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ABSTRACT

Integrated manufacturing is an approach that applies information technologies and new types of work organization to integrate machines, information, and people. The trend toward integrated manufacturing is worldwide and irreversible, and is evidenced and reinforced by these activities and characteristics: development of new technologies f flexibility; sophistication of world markets; application of integrated types of work organization; and industry restructuring. As integrated manufacturing is implemented, there will be increased need for people with cross-disciplinary, higher-level, and cognitive skills as well as a wider range of skills. The implications for training adults include the following: (1) there must be a greater emphasis on conceptual learning; (2) courses and course administration should be more flexible; (3) cross-disciplinary training programs should be developed; (4) generic skills such as computer literacy, process development, and quality improvement should be integrated into existing vocational courses; (5) special programs for managers and supervisors should be developed; (6) efforts to retrain workers already on the job should be increased; and (7) industry's level of commitment to training should be increased. (A reference list of 91 citations concludes the report.) (CML)

TAFE

TAFE NATIONAL CENTRE FOR RESEARCH AND DEVELOPMENT

TRAINING FOR INTEGRATED MANUFACTURING

A Review of Recent Literature

Geoff Hayton

Mohammed Harun

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FOREWORD

This publication is an outcome of an in-house research project of the TAFE National Centre for Research and Development. The project is entitled: 'Training and retraining in integrated manufacturing' and involves, in addition to this literature review, a survey of industry and educational institutions in Australia and overseas. The final project report, to be published in 1989, will contain a summary of this literature review together with the survey results, case studies, and policy suggestions for TAFE. The authors would welcome comments on this review, especially before publication of the final project report.

The TAFE National Centre for Research and Development acknowledges the support of the Flinders University of South Australia in arranging the attachment of Mohammed Harun to the Centre to undertake research on the project as part of his post-graduate study. Valuable comments on the draft of this monograph were provided by C. Bridges-Taylor, R. Curtain, W.Hall, A. McFarlane, R. Meeks, P. Monie, J. Oxnard and P. Tucker.

CONTENTS

ABBREVIATIONS

ABS	Australian Bureau of Statistics
ACTA	Australian Council for Tertiary Awards
AMT	Advanced manufacturing technology
ASCO	Australian Standard Classification of Occupations
ASIC	Australian Standard Industrial Classification
CAD	Computer aided design
CAM	Computer aided manufacturing
CHIM	Computer and human integrated manufacturing
CIM	Computer integrated manufacturing
CIMM	Computer integrated manufacturing and management
CNC	Computer numerical control
DITAC	Department of Industry, Technology and Commerce
EDI	Electronic data interchange
FMS	Flexible manufacturing system
GDP	Gross domestic product
JIT	Just-in-time
MRP II	Manufacturing resources planning
NC	Numerical control
TAFE	Technical and further education
TQM	Total quality management

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1. INTRODUCTION AND DEFINITIONS

Integrated manufacturing is important in Australia's manufacturing industries simply because over the next five years it must be implemented by medium to large volume manufacturers to attain international competitiveness - those that don't may not survive. It is also important in vocational education and TAFE in particular because training and retraining for integrated manufacturing requires significant changes to a wide range of existing courses and the introduction of new courses. The success of integrated manufacturing is largely based on the skills within our workforce.

Integrated manufacturing encompasses a wide variety of technical and sociological disciplines and issues. This review aims to give an overview of the main issues, with a focus on training implications for industry and for TAFE. After defining some key terms, this review will:

- outline the key elements of integrated manufacturing;
- describe the context of integrated manufacturing with reference to Australian and world-wide trends;
- outline the workforce skills required for integrated manufacturing;
- discuss the training responses required.

After searching the literature for this review, it was found that:

- the literature on or related to integrated manufacturing is prolific and is mostly published within the last five years;
- most articles or books cover technical aspects or sociological aspects whereas few cover both;
- there were very few 'primary' articles or books, that is, articles or books written by people with experience in introducing integrated manufacturing.

The last point indicates a need for the publication of case studies of firms that have introduced integrated manufacturing.

A variety of terms is used in the literature to describe the phenomenon of integrated manufacturing. The terms describe concepts which overlap considerably but are not equivalent. The frequently used term *flexible manufacturing* covers technical and human aspects of integrated manufacturing (Ebel 1985; Bolwijn et al. 1986), whereas the narrower term *flexible manufacturing system* (FMS) covers technical aspects only (Holland 1984). The term *integrated manufacturing* describes an approach to manufacturing involving technical and human aspects (Mortimer 1985; DITAC 1987b), whereas the narrower term *computer integrated manufacturing* (CIM) refers to the technical aspects of integration of machines using computer technology (Roberts 1984; Ranky 1986). The term *advanced manufacturing technology* (AMT) is used to refer to the range of technical components of integrated manufacturing (NEDO 1985), though some writers state or imply human aspects also (Manufacturing Studies Board 1986; Craven and Slatter 1988). Other terms closely related to integrated manufacturing are:

- computer and human integrated manufacturing (CHIM) (Brodner 1987; Wobbe 1987);
- Computer integrated manufacturing and management (CIMM) (McFarlane 1988);
- flexible specialisation (Piore and Sabel 1984; Wobbe 1987);
- continuous flow production (Bolwijn et al. 1986).

It is important to have a broad term which describes the new approach to manufacturing in which both technical and human aspects of integration are crucial. The term *integrated manufacturing* meets this need. Our definition of *integrated manufacturing* draws together the ideas of a range of writers: Piore and Sabel 1984, p.17; Bolwijn et al. 1986, pp.305-308; DITAC 1987b, pp.3-6; Wobbe 1987, p.6. It states:

> *Integrated manufacturing is a broad term describing a management approach which aims at simultaneously achieving efficiency, quality and flexibility through integrating all aspects of a manufacturing organisation's operation. It involves the integration of:*
>
> - *machines;*
> - *people;*

- *people and machines;*
- *systems and procedures,*

through the application of information technologies and integrated types of work organisation.

The term *information technologies* is used here in the broad sense to include computer and communication technologies (Hall et al. 1985, pp.25-7).

Integrated manufacturing is not a particular system, technology or CIM (Computer integrated manufacturing) but a long term strategy which, for each manufacturing organisation, will involve a particular combination of several techniques and technologies such as CIM, CAD, CAM, MRP II, JIT, TQM, FMS. Integrated manufacturing transforms the manufacturing function from a batch process towards a *continuous flow production* operation, starting with customer orders and ending with product delivery. The resulting simultaneous improvements in efficiency, quality and flexibility can provide manufacturers with a powerful competitive weapon.

Closely related to integrated manufacturing are *flexible manufacturing* and *continuous flow production*. *Flexible manufacturing* is the term more commonly used in Europe and Japan to describe integrated manufacturing, though there is a slight difference in emphasis. Flexible manufacturing emphasises flexibility (together with price reduction and quality improvement) whereas integrated manufacturing emphasises the means of achieving this through integration of operations and systems. However, for the purposes of this paper, the terms flexible manufacturing and integrated manufacturing may be used interchangeably.

Continuous flow production is a way of manufacturing characterised by the fact that products are almost continuously being worked at. In other words, as little time as possible is wasted on waiting, transport and being in stock. Furthermore, a variety of products may be produced in the same production process (Bolwijn et al. 1986, p.175). Thus, continuous flow production is one of the visible outcomes of successful integrated manufacturing.

2. UNDERSTANDING INTEGRATED MANUFACTURING

Most of the large manufacturing companies of today were once very small businesses. The founders knew every aspect of the business and everything that was happening at any given time. But as these businesses grew, individuals could no longer cope with all the skills involved, nor could they keep track of everything that was happening. It seemed natural to divide tasks and allocate them to people with specialist skills (Mortimer 1985, p.29).

It became clear that greater efficiency could be achieved through:

- greater specialisation of labour (because people can more easily learn a smaller range of tasks and perform them more efficiently):
- mechanisation of specialised manufacturing operations (because machines could perform simple tasks faster and more consistently).

Thus, as manufacturing businesses grew, labour became more specialised, more manual operations were mechanised, and areas of specialisation became departments within the larger organisation.

However, greater specialisation has a price. More complex systems for moving materials and information are required, resulting in greater administrative overheads. Modern management techniques were devised to manage this complexity rather than eliminate it. Today most manufacturing companies in western countries have overheads of over 200% of direct production costs (Mortimer 1985, p.30; Brodner 1987, p.33).

Integrated manufacturing provides a very effective alternative but it requires a radically different way of thinking. Integrated manufacturing is a new manufacturing philosophy, not just a new technology such as computer integrated manufacturing (CIM). The philosophy involves reducing complexity and bringing the whole manufacturing operation, not just production, into a single, well-coordinated whole unit. CIM technology may be introduced in the later stages of implementation of an integrated manufacturing strategy.

