

Engineering Management in Australia: An Overview of Current Practices

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Abstract

Engineering Management (EM) has a long history in Australia as far back as 1968. However, a review of scholarly papers has revealed a lack of attention from researchers for this discipline in the past 10 years, especially topics about industrial demand and competency. This paper is to provide a review of current EM practices in Australia, classified into Occupation and Market demand, Professional Society, and Required Qualifications and Competency. A review of EM practices in Australia has been conducted through 24 scholarly papers from 1991 to 2022 along with a statistical analysis of data from government and professional society. The review has revealed the increasing market demand for engineering managers (EMers). Temporary and permanent visa has been offered since 2005 and 2012 respectively to fill the gap in the domestic market. The EM career path with required years of experience and the trend of qualifications are also synthesized from different research and data. Different from the US, Australia is lacking a professional society that is dedicated to the management and promotion of this discipline in the country. EM competency is currently defined by Engineers Australia (EA) only for migration purposes. The paper raises the awareness of management skills for all engineers on their engineering career path. This paper also provides implications for strategic plans, particularly for educational institutions in developing engineering management programs. Further, recommendations for future research directions are outlined. This is the first literature review paper on EM practices in Australia.

Keywords

Occupation, Career Path, Competency, Education, Professional Society.

1. Background

In Australia, EM is found as far back as 1968 with the definition of the coupling of management with technical work (Lloyd, 1968). Nationwide, since the 1980s, the role of management has been confirmed to play a vital role in practice for professional engineers (Young, 1986) and to be a requirement for all engineering activities (Young, 1987b). The role of EM education in Australia has been mentioned to prepare engineers to further steps in their career path to leadership and managerial roles since 1986 (Young, 1987b).

Given the long history of EM in Australia, the researchers have conducted a literature review on scholarly papers about EM practices in Australia.

1.1. Literature Review Process and Results

The literature review process commences with articles that are located at the intersection of Engineering Management/Engineering Manager and Australia until the date. Articles are gathered based on searching titles, abstracts, and keywords. The papers are classified into different themes as described in Figure 1.

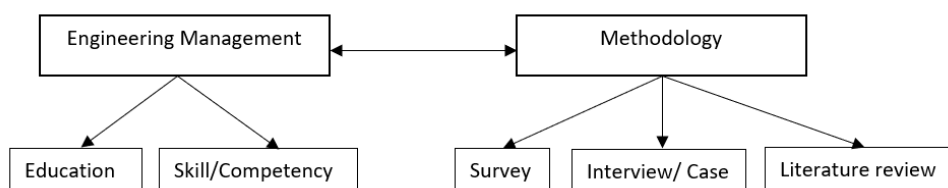


Figure 1. Literature Classification Scheme

The result of 24 papers is described in Table 1. Figure 2 shows the number of articles over time.

Table 1. Reviewed papers with themes

Reference	Area		Methodology		
	Education-related (Programs, Students)	Industry-related (Demand, Competency)	Survey	Interview/ case	Literature review
(Balzer, 1984)	X		X	X	
(Young, 1987a)	X				X
(Ward, 1991)	X				X
(Lloyd, 1991)	X	X			X
(Young, 1991)	X				X
(Young and Babcock, 1997)	X				X
(Palmer, 1999)	X	X	X		
(Solem and Young, 1999)	X				X
(Palmer, 2000)	X	X			
(Palmer, 2002)	X	X	X		
(Palmer, 2003a)	X	X	X		
(Wang, 2003)	X			X	
(Kasser et al., 2005)	X			X	
(Gibson et al., 2005)	X				X
(Stewart, 2006)	X			X	
(Palmer, 2006b)	X			X	
(Palmer, 2006a)	X			X	
(Goh, 2007)	X				X
(Stewart, 2007)	X		X		
(Palmer, 2007)	X		X		
(Goh, 2008)	X				X
(Goh et al., 2008)		X	X		
(Goh et al., 2010)	X				X
(Ho et al., 2022)	X				X

