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Digital Factories: the Hidden Revolution in Australian Manufacturing

A Study Commissioned by the Department of Communications, Information Technology and the Arts

Dr John Howard

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Preface

This is a report of a study of the use of information and communication technologies (ICT) in ‘non-ICT’ manufacturing companies.

The study was based on a series of profiles of companies across the manufacturing sector, together with research material and knowledge provided by the study team.

I would like to thank the managers in companies that gave time for interviews and the subsequent validation of the interview notes that formed the basis of the profiles.

I would also like to thank my colleagues and members of the study team who assisted in this project – Jock Rowland for undertaking many of the interviews and writing up profiles, Dr Mark Matthews for editorial advice and contributions, and Anne Howard for arranging interviews and schedules, assisting with research, proof reading and final production.

Nathan Brumby from Software Engineering Australia (National) Limited and Dr Tony Strasser, from Sinclair Knight Merz reviewed the document and made important and useful suggestions.

Project management staff in the Department of Communications, Information Technology and the Arts were particularly helpful, and patient, in providing guidance and feedback during the course of the study. I would like to thank particularly Dr Janet Pagan, Ralph Curnow and Julie Martinsen from the Department.

Responsibility for the content of the study, remains, however, with the study team.

Dr John Howard
Managing Director
Howard Partners
Canberra
September 2005

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Executive Summary

The Department of Communications, Information Technology and the Arts commissioned Howard Partners to undertake a study of the development, application and use of information and communication technologies (ICT) in non-ICT manufacturing industries.

The purpose of the study was to provide an analysis of how ICT is being developed and used within the non-ICT manufacturing sector. The study also examined the impact this ICT is having on companies’ operations, productivity, business models and competitive positions.

The key messages from the study are:

- ICT is pervasive throughout the manufacturing sector and in manufacturing businesses. It is evident in all aspects of the value chain – research, product development, production, supply and distribution, customer relationships and post sales service. ICT is also used extensively in corporate management and in administrative support functions. However, different ICT systems are not always well integrated – particularly between manufacturing and corporate systems.
- Industry sectors that in the past may have been described as ‘low tech’, or ‘old’ economy, are in fact very clearly ‘high tech’ in the way they develop and use ICT. Modern manufacturing and business processes now use ICT to support research, product development, production, supply and distribution, and in service support.
- There are substantially different outcomes among companies that spend similar amounts on ICT. The differences in productivity and profitability are due to the way ICT is developed, applied and used in a business context. ICT development, application and use in manufacturing is very much a management, issue. In the companies covered in the study, board level and senior management support for ICT investment is on the basis of validated business opportunities and demonstrated return on investment.
- Companies in highly technical areas of manufacturing, and where ICT generated knowledge is a core capability, have largely built that capability in-house. However, other companies develop their ICT capability through contract and partnership arrangements with providers of proprietary software and their service providers. They also work with a range of smaller specialised software developers working in niche areas and in research organisations.
- The study demonstrates that ICT is a significant enabler of product, process and business model innovation within the manufacturing sector. ICT also enables innovation in contractual relationships, alliances and partnerships between manufacturing companies and specialist ICT providers, and with customers and suppliers.
- The study indicates that the competitive advantage provided by ICT intensive products is not the ICT *per se*, but the attributes, properties and customised service offerings that the ICT enables and which are

embedded in the product. In other words, clever use and incorporation of ICT becomes a differentiator. This re-affirms the contemporary view in business strategy and marketing that customers do not purchase products: they purchase the stream of valued added services that products provide.

- Effective executive managers in manufacturing businesses require an appreciation of the process improvement, product enhancement and market development possibilities enabled by ICT. Conversely, ICT managers need to possess knowledge and expertise in the way in which ICT can be adopted, applied, and used in a business and commercial context.
- Australian manufacturing industry requires a robust and capable ICT sector with the capacity to handle the ongoing development, maintenance and support functions that enable both breakthrough and continuous innovation in manufacturing businesses.

The interviews and supporting research demonstrate that:

- Digital networks and more powerful computing allow companies to collect, communicate, exchange and analyse data more quickly and cheaply than ever before – enabling manufacturing businesses to adopt a broader range of strategies for the management of their core functions and processes.
- Increasingly, ICT is regarded as an important element of corporate infrastructure. However, ICT differs from other infrastructure assets in that it supports the generation of knowledge that can be adopted, applied and used for innovation in business and manufacturing processes and in enhancing the functionality of products and services.
- There are major issues concerning functional integration in the management of information between the corporate and production areas of a manufacturing business. Additional productivity and performance enhancements may accrue to those companies that successfully integrate process control systems with corporate systems, for example through software solutions.
- A major challenge in this area is encouraging managers to trust software and machine generated data, monitoring and analysis to validate processes – without the need for additional physical inspection and intervention.
- ICT allows companies to develop close relationships with customers through on-line and Web-based ordering and secure, advanced communications systems. Success in this area often depends to a large extent on the level and sophistication of ICT use on the part of customers.

The study examined specifically the extent to which non-ICT manufacturing firms can gain competitive advantage from ICT. It found that the key factors relate to the way ICT is used in combination with other technologies and in the way in which it is applied and managed. In particular:

- ICT enables disparate scientific and technical information to be tracked and integrated, thus reducing uncertainty and risk in product integrity and quality. These reductions in risk can be critical in industries such as food processing – where there are strong public health standards to meet.

- Considerable ICT is ‘hidden’ in manufacturing in the sense that companies are designing, developing and enhancing ICT applications that are incorporated into non-ICT products or services and internal business processes.
- Business process information is used to improve the efficiency (managing inputs, increased coordination both internally and externally), effectiveness (product quality) and flexibility (mass customisation, new products and services) of various business processes including procurement planning, production, marketing and distribution.
- The availability of digital information is driving new management possibilities and the development of new business models. For example, geographically dispersed supply chains can be monitored and controlled through ICT. Companies are also using the information capabilities of ICT to support outsourcing of all activities they perceive as non-core.
- The sale of a single product may now mean that a commercial relationship with a customer continues into the future through an ongoing information link. This link can enable product and process improvements by capturing information about product performance.
- Information links also allow firms to bundle products with services and lock customers into product enhancements and purchase of value added services – including project management and consultancy. These services may be more profitable than original product offerings.
- Developments in ICT have provided small companies with an opportunity to take a major role in industrial and technological innovation. For example, as end manufacturers they are able to make use of the computing power previously only available to large corporations. Similarly, small companies can become niche market suppliers with the aid of specialised software in a range of smart or intelligent manufacturing applications.
- Overseas supplied enterprise software often requires further investments in, and developments of, specialised plant based intelligence systems and process execution systems in order for it to achieve its full potential in industry and business specific operating environments.
- Industry–university cooperative and collaborative research centres and institutes in the manufacturing arena play a significant role in supporting this hidden ICT use. The research outputs of many centres are ICT software, hardware, tools and products designed for adoption in manufacturing processes.

This study indicates that it is becoming increasingly difficult to distinguish between the productivity and performance impact of ICT *per se* and the wider set of drivers of manufacturing productivity and improved business performance. The main lesson from these interviews is that when ICT is tightly integrated with other business functions, productivity and performance improvement will follow.

As the pervasive impact of ICT grows, ICT is likely to become a less easily distinguishable cause of improved productivity and performance. This generates the paradox that the stronger the productivity impact of ICT – the harder it is to measure that impact. It also implies that existing studies under-estimate ICT’s role in transforming manufacturing.