CIM is a powerful technology and a potentially key part of integrated manufacturing, but it must be seen as only a part of any comprehensive integrated manufacturing strategy.

The most effective integrated manufacturing strategy will vary from company to company. However, companies adopting an integrated manufacturing strategy will usually undertake the same three steps:

- simplify;
- integrate;
- apply CIM technology as appropriate.

(Mortimer 1985, p.30).

Each of these three steps will now be discussed.

SIMPLIFICATION OF MANUFACTURING

Simplifying a manufacturing organisation has a number of direct and indirect benefits (Bolwijn et al. 1986, p.145). The typical manufacturing operation of today is surprisingly complex. Complexity can be seen in the flow of materials and products from goods inwards to despatch, and in the flow of information among information centres such as :

- management;
- marketing and sales;
- product design;
- engineering;
- purchasing;
- production/assembly;
- quality management;
- distribution.

Complexity in the flow of materials and products leads, in part, to a large amount of capital being tied up in stocks of raw material, material in progress, work in progress, finished parts and finished products. Only a small fraction of time is spent on production or assembly, most time is spent 'waiting'.

Complexity in the flow of information leads to large piles of paper waiting on desks for attention. This in turn leads to reduced efficiency and lower quality due to the inevitable occurrences of information transfer deficiencies.

In a complex system of material and product flow and information flow, any unplanned event - delays, market changes, machine breakdowns and labour disputes - can be disastrous.

Various methods of analysis may be used to help plan for simplification of manufacturing. The aim should be to complete everything in the simplest and most timely way with simple and efficient information flow.

INTEGRATION OF MANUFACTURING

Integration should involve all aspects of manufacturing, not just production. Thus marketing, sales, purchasing, product design, production and distribution should be integrated through simple, timely and efficient flows of information and materials. The main components of integration are:

- machines;
- people;
- people and machines;
- systems and procedures.

The development of information technologies has greatly broadened the scope for integration of machines. The integration of machines may involve one or more of the following forms:

- the linking of two or more dedicated machines with respect to material flow and/or information flow;
- the consolidation of two or more operations in a programmable machine or robot;
- the linking of two or more functions such as design and production.

The integration of people may involve one or more of the following:

- a flat management structure with few hierarchical levels;

- the consolidation of departments;
- the formation of multi-task teams.

Integration through new approaches to work organisation is discussed in a later section.

The integration of people and machines may involve improving the effectiveness of the person-machine interface, usually through computer technology, so the person has more control over the machine. This would result in the operator and machine working more efficiently and more flexibly, and would increase the level of responsibility that should be given to the operator.

The integration of systems and procedures such as:

- Manufacturing resources planning (MRP II);
- Just-in-time scheduling (JIT);
- Total quality management (TQM),

should be introduced or modified to realise corporate strategies. Integration involves ensuring that standards and protocols are common to all systems and procedures introduced.

Integration may occur both within and outside the organisation. A step towards integration of companies, such as a manufacturer and its supplier and client companies, has been taken by implementing Electronic Data Interchange (EDI) in the automotive manufacturing industries in the USA, Europe and Australia. This involves paperless transfer of business documents between participating companies (Baker 1988).

For all components of integration, the current wisdom is that integration should be planned 'top down' (that is, from corporate goals to shop floor) but implemented 'bottom up'. This approach requires firstly the definition of corporate goals and then, based on these goals, the formulation of an integrated set of strategies such as a business strategy, a manufacturing strategy and an information systems strategy (Hayes and Wheelwright 1984, pp.24-35).

APPLICATION OF CIM TECHNOLOGY

CIM is a technology which may form an important part of an integrated manufacturing strategy for a company. CIM is a powerful tool but it should be viewed in context - its potential is only realised in a well-planned integrated manufacturing strategy, and CIM technology is still developing.

CIM uses computer hardware and software to provide the flow of all information between people and machines in a manufacturing organisation. Fully developed CIM would result in little or no information being transferred orally or by documents, with all essential information being transferred and/or stored electromagnetically. This would embrace:

- management information;
- orders;
- accounts;
- design information;
- engineering information;
- production planning and control.

3. MANUFACTURING INDUSTRY TRENDS

The changes to Australia's economy need to be understood in the context of long term trends and Australia's position in the world economy of developed and developing nations. However, without examining those aspects now, industry trends in Australia are reasonably clear. In common with most other developed nations, Australia is experiencing the following changes to its economy:

- a major structural shift in employment from manufacturing to service industries, with an expected shift to leisure/entertainment industries;
- the development of 'new' industries (alongside industries hundreds of years old), such as information technology and biomedical technology, with an expected movement towards new materials technologies;
- a trend away from mass production towards integrated manufacturing.

Each of these changes has resulted from long-term trends, and when viewed over a ten year period, they are substantial.

EMPLOYMENT TRENDS

Employment in the manufacturing industries in Australia has remained steady at a little over one million workers over the past ten years, whereas there has been substantial growth in employment in the service industries over the same period (see Table 1). Over the next ten years employment in manufacturing is expected to remain about the same while most of the growth in employment is expected to be generated in the leisure/entertainment industries. Even allowing for this change, employment in manufacturing in Australia is a substantial and important part of our economy.

TABLE 1: EMPLOYMENT IN MANUFACTURING IN AUSTRALIA.

Number of employed persons (in August of each year) by industry subdivision: Australia ('000)		
YEAR	Manufacturing (% of total)	Total - all industries
1968	1,263.6 (25.0%)	5,055.6
1978	1,185.3 (19.9%)	5,969.6
1979	1,220.8 (20.2%)	6,041.5
1980	1,233.6 (19.7%)	6,246.7
1981	1,230.9 (19.4%)	6,356.3
1982	1,192.7 (18.8%)	6,347.6
1983	1,133.7 (18.2%)	6,232.7
1984	1,141.4 (17.7%)	6,462.3
1985	1,109.4 (16.7%)	6,646.1
1986	1,126.7 (16.4%)	6,885.7
1987	1,151.4 (16.3%)	7,073.2
1988	1,199.4 (16.4%)	7,330.1

Source: *ABS Catalogue No. 6203.0: The Labour Force - Australia*

<u>Note</u>: *The real contribution of manufacturing to Australia's economy has not declined to the extent suggested by these figures because.*

significant gains in manufacturing labour productivity have been achieved over the period;

employment in firms providing consulting services to manufacturers has increased over the period, and this employment is not included in the manufacturing subdivision.

EMERGING INDUSTRIES

The faster growing markets (for both products and services) in the world have been in the 'new' industries such as information technology and biomedical technology - the so-called 'high-tech' industries. It is important to distinguish high-tech *products* (such as the computer chip) from high-tech *manufacturing techniques* (such as CAD/CAM), as sometimes the terms are confused. The development of these industries in Australia is important because of their growth potential and Australia's potential to succeed in certain niches of the high-tech industries. However, high-tech manufacturing techniques are of wider importance because they potentially affect all manufacturing industry, not just a small (though growing) part of it.

THE TREND FROM MASS PRODUCTION TO INTEGRATED MANUFACTURING

Mass production has been the dominant approach in manufacturing industries in the developed countries for almost a century (Mathews 1988, p.2). It has influenced the design of jobs, industrial relations, and the training system.

Until recent years, the broad trends this century in the manufacturing industries were:

- greater refinement of mass production techniques through 'time and motion' studies and other approaches;
- greater specialisation of machinery;
- specialisation of skills of workers, leading to 'de-skilling';
- segmentation of occupations.

This approach to manufacturing management was first practised in a systematic way by Frederick Taylor, and the whole mass production approach is often referred to as 'Taylorism' (Mathews et al. 1987; Mathews 1988).

But mass production is based on price competition in a stable mass market, and many writers point to:

- the development of new technologies of flexibility; and

- the increasing sophistication of world markets,

as causing the demise of mass production while encouraging the development of integrated manufacturing.

In the early 1980s Horst Kern and Michael Schumann (1987) identified the emergence of 'new production concepts', as opposed to Taylorism, in German industry where new computerised production systems were being installed. Michael Piore and Charles Sabel (1984) analysed world economic and social trends and concluded that a new approach to manufacturing, which they termed 'flexible specialisation', with roots in the traditions of craft production, was becoming a viable alternative for manufacturers in western countries.

