INDUSTRIAL ENGINEERING AND ENGINEERING MANAGEMENT IN AUSTRALIA

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ABSTRACT

Since 1998 Monash University has operated its degree of Bachelor of Engineering (Engineering Management and Industrial Engineering). This is a degree targeting a critical area of engineering employment which has been largely ignored by Engineering Faculties in Australia.

The challenge facing the BE(IE&EM) degree is that despite the fact that the degree concepts are well known in other parts of the world, the subjects are not well known in Australia. Before they will take up the degree, potential students need to be educated in the nature and importance of engineering management and industrial engineering, they want to be sure that the core subjects are interesting and challenging and they want to know what advantages the degree will give them in the employment market.

INTRODUCTION

The degree is an amalgam of two different concepts - Engineering Management and Industrial Engineering. There are sound reasons why both of these concepts are embodied in the degree.

Engineering management

Management is a broad term involving a number of diverse disciplines such as the management of people, finances, sales and marketing but it also involves the management of the equipment and production and the design and development of products, processes and projects.

Engineering management is that management which is focussed on the latter area of management, the management of the physical assets and activities of the business and the development of new processes. This is an area which is not commonly dealt with in great detail in management schools and yet it is fundamental to all successful businesses. Engineering skills are clearly critical in these management areas, but as yet few Engineering Schools spend very much time on them. The engineering focus in education continues to be very much at the nuts and bolts, even complete product but not at the totality of business level.

Though this definition of engineering management emphasises the physical assets and products, these things cannot be separated from the people who use them or the financial issues. For this reason training in engineering management must encompass a wide appreciation of many management areas, in particular personnel, finance and marketing.

Because engineering is so important to business, a large proportion of engineers are employed in the management area and this proportion increases as engineer's careers develop. Surveys of engineers (taken from members surveys of the engineering members of the professional association APESMA) indicate that 35% of engineers think of themselves as carrying out the function of management. The proportion

changes with the age of the engineers interviewed. Soon after graduation the proportion is 15-20% rising to over 50% by the age of 45 as shown in Figure 1.

The role of management training in the engineering course has been discussed extensively in recent years [1]. The IEAust requires a 10% minimum course content at present. BE(IE&EM) because of its high human factor focus contains more training for management and the Monash degree is over 20% management. The BE(IE&EM) degree seeks to be at the leading edge of management sciences and so there are substantial aspects of mathematics, such as operational research, statistics and systems simulation.

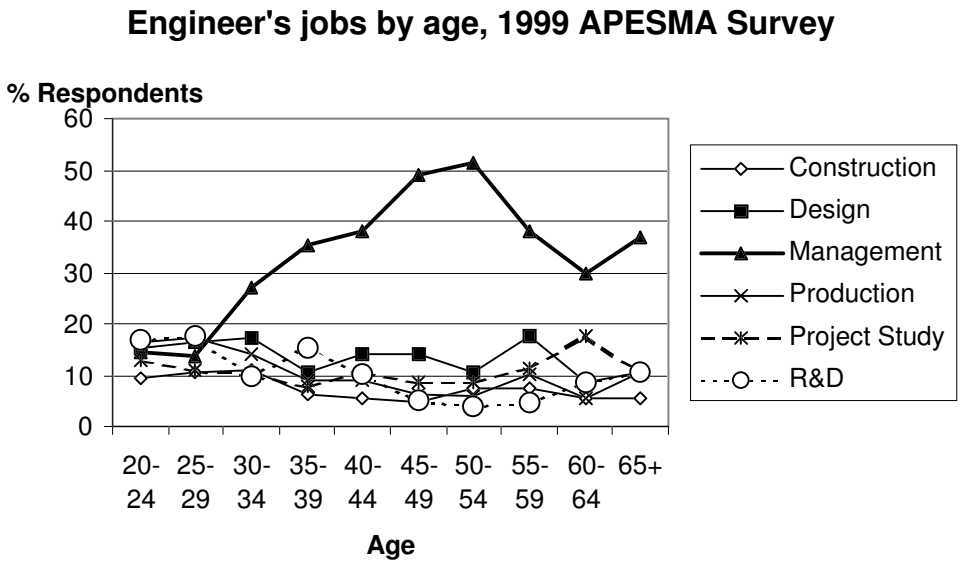

Figure 1 How engineers tend to become managers.