To adopt a metaphor used by the US economist Dick Nelson – attempting to isolate the productivity and performance impact of ICT in manufacturing may be becoming rather like trying to allocate credit for a good cake to the quality of a particular ingredient rather than to the complex interaction of *all* the ingredients. Without a particular ingredient, and of sufficient quality, the desired outcome may not be possible. However, at the end of the day, it is the experience, talent and creativity of management that determines which ingredients to add and the way in which these complex interactions are shaped.

The challenges for industry and policy makers include:

- Approaching and managing ICT investment from a business rather than a technology perspective and building effective linkages between general management, business unit management and ICT management teams;
- Recognising the criticality of software development, application and use as an enabler of innovation in just about all aspects of manufacturing activity;
- Effectively integrating production and corporate ICT systems to allow seamless real time information flow and the generation of new management information as a basis for improved decision making and management of risk;
- Promoting a culture of cooperation and collaboration in relation to research, training, and skills development among businesses, universities, publicly funded research organisations, and the vocational education and training sector;
- Building the skills needed to support the critical flows of information between the various functional areas of an enterprise, the ability to turn data into information and knowledge, and to ensure that this is applied and used for the benefit of the company;
- Using the information and knowledge to create and market improved products with enhanced service offerings; and
- Ensuring that ICT education and training systems address the ICT management and application skills requirements for both corporate and production systems.

SMEs, which constitute a significant proportion of Australian manufacturing, face additional challenges in sourcing specialised ICT capability. These include framing appropriate ICT project specifications and finding trusted suppliers and service providers in a highly competitive market that has few barriers to entry. Industry based accreditation and certification would go some way to addressing this form of market failure.

With the continuing globalisation and concentration of the ICT sector it is important that the ICT industry in Australia maintain a capacity to provide for and service the unique requirements of Australia’s manufacturing sector. Both corporate and production systems must be sufficiently adaptable to suit both the larger and the smaller users of ICT in ways that contribute to both industry productivity and business profitability.

1 Introduction

The Department of Communications, Information Technology and the Arts commissioned Howard Partners to explore the use of information and communication technologies (ICT) by what have been referred to as non-ICT manufacturing businesses.

OECD publications and reports identify the ICT manufacturing sector as covering 'production intended to fulfil the function of information processing and communication, including transmission and display, using electronic processing to detect, measure and/or record physical phenomena or to control a physical process' (OECD 2004)

1.1 Study purpose

The purpose of the study was to provide an analysis of how ICT is being developed and used within the non-ICT manufacturing sector and the impact this is having on companies' operations, productivity, business models and competitive positions.

The first part of the study comprised a review of Australian and overseas literature on ICT utilisation and innovation in manufacturing and its impact on business performance. This review provided background for the second part of the study, which involved a series of interviews with over 20 non-ICT manufacturing companies across a range of sectors to profile the scope of ICT adoption, application and use in their business processes and incorporation in products and service offerings.

The interviews also sought to document the role and contribution of ICT to innovation and the extent of 'hidden' ICT development, production and/or sale[1], and to identify the factors that stimulate, facilitate and/or inhibit ICT enabled productivity enhancements.

For the purposes of this study, ICT is taken to cover component and final products (including hardware and software) and services that utilise electronic, photonic or similar means to collect, record, convert, store, process, analyse and communicate data and/or information. It includes, for example, satellite imaging, electronic or computerised controls, prototype modelling, robotics and sensors, mobile phones, algorithm development tools, decision making tools, local area networks (LAN) and control networks in factories, radio tracking, smartcards, biometrics and security technologies.

The approach taken for the study is set out in more detail in Attachment 1.

1.2 Background

The ICT Framework for the Future Report, *Enabling Our Future* (Framework for the Future Steering Committee 2003) concluded that ICT has a broad role, providing a set of enabling technologies and related products and services that

[1] Examples of how ICT development, production and sale can be "hidden" include where a non-ICT company elects: to design / develop its own ICT because off-the-shelf components, services or applications are either not available, too costly or not suitable; to produce its own ICT because it is a business critical input to a non-ICT product being produced; to exploit other market opportunities by also selling ICT; or to enhance the value of its non-ICT products by bundling them with ICT products or services.

underpin the development of Australia as an information or knowledge economy.

Enabling Our Future observed that many of the new business opportunities for Australian firms will depend on their capacity to develop new ICT-based products and services which respond to the expanding role of ICT across the economy and society. The report also highlighted the importance of a substantial level of ICT production and capability in Australia. It recommended that the information base for the ICT industry be improved. In particular, the report concluded that Australia needs:

- A comprehensive collection of data about the ICT industry which fully recognises the breadth and pervasive nature of the industry and that moves beyond traditional classification categories; and
- A better understanding and measurement of the productivity benefits of ICT across the economy and the contribution of ICT to exports in other sectors.

Considerable progress has been made in improving the level of understanding in relation to the second of these issues. However, it has mostly been from an economy or industry-wide perspective and the research has focused mainly on the adoption and utilisation of computers, the Internet, e-commerce and corporate ICT systems. This report addresses the application and use of ICT in business processes and specifically in manufacturing processes outside the ICT manufacturing sector.

1.3 ICT and its contribution to productivity improvement

The manufacturing sector has been the subject of a number of recent studies on the contribution of ICT to productivity improvement.

A recent NOIE study (National Office for the Information Economy 2004) concluded that, in addition to microeconomic reform, new technology, including ICT, has made a much more significant and direct contribution to productivity growth than previously suspected.

There are, however, wide disparities in the productivity growth rates of different manufacturing industries, and it appears that the less technology oriented and lower capital industries are recording lower productivity growth rates. The NOIE study found a strong correlation between domestic ICT inputs and productivity growth.

Other studies have explored the way that firms have been successful in realising productivity gains by changing cultures and work and management practices (Australia. Productivity Commission 2004; National Office for the Information Economy 2003). However, relatively little attention has been given in studies of ICT adoption to developing a holistic view of the role of ICT in industry sectors and in businesses, and how it is being used in their strategies to gain sustainable competitive advantage.

1.4 ICT issues specific to the manufacturing sector

The manufacturing sector has been selected as the focus of this study for a number of reasons:

- The sector makes an important contribution to the Australian economy in terms of employment, Gross Domestic Product (GDP) and exports.
- Growth over the period 1977-78 to 2000-01 has averaged two per cent per annum, slightly slower than GDP growth. Manufacturing comprises 13 percent of GDP and is of growing importance to trade. The share of manufacturing exports (as a percentage of GDP) has almost doubled over the period 1978-79 to 2000-01 rising from 3.95 percent to 7.21 percent (National Office for the Information Economy 2004).
- The scope for incorporating and utilising ICT throughout the whole business of a manufacturing company is very broad. Analysis of Australian Bureau of Statistics (ABS) labour force data[2] reveals that around half of all skilled ICT workers are employed outside the ICT sector, with a significant proportion of these people employed in the non-ICT manufacturing sector.
- Estimates based on ABS data suggest that non-ICT companies in the manufacturing sector were responsible for around eight percent of all business expenditure on ICT research and development in 2001-02[3].
- It is well recognised that the long term sustainability of the Australian manufacturing sector will depend on its ability to adapt and compete in an environment which includes increasingly globalised markets and value chains (Australian Industry Group 2002, 2004; Economist Intelligence Unit 1997; Howard 2001, 2002a; Howard and Johnston 2001).

While a number of economic and econometric studies (Gretton, Gali, *et al.* 2003; National Office for the Information Economy 2004) have suggested that ICT has made a significant contribution to productivity in manufacturing, these gains have not been consistent across the sector. What has not been explored to the same extent is the way in which ICT has assisted businesses in increasing sales, net income and competitive advantage. It is these management issues that form the focus of this study.