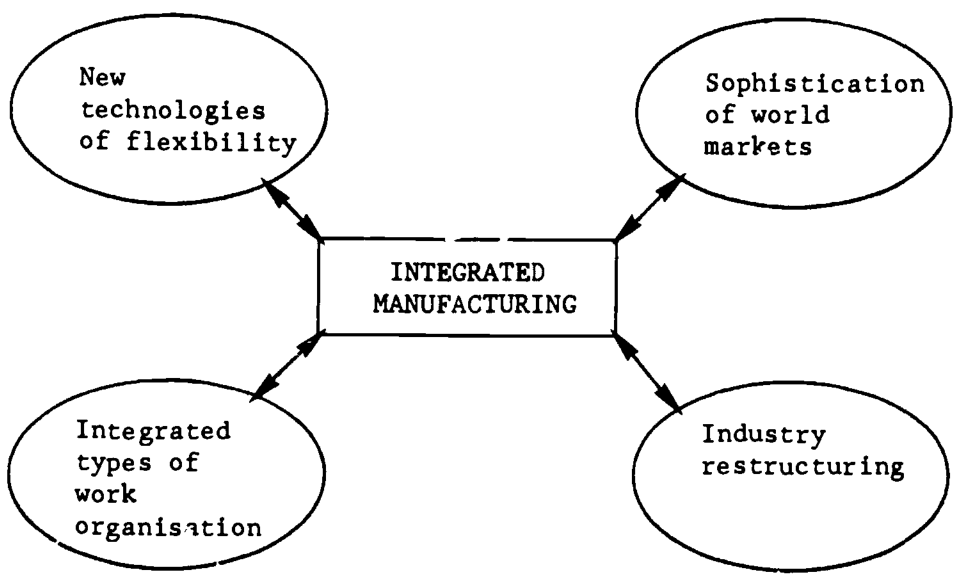
In addition to new technologies of flexibility and sophistication of world markets, two other important factors in the trend towards integrated manufacturing are:

- the application of 'integrated types' of work organisation;

- the implementation of industry restructuring.

Thus we have identified four major factors, discussed in the literature, in the trend towards integrated manufacturing, and these are illustrated in Figure 1. (In addition, a summary of the trends associated with the change from mass production to integrated manufacturing is given in Figure 10.) A discussion of each of the four factors follows.

FIGURE 1: **THE FOUR FACTORS IN THE TREND TOWARDS INTEGRATED MANUFACTURING.**



New technologies of flexibility

Piore and Sabel (1984, pp.258-261) discuss the relative costs of the three approaches to manufacturing:

- traditional craft production;
- mass production;
- integrated manufacturing or 'flexible specialisation'.

In this context, the *traditional craft* approach means the complete manufacturing, including design and production, of products by one person (or a very small team of people), with each person using a broad range of skills.

The *mass production* approach involves the use of specialised labour and dedicated equipment, each item of equipment performing a specialised part of the fabrication or assembly of the product.

Figures 2, 3 and 4 illustrate the relative costs and the reason for the emergence of integrated manufacturing.

FIGURE 2: **THE COSTS OF TRADITIONAL CRAFT AND MASS PRODUCTION**
(Adapted from Piore & Sabel 1984, p.259, and Lynch 1976, p.129).

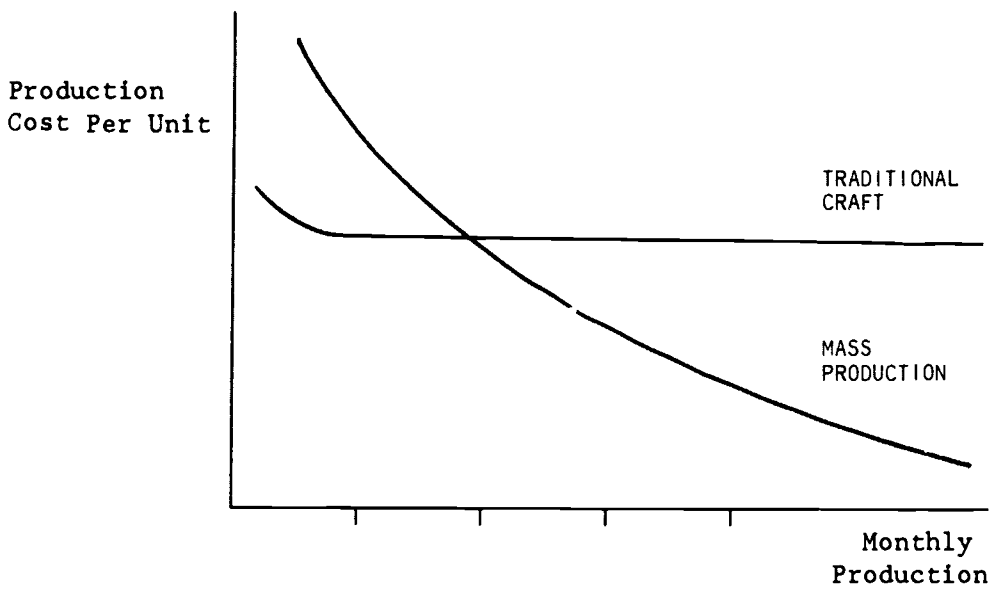


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FIGURE 3: **COSTS OF THE THREE TYPES OF MANUFACTURING APPROACH - 1980s** (Adapted from Piore & Sabel 1984, p.259, and Lynch 1976, p.129).

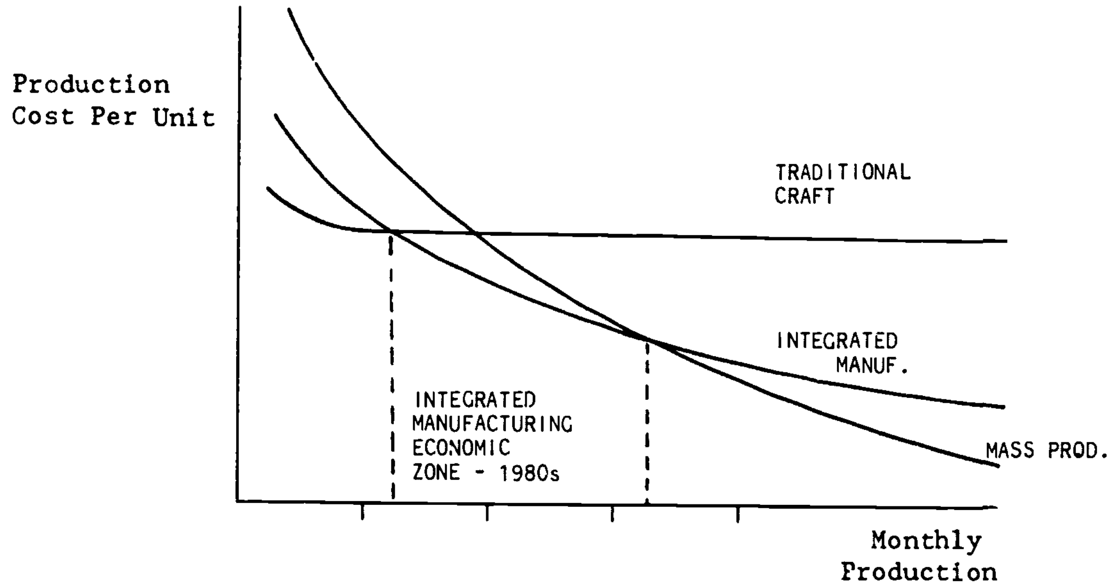
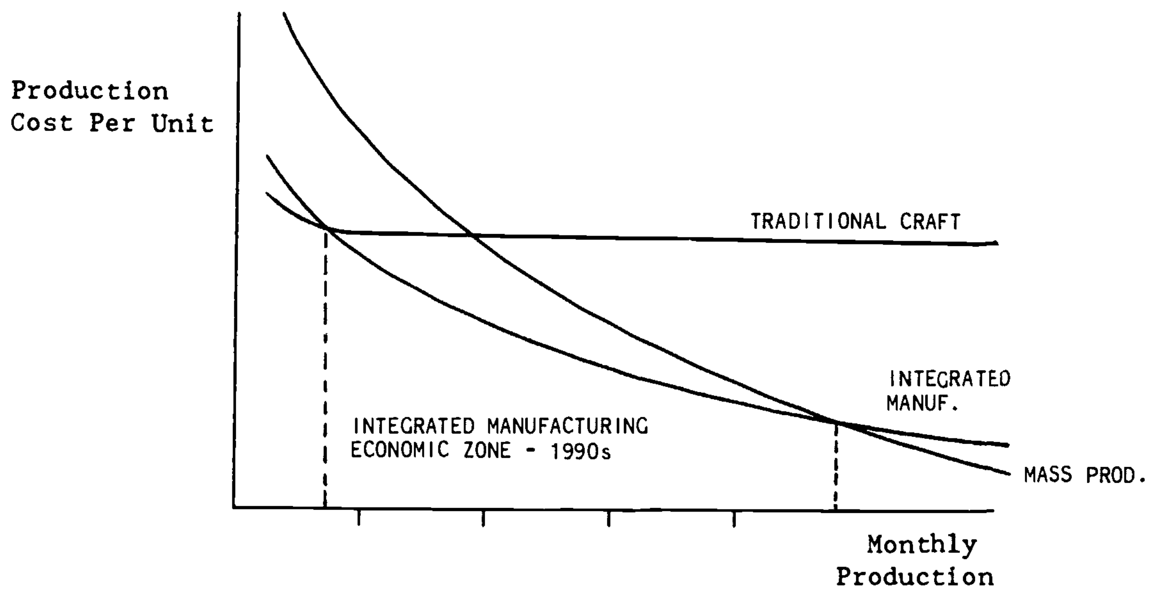


FIGURE 4: **COSTS OF THE THREE TYPES OF MANUFACTURING APPROACH - 1990s** (Adapted from Piore & Sabel 1984, p.259, and Lynch 1976, p.129).