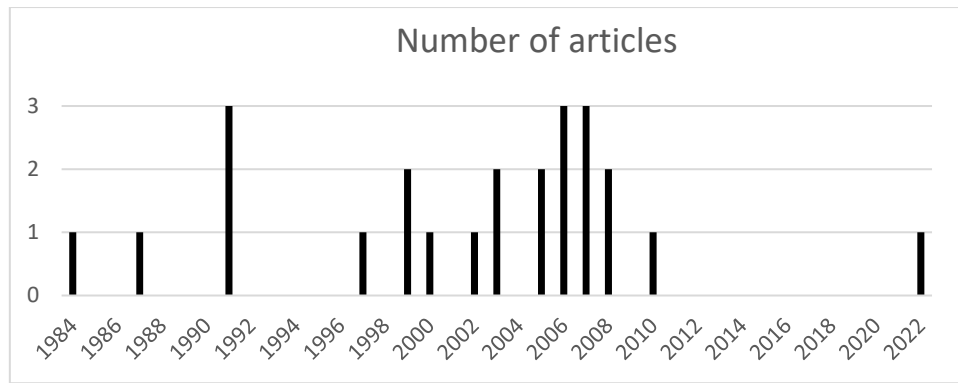


Figure 2. Number of articles over time

1.2. Research Gap and Objective

Figure 2 shows an infancy in the scholar research of EM practices in Australia in the past 10 years. In addition, it can be clearly seen from Table 1 that research on industrial practices have received less attention from scholars.

Given the limitation of research in the current industrial practices of EM in Australia, this research is to provide a review on EM practices, including Occupation and Market demand, Professional Society, and Required Qualifications and Competency. This paper will not only fill the research gap, but also provide an insight on the current practices for both educational institutions and practitioners for strategic decisions.

2. EM practices

2.1. EM as an occupation and career

In Australia, the EMer was first listed in the first edition of the Australian Standard Classification of Occupations (ASCO) list in 1986. Data from the Department of Home Affairs shows that since 2005, temporary skilled visas for EMers have been opened for migrants (Affairs, 2022b). Since 2012, it has been one of the occupations in need of permanent migrant engineers (Australia, 2019).

The EM concept is affirmed to have a long history back with around a thousand years ago (Dow, 2010). This term is well-known as the transition of an engineer from a technical to management responsibility (Palmer, 2003b, Tanner, 2003). This promotion happens sometime in a typical engineering career path regardless of whether and when (Srou et al., 2013, Palmer, 2003b). In Australia, a survey in 2008 also found that engineers had the same reason for moving into management positions as a natural career progression with 56.1% of responses (Goh et al., 2008).

According to Lannes (2001), a typical engineering career path includes 3 phases and EM is the second phase (Tanner, 2003). This phase will be usually after the first 5 years working in the technical field and will last from 5 to 25 years (Lannes, 2001). The data of average years spent in these roles in Australia is illustrated in Table 2. The literature has revealed an average of 6.5 -8.3 years' experience in engineering roles and 20 years as a manager. Engineers usually start their management roles at the age of 40s.

Table 2. Average age and years' experience in the roles

Published Year	Reference	Number of Years/ Average Age in technical roles	Number of Years/ Average Age in management roles
1984 (surveyed year of 1973)	(Balzer, 1984) (Young, 1987a)		20-25 years: 50-60% of engineers After 40 years old: 50%
1999	(Palmer, 1999)	Mean of 8.4 years (a range of zero years to 35 years)	
2000	[19]	Mean of 14.3 (a range of 0 to 54 years) *Note: survey of EM academics	Mean of 10 years (a range of 1 to 40 years) *Note: survey EM academics
2008	(Goh et al., 2008)	40%: 1-5 years 24%: 6-10 years	30%: 21-30 years 24%: 11-20 years

		Average of six and half years	Average of 22.5 years (a range of 3 to 45 years)
2021	(Insights, 2022)		Average age of 45 (between 35 and 54)

2.2. Market demand

Statistics by the Australian Taxation Office show that EMers together with mining engineers are some of the country's highest-paid professionals (Diemar, 2022). EMers have the median full-time earnings and median hourly earnings much higher than weekly earnings for all jobs (\$3,610 vs \$1,593 per week, and \$96 vs \$41 per hour) (Insights, 2022).