[2] Unpublished ABS data extracted from Labour Force Survey 2004.
[3] Unpublished ABS data extracted from Survey of business expenditure on research and experimental development.

2 The role of ICT in manufacturing industries

In this section the role of ICT in manufacturing is examined from a broad, industry wide perspective. In subsequent chapters the role of ICT is examined more from the perspective of individual businesses.

2.1 The pervasiveness of ICT in contemporary manufacturing

Through its capacity to integrate and blend a number of knowledge intensive technologies, ICT can enable Australia’s traditional manufacturing base to be competitive in a global environment. Innovative use of ICT can result in new sales channels, new product capabilities and product differentiation. ICT can also reduce costs, increase productivity and improve the base for strategic decision-making and risk management. These results should be reflected in enhanced business performance – as indicated by sustained profitability and viability.

A distinction is often made in the manufacturing sector between information technology, which relates to the corporate and business activities of a company, and process control, which relates to the management of production activities. As process control devices move from electrical to electronic (and from analogue to digital) instrumentation, and incorporate more integrated circuitry with a capacity to generate very substantial amounts of information, the technological distinction between ICT and process control becomes blurred.

The study confirms the pervasiveness of ICT throughout the manufacturing industry. The scope of ICT embraces:

- Corporate systems that are oriented towards enterprise resource planning (ERP), supply chain management (SCM) and customer relationship management (CRM).
- Manufacturing systems such as product lifecycle management (including computer assisted design and manufacture (CAD/CAM)) and process execution (such as supervisory control and data acquisition (SCADA) systems).
- Control systems for programmable logic controllers (PLCs), robots and other hardware embedded in machines and equipment
- Monitoring and surveillance systems used in relation to functions such as security, health and occupational safety, and the building and work environment.
- Extensive incorporation of ICT in products and services.

The pervasive role of ICT in manufacturing has been largely overlooked in contemporary discussion and commentary relating to the information and knowledge economy. For example: ICT enabled devices used in production operations are usually described as ‘control hardware’ and the software that drives them as ‘process control systems’; production machinery and a large range of industrial equipment that incorporate ICT hardware and software, including precision tools and welding devices, are rarely described as computer equipment.

Whilst having the technical characteristics of computers, these ICT enabled devices and equipment do not look like computers in that they do not have screens, keyboards, mice and other peripherals attached to them.

Common measures of ICT intensity in industry are frequently based on counts of the screens and keyboards – presupposing an office paradigm and a services sector orientation. For example, *MIS* Magazine assesses Australian ICT usage based on screen counts. A better measure might be one couched in terms of the overall level of programmable processing capacity. ICT intensity defined in terms of programmed processing units would provide a better indicator of integrated or embedded ICT across all industry sectors.

Given the pervasiveness of ICT, the potential for ICT enabled productivity and performance improvement goes far beyond electronic commerce and merchandising across the Internet. However, the study indicates that as with all technologies, the impact of ICT in manufacturing derives from the way in which technologies are adopted, applied and used in business contexts.

2.2 ICT applications

In broad terms, ICT applications in manufacturing include the following (National Academy of Sciences 2003a):

Hardware –

- Computers and processors – workstations, mainframes, servers, personal digital assistants, programmable logic controllers (PLCs), bar code readers.
- Communications devices and infrastructure – telephone, local area network, wide area network, wireless networks, radio frequency identification devices (RFIDs).
- Actuators or effectors – robot arms, automated ground vehicles, numerically controlled cutters, micro-actuators.
- Sensors – dimensional gauges, machine vision, tactile and force sensors, temperature sensors, pressure sensors.

Software –

- Commodity products, acquired ‘off the shelf’ – such as operating systems, enterprise resource planning (ERP) systems, customer relationship management (CRM) systems, supervisory control and data acquisition (SCADA) systems, decision support packages.
- Differentiable and customisable products – such as process models and algorithms, business process configurations.
- Software for the storage and management of intellectual property – including customer information, business capabilities and procedures, resources, designs, formulas, recipes, configurations, analyses.
- Optimisation software – including artificial intelligence.
- Embedded firmware.

Adoption and use of ICT applications have, in effect, changed the orientation of manufacturing operations from predominantly mechanical and electric to electronic and digital.

In addition, ICT makes it possible to transmit, store and process larger amounts of data and information and to access a broader range of knowledge sources. In this context ICT is a core technology in manufacturing in the sense that it can bring information and other knowledge to the key functions of design, production and distribution.

As digital networks and more powerful computing allow companies to collect, communicate, exchange and analyse data more quickly and cheaply than ever before, manufacturing businesses are able to adopt a broader range of approaches (strategies) to the management of their core functions and processes (Hagel and Singer 1999). This can lead to better informed business decisions and reduce levels of uncertainty and risk.

2.3 Drivers and enablers for adoption

Computer chips and their increased connectivity have become the key element in many automated and semi automated business processes. This has been driven by the rapidly falling price of integrated circuits, the speed with which ideas can be turned into action and a seemingly endless scope of consumer and industrial applications.

The miniaturisation of computer processors, the availability of electronic (and more recently photonic) sensors, and increased processing power, together with the development of specialised manufacturing software, has meant that ICT has become an integral element of production equipment and machinery. Computers and production machinery in a modern manufacturing environment can no longer be identified and described as separate pieces of equipment.

This descriptive overlap between computers and production machinery makes the statistical separation between ICT and non-ICT equipment highly artificial and can understate quite significantly the level of ICT use in manufacturing. Miniaturisation and software has, for example, enabled machine tools to be programmed and to perform highly complex industrial design functions with minimal human intervention. They have also reduced error margins.

Stand alone computers are, nonetheless, present in a manufacturing environment and are used to collect, store and analyse machine process data as well as linking with corporate systems in relation to order fulfilment, inventory management and reporting.

The interviews demonstrated how ICT is embedded in tools and equipment used for cutting, moulding and joining. In many of these areas, the high levels of accuracy and precision required in cutting, shaping, moulding and welding can only be achieved by machinery that has embedded ICT design and control systems. Stereolithography machines are used for cutting scale models for power boats at boat builders Whitley Marine, whilst ICT enabled welding equipment is used by Bluescope Steel for joining sheet steel at its Port Kembla steelworks. These activities are described in more detail in the case study documentation accompanying this report.

The interviews also indicated that the Internet has transformed the ways in which many firms communicate, undertake transactions and exchange information. It improves operations through the exchange of information about distant manufacturing processes, delivers information about the manufacturing process itself and facilitates project management of geographically-dispersed teams. Snap Printing, one of the companies included in the study noted the way in which the Internet allows customers to input into design, ordering and print production.

Developments in telecommunications based on optical fibre technologies have allowed for a huge expansion in the volume of data that can be transmitted around the world at a rapid speed and high quality. This capability is supplemented by data compression technologies that allow for the continued use of the copper wire technology in home and small business establishments. Designers and engineers at Bosch Industries, a company also interviewed for this study, collaborate in real time in product development from company locations around the world.

These developments in technology have provided small companies with an opportunity to take a major role in industrial and technological innovation. In particular, small manufacturing companies are generally able to afford to purchase the computing power that was previously only available to large companies, and yet retain the flexibility, responsiveness, and creativity that is a characteristic of many smaller firms (Howard and Johnston 2001).