In Figure 2 traditional craft production is contrasted with mass production. The almost flat curve for traditional craft production reflects the low initial cost, with most cost being direct labour. The slightly higher costs at low production are associated with learning or relearning. The steeply descending curve for mass production reflects the high initial cost of equipment and high indirect costs (with a sophisticated organisation required to co-ordinate the array of specialised labour and specialised dedicated equipment) and low direct labour cost. Traditional craft production has high flexibility but is only cost-competitive at low production volumes, whereas mass production has low flexibility but is cost competitive at high production volumes.

With the development of programmable equipment such as NC machines and robots, flexibility associated with integrated manufacturing without high labour costs becomes possible. The low volume cost of integrated manufacturing is lower than mass production because fewer machines handling a wider variety of tasks are required. Also, indirect costs are lower for integrated manufacturing. Figure 3 shows that in the 1980s, integrated manufacturing is more economic than traditional craft or mass production in the middle range of production volume. Figure 4 shows the integrated manufacturing curve for the 1990s which is lower than that for the 1980s because of the further development and relative cost reduction in programmable equipment and development of work organisation aspects of integrated manufacturing. This indicates a broader range of production volume for economic integrated manufacturing in the 1990s. It is expected that this will affect manufacturers in the medium to large volume assembly industries, that is, the second category in the classification of manufacturing industries in Table 2.

The relative costs will vary from product to product and will, of course, depend on a number of other factors, including:

- the extent to which integrated types of work organisations are implemented to reinforce the benefits associated with integrated manufacturing 'hardware';

- industry restructuring.

TABLE 2: A CLASSIFICATION OF MANUFACTURING INDUSTRY BY PRODUCT TYPE AND VOLUME OF PRODUCTION

(related to classes within the Australian Standard Industry Classification, 1983)

1. SMALL VOLUME ASSEMBLY (1 to 100 units per month*)

   e.g. medical equipment
   telecommunications equipment
   scientific equipment

2. MEDIUM TO LARGE VOLUME ASSEMBLY (100 to 10,000 units per month*)

   e.g. clothing
   structural metal products
   sheet metal prducts
   hand tools
   automobiles
   video and audio equipment
   electronic equipment
   household appliances
   water heating systems
   industrial machinery and equipment
   plastic and related products

3. VERY LARGE VOLUME ASSEMBLY (over 10,000 units per month*)

   e.g. printing
   metal fastners

4. PROCESSING INDUSTRY

   e.g. food processing
   pharmaceuticals
   textiles

*<u>Note</u>: *Volumes refer to the number of units of each product produced in a month by the largest producers in Australia.*

These factors and others will blur the relative costs of mass production and integrated manufacturing, so even if price were the only component of competitiveness, both approaches to manufacturing will continue side by side for many years to come (Piore & Sabel 1984, p.5; Wobbe 1987 p.5).

Sophistication of world markets

The above analysis indicates that cost reduction will underpin the trend from mass production to integrated manufacturing in the 1980s and 1990s, but product price is not the only component of a company's competitiveness. The three most important components of product competitiveness in the marketplace today are:

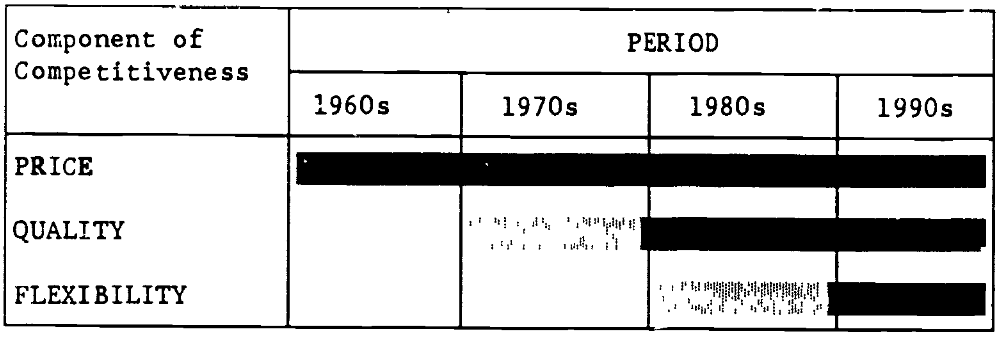
- price;
- quality;
- flexibility.

A company is competitive if it can offer lower prices, higher quality and greater flexibility compared to competing manufacturers. (Bolwijn et al. 1986, p.133; Brodner 1987, p.32). Greater flexibility includes:

- the development of new products or a greater variety of products;
- fast responses to market demand;
- short lead times from order to delivery.

There has been a trend towards greater sophistication of markets in western countries with greater market demand for quality and flexibility in recent years. The broad trend is illustrated in Figure 5. Naturally, the relative importance of each component of competitiveness will vary from industry to industry and product to product.

FIGURE 5: **THE BROAD TREND TOWARDS LOWER PRICES, HIGHER QUALITY AND GREATER FLEXIBILITY FROM 1960s TO 1990s** (Adapted from Bolwijn et al. 1986, p.133).



<u>Note</u>: *moderate component of competitiveness*

■ *substantial component of competitiveness*

Many writers agree that integrated manufacturing has a crucial advantage over the mass production approach with respect to product quality and flexibility (Bolwijn et al. 1986; Brodner 1987). For example, Brodner (1987, p.32) sees integrated manufacturing (or 'flexible specialisation') as competitive for high volume, customised quality-competitive products (that is, the fourth cell in the matrix of Figure 6).

FIGURE 6: **MATRIX OF PRODUCT STRATEGIES** (From Brodner 1987, p.32: Fig.2)

	Standardized price-competitive products	Customized quality-competitive products
Low volume	Specialized component production	Craft production
High volume	Mass production	Diversified quality production

Integrated types of work organisation

The literature of the early 1980s was divided between those writers who thought the new technologies of flexibility would require a reduction in skills and eventually lead to the 'unmanned factory' and those who thought the new technologies would require an increase in skills and would emphasise the importance of the human contribution to industry. A considerable body of recent research has shown that both outcomes are possible but the latter outcome is thought by many to be more likely to provide industry competitiveness. In other words, companies can choose to introduce new technologies in two major ways but the way that emphasises a combination of high skill and new technology is believed by many to be superior.

Mathews (1988) calls the low skill/high technology option 'Computer Aided Taylorism' and the high skill/high technology option 'skill dependent innovation'. He states:

> One line of development extends the time-honoured principles of job fragmentation, standardisation of routines, and transfer of intellectual functions to software, leaving as little discretion as possible to operators. This is a route I propose we call 'Computer Aided Taylorisation'.
>
> The other is a strategy that departs from principles of work organisation inherited from the heyday of mass production, and instead aims to maximise productivity by maximising flexibility of operation, which in turn requires commitment to a system of worker autonomy and skilled decision-making, interacting with information provided by computer systems as aids to decision-making rather than as instructions or demands for data. I propose that we call this strategy one of Skill Dependent Innovation (SDI). (1988, p.15).

Similarly, Wobbe (1987) describes the fundamental choice between CIM (computer integrated manufacturing) and CHIM (computer and human integrated manufacturing). He states:

> The CIM (computer integrated manufacturing) concept reflects the revival in recent years of an old technocentric production ideal: the unmanned factory, now equipped with the very latest means of computer control. This tradition of technocentric thinking leads industrial and research policies down the wrong road becuase it suggests that human labour should in

principle be excluded from production. . . . Research has clearly revealed that, unlike previous automation technologies, which attempted to replace human production work with technology, CIM is a communication and organization tool that influences co-operation in and outside companies and so makes greater demands on human labour at both management and shop-floor level. . . . To reflect the future requirements of production more accurately, we have therefore chosen the term CHIM, standing for 'computer and human integrated manufacturing', in order to demonstrate the interplay of technology, organisation and human skills in production (1987, p.6).