Industrial Engineering

Industrial Engineering is complimentary to engineering management and is clearly defined independent branch of engineering recognised by the major institutions.

A short definition of industrial engineering is "the design of productive processes". This definition differentiates Industrial from other branches of engineering which tend to concentrate on the design of things, or on parts of a productive process. IE by contrast considers the entire productive activity. Table 1 gives an official definition from the IEAust as reported in the National Competency Standards for Professional Engineers [2].

All businesses need high calibre people who can consider the productive system comprehensively and who can design systems which can increase productivity and make products of higher quality. Industrial engineering is specifically aimed to be training for such tasks.

An Industrial Engineering degree has been offered by Monash since 1982 and several hundred ~~of~~ graduates are now working in industry and business. The new degree builds on the strengths of that degree while reorienting it to more recent changes in the economy which require even further management skills.

The Industrial Engineering and Engineering Management disciplines have undergone vigorous development in the hundred years since the concepts were first conceived over a hundred years ago [3]. Many people associate the topics of work standards, time

Industrial Engineering is the technical and human aspects of quality and productivity

"Industrial engineering is the engineering discipline concerned with the planning, organising and operation of industrial facilities and processes for the economic, safe and effective use of physical and human resources. Industrial engineering is applied design for the integration of material, human and financial resources, and of production sequences and methods, optimum flows and layouts, and of work methods and procedures, labour organisation, and in economic evaluation of facilities, processes or techniques. Specific expertise areas include:

Industrial engineering practices
Materials handling engineering
Operations research
Safety and environmental engineering
Manufacturing process engineering
Methods engineering
Quality assurance and control"

Table 1 Definition of Industrial Engineering and Specific Expertise Areas, IEAust.

Technology
Information Technology
Computer-Integrated Business
Manufacturing Engineering
Service Technology
Human Dimensions
Organisational Design
Work Design
Ergonomics/Human Factors
Planning, Design and Control
Product Planning
Engineering Economy
Methods Engineering
Performance Measurement and control of Operation
Facilities Design
Planning and Control
Quality Assurance
Quantitative methods for decision making
Probability Theory and Models
Statistics for Industrial Engineers
Computer Simulation
Optimisation

Table 2 Main Subject Areas in Salvendy's Handbook of Industrial Engineering5

and motion study and related activities with Industrial Engineering. While they are important, a modern view of Industrial Engineering such as exemplified in Salvendy's Handbook [4], these subjects of contribute only about 5 chapters out of 108 (the main chapter headings of this book are given on Table 2). In the Monash BE(IE&EM) course these topics occupy perhaps 4-6 credit points out of 192 credit points required for the degree.

THE NEED FOR THE DEGREE

Changes in the Australian economy.

Figure 2 shows some of the changes in the Australian economy which occurred in the last decade. There are two issues of special interest for the professional engineering labour force.

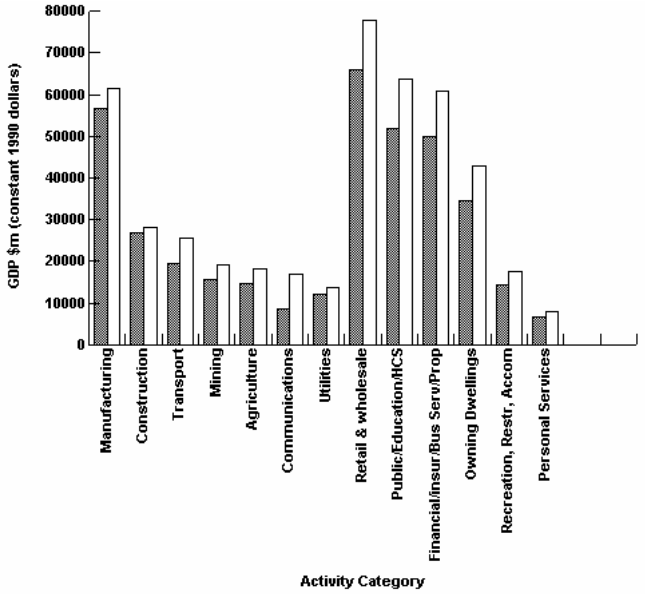

Figure 2 GDP value in constant dollars for several major sectors of the Australian economy
Note substantial growth in all sectors but particularly in services areas. Communications also is very strong in this period because of the introduction of mobile phones, Internet and cable.