In addition, the falling cost of ICT and its expanding functionality makes it possible for small companies to compete against large companies in global markets (Bryan, Fraser, *et al.* 1999; Howard and Johnston 2001). Connectivity through ICT enabled networks allows small companies to work as technology suppliers and/or innovators to larger manufacturing enterprises in science and technology clusters (Bresnahan and Gambardarella 2004; Humphreys 2004; Singelton 2004).

Evidence of technology clustering effects reinforces the findings of the ICT Framework for the Future Report, *Enabling Our Future* (Framework for the Future Steering Committee 2003), which also identified the importance of connectivity and opportunities for SMEs in supporting global multi-national companies (MNCs).

In terms of developing new products, new processes and new business models, ICT is an important enabler of innovation in businesses. The technological possibilities offered by ICT play an important role in shaping the way in which business opportunities and problems can be defined, tackled and resolved. While ICT has a role as an enabler, management experience, creativity and talent are the key drivers of innovation.

In a business environment, boards of directors and executive management are responsible for making decisions concerning the way in which technology is adopted, applied and used. This study found that technology awareness and commitment from governing boards and senior management was associated with a high level of commitment to ICT enabled technological innovation.

2.4 ICT utilisation

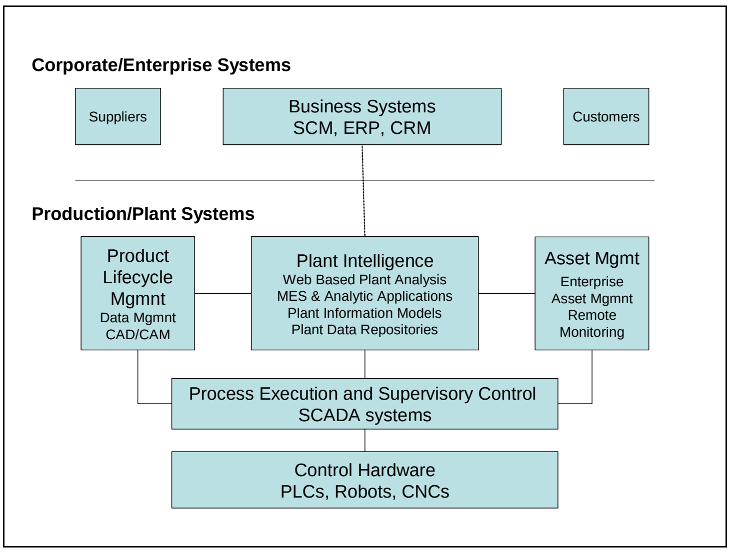
In many manufacturing businesses, the take-up and utilisation of ICT has taken concurrent but distinct paths: one that focuses on corporate functions, associated with managing the manufacturing enterprise, and the other that is concerned with engineering applications that focus on production in a factory environment.

The features of each path are broadly as follows:

- Corporate, or enterprise, systems – covering enterprise resource planning management (ERP) systems, customer relationship management (CRM) systems and supply chain management (SCM) systems. These systems focus on corporately managed interests and activities such as finance, human resources, purchasing and the order fulfilment process.
- Production, or plant, management systems – covering a range of areas, including:
  - Product lifecycle management systems – including product design and development, data management and computer aided design and computer aided management (CAD/CAM) systems.
  - Asset management systems – allowing identification and tracking of physical assets in order to perform scheduling and maintenance tasks with greater efficiency.
  - Plant intelligence systems – allowing decision makers to make business sense out of plant data in real-time, drawing on information generated through the production process.
  - Process execution systems – software applications that allow operators and process engineers to better manage their production processes.
  - Control hardware – covering 'industrial-hardened' personal computers, computer numerical control (CNC) systems, programmable logic controllers (PLCs) and robotics.

The relationship between corporate and production systems is illustrated in Figure 1

Figure 1: Framework for representing ICT in manufacturing



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Aspects of adoption and application in each of these areas are discussed below.

2.4.1 *Corporate systems*

At the corporate level, major commitments have been made by manufacturing businesses for acquisition, development and implementation of ERP, SCM and CRM systems. The performance and effectiveness of these systems have been the subject of a great deal of comment and criticism in contemporary management literature, particularly in journals such as the *McKinsey Quarterly* and *Harvard Business Review* (Carr 2003; Farrell, Terwilliger, *et al.* 2003; Kempis and Ringbeck 1998; Monnoyer 2003) [4]. In general terms, investments in corporate ICT have been seen as underperforming.

It has been argued that part of the reason for underperformance of ICT systems, and their failure to achieve their full potential, is that decisions about the use of ICT have been made at the corporate level and have principally focussed on the needs of corporate functions, such as accounting, finance, human resources and the order delivery process. Consequently, integrating corporate systems with production systems has been a major challenge, particularly where they have limited capacity for interoperability with specialised manufacturing operations (Ake, Clemons, *et al.* 2004).

This observation was supported in a number of the interviews undertaken for the study and will be canvassed further in Section 2.4.3 below.

2.4.2 *Production systems*

Plant intelligence systems extract and convert real-time data generated by production machinery, warehouse systems, production planning software and other systems and turn them into useful information for business decisions. New communications technologies and advanced software tools now allow manufacturers to adopt, experiment and implement new information and decision systems that finally wire the 'last few feet between the top floor and the factory floor'[5].

Some analysts and leading companies believe that in two to three years, businesses that are not making daily decisions based on real-time data will struggle to survive[6].

Process execution and supervisory control systems serve as a conduit for both communicating with the hardware and extracting real-time data from the industrial processes they control. They help manufacturers visualise plant floor operations, perform supervisory functions and deliver the production data that feeds reliable, up to date information to the higher-level analytic applications in manufacturing execution systems.

Potentially, manufacturers can increase production, maximise quality and efficiency and improve regulatory compliance through the adoption of process execution and supervisory control systems.

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[4] Overseas studies suggest that ERP systems have had negative productivity impacts in some instances.
[5] See "intelligent manufacturing" at http://www.advancedmanufacturing.com/January04/intelligent.htm . Accessed 18 October 2004.
[6] Ibid.

SCADA and supporting systems allow machines to ‘learn’ as well as be instructed, and to report a vast range of process information that can be used for subsequent review and analysis of performance. Whilst less error prone than human direction, there is often a need for a ‘machine override’ when ‘things don’t look right’. This sort of intervention requires the skills, knowledge and experience of ICT professionals, engineers, business managers and a wide range of science professionals and an understanding of the logic of the interactions between machines and ICT.

Control hardware represents the durable assets that are used to physically manufacture products, maintain the flow of materials and protect the safety and quality of what is being produced. Although this hardware is constituted as ICT, and includes advanced processors, integrated circuitry and wireless capabilities, it is generally referred to as production machinery and equipment.

Control hardware does not appear physically as computer equipment; there are very few ‘screens’ and keyboards associated with its operation. In the current factory environment hardware is programmed at the time of manufacture (like a photocopier in an office environment), or installation (like a PABX) and then upgraded remotely and maintained through laptops or Personal Digital Assistants (PDAs).

ICT enabled production systems allow for increased monitoring and control over a much larger scale of operations, reduced need for human direction and supervision, and greater flexibility in responding to customer orders. At the same time, ICT enabled automation is calling for people skilled in the technologies required to manage, operate and maintain the facilities based on digitised flows of data and information.

Arnott’s Biscuits

Arnott’s Biscuits uses product lifecycle management systems (PLMS) and tools for product development and monitoring. In production, ICT tells the highly automated production machinery ‘what to do’ through computer aided manufacturing (CAM) technologies and SCADA software. Very few machines run without a technology interface. ICT is used extensively in the order fulfilment processes. ICT is also used to monitor and manage ancillary services such as air conditioning and security. Finally, ICT allows for better use of the data that is collected from production processes in applications such as statistical process control which, in turn, can facilitate productivity improvements.