Also, Brodner (1987) describes the choice between the *technocentric approach* with its ultimate goal being the 'unmanned factory', and the *anthropocentric approach* of 'skill-based manufacturing'.

The high skill/high technology option in manufacturing therefore involves a combination of the application of information technologies and integrated types of work organisation which depart from the Taylor tradition of specialisation and fragmentation of skills. (Boyer 1988). This whole approach to manufacturing we have defined as integrated manufacturing.

'Integrated types' of work organisation are based on some or all of the following approaches:

- flat management structure with few hierarchical levels;
- skill enhancement with a lower degree of specialisation;
- smallness of scale (organisations become based on 'economy of scope' rather than 'economy of scale');
- teamwork where a small group of workers perform multiple functions.

Responsibility for key organisational goals such as efficiency, quality and flexibility is shared by all members of the team rather than left to specialists.

Much of the literature discusses the changes in work organisation associated with the change from mass production to integrated manufacturing. The strict hierarchical structure of specialised work organisation associated with mass production, as shown in Figure 7, will change into a 'more integrated approach' to work organisation, as shown in Figure 8, with the full implementation of integrated manufacturing, (Ebel and Ulrich 1987 p.359; Rutt et al. 1986, p.253).

In the strict hierarchical structure decision-making is centralised, a well-defined role for each worker will exist and most problems will be solved by having a system of rules and regulations. The tasks or activities of the organisation are broken down into specialised activities and every unit will be confined, as far as possible, to the performance of a particular activity. Therefore, the emphasis is on specialisation and the precise definition of methods, duties and authority.

FIGURE 7: WORK ORGANISATION INVOLVING STRICT HIERARCHICAL STRUCTURE AND SPECIALISATION WORKING ORGANISATION

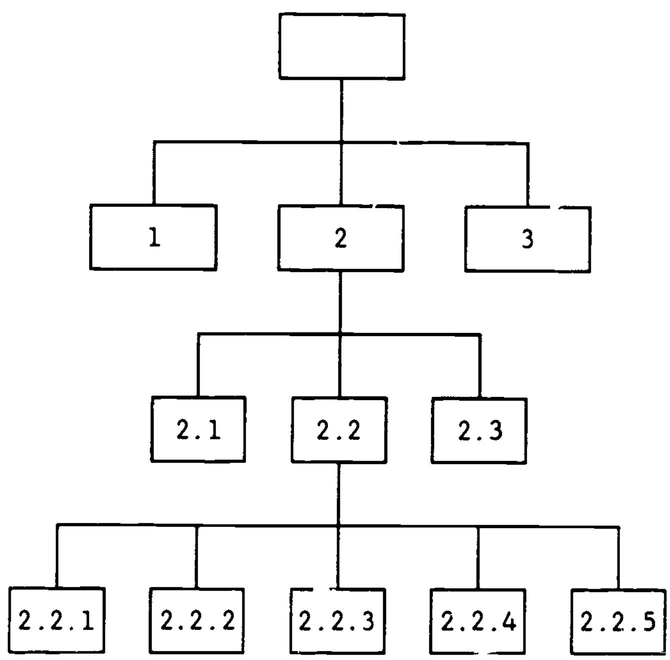
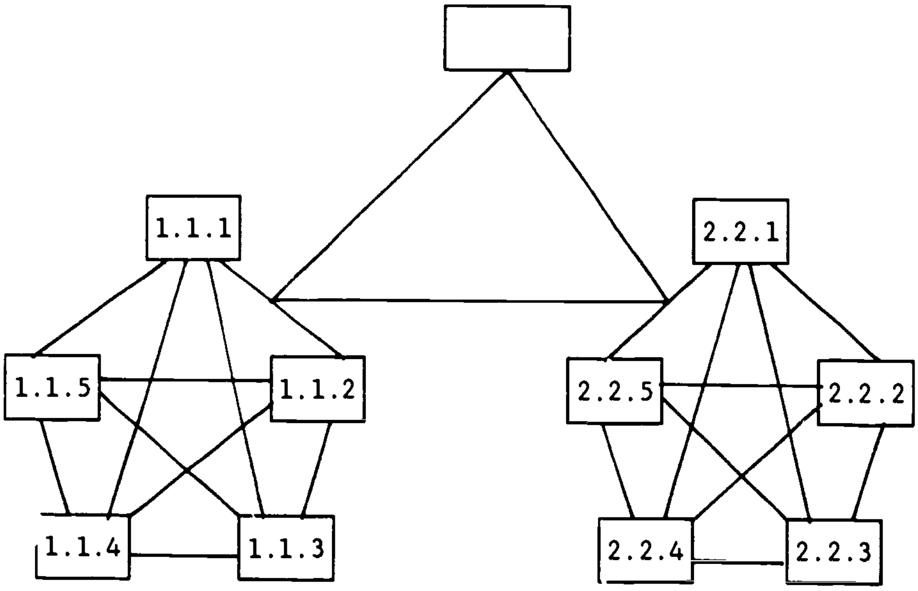


FIGURE 8: AN INTEGRATED TYPE OF WORK ORGANISATION



On the other hand, an integrated organisation will mean a much flatter management structure with 'fewer hierarchical levels, fast feedback systems, low degree of functionalisation, and smallness of scale' (Bolwijn et al. 1986, p.146).

An integrated organisation is structured in a cellular nature where each cell performs a variety of functions, both production and non-production - the 'staff departments are integrated in the line as far as possible' (Bolwijn et al. 1986, p.146). These cells are decentralised, loosely joined, and semi-autonomous. It is an organisation within an organisation.

The literature revealed that to fulfill the requirements of integrated manufacturing, these cells should have an emphasis on productivity and be result-oriented. They should also focus on performance in terms of efficiency and effectiveness. With regard to the cells membership, Bolwijn et al. (1986) argued that members should be responsible to the cell team resulting in a much higher sense of identity and belonging. Responsibility for the achievement of the key organisation goals such as efficiency, quality and flexibility will be shared among them.

The literature also suggested that the introduction of integrated manufacturing will have a great effect on interdepartmental relations, increasing interdependence and teamwork. It indicated that if flexibility is required, large manufacturing factories should be re-structured into small scale units.

In this new type of work structure, although the operators tend to be specialised in their work, they are integrated and may report directly to the top manager. Each operator not only has to control the quality, but should also have the ability to track the causes of poor quality. In the integrated approach people at all levels in the organisation spend time on each of the following three generic activities:

- INNOVATION - large (infrequent) improvements in processes or products through revolutionary ideas or research;
- IMPROVEMENT - small (frequent) improvements in processes or products through ideas, research and development;
- CONTROL - maintaining costs, processes and products within set limits or close to targets.

Hayes and Wheelwright (1984) have criticised manufacturing management in the USA because of its emphasis on innovation (the 'great leap forward') while neglecting the incremental approach of small but frequent improvements in production. The latter approach places a premium on long-term commitment, planning, and the skills of people at the lower levels of the organisation (Mathews 1988, p.4).

The difference between integrated manufacturing and the traditional manufacturing organisation is illustrated in Figure 9. In 'integrated organisations' production workers are called upon to improve quality systematically and improve manufacturing generally.

