expanding the scope of the investigation to include project engineers from other industries or other organisations would be valuable. Further research will make clear which competencies are unique to company X resulting from their culture, industry and style of work, and which are generic competencies.

**Establish a scale for measuring impact:** Design research that will allow a scale of importance and impact to be established for each competency. This can be done with the participants from this study or with an expanded group. Information on the relative value of the various skills will provide insight into the nuances of project engineering in different applications.

**Early vs Late Career Competencies:** Research into how project engineers value or struggle with various competencies at different stages of their career may be invaluable to the mining industry. It could enhance learning and development strategies, clarify training requirements and improve the profession overall.

**Education:** Further to an investigation of early versus late career competencies, research can be extended to the development of these capabilities in tertiary education or post-graduate programs. Findings from this type of research can benefit engineers from other disciplines, who would broaden their skillset and have a more rounded education if taught project engineering competencies alongside traditional engineering competencies.

**Qualities and Values:** As mentioned when discussing action and approach to work group of competencies, there could be value in investigating the role that identity, values and self-perception play in the high performance of project engineers.

# References

Engineers Australia (2019). *Stage 1 Competency Assessment Booklet.* Retrieved 10 September 2020, fromhttps://www.engineersaustralia.org.au/sites/default/files/Stage%201%20Guide_November%202019.pdf

Farr, J., Walesh, S., & Forsythe, G. (1997). Leadership Development for Engineering Managers. *Journal Of Management In Engineering*, *13*(4), 38-41. doi: 10.1061/(asce)0742-597x(1997)13:4(38)

Flanagan, J. (1954). The critical incident technique. *Psychological Bulletin*, *51*(4), 327-358. doi: 10.1037/h0061470

Heslin, P. (2005). Conceptualizing and evaluating career success. *Journal Of Organizational Behavior*, *26*(2), 113-136. doi: 10.1002/job.270

Hodgson, D., Paton, S., & Cicmil, S. (2011). Great expectations and hard times: The paradoxical experience of the engineer as project manager. *International Journal Of Project Management*, *29*(4), 374-382. doi: 10.1016/j.ijproman.2011.01.005

Kujala, S., Artto, K., Aaltonen, P., & Turkulainen, V. (2010). Business models in project-based firms – Towards a typology of solution-specific business models. *International Journal of Project Management*, *28*(2), 96–106. https://doi.org/10.1016/j.ijproman.2009.08.008

Kurvers, R. H., Herzog, S. M., Hertwig, R., Krause, J., Moussaid, M., Argenziano, G., Zalaudek, I., Carney, P. A., & Wolf, M. (2019). How to detect high-performing individuals and groups: Decision similarity predicts accuracy. *Science Advances*, *5*(11). https://doi.org/10.1126/sciadv.aaw9011

Male, S. (2010). Generic Engineering Competencies: A Review and Modelling Approach. *Education And Research Perspectives*, *37*(1), 25-51, 124.

Miles, W. (2013). *The relationship between project manager and project engineer, and its impact on project performance* (Doctor of Management). University of Phoenix.

O'Connor, P., O'Dea, A., Flin, R., & Belton, S. (2008). Identifying the team skills required by nuclear power plant operations personnel. *International Journal Of Industrial Ergonomics*, *38*(11-12), 1028-1037. doi: 10.1016/j.ergon.2008.01.014

Passow, H.J. & Passow, C.H. (2017). What competencies should undergraduate engineering programs emphasize? A systematic review. *Journal of Engineering Education, 106 (3), 475-526.* doi: 10.002/jee.20171

Qualitative Data Analysis Software | NVivo. (2020). Retrieved 10 September 2020, from https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

Robledo, I., Peterson, D., & Mumford, M. (2011). Leadership of scientists and engineers: A three-vector model. *Journal Of Organizational Behavior*, *33*(1), 140-147. doi: 10.1002/job.739

Satnani, H., Marinelli, M., Male, S.A. and Hassan, G.M. (2020). Engineering Graduates working in maintenance within the mining industry in Australia: capability and conceptual gaps. In *Australasian Association for Engineering Education Virtual Conference 2020: Disrupting Business as Usual in Engineering Education*. Australasian Association for Engineering Education.

Shockley, K., Ureksoy, H., Rodopman, O., Poteat, L., & Dullaghan, T. (2015). Development of a new scale to measure subjective career success: A mixed-methods study. *Journal Of Organizational Behavior*, *37*(1), 128-153. doi: 10.1002/job.2046

Tremblay, M., Wils, T., & Proulx, C. (2002). Determinants of career path preferences among Canadian engineers. *Journal Of Engineering And Technology Management*, *19*(1), 1-23. doi: 10.1016/s0923-4748(01)00043-1

Viergever, R. (2019). The Critical Incident Technique: Method or Methodology?. *Qualitative Health Research*, *29*(7), 1065-1079. doi: 10.1177/1049732318813112

Walker, S. (2015). The EPCM Perspective. *Engineering and Mining Journal*.

Weiss, D. J., & Shanteau, J. (2014). Who's the Best? A Relativistic View of Expertise. *Applied Cognitive Psychology*, *28*(4), 447–457. https://doi.org/10.1002/acp.3015

Williams, J. (2020), *WA.gov.au*, Government of Western Australia, available at: https://jtsi.wa.gov.au/docs/default-source/default-document-library/wa-economic-profile-pdf-0620.pdf?sfvrsn=5206711c_4 (accessed 2 May 2021).

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