This study found that in the current manufacturing environment, investments in digitised plant and equipment are not being viewed as an ICT investment – in the same way that investment in mechanised electrical equipment is not thought of as the purchase of electric motors. However, in terms of delivering overall productivity and performance gains in manufacturing, the major source of advantage for companies at this stage derives from improvements and innovations in production systems (Ake, Clemons, *et al.* 2004).

It has been argued that during the 1990s ideas about how to use ICT to improve plant operation were largely ignored – and in many instances continue to be ignored – at a time when computer technologies have become more sophisticated and increasingly applicable in the manufacturing context (Ake, Clemons, *et al.* 2004). This reflects differences in corporate cultures and understandings of the potential application and use of technology, and between the cultures of the corporate and operational parts of a company. One production manager consulted for this study advised that he had obtained approvals for an ICT enabled innovation on an incremental basis, rather than on a whole of project basis, as he was convinced the larger proposal would have been rejected on the basis of cost and risk considerations.

Resolving the inter-relationship between corporate and production systems is currently a major challenge in the development of management execution systems (MES). These systems seek to integrate the order fulfilment process with the production process, as well as making more effective use of machine generated data to validate and certify interacting processes, allow for more effective sequencing of processes and real time reporting of performance information. MES functionality can be included in either ERP or SCADA systems.

2.4.3 Adapting corporate systems to meet production requirements

Only a very few manufacturing businesses have developed effective interfaces between production and business systems in a way that allows real time information to flow between the factory environment and the corporate management setting.

In many manufacturing enterprises the two systems remain entirely separate with paper based interactions between the two. For example, orders may be received and entered into business systems, bills of materials prepared and then re-entered into production systems: this of course invites errors. In this study, Prowler Proof Doors provides an exemplary example of successful systems integration between corporate and production requirements.

Practices in the manufacturing sector contrast with the finance sector, for example, where transactions data are extensively aggregated into management information and reporting systems. The profiles included in the study identify several manufacturing companies that have traversed the barrier between enterprise and production systems – as well as a few where the barriers still remain.

As a result of the separate development paths of corporate and production systems, many enterprise resource planning (ERP) and other corporate systems are not sufficiently adaptable for manufacturing operations. They are often unable to support the smooth flow of data across the functions of ordering, scheduling, production, delivery and billing or to meet the detailed functionality needs of different industry and business requirements – particularly in relation to scale and variation in production schedules (Ake, Clemons, *et al.* 2004).

ERP has not always been appropriately applied to manufacturing businesses, with essential elements of manufacturing processes sometimes not acknowledged. That is, systems developed in a corporate context often did not understand that the amount of materials needed to produce a product can vary; that scheduling must be dynamic rather than static; and that quality, instead of always being black or white, can be a matter of degree (Ake, Clemons, *et al.* 2004).

As a result of these issues, effective use of ERP systems requires adaptation and ingenuity in linking to production systems. Moreover, apart from functionality considerations, an important reason for the lack of integration is difference in use: while corporate systems are driven by customer relationship, management, reporting and accountability requirements, production systems are driven mainly by a search for operating efficiencies. Quite often systems are based on and developed from different operating platforms.

A major constraint in achieving successful integration relates to cost and scale. In the SAP enterprise resource planning environment, for example, costs of achieving a production-corporate interface were reported by ICT professionals contacted during the study as being expensive and exhibiting low end return on investment. There is, however, an increasing range of software available to build the bridge between corporate and production requirements and uses of ICT. Nonetheless, this study indicates that there can be substantial costs associated with building certified connections between proprietary ERP systems and production systems.

It has also been argued that over the years many manufacturing companies have allowed a corporate ICT culture to assert control over most aspects of ICT. This follows from the centralisation of ICT functions in many conglomerate businesses as executives looked for consolidation and economies of scale. Centralisation was followed by decisions to outsource with a view to achieving cost reductions. It is now appreciated that companies outsource to acquire a capability which would be difficult to develop and retain internally (Quinn 2002; Quinn, Baruch, *et al.* 1997, 2002).

Whether driven corporately or operationally, the effective link between ERP systems and factory floor automation systems is seen as a critical tool for companies to gain a competitive edge through improved operations, collaborative production and corporate accountability. In order to realise this potential, managers have to understand the contribution of technology generally, and information technology specifically, to innovation and business performance.

2.5 The significance of ‘hidden’ ICT production

The term ‘hidden’ ICT production is a reference to a situation where a company elects to design and develop its own ICT. The interviews indicated that the reasons for this include where the required components, applications and services are either not available, unsuitable, or too costly to source from other businesses. From the companies interviewed in the study, examples of ‘hidden’ ICT include:

- Hardware – where companies develop their own integrated circuits and control devices for use in their own and related production processes and products (for example, Robert Bosch).
- Software – where software applications are integral to business and product functionality, and companies develop their own software to operate hardware devices (for example, Orica Mining Services, Vision BioSystems, Bluescope Steel).

- Services – a range of professional services firms and research organisations develop ICT applications that become part of their product and service delivery strategies. The software becomes a 'product' that is intended to support professional advice and consultancy – and may be marketed separately (for example, Proteome Systems).

Two examples from interviewed companies illustrate these points.

Vision BioSystems

Vision BioSystems (VBS) is a medical equipment manufacturer that relies heavily upon ICT. Indeed, standard Dell computers are built into some products. Almost all of the software that is core to the company's product performance is developed in-house (either within VBS itself or within the larger group of companies to which VBS belongs).

Eight software engineers are employed in Melbourne (out of 120 staff in that city and 220 staff world-wide). The capacity to develop software in-house acts as a catalyst for leveraging the capabilities provided by brought-in systems and sub-assemblies.

As an innovative, high technology company, Vision BioSystems provides an example of the way ICT production is 'hidden' in the process of manufacturing medical devices and in the functioning of the devices themselves.

The production, manufacture and use of 'hidden' ICT also has had the effect of making traditional 'old economy' companies, such as mining equipment and services companies, appear as 'high tech'. Orica Mining Services provides a good example of this transformation.

Orica Mining Services

Orica Mining Services manufactures commercial explosives and detonators for use in the mining, quarrying and construction industries. ICT is used to innovate in several key aspects of blasting technology and to control production plants for explosives.

Innovations in blasting technology involve the development and use of software to mathematically model geological structures and explosions in order to optimise blast designs. Detonators now incorporate microprocessors, allowing the more precise timing and sequencing of blasts that is necessary to optimise and predict the explosion process.

Blast optimisation and safety are also enhanced by using mobile manufacturing units (MMUs) with custom designed, computer-based process control systems to manufacture and deliver bespoke explosives compounds on-site.

In combination, these aspects of ICT-dependent blasting technology deliver greater cost-effectiveness and lower risk in blasting operations.

In-house developed software is used whenever existing systems cannot deliver the required functionality. The development of these proprietary software systems has been assisted by collaboration with publicly funded research organisations in Australia.

In these examples, ICT is an integral part of the manufacturing transformation process and provides the basis of product functionality and service delivery. That ICT has been largely developed in-house. Yet, companies are, respectively, in the business of manufacture and sale of medical devices, and manufacture and delivery of services relating to explosives.

Feedback from the companies covered in the study indicates that engineers, rather than ICT professionals, are frequently involved in writing and enhancing programs for use in devices and equipment and in industrial design and production control systems. In an overall sense, therefore, the extent of this 'hidden' ICT in manufacturing is difficult to gauge.