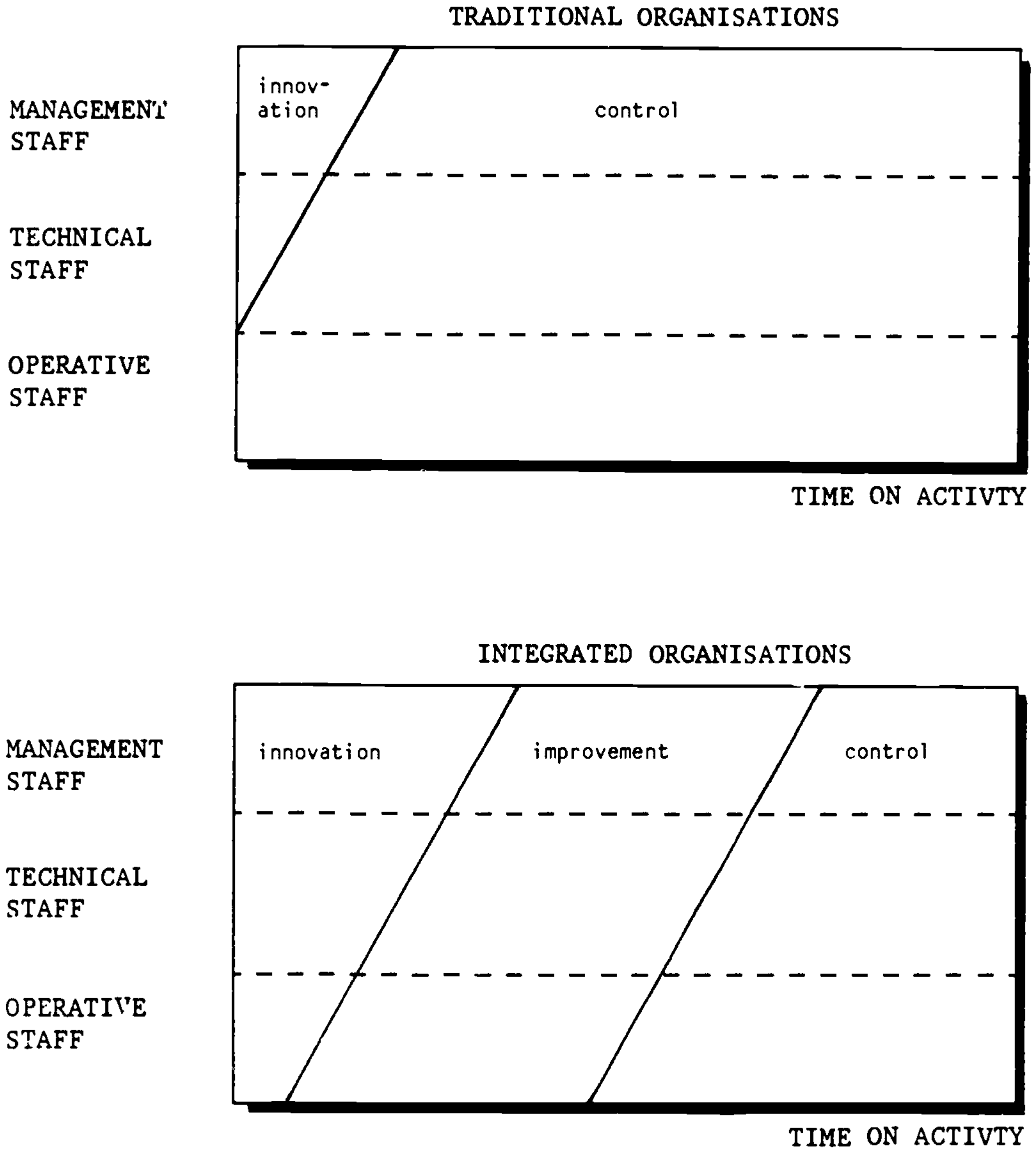
As well as controlling the quality of their products, workers may also do servicing and maintenance routines. In short, production workers will need a broader range of functional skills and this underlines the importance of multi-disciplinary training programs.

Industry restructuring

We define industry restructuring as:

> the substantial changing of work structures across an industry though changes to industrial awards and informal agreements which allow new approaches to work organisation to be implemented within individual organisations. (Hall & Hayton 1988, p.1).

FIGURE 9: **EMPHASES ON INNOVATION, IMPROVEMENT AND CONTROL IN TRADITIONAL AND INTEGRATED ORGANISATIONS**



Companies planning to implement integrated manufacturing may move in a small way towards integrated types of work organisation but may come across barriers to change (Curtain 1988, p.7). The present structure of industry in Australia and other western countries is based on:

- mass production techniques;
- specialisation of machinery;
- specialisation of the skills of workers;
- segmentation of occupations.

This has resulted in a large number of trade occupations. There are fewer paraprofessional and professional occupations, but even at these occupational levels, boundaries between 'disciplines' are difficult to cross. This in turn has shaped the structure of industrial relations, unions, and education and training systems. Industrial awards in Australia are based on a large number of carefully defined occupational classifications, and the union structure is mostly based on occupations rather than industries. Tertiary educational institutions often have structures mostly based on occupations.

To achieve integrated types of work organisation, industry restructuring is occurring in Australia and other western countries and this is likely to affect:

- industrial awards;
- the structure of unions;
- the educational system;
- accreditation and certification.

Integrated types of work organisation will lead to a new occupational structure in Australia. In this structure there will be fewer trade occupations, with each trade covering a broader band of skills. The boundaries between trades and between disciplines at the professional level will either be eliminated or be easier to cross. There will be fewer restrictions on individuals moving between occupational levels because of greater articulation between different educational qualifications (Hayton and Cheyne 1988; DIR 1988).

In the new occupational structure, greater flexibility within each (broader) occupational classification is allowed, and occupational mobility by the crossing of one or more boundaries is easier and more likely. Easier crossing of boundaries is likely to occur through greater integration and articulation of vocational courses. However, in the foreseeable future, traditional core skills are likely to be retained.

Australia is presently in the transition between the 'old' and 'new' occupational structures. In the printing industry, for example, there were over twenty trades in the 1960s, fourteen trades in the 1970s and five trades since 1977. At the paraprofessional level in engineering, there is evidence of a significant number of multi-discipline occupational clusters (Hayton 1986, pp.137-142).

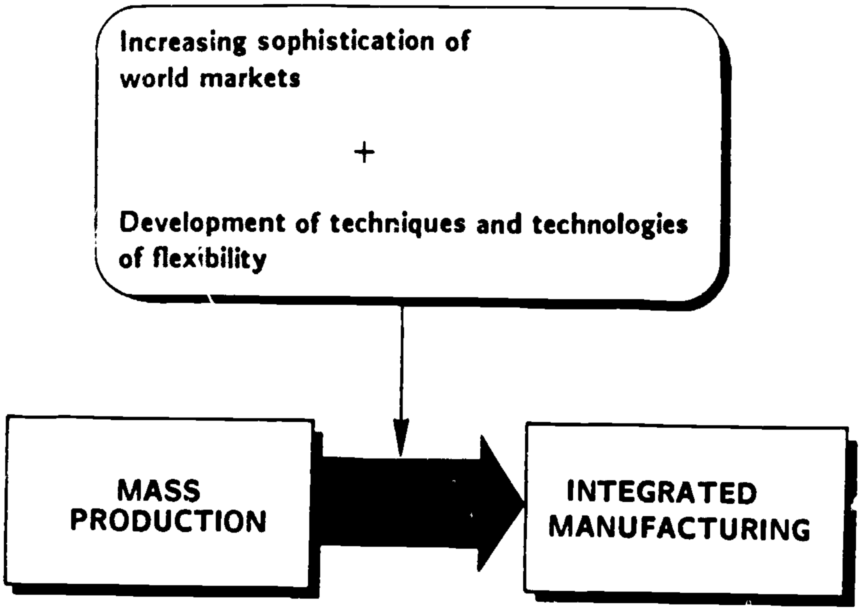
Summary

The recent trend away from mass production to integrated manufacturing is expected to continue in western countries over the next ten years or more, and will be particularly apparent in the medium to high volume industries. Many writers see this trend as important and as fundamental as the change from craft production to mass production in the 19th century. Ironically, many aspects of integrated manufacturing are closer to craft production than mass production.

Figure 10 lists the main characteristics of mass production and integrated manufacturing and illustrates the sorts of changes that may be expected in a trend towards integrated manufacturing. Most of these issues are discussed in the following sections.

With the trend towards integrated manufacturing in Australia continuing, major changes to the training system and the way we collect labour market data will be required. Present labour market data collection is based on a pattern of specialised, well-defined and stable jobs. Integrated manufacturing has jobs with a much broader range of duties needing greater flexibility. High skill marketing, research and development, design and production workers will be required. In integrated manufacturing, the introduction of new technology generally results in an increase in the skill requirements for most workers, whereas in mass production the reverse generally applies.

FIGURE 10: THE TREND FROM MASS PRODUCTION TO INTEGRATED MANUFACTURING
(Adapted from Figure 2 in Hayton 1988).



MASS PRODUCTION	INTEGRATED MANUFACTURING
stable mass markets	changing specialised markets
mainly large corporations	mainly small corporations and large corporations divided into smaller production units
specialised, well-defined stable jobs	broad 'multiskilled' jobs requiring flexibility
production workers have little control over production	production workers have much control over production
many middle management and clerical jobs; few marketing, research and development and design jobs	few middle management and clerical jobs; more marketing, research and development, and design jobs
low skill production and clerical workers; high skill middle management workers	high skill marketing, research and development, design and production workers
narrow initial training; specialised on-the-job training	broad (but relevant) initial training and continuing retraining
many 'trade' unions	fewer 'industry' unions
across industry trade/occupation agreements between management and unions	industry and single enterprise agreements
job security and career progression through seniority	job security and career progression through skill enhancement
new technology introduced to increase productivity with reduction in skill requirements	new technology introduced to increase flexibility or provide innovative products with increase in skill requirements
competitiveness through stability and cost reduction by specialisation of people and equipment	competitiveness through innovation and adaptability by flexibility of people and equipment

4. SKILLS REQUIRED FOR INTEGRATED MANUFACTURING

Integrated manufacturing has been heralded by some writers as the forerunner of the 'unmanned-factory'. On the contrary, it will require a higher level of skill and different types of skills for its operation. Its introduction into the manufacturing sector will affect the workforce - qualitatively and quantitatively, as it involves a re-organisation of the entire production/manufacturing process. The highly automated and computer-integrated manufacturing and production techniques not only have the potential to bring remarkable improvements in quality and flexibility, but also operate 'with a very low level of manning' (McDerment 1987, p.19). However, 'large segments of the labour force will require extensive training or retraining in computer-related skills' (Gordon and Kimball 1985 p.316).