1) *Growth in services*.

Services are defined by the Australian Bureau of Statistics (ABS) as those things which are not specifically primary production (mining and agriculture) and manufacturing. The service sector has been on a continuous growth through out Australian history. The change of proportion is mainly caused by growth in several sectors which when one examines them do not include obvious large opportunities for traditional engineering specialities.

- Financial services,
- Retail and wholesale trade,
- Owning of dwellings,
- Public sector,
- Recreation and
- Transport and Distribution

This change in the Australian economy is affecting the attractiveness of traditional engineering careers such s mechanical, electrical and civil engineering compared to career paths specifically oriented toward the services sector such as retail, finance and management.

The experience with Industrial Engineering contrasts with this concept since many Monash graduates are employed in just these growth sectors. There has been significant uptake of graduates in particular by banks and financial institutions, management consulting firms (many of which had their origins in the accounting profession), retail and transport organisations.

1) *Changing nature of traditional engineering areas*.

Traditional areas for the employment of engineers have been manufacturing, utilities and construction. The general picture in these areas is stability or retreat when considered in terms of proportion of GDP. As seen ~~on~~ *in* Figure 2, in terms of stable dollars, the growth in the traditional engineering sectors is much smaller than the service sector (with the exception of telecommunications which had a burst of growth in the 1990s). Many of the businesses involved in traditional engineering such as electricity, railroads, telecommunications, have been changing dramatically. There has been changing ownership and they are entering significantly more competitive

environments including export areas. Efficiency and productivity are key issues in all these businesses and has affected the nature of professional engineering employment.

Many engineers in traditional engineering employment now find themselves engaged in seeking productivity improvements for these businesses. They carry out activities carrying titles such as quality improvement, value analysis or business analysis. These are clearly roles for which Industrial Engineers are trained.

On the other hand, one view of service businesses such as banks, transport companies and super market chains is that they too are kinds of process industries. One bank executive working with Monash described her organisation as a "paper factory". It is a paper factory which demands 100% accuracy. Essentially most businesses handle information, services activities and materials and even change materials from one form to another. The success of these businesses depends on the efficiency of these operations.

Manufacturing, which has often received a bad press because of reduction in shop floor employment, has actually grown considerably when measured in terms of constant value dollars. This can be seen clearly in Figure 2. Manufacturing growth has been achieved by great effort on part of Australian enterprises in the area of improvement of productivity and quality and this has been done in an environment of increasing global competition. Some of this improvement is achieved by factors such as automation and equipment but substantial improvements are possible by reorganisation of the work methods. These changes have tended to emphasise people of higher skills and there is now a significant shortage of capable professionals throughout manufacturing in Australia. Our graduates are now playing key roles in many of the companies involved in these improvements, especially in the automotive manufacturing sector.

The importance of this to Industrial Engineering is that all the factors discussed above are just the areas in which Industrial Engineers specialise.

One thing to consider is to distinguish the contribution which can be made by Industrial Engineers from that which can be made by manufacturing and other "equipment oriented" engineers. This distinction was defined most clearly recently when the manufacturing manager of General Motors in Melbourne stated that "The company has realised that the emphasis placed on machinery by the hiring of large numbers of Manufacturing Engineers has to be balanced by the work of Industrial Engineers - people who are expert in the human factors of production."

International opportunities

One of the key issues for any potential student considering taking up a degree is the international recognition of that degree on completion. Industrial engineering is an important branch of engineering worldwide and indeed is a much more common degree in countries in Asia, North America and Europe. The US situation is shown on Table 3. Not only is it the fourth largest branch of engineering at 14% of 2000 employment it has grown strongly since it was only 8.9% of the 1990 engineering work force. Table 3 represents an interesting story in its own right since on this table is captured the 1990 position and the projections of the US Bureau of Labor Statistics in an earlier paper56. The Bureau was very low in relation to Industrial Engineering in its 1990 predictions. Industrial Engineering has grown strongly in a total US engineering workforce which has basically remained stable over the decade. This thus opens the question whether its future conservative prediction is also incorrect.