2.6 The knowledge base of ICT investments

The businesses consulted for this study indicate that ICT investment is tightly controlled. This contrasts sharply with the technology boom of the 1990s when technology spending was relatively unrestrained. Technology investments were heavily marketed by vendors, service providers and consultants on the basis of ‘must have’ selling strategies. This approach was particularly prevalent in corporate ICT.

The study found that the manufacturing companies consulted now adopt a more deliberative approach and invest in ICT as part of their overall capital expenditure decision process and innovation strategies. Often ICT is part and parcel of a production, processing or analytical capability that is being acquired and may not even be identified in the decision making process as ICT. Processors, sensors and operating systems are embedded in the machinery that not only drive operations but also deliver information about performance – and may even suggest corrective action.

In contemporary business journals, ICT is increasingly being seen as an infrastructure investment and approached on the same basis as other corporate investment decisions (Carr 2003, 2004).

Simplot

To ensure it is focused on business outcomes, and not technology, Simplot has consciously chosen to label ICT activities as ‘information services’ (IS). It employs ‘business analysts’, not ICT specialists, to reinforce the focus on understanding requirements and outcomes.

The company also has an ICT investment ‘rule’: 8 of every 10 ICT projects must be driven by business needs – only 2 of 10 may be ICT driven or IS initiated. The business case must be made for all proposals. The introduction of Internet Protocol (IP) phones was given as an example of an IS initiated project that was implemented because it produced dollar savings.

It is important, however, for companies to be aware that ICT differs from other infrastructure assets in that it supports the generation, transfer and sharing of knowledge that can be adopted, applied and used for innovation in business and manufacturing processes and in enhancing the functionality of products and services.

The ability of ICT to support continuous monitoring, fast data processing and sophisticated data analysis has led to an improvement in the availability of critical management information. The scope and amount of information that can be extracted from business (corporate and production) processes has increased and frequently can be analysed in real time.

Business process information can then be used to improve business efficiency (managing inputs, increased coordination both internally and externally), effectiveness (product design and quality) and flexibility (mass customisation, new products and services) of various business processes including procurement planning, production, marketing and distribution.

In several of the businesses consulted for the study, process by-product data is aggregated and analysed using statistical packages (such as SAS) to identify inherent relationships and linkages, which is then used for process optimization – that is, to reduce variability, enable better control, enable lean manufacturing and eliminate waste.

2.7 Conclusion

This chapter has drawn attention to the pervasiveness of ICT in manufacturing by pointing to the way in which it is embedded in corporate management systems as well as in design, production equipment, and distribution systems, and in manufactured products and associated services. There are few activities in a manufacturing environment that are not impacted in some way by ICT. However, in drawing attention to the pervasiveness of ICT, it is also apparent that the presence of ICT is not always easy to discern.

Whilst most accounts of ICT intensity in industry are based on counting ‘screens’ (and numbers of people using them), such an approach will generally understate the level of ICT application, adoption and use in manufacturing as the technology is often embedded in devices, equipment, machinery and products. There are few screens or keyboards – but many processors represented as programmable logic controllers, communications devices, robots, sensors, and more recently, RFID devices.

In addition, many manufacturing businesses, particularly in the high technology areas, develop their own hardware, software and services applications in-house to meet their own specific and customer requirements. This means that much ICT activity is ‘hidden’ from the view (and from official statistics) of the more general ICT sector. The ICT is hidden because it is an input in the production of manufactured products and the services that those products deliver.

At the same time, however, manufacturing companies seek to acquire ICT capability from the ICT sector where capability is available. As will be discussed later in the report, this requires an ICT sector, and particularly a software and services sector, that is capable of addressing the special and unique requirements of Australian manufacturing.

In this environment, modern factories are becoming less oriented towards manual, mechanical and electrical applications and more to the automatic, electronic and digital. In these circumstances a better way to understand the pervasiveness of ICT in manufacturing might be to estimate the capacity of programmable processing units – rather than the number of computer screens. This could help to improve our understanding of how important ICT is to industry and our ability to use it in contributing to enhancing Australian manufacturing performance. It also has implications for the way we think about the skills required in a manufacturing environment.

The development of ICT in manufacturing has followed two distinct paths. One has followed a concern with resource planning and control, customer relationships and relationships with other businesses along the supply chain. This path has had a strong financial and corporate management foundation. Another path has developed with a focus on production management – with a strong engineering orientation.

Separate cultures have emerged around each approach with the result that businesses have sometimes found it difficult to achieve effective integration of systems on an enterprise wide basis and in ways that contribute to enhanced productivity and profitability. The interviews demonstrated, however, that investment in ICT is being approached on the basis of the contribution that it will make to bottom line performance and other indicators of corporate success.

Whilst there has been a tendency to see ICT as ‘infrastructure’ – like electricity and other production inputs, it is important to appreciate the unique nature of ICT through the way in which it supports the generation, transfer, processing and application of knowledge. The critical issue in a manufacturing environment is the way in which this knowledge is captured and used to improve all forms of business process, create new products and service offerings, and develop strong and long-term relationships with customers. The productivity and performance enhancing aspects of ICT that flow from this are addressed in the next chapter

3 ICT, productivity and business performance

The study looked at the role and impact of ICT on a number of aspects of business performance. Of particular interest is the way in which ICT contributes to productivity growth and enhanced profitability achieved through firm level competitive advantage.

The contribution ICT makes to productivity improvement is examined first, followed by an assessment of ICT’s contribution to competitive advantage and improved business performance across a range of business functions. The chapter concludes with a discussion of the role of management in driving ICT enabled performance improvement.

3.1 The contribution of ICT to productivity

The study has found that in the manufacturing industry environment the key ways in which ICT can increase productivity are through its capacity to reduce costs, increase the capability of machinery, and provide increased flexibility in production planning and scheduling.

ICT allows for increased scale and speed of machinery operations as well as an expanded management span of control/coordination. Increased capability comes about through the digital control hardware embedded in the machinery and the process execution systems that monitor and control factory operations.

Additional productivity and performance enhancements may accrue to those companies that successfully integrate process control systems with corporate systems through software solutions such as manufacturing execution systems (MES). A major challenge in this area is encouraging managers to ‘trust’ software and machine generated data, monitoring and analysis to validate processes without the need for physical inspection and activation.

Detailed discussions with managers indicated that in the factory environment, the impact of ICT on labour productivity can be dramatic as a result of its capacity to fully automate production processes and systems.

In the corporate environment, the interviews indicated that substantial productivity gains have been achieved by sales teams through the adoption of customer relationship management (CRM) systems that provide for electronic transfer of orders from the field to systems that manage the order fulfilment process.

B&D Doors

B&D Doors use ICT to link orders to its computer aided design (CAD) systems and numerically controlled machine tools. This reduces lead times for producing products to customer specifications and lowers the cost of production, mainly by reducing the need for human intervention in the production process.

Notwithstanding the importance of ICT to achieving these outcomes, expenditure on computer hardware and software accounts for only a fraction of the total investment needed to drive productivity gains. The largest share of investments goes toward redesigning and changing the business processes and the relationships between businesses, their suppliers and customers. In the contemporary business environment, however, business process redesign and system design are complementary.

These complementary investments are less visible but arguably more important in ensuring an observable bottom-line impact. Research at the MIT Centre for e-business reported in a recent article in the *MIT Technology Review* reaches the following conclusion:

> The unsung heroes of the IT revolution have not been the microchip and the Web browser, but rather the creative, diligent, and painstaking work done by those who have been rethinking supply chains, customer service, incentive systems, product lines, and 1,001 other processes and practices affected by computers. Investments of intangible capital constitute the real source of today's productivity growth (Brynjolfsson 2004).