The application of integrated manufacturing can both generate new jobs and at the same time eliminate and restructure existing jobs. Some functions will diminish in importance, while others might become more important and new elements will be added to the skills needed. Depending on the product and process, much of the work done by semi-skilled and unskilled workers might not be required (Ebel 1985). 'Automation is removing unskilled jobs fast...' (Chown 1985 p.24)

The literature revealed that integrated manufacturing systems will present a challenge to the training system. It will have important implications - in terms of skills and knowledge requirements and the number of skilled workers required - quantitatively and qualitatively. Integrated manufacturing also can and will reshape and create new demands for high-quality training and retraining programs. These are important issues in the installation of integrated manufacturing in factories. Training and retraining are 'no longer viewed as aids to adjustments but rather as basic factors that will be part of the architecture of future systems' (d'Iribarne 1987, p.7).

The trend towards integrated manufacturing systems has considerable implications for training and retraining in Australia. Many writers assert that the greatest training need will be at the lower levels of the factory, i.e. technicians and tradespeople. Technical and further education (TAFE), as the main provider of initial training for technicians and tradespeople, will need to assimilate this new technology into its training activities.

Some of the skills required by the introduction of integrated manufacturing as revealed by the literature are discussed below.

NEED FOR CROSS-DISCIPLINARY SKILLS

The introduction of integrated manufacturing will change the skill requirements in the manufacturing sector. Integrated manufacturing is a cross-disciplinary field. The literature shows that this results in a need for training for broader skills (Roberts 1984; Cross 1984; Franchak and Smith 1986; Miller 1986; Economic Commission for Europe 1986; DITAC 1987a).

Highly specialised and narrowly-defined work tasks will be replaced by 'so-called flow-oriented work organisations where work is more broadly defined and carried out by teams of workers having multi-disciplinary skills' (Economic Commission for Europe 1986, p.134). Development of multi-skilled workers is essential to perform a variety of functions on the shop floor and also to support the multi-disciplined equipments of integrated manufacturing (Roberts 1984).

Workers involved in maintenance activities will encounter changes in the skill requirements. They 'will need to know how to solve mechanical, electrical and electronic problems rather than one class of problems alone' (Miller 1986, p.384). This broad-based type of skills and knowledge is needed for fault diagnosis - the maintenance worker must first understand the whole process of integrated manufacturing before he/she will be able to locate and repair the fault. He/she 'must be able to identify the source of the trouble and get the machine operational without any unnecessary delay. The only way he/she can be truly effective is if he/she has been trained both in the necessary disciplines and in the way they interact' (Roberts 1984, p.6).

The integration of various fields of engineering in an integrated manufacturing system will require a 'flexible' and multi-skilled tradesperson. Flexible in this context means that 'employees can be redeployed quickly and smoothly between activities and tasks. . . skilled craftsmen moving between mechanical, electrical, electrical and pneumatic jobs . . . indirect and direct production jobs . . .' (Atkinson 1984, p.28). This will create training and retraining needs for the formation of a 'new' workforce which will be able to perform a broad range of activities and functions. A tradesperson whose training had been restricted to the traditional crafts or specialities, will find it difficult to be absorbed into the integrated manufacturing processes. Therefore, training and educational establishments should develop and support new cross-disciplinary programs/courses, such as 'mechatronics'. These programs should be much broader in scope compared to the traditional narrow-focus on specific machine operation (Majchrzak 1986; Ford 1987b). However, as discussed later, the new programs will need to be more than just cross-disciplinary.

The flexibility described above should be seen as a positive outcome for both the employer and the employee. As far as possible the aspirations of individual workers should be catered for. The need for cross-disciplinary skills and a generally higher level of skill should enhance the job satisfaction of the workforce at the shop floor level. Some writers suggest that any changes in this direction should be placed in a framework of career path development and consultation between management and the workforce at the industry level and the plant level (DIR 1988; Curtain 1988a).

NEED FOR A HIGHER LEVEL OF SKILL

Most of the authors in the literature surveyed tended to agree that integrated manufacturing will require higher levels of skill for many of the jobs. It is a highly technology-intensive activity and will demand a workforce with a higher skill level for its installation, operation, programming and maintenance. The integrated manufacturing process will be highly automatic and in order to achieve maximum efficiency, it will be designed for a high degree of process integration and production continuity. These systems require a higher level of maintenance expertise.

Maintenance work for integrated manufacturing systems can be of two types: minor and major. The former is usually done by the operators themselves, while the more complex service routines and breakdowns of the latter will require workers with specialised skills of system control and fault diagnosis. The effectiveness of the maintenance work will depend on the broad range of skills of the maintenance worker.

Integrated manufacturing will also require workers who are familiar with sophisticated testing tools, instruments and equipment that are necessary for its application.

Given this situation, there is a need for a comprehensive effort for training and retraining aimed at a higher skill level and at fault diagnosis and maintenance.

THE IMPORTANCE OF COGNITIVE SKILLS

As mentioned earlier, integrated manufacturing will bring changes in skill requirements, both in existing work and in new jobs that will be created. There will be an increase in importance in cognitive skill as compared to psycho-motor skill - a shift from manual to mental work (Miller 1986). 'Practical skills have to be complemented by a higher degree of theoretical skills in science and in modern technologies...' (Economic Commission for Europe 1986, p.133). Gordon and Kimball (1985) referred to this as 'knowledge-intensive' labour due to the knowledge-intensive character of integrated manufacturing.

The increased use of sophisticated electronics will mean a major restructuring of the traditional skills, especially in maintenance work. Diagnostic skills will be based on a deep theoretical understanding of a number of core disciplines. There will be an increasing application of abstract thinking and mental skills.

Analytical and problem-solving skills will also increase in importance. The Canadian CAD/CAM Council for the Advancement of CIM (1986) argued that conceptual and analytical skills will be used frequently rather than motor skills.

These changes place traditional training programs/courses in question, particularly where practical training is concerned.

THE IMPORTANCE OF AFFECTIVE SKILLS

The introduction of integrated manufacturing requires a general acceptance by management and the workforce, at both industry and plant level, of the need for change (Curtain 1988a, pp.4-6; DIR 1988, p.17). The significant change in attitudes required at the plant level is described by some authors as a change in the 'culture' of the plant. The culture of a plant is a pattern of beliefs about what is right, important, or acceptable, shared by the people who work there (Manufacturing Studies Board 1986, p.21).

An important issue discussed in the literature is that of *control*, and this is closely related to management and workforce attitudes. Shaiken et al. (1986) concluded from case studies of U.S. manufacturing firms in the early 1980s that programmable technology and flexible manufacturing systems were being introduced in a way that tended to increase production control by senior management rather than increase control at the shop floor level. Fully integrated manufacturing requires some control over production to shift from senior and middle management to the shop floor. However, management must be prepared to relinquish some control over production, and operators must be prepared to accept more control, for this to happen.

The U.S. Manufacturing Studies Board (1986) have presented a table which summarises the cultural change required at the plant level for the introduction of integrated manufacturing, and this is reproduced in Table 3.

The Australian Senate Standing Committee on Industry, Science and Technology (SSCIST), in its report entitled 'Manufacturing industry revitalisation', identified ten *key attitudes* which require change, and these are:

- insularity;
- complacency;
- indifference to economic realities;
- confrontation in industrial relations;
- apathy;
- media bias;
- lack of confidence;

- dependence;
- hesitancy about technology;
- resistance to change. (SSCIST 1988, pp.43-64)

TABLE 3: **PLANT CULTURAL CHANGE REQUIRED TO INTRODUCE INTEGRATED MANUFACTURING**
(Adapted from Table 4 in Manufacturing Studies Board 1986, p.22)

Organizational Aspect	Traditional Practice	Shift to Practice Compatible with Integrated Manufacturing
Authority	Base on position	Base on knowledge
Decision making	Locate close to the top	Locate close to required action
Employee contributions	Limit knowledge and skill	Enhance knowledge and skill
Information	Closely control	Share widely and use a number of media
Rewards	Reward individual performance	Reward teamwork and collaboration
Status	Highlight differences in attire, parking, eating facilities, and so on	Mute such differences
Supervision	View supervisor as "watchdog"	View supervisor as resource

RETRAINING NEEDS OF THE WORKFORCE IN THE EXISTING METAL-WORKING TRADES

Some writers assert that integrated manufacturing is not likely to generate greater employment in the metal-working industries. Miller (1985) found that 80 - 90% of the robots used in the US and Japan were installed in the metal-working sector of manufacturing. He defined metal-working as any activities that 'involved to some degree the shaping, finishing and assembling of metal products . . . metal-cutting machines, metal-forming machines, joining equipment . . .' (Miller 1985, pp.74-75).