The National Skills Commission has predicted a very strong future demand for EMers with 11.7% increase for next 5 years, likely to reach 26,900 by 2026 (Commission, 2021a). The demand for this occupation is at top 2 in the occupation group of manager (group 113) (Commission, 2021b) (Figure 3). Similarly, this demand is on the rise with 12.8% over the next five years by Seek (Diemar, 2022).

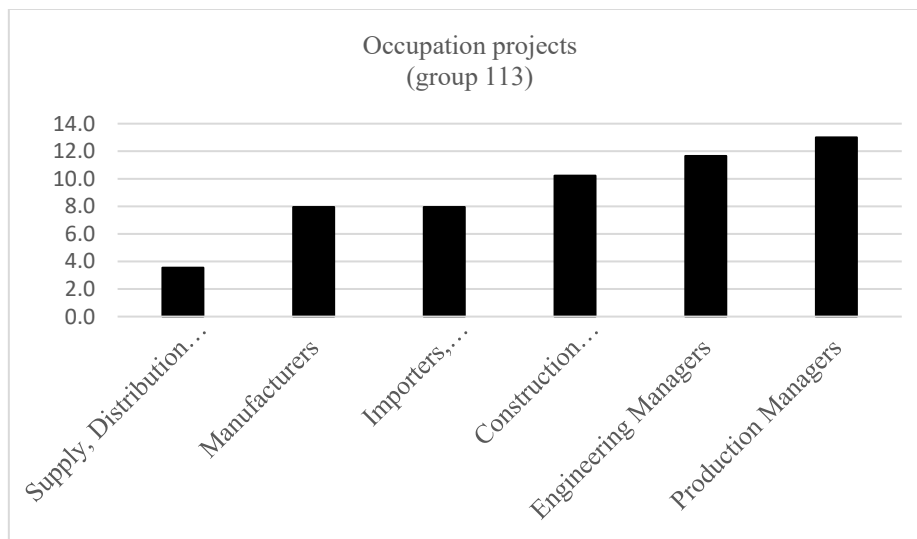


Figure 3. The 2021 Employment Projections

Table 3 shows the demand for temporary and permanent visas with the data from Immigration Department (Affairs, 2022b, Affairs, 2022a).

Table 3. Demand for temporary and permanent visas for EMers

Year	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-06/22
Temporary skilled visas	367	385	551	533	464	559	669	533	439	310	240	388	245	16			
Temporary Skilled Shortage													24	370	284	233	251
Total Temporary skilled visa	367	385	551	533	464	559	669	533	439	310	240	388	269	386	284	233	251
Permanent visa							165	160	139	122	121	96	91	75	52	46	
Total	367	385	551	533	464	559	834	693	578	432	361	484	360	461	336	279	251

2.3. Professional Society

In the US, the EM professional society was established with the emerge of the America Association of Engineering Management (ASEM) in 1979 (Kocaoglu, 2009). ASEM has officially published a guidebook - A Guide to the Engineering Management Body of Knowledge (EMBoK®) - as a foundational reference for this discipline and professional curriculum development (Dow, 2010, Radhakrishnan and Pettit, 2019). Further, ASEM provides a standard framework to define the characteristics of a successful master of EM (MEM) (Westbrook, 2006, Peterson, 2005).