The MIT research indicates substantially different outcomes among companies that spend similar amounts on ICT. In other words, ICT is important in contributing to business performance through the way it is used rather than for what it is. Driving the way ICT is adopted, applied and used is a management rather than a technology issue. The study supports research findings reported in leading business journals that, without creative management and understanding of the business context, the potential benefits to be gained from ICT will not be achieved.

Some national and global ICT companies have recognised the close and symbiotic relationship between business processes and ICT systems and are expanding their capacity to provide business improvement services on a contract and consultancy basis. Increasingly, these companies are seeking to provide services on a partnership basis where consultants are closely involved in the work of a client's business in an endeavour to achieve productivity and efficiency gains through ICT enabled process, product and supply chain innovation.

The trend among the ICT vendors towards consulting and partnership strategies is reflected in substantial internal investment to build capability and in mergers and acquisitions – such as the merger between IBM and PricewaterhouseCoopers consulting. However, this study found some resistance on the part of manufacturing enterprises who do not wish to cede control of their core business processes to third parties.

Measuring ICT's contribution to productivity can be more difficult in non-ICT manufacturing sectors, particularly when it is embedded in machinery and equipment designed to provide non-ICT outputs and where the associated productivity benefits are primarily realised by a non-ICT function or outcome. For example, ICT enabled medical equipment and diagnostics may increase the accuracy and speed of tests, extend the range of tests possible and the locations where they can be undertaken, and deliver more accurate diagnoses. In this situation, productivity gains are realised in the health services sector. In addition, the source of gains is the manufacturing sector not the ICT sector.

3.2 ICT contribution to competitive advantage

The study examined the extent to which non-ICT manufacturing firms can gain competitive advantage from ICT. It found that the key factors include the way ICT is used in combination with other technologies and the way in which it is applied and managed. The study's findings support management literature that investment in ICT does not, of itself, yield competitive advantage or enhanced business performance (Briggs 2004; Laartz, Monnoyer, *et al.* 2003).

Simplot

Simplot does not see ICT as providing competitive advantage: the role of ICT is to assist innovation and least cost manufacturing. Ensuring that the sales force has access to automated processes, for example, is a market place imperative and a priority that may provide short term advantage. But it is in essence a necessity for survival rather than a differentiator. On the other hand, Class A operational excellence (a manufacturing quality certification), underpinned by ICT/IS, does provide a competitive advantage. Intrinsically this is an opportunity available to everyone in the industry but the reality is that not all companies pursue it. The key is therefore the company's desire and ability to adapt the available technology better than its competitors.

The impact of ICT varies across manufacturing industry sectors and among businesses. For example, this study indicates that:

- In fast moving consumer goods industries, ICT has enabled companies to move from a product focus to a customer focus by being able to manufacture more closely to customer preferences/requirements rather than to production possibilities.
- In globally oriented and highly competitive industries where Australian–based companies are essentially price takers, businesses need to keep up with the technological change and developments in order to stay in the market.
- In monopoly–oriented industries, companies choose carefully those technologies that are going to impact on bottom line performance and create shareholder value – for example, Australian newspapers have moved slowly in their on-line and multi-media offerings.

For some commodity producers, such as in clothing manufacture, ICT has enabled transformation from a staple commodity business to a fast moving consumer good category. Underwear for example, is now merchandised like a grocery line rather than retail clothing.

Acquisition and ownership of technology assets does not of itself bestow any market place advantage: advantage is created in the way assets are utilised, and in ways that create distinctiveness, or a distinctive capability.

A company has a distinctive capability when it has something that other companies find difficult, if not impossible, to replicate. Distinctive capabilities are reflected in a company's brand, image and reputation, its governance, management team and staff, its internal and external relationships and networks, and in its commitment to innovation (Kay 1994, 1995).

This study found that ICT plays an important role in assisting companies to develop their distinctive capabilities in these areas. Drawing on the interviews, it is apparent that:

- ICT has been instrumental in enabling companies to merchandise high profile brands at the required volumes, at accessible locations, with acceptable margins and to a high product standard.
- ICT can increase the quality, quantity and availability of information shared between suppliers and customers reinforcing information flows that inform decisions on production and processes.
- ICT assists companies in innovation and new product development through simulation techniques and flows of knowledge, information and ideas across and within industry sectors.

- ICT enables companies to undertake product development on a continuous, real time, global basis.

In many of these areas, the main source of ICT–related competitive advantage derives from the computer programs (software) that are acquired, developed and applied in specific business situations.

Proteome Systems

Proteome Systems, a pioneering business in the growing field of proteomics[7] relies upon ICT to build its distinctive competencies. A strategic alliance with IBM has provided much of the wherewithal to do this.

The company reflects the 'classic' innovation trajectory – using existing technologies in new and creative combinations to make products and services that customers need and will pay for.

In effect, Proteome Systems is a value-added re-seller of IBM equipment and 'middleware' (databases and data storage systems). The distinctiveness of the company, and its capacity to create value, is based upon its highly talented scientists coupled with the capacity to develop in-house software that integrates a range of different instruments.

Proteome has also used existing ICT technology in its design and development of new chemical analysis medical instruments and devices. ICT components and software have been embedded into protein analysis equipment and Proteome is innovatively using existing ICT nano-tech printing technology to change how chemical analysis of proteins is done – by 'printing' the chemicals needed for the analysis onto the proteins (instead of the traditional method of taking the proteins to the chemicals).

Alliances with ICT companies such as IBM allow the company to focus on what it can do well that competitors can do less well, whilst avoiding the need to develop all of the necessary technological capabilities and systems.

3.3 ICT in product development and production planning

ICT plays an important role in managing a company's product portfolio and in allowing for greater flexibility in production planning and scheduling.

Arnott's Biscuits

ICT is critical in helping Arnott's Biscuits to manage the evolution of its product portfolio whilst also benefiting from economies of scale. Product life cycle management systems assist the product development process and issue electronic instructions to production equipment to monitor how the production process is actually performing – providing key information for use in future new product development projects.

Australian company CITECT (which has a global market for its services) has developed specialist software for Arnott's for ingredient selection and weighing through to packaging. Arnott's also uses its own ICT staff to customise and make complementary changes to its existing and proprietary ICT systems to optimise the utility of its product life cycle management systems.

Designers and engineers in product development and production processes in the fast moving consumer goods sector use digitally enabled machines to meet customer requirements for quality, reliability and functionality, as well as business needs for efficiency and control over costs.

[7] Proteomics is the study and cataloguing of proteins in the human body. Knowledge of proteins and how they interact with each other is a key element in drug development.

3.4 ICT in enabling collaboration, customer relationships and client service

ICT facilitates collaboration among companies and with clients and customers. Boeing Australia, for example, will partner with other Boeing companies to develop ICT applications for use in production. The company also levers off its parent – which is a customer as well as an owner/investor. In the aerospace and other industries, ICT vendors like to talk of ‘partnering’ with companies, but they are still essentially suppliers of products or services for them. Many companies like to keep an arm’s length relationship and do not want suppliers to be too closely involved in their business strategies.

ICT allows companies to develop close relationships with customers through on-line and Web-based ordering and secure, advanced communications systems. Success in this area often depends to a large extent on the level and sophistication of ICT use on the part of customers and sales representatives.