The introduction of automated equipment and integrated manufacturing means that there would be a move away from the traditional skill areas - some manual expertise will be replaced by operation of a control panel. The changeover from the straight mechanical to the integration of mechanical, electronic and/or fluid power systems will result in changed job content and work methods requiring the need for retraining in multi-disiplinary skills.

Although metal-workers, electricians and other traditional groups of skilled workers might still be needed in both the production and maintenance activities of an integrated manufacturing system, their job content and training requirements are expected to be changed.

The existing workforce in the traditional trades consists of people with a wide range of educational backgrounds and ages. Training institutions must design updating and upgrading programs that are adaptable and suitable to the trainee's skills and background.

Retraining programs for those who are already in traditional trades can provide the necessary workforce for integrated manufacturing in a much shorter time than it would take to train a new workforce.

THE IMPORTANCE OF SERVICES RELATED TO INTEGRATED MANUFACTURING

From 1985 to 1986, the service industries took a 73% share of the Australian Gross Domestic Product (Hadler 1987). Although newly industrialised countries are increasingly competing in markets where large-scale labour services are involved, fortunately so far Australia has an edge in the construction management, operation and maintenance, architecture and engineering and educational services. The introduction of integrated manufacturing will create a big demand in consulting services associated with integrated manufacturing.

There is a need for training in the servicing sector of integrated manufacturing. Australia must seize the opportunities for providing greater involvement in the integrated manufacturing industries especially in areas of consultation, operation and maintenance. The training system should provide training in these areas.

LABOUR WITH A HIGHER EDUCATIONAL LEVEL

The introduction of integrated manufacturing will encourage a change in the educational level of the operational workforce. Better working environments might encourage people with a higher educational level to do jobs in the manufacturing sector.

There are implications for selection and placement procedures for training institutions. The design of training programs and determination of training standards will also be affected.

THE USE OF SKILLS BY MANUFACTURING ENTERPRISES

For enterprises moving towards integrated manufacturing, the best use of skills requires a new approach to work organisation involving the removal of many existing practices by employers and unions. The current negotiations in Australia on restructuring in the metal industries are expected to result in a framework for the broad changes required. However, it will still be up to each enterprise to realise the full potential of the techniques and technologies of integrated manufacturing and the new award structure in order to fully use and develop its workforce skills. Curtain (1987b) and Marceau (1987) have described many of the factors restricting the full use and development of skills in individual enterprises.

5. TRAINING RESPONSES FOR INTEGRATED MANUFACTURING

The introduction of integrated manufacturing in Australia will have a major effect on Technical and Further Education (TAFE) course content and course structure. Courses preparing individuals for integrated manufacturing (involving, as discussed in earlier sections, higher skill, new technology and integrated work organisation) will need to develop the individual's abilities to:

- adapt to changes in technology;
- more readily transfer skills to new areas of specialisation;
- combine skills in two or more disciplines;
- readily accept and seek retraining at appropriate points throughout working life;
- pass on knowledge to others;
- appreciate business competencies.

With respect to course content, there will need to be:

- greater emphasis on conceptual learning;
- greater emphasis on scientific and technological 'literacy', the social implications of technological change and quality concepts in primary, secondary and tertiary education;
- the deveopment of investigative and problem-solving skills:
- the development of 'learning to learn' skills;
- the development of teaching skills;
- the development of a broader awareness of the industry and industry restructuring in vocational courses;
- the development of team skills and skills associated with working in more complex, less regimented management structures.

The keyword for appropriate course structures of the future is flexibility, and it has been suggested that this could be achieved more readily by a modular course structure with broad-based modules early in the course. (Hayton 1986, p.140; Hall & Hayton 1988, p.7). Each module should be able to stand alone and be capable of being separately assessed. However, some modules will need to specify pre-requisite skills or modules. The structure should allow for multiskilling, multiple entry and exit points, and retraining.

This flexibility is only possible if:

- the length of the course (or period of study) is not considered a major criterion of learning success;
- courses specify the competency standards to be achieved and the conditions under which the competencies are to be achieved (DOLAC 1988);
- courses can be developed, approved, accredited and reaccredited quickly.

TAFE courses will need to allow for both horizontal mobility (e.g. between trades or subject disciplines) and vertical mobility (e.g. between job levels and between academic awards or institutions). Such flexibility could mean:

- course structures which allow a greater range of choices in combinations of subjects or modules, including cross-disciplinary combinations across related disciplines such as mechanical and electrical engineering and even across traditionally unrelated disciplines such as engineering, accounting and psychology;
- course structures which allow multiple entry and exit points and retraining;
- a restructuring of education towards administrative groups and courses based on industry groups rather than occupations;
- greater integration, articulation and accreditation between educational institutions and company-specific training and between the educational sectors of secondary, TAFE, advanced education and university (Parkinson et al. 1986; Dawkins 1988).

There is evidence that many TAFE courses will require major re-organisation. Urgent specific training needs include:

- the need for modified TAFE courses, especially in engineering courses;
- the organisation of effective training programs for operators in the service industries of integrated manufacturing;
- a higher level and specialised vocational training, especially in maintenance, total quality control, programming, and CIM system development;
- programs for the development of a higher level of cognitive skill;
- the development of new cross-disciplinary training programs;
- the integration of new skills into existing vocational programs, like computer literacy, higher mathematical and analytical skill, process development and quality improvement;
- appropriate and relevent programs and courses for supervisors and managers so as to 'achieve the desired benefits from . . .' integrated manufacturing (Majchrzak 1986, p.117); and
- greatly increased retraining for upgrading and updating the skills of the existing workforce whose skills and job content will be modified and changed.

In addition to the major changes in training outlined above, a greatly increased need for retraining is associated with the introduction of integrated manufacturing, and this is referred to in the last point above. The use of the term *retraining* in this paper is not meant to imply the discarding or changing of skills acquired through previous training, but rather the supplementation of existing skills with new skills through training.

This will require industry to make a higher level of commitment to training (Hall 1987; 1988; Dawkins 1988). This need may be partly met by TAFE and other training providers offering modules from larger accredited courses. To meet the range of needs of people in the workforce, flexibility in course provision is required. Two types of retraining may be distinguished:

- courses which 'update' skills in cases where new technology is being introduced;

- courses which provide additional skills in a new area (including 'multi-skilling').

Both types of retraining will be required for integrated manufacturing.

The balance of the retraining need may be met by industry itself through a variety of training arrangements, including:

- in-house training using in-house trainers (both 'professional' trainers and skilled operators with a training role);

- in-house training using external trainers;

- off-site training funded by individual companies.

Each may involve TAFE or private training consultants in the planning of training (including training needs analysis and curriculum development) and/or delivery of training (Hayton et al. 1988; Hall 1988).

6. SUMMARY

Integrated manufacturing is more than a refinement of mass production. It should not be seen as simply the application of new technology to manufacturing. It is a significant new approach which applies information technologies and new types of work organisation to achieve integration of machines, information and people. In some aspects it is closer to craft production than mass production.

The trend towards integrated manufacturing is world-wide and irreversible, though many manufacturers may still stay with the mass production approach for many years to come. The trend towards integrated manufacturing is evidenced by and reinforced by:

- the development of new technologies of flexibility;
- sophistication of world markets;
- the application of integrated types of work organisation;
- industry restructuring.

As integrated manufacturing places greater emphasis on the human contribution to manufacturing, in addition to the application of technologies such as CIM, then greater demands for skills will occur as integrated manufacturing is implemented. There will be a need for:

- people with cross-disciplinary skills;
- a generally higher level and broader band of skill for people entering and people already in manufacturing jobs;
- greater emphasis on cognitive skills.

The training implications of integrated manufacturing for technical and further education (TAFE) and other sectors of education are many, and these are discussed in Section 5. Some of the more important include:

- greater emphasis on conceptual learning;
- greater flexibility in course structure and training provision;

- the development of cross-disciplinary training programs;

- the integration of 'generic' skills such as computer literacy, process development and quality improvement into existing vocational courses;

- special programs for supervisors and managers;

- a greatly increased need for retraining of existing workers;

- a generally higher level of commitment to training by industry.

Like the change from mass production to integrated manufacturing, the associated changes in vocational education required over the next few years will be profound and far-reaching.

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