US data 1990 and 2000	Electrical, electronics, computer	Mechanical	Civil	**Industrial**	Environmental	Aeronautical	Chemical	Mining Nuclear Petrol.	Materials	All
% 2000	24	15	16	**14**	4	3	2	2	2	100
1000s employed 2000	338	221	232	**198**	52	50	33	6.5+14+9 = 30	33	1500
1000s employed 1990	426	233	198	**135**	Nil	73	48	39	18	1500
US Bureau of Labor Statistics 1990 projection	571	289	257	**160**	Not included	88	54	40	22	1900
Actual growth compared to predicted	Lower	Lower	Lower	**Higher**	New	Higher	Lower	Lower	Higher	Lower
Current US BoLS predicted growth	Average	Average	Average	**Average to below**	Above average	Average	Below average	Stationary or Decline	Decline	Below average

Table 3 Engineering branches 2000 US employment and projections

US Bureau of Labor Statistics from web site http://www.bls.gov/oco**.**

The table also includes 1990 data and 1990 projection which shows that the Bureau has significantly under predicted industrial engineering growth.

Industrial Engineering has a strong tradition in Germany, Scandinavia, Japan and most industrialised nations. In Hong Kong the new University of Science and Technology has established a large department in Industrial Engineering and Engineering Management. We also see Industrial Engineering with strong roots in Taiwan, Thailand, Indonesia and the Gulf States and we receive both undergraduate and post graduate students from these areas. Our degree also is attractive to many students from Singapore and Malaysia.

Matching training to needs

The subjects of an Industrial Engineering and Engineering Management degree are so important that they are often picked up by engineers and other managers after they graduate. In a Graduate Diploma in management or a Masters of Business Administration there can be found subjects which are include*d* in the Monash IEEM degree at an undergraduate level. MBAs and Graduate Diplomas have achieved a high level of participation in Australia because engineers and other professionals find that in the work place they are soon concerned with subjects such as quantitative decision making, facilities and work design and quality management which were not covered in their original degree.

In Victoria about 1600 students graduated in Engineering so the Monash BE(IE&EM) course will account for only about 1.5% of local graduates. This would appear to be much lower than the potential needs of industry if measures such as the United States situation are taken as a guide where 14% of all engineers are classified as industrial engineers (see Table 3).

Job advertising for Industrial Engineers by name is not high in Australia. There are only a few such advertisements each month. However there are a significant proportion of employment advertisements which fall into the category of engineering management. In the second half of 1992 this proportion was over 21% (IEAust survey of metropolitan newspapers).

Numerous advertisements can be identified each week which our graduates could consider. These fall into categories such as

Production, Manufacturing or Process Engineering
Quality Management/Control
CAD/CAM, Automation
Health & Safety
Scheduling and Planning
Bank Analyst,
Business systems analyst
Business re-engineering
Logistics Management, and

Many of these categories were identified as important growth employment areas in a survey of a wide range of Australian organisations7.

Student demand

Student demand for Industrial Engineering and Engineering Management as such is not high because only very few high school students have studied the engineering profession adequately to know what an IE&EM career involves. Indeed IE&EM is significantly different in concept to the other branches of engineering, in its focus on processes rather than things, so it is not easy to stereotype with objects such as bridges, aeroplanes and so on.

Since it is a branch which deals with large numbers of management concepts it is probably most attractive to students who may not think of doing engineering at all, even though their entry scores are adequate in science and mathematics. These are students who may choose management or business degrees, computing or accounting. These students would have interests such as how organisations work, the relationships between people, multi disciplinary problem solving and having a management career path. This sort of interest profile suits industrial engineers as well. From our current experience at Monash there is a relatively high proportion of female students who undertake IE&EM but there is scope for many more who may not presently be considering engineering careers.

Industrial engineers can have significant advantages over graduates of purely business type degrees in industry, because they have a thorough base in engineering. A BBus (Manufacturing Management) course for example has low levels of technical content and requires lower mathematical skills. Experience of working in a manufacturing environment suggests that the most effective way for a graduate to lead tradespeople and other workers is by knowing as much as possible about the technicalities of work. People of no technical background will receive little respect from shop floor people when they are faced with practical problems. Indeed businesses are often faced with the complex multi disciplinary technical and human problems which is the ideal environment for the graduates of BE(IE&EM).