In Australia, the Institution of Engineers Australia (IEAust) has taken the initiative of the Society for Engineering Management Australia (SEMA) with the prime objectives of providing professional society activities for all members, including EMers, general managers, or aspiring to a management role (Lloyd, 1991). SEMA was established in March 1990 (Eschenbach et al., 1991). And SEMA was the managerial arm of the Institution, providing a national focus and co-ordinating mechanism and having a crucial role in the future of the profession (Lloyd, 1991). However, SEMA went to recess in 1997 (Eschenbach, 1996).

Currently, EA has nine colleges which are each led by a College Board. The College of Leadership and Management is representing engineering professionals across all disciplines who are seeking to become managers, or already managers. However, Engineers Australia does not accredit master programs which only offer engineering practice and management (King, 2008), none of EM master programs has got the accreditation.

2.4. Certification/qualification

The pathway to EMers can be through university or Vocational Education and Training (VET) and a degree in a relevant engineering field is usually needed to work as an EMer (Insights, 2022). The data in 2016 shows that 70% of EMers hold a higher education degree (Insights, 2022). This number is relatively higher than the all job averages with around 32% of respondents holding a bachelor or postgraduate degree (Figure 4).

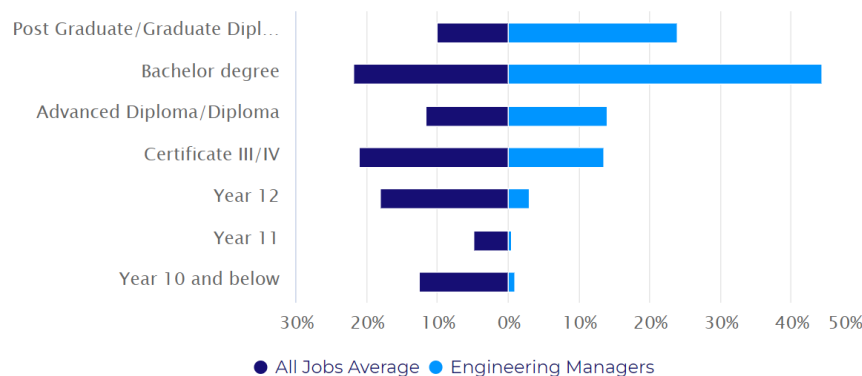


Figure 4. EM level of education. Adopted from (Insights, 2022).

Many organizations start to require certificates for EMers (Remer and Ross, 2014). In the US, ASEM has established multi-level professional certifications, a formal method to confirm an individual's competency (knowledge, education, and experience) of managing technical organizations. Currently, there are two levels, Certified Professional in EM (CPEM) and Certified Associate in EM (CAEM), which have been the most important industry-recognized certification for technical managers (ASEM, 2022). The certification exam is required with the requisite background for approval. Different from the US, the certification for EMers is only available for the purpose of migration (Australia, 2019).

The comparisons of qualification requirements between the US and Australia are summarised in the next table.

Table 4. Certified EMer requirements

Country	Degree	Required experience	
The U.S	Bachelor or Master (Engineering or related Technology)	CPEM: Plus 4 years Exam required	CAEM: No experience required Exam required
	Master (EM from ASEM certified program)	CPEM: No exam required	CPEM: No exam required

Australia	Bachelor degree or higher in engineering or in an engineering-related field	Plus Five years of experience as an engineering professional/ OR two years of employment as an EMer. Persons reporting to them who are at the managerial level Competency demonstration report (CDR) required
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It can be easily seen that the qualification and experience requirements are quite similar between the two countries with a higher education qualification in engineering or related technology; and 4-5 years' experience.

2.5. Skills and competency

Management is mentioned to be an essential and integral part of the duties of most professional engineers (Young, 1987a) (Ward, 1991). Engineers are mentioned to spend a significant proportion of the work that is predominantly on management (Balzer, 1984). In 1991, IEAust published the Guidelines for Management Studies in Engineering Undergraduate Courses as a 17-unit model syllabus. Currently, the EA accreditation system requires 10% of student effort within the total learning experience for Integrated exposure to professional engineering practice, including management and professional ethics.