The term "Industrial Engineering"

Monash has decided to use the term Industrial Engineering in the title of the BE(IE&EM) because IE is an important international discipline recognised by the important engineering institutions around the world including the Institution of Engineers Australia (IEAust). There are numerous working professionals who have these words on their testamurs and there are institutions such as the Institute of Industrial Engineers and journals which use the term in the title. These facts mean that the term is well recognised by those who need to know, the crucial managers and employers8.

The importance of the term worldwide can be gained by a few minutes Internet searching on the words "Industrial Engineering". Immediately dozens of home pages from distinguished institutions such as University of California at Berkeley, Columbia University, Stanford, and Georgia Tech are found. Georgia Tech has the largest Industrial and Systems Engineering program in the world with over 500 students entering each year.

ENTRY TO BE(IE&EM) AT MONASH

Entry routes to the degree are very wide. Basically students finishing any first or second year in Engineering in any discipline can be considered for transfer to the BE(IE&EM). This permits people who may have a special interest in another engineering discipline to transfer to BE(IE&EM) with that speciality.

The BE(IEEM) has a common first year with the all the other disciplines of Engineering at Monash. Students who intend to do BE(IE&EM) are encouraged to take a special elective of Engineering Management in First Year.

In second year the set course has similarities to the Mechanical Engineering degree. However four out of twelve subjects (Industrial Engineering, Engineering Management, Manufacturing Processes and Business Processes) are completely different, and the other eight are specially presented for BE(IE&EM) students. This means of course that some subjects of the Level 2 Mechanical Engineering degree are presented in a reduced form.

The final two years are basically unique to BE(IE&EM). If students enter at level two or three from some other engineering degree, they will have to take the special subjects missed in levels one and two but there are special arrangements for this to be done within the normal subject load.

Monash will also consider transfer from students finishing any first two years Engineering at any recognised University for transfer into BE(IE&EM) for levels 3 and 4.

While all engineering courses are under continuous revision because of technology change, BE(IE&EM) is probably more sensitive to changes in other areas such as economics, industrial relations, social sciences and business management. As a result course content of industrial engineering is in many ways changing more rapidly than other branches. Details of the course are shown on the home page for the BE(IE&EM) program.

A summary of the subject list of Levels 2 to 4 are given in Table 4

Table 4 SUBJECT LIST
Bachelor of Engineering (Industrial Engineering and Engineering Management)

Level 1
The standard level 1 is taken. Students may choose to do an elective (Engineering Management) which then allows them to do a different subject in level 2.

Level 2 (12 subjects)

Industrial engineering
Engineering management
Manufacturing Processes
Business Processes
Multivariable calculus for engineering
Linear algebra and differential equations for engineering
Engineering practices:- drafting
Engineering practices: design process
Fluids and energy
Materials selection
Systems engineering
Computer programming

Those students who have done Engineering Management in Level 1 may choose to do Special project or Risk analysis

Level 3 (8 subjects)
Facilities planning and design
Quality systems
Systems modelling and simulation I
Engineering computations
Engineering economy
Database management
Design for manufacture
Professional practice for engineers I

Level 4 (8 subjects)
Core subjects
Engineering practice: project thesis A
Engineering practice: project thesis B

Elective subjects *(select six, of which at least four must be chosen from subjects offered by the department of Mechanical Engineering) Example:*

Production planning and control
Design of productive systems
Computer integrated manufacturing
Systems modelling and simulation II
Professional practice for engineers II
Industrial marketing
Systems reliability and maintenance
Managing strategic change

CONCLUSIONS

The paper outlines the degree and the objectives of the Bachelor of Engineering (Industrial Engineering and Engineering Management). The importance of the degree to Australian business lies in the fact that the training relates well to the major growth areas of the Australian economy and the needs of individual businesses. The degree presents many important subjects and forms of training not included in Business and Economics degrees.

The importance of the BE(IE&EM) to the engineering profession lies in the employment possibilities in sectors of the economy where engineers have not been well represented. There is also potentially a wider group of students who may become interested in Engineering when they realise IE is a degree which gives them permanent advantage in business employment. The attractiveness of the degree and its employment opportunities for female candidates is also of importance.

The BE(IE&EM) degree is being offered at Monash with a wide range of entry options permitting students to enter at levels 1, 2 and 3 even from other degrees.

ACKNOWLEDGMENTS

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