In the US, the CPEM® and the CAEM® tests are both based on the EMBoK®. It is the official guidebook with 10 domains which has been built from a global perspective (Shah, 2019) and used as a foundational reference for this discipline and professional curriculum development (Dow, 2010, Radhakrishnan and Pettit, 2019). In Australia, regarding competency for EMers for migration purposes, the CDR requires EMers to demonstrate 8 knowledge and skill base competency with detailed indicators of attainment. These domains and competencies are described in Table 5.

Table 5. EM domains and competency

The 1991 Guidelines for Management Studies in Engineering Undergraduate Courses	EA competency Elements for EMers	EM Body of Knowledge
<ol style="list-style-type: none"> 1. Communication skills 2. Project Management 3. Supervision and Leadership 4. Economic Evaluation of projects 5. Innovation 6. Operations and Quality management 7. Human resource management 8. Business strategies 9. Organizational behaviour 10. Theories of management 11. Engineering and society 12. Management science 13. Finance 14. Economics 15. Legal studies 16. Marketing 17. Accounting 	<ol style="list-style-type: none"> 1. Manages people (7 indicators); 2. Contributes to engineering business strategies (9 indicators); 3. Manages the implementation of engineering plans within the business (9 indicators); 4. Develops client relationships (5 indicator); 5. Manages resources (6 indicators); 6. Manages suppliers (4 indicators); 7. Monitors engineering business performance (3 indicators); 8. Manages business information (3 indicators). 	<ol style="list-style-type: none"> 1. Leadership and Organisational Management; 2. Strategic Planning and Management; 3. Financial Resource Management; 4. Project Management; 5. Quality Management System; 6. Operations and Supply Chain Management; 7. Management of Technology, Research, and Development; 8. Systems Engineering; 9. Legal Issues in EM; 10. Professional Codes of Conduct and Ethics.

Scholarly, there are four papers investigating the required skills and attributes through survey method. These are listed in Table 6.

The latest broad-scale survey shows that the required competency for EMers has changed over time with the emerge of soft skills and interpersonal skills at the top 10 such as integrity, drive/ ambition and so on. Recently, in the report of Engineering 2035 by the Australian Council of Engineering Deans, besides management skills, most employers expect engineering graduates to have employability attributes which enable industry immersion, such as appreciation of all risk principles, or global / external perspectives etc. (Lawrence, 2020).

Table 6. Reviewed papers with surveys about EM skills

Paper	Surveyed Year	Participant	Number of responses	Survey factors
[17]	Not mentioned (paper published in 1999)	Mature Age Undergraduate Engineering Students at Deakin University	28	Rate the importance of 17 elements of Guidelines for Management Studies in Engineering Undergraduate Courses
[19]	1998	Australian academic staff members	41	
[20]	1996 to 1999	Recent Graduates Engineering Programs from Deakin University	42	Importance of management skills as identified by respondents
[32]	2007	New graduates to CEOs (Bachelor's degree in Engineering)	82	Importance of skills/attributes and training requirements

3. Implications

3.1. Educational institution

EM education has a vital role in preparing engineers with leadership and managerial skills for their career success (Young, 1987a). While academic discipline EM is well-established and recognized by Accreditation Board for Engineering and Technology (ABET) with programs at bachelor's, master's, and PhD levels (Sarchet and Baker, 1995, Daughton, 2017). In Australia, there are no EM undergraduate and PhD programs. Interestingly, before 2009, there were accredited EM bachelor programs which were combined or embedded within other programs. However, this type of bachelors' program is no longer in accreditation list. Instead, there are dual-degree programs between Engineering and Commerce/Business/Management and the Engineers Australia Institution has required 10% content of professional engineering practice, including management and professional ethics from 1995 (Gibson et al., 2005). With the distinct characteristics of managing engineering, which is mentioned to be different from managing most other activities due to the nature of engineering (Misra, 2008), appropriate EM programs must be specified in conjunction with engineering relationships; and different from a generic business or management course (Kauffmann et al., 2015). Given the rising demand for EMers, whether EM programs should be provided by Australian institutions.

Practitioners also agree that a postgraduate degree in EM is one of the factors in engineering career progression (Srouf et al., 2013). More and more graduated engineers are seeking higher education in management (Palmer, 2003b). This has been also confirmed in an Australian context with a growing number of mature-age engineering students continuing to upgrade their qualifications (Palmer, 1999, Palmer, 2000). To fulfil the local Australian needs, MEMs have been implemented to fill an important gap in the training of EMers in this country (Balzer, 1984). The data from the Australian Council of Engineering Dean (ACED) shows that there are 22 ACED providers with 34 MEM programs in 2020 (Crosthwaite, 2021). However, MEM education is scattered in many different programs (Ho et al., 2022) with courses being designed to meet the demand (Sarchet and Baker, 1995). Furthermore, it is mentioned that since EMers still need to have deep knowledge of their specific technical skills, engineering faculties (rather than business faculties) should get involved in designing and adjusting the curriculum to respond to this need (Goh, 2007) and to better reflect the needs of changing operating environment (Goh et al., 2008). Given the big tent of EM discipline, whether there should be a common ground on program content for the masters' degree.

Educational institutions need to develop emerging management skills for engineers to meet contemporary demands (Sarchet and Baker, 1995). For example, the sustainability theme is suggested by both ABET and ASEM as a part of EM graduate educational programs (Radhakrishnan and Pettit, 2019). Or with the 4th Industrial Revolution and the big data era, EMers need to be well-trained for new roles and to leverage intelligent techniques to solve complex problems (Markl and Lackner, 2019) (Shi, 2016) (Kahraman and Çevik Onar, 2015). The report of Engineering 2045 also mentions that the industry emphasizes the importance of the ability to work within next-generation industries and applications, such as immersive technologies, AI, or automation (Lawrence, 2020).

3.2. Professional society

In 1991, a linkage among three Societies (Australia – the US – Canada) was created with an agreement to form an International Federation of Engineering Management Societies (Lloyd, 1991). The highly developed EM

culture in North America with its extensive postgraduate studies and research in EM is mentioned to be extremely beneficial for the Australian profession (Lloyd, 1991). ABET develops the accreditation guidelines for all EM programs based on suggestions for changes by ASEM and by the Engineering Management Division of the American Society for Engineering Education (Wiebe and Babcock, 1989). Furthermore, the CAEM® and CPEM® certification is mentioned to be global with EMers working around the globe. A new collaboration with ASEM for using use global professional standards to certify MEM and professional certifications would benefit the EM community in Australia.

3.3. Future research

The literature review has indicated the gap in recent research to investigate EM practices in Australia. Broad-scale surveys with current EMers would provide an insight into EM current practices as well as emerging competency and skills in the era of data and industry 4.0. This would predict the future of EM skills as well as develop implications for education and training.

Furthermore, research on EM in times of crisis and the future will also be beneficial for professional engineers to prepare to ensure a smooth transition into the new changing workplace and role.

4. Conclusion

This paper has filled the gap of a review paper on EM practices in Australia. The data has revealed the high demand for this occupation in the market with the solution of the temporary and permanent visas for EMers to bridge this gap. The career path with the requirements of qualification and experience years is also analysed with the results of the dominance of higher education, the average year of 6.5 -8.3 years in engineering roles and 20 years in management roles. Furthermore, the EM skills are also analysed by reviewing the competency requirements from a professional society.

The paper ends with recommendations for strategic plans for educational institutions in developing EM programs at the undergraduate and postgraduate levels. A suggestion of a professional society in collaboration with other international association to leverage EM society in Australia is also provided. Last but not least is the directions for future research with the need of broad-scale research on the current practices and future of the EM discipline.

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