Prowler Proof Doors

Prowler Proof provides a wide range of products manufactured in fully welded aluminium. Each item is manufactured using precision electronic cutting equipment and state of the art welding machinery. All products are custom made to individual client requirements, and treated and powder coated to give a long lasting and attractive finish.

ICT is used to fully automate the order fulfilment process using Web-enabled technologies from order through to despatch. The on-line order process integrates with the production process that relies on ICT to fully automate production from cutting the aluminium strip, through welding, painting and packaging. There is no ‘batching’. ICT allows for a ‘production run of one’, with each order being an individual product.

The technology involves a great deal of complexity but provides for a high level of individual customisation.

ICT also allows companies to have a continuous engagement with clients following production, delivery and sale. Technology allows information on product performance to be relayed to manufacturers for monitoring, quality assurance and triggering service and maintenance actions. For example, Orica Mining Services embeds ICT into mining equipment to perform this task.

3.5 Management issues

Most businesses have focused on using ICT to support basic business functions and deliver outcomes relating to cost reduction, increased quality and reliability, and improved scheduling. Although the issue has been around in management circles for at least 15 years (Ernst & Young 1989; Scott-Morton 1991), fewer businesses have effectively aligned their business and ICT strategies or used ICT to leverage innovation.

Since the technology sector down turn, the role of ICT managers in contributing to business strategy and innovation is now receiving a great deal more attention within the ICT industry. A recent issue of *CIO: The Magazine for Information Executives* is devoted to innovation (Bushell 2004).

In larger companies, divided ownership of and accountability for ICT can reduce the opportunity for innovation. It is argued that while business unit leaders have developed a greater understanding of the strategic impact of technology, in traditional business structures ICT professionals continue to control the investments (Mark and Monnoyer 2004).

The risk of this split in responsibilities for ICT is that business unit leaders may not fully appreciate the possibilities of technology, while ICT managers may not fully appreciate the drivers of the business and the full range of areas where ICT may be useful. The broader risk is that managers, in general, may not be aware of the strategic importance and contribution of ICT throughout the business.

Several companies consulted for the study had been acquired by venture capital investors who introduced major changes in the top management team, who in turn restructured the companies around the business enabling opportunities provided by ICT. The study found that a number of companies had outsourced their ICT support functions allowing a greater focus on the strategic use of ICT – that is, to support innovation.

3.6 Conclusion

This chapter has drawn attention to the role of ICT in enabling competitive advantage through the way it is used in a range of business processes and products. This is against a background of ICT being acquired on the basis of investment proposals justified on return on investment.

ICT also enables competitive advantage through its capacity to generate and apply knowledge and build firm level distinctive capabilities. Distinctiveness can be generated in design, in product development, production processes, in customer relationships and ongoing client service.

The interviews indicated that ICT has made an important contribution to productivity growth and in firm level business performance. However, the capacity to bring about these improvements relies on people thinking about new ways of approaching design issues, new ways of organising production and new ways of managing a supply chain, as well as an appreciation of the possibilities ICT opens up.

The role of people in enhanced performance points to the critical role of management leadership and direction in ensuring effective integration between productivity gains at the production level and performance gains at the corporate level.

The company interviews indicated that the increased availability, flow and application of knowledge and information within the sector based on the use of ICT has had a positive impact on the critical business functions of planning, production, marketing and distribution.

Adoption, application and use of ICT varies considerably across those industry sectors profiled. Variation is related to industry structure, the level of competition and the nature of the product and service offerings.

Software underlies every aspect of productivity and performance improvement. Australian manufacturing businesses need access to software that reflects the research and development (R&D) input of globally oriented software firms but is relevant and applicable to local conditions. This requires a strong Australian software development sector that is attuned to Australian manufacturing needs and a services sector that has both national and international linkages.

4 ICT and innovation

The purpose of this section is to examine the relationship between ICT and innovation in manufacturing businesses. The contribution of ICT to business innovation is examined from the perspectives of sustained change and improvement in manufacturing process, product development, supply chain management and the development of new business models.

It becomes clear that ICT and business innovation are closely coupled and the ability to capture the opportunities of innovation are contingent on approaches to investment and management of ICT capability.

4.1 Innovation, business strategy and ICT

From a business perspective, innovation is the means by which businesses exploit areas of external and internal change that offer commercial opportunities (Drucker 1985; Howard 2001, 2004a; Miller and Morris 1999; Schumpeter 1989). Often it begins with an idea that is transformed into a concept that includes some new combination of what is already known and can be implemented to serve some commercial purpose. Innovation is essentially a human activity and nurturing innovation is an essential function of management and a key responsibility of managers.

It is not possible to define a list of attributes, or traits of an innovative manager. There have been numerous studies that attempt to link business success to management traits, the latest being Joyce, William and Nitin Nohira. 2004. *What Really Works: The 4+2 Formula for Sustained Business Success*. In all this work, innovation is, however, recognised as a core management responsibility, along with leadership, knowledge of technologies and business acumen.

Many companies committed to innovation adopt a strategy based on generation of new ideas, support for experiments flowing from ideas and commitment to new ventures flowing from successful experiments (Baghai, Coley, *et al.* 1996, 1999; Cooper 2001; Hamel 2000). Decisions to allocate resources to nurture ideas, conduct experiments and enter into new ventures are generally approached on the basis of a capital expenditure/investment appraisal decision, and on a project-by-project basis, using a business management model.

Consistent with this investment approach, the internal research and development (R&D) divisions in some firms now charge user divisions for the innovation results produced. These R&D divisions are also being market tested against independent research laboratories, including publicly funded research organisations and universities, and against opportunities to acquire innovation from start-up companies (Kurtzman 1998). This pattern reflects the spread of open innovation strategies among manufacturing companies.

Historically, strong R&D capability in large industrial enterprises provided a barrier to entry in many manufacturing sectors. However, changes in the way R&D is performed, particularly in relation to information and communication technologies, means that internal R&D capability is no longer regarded in this way. An emerging model of open innovation is becoming apparent where companies source innovation capability externally through acquisition of technologies developed in research organisations and smaller technology-based companies (Chesbrough 2003b; Linder, Jarvenpaa, *et al.* 2003a, 2003b).

Companies have also become much more active in trading their patent portfolios and universities and publicly funded research organisations are giving more attention to recognition, licensing and/or sale of their intellectual property. Much of this intellectual property is ICT related (Howard 2003, 2004b).

An important aspect of industrial innovation is now based on companies, universities and publicly funded research organisations creating spin-off companies to develop and market new discoveries and inventions to end-users. These users may be a final consumer but are more likely to be established corporations. This feature of industrial innovation is particularly apparent in the life sciences and in industries that utilise ICT applications as a basis for innovation. The trend in venture capital financing is towards support for start-up companies that have developed technology solutions that enable innovation in established industry sectors (Howard 2002b, 2002c; Howard Partners and *Australian Venture Capital Journal* 2002).

This study provides some evidence to support contemporary management research which suggests that larger corporations that use ICT and other enabling technologies in taking new products and services to market are tending now to invest less in internal R&D and more in scouting and acquiring technology through licensing and investments in spin-off companies (Chesbrough 2003a, 2003b). Alternatively, they enter into meaningful strategic alliances with small and medium sized companies whose business model is to increase the value of the technology/discovery and sell it on quickly. This trend may be one of the factors that underlies decreases in the measured R&D in the manufacturing sector in recent years.

More generally, outside perspectives and competencies that are important for innovation flow into and out of organisations through many routes:

- Partnerships with universities.
- Alliances and acquisitions.
- External venture investments.
- Recruiting and hiring.
- Customers and suppliers.
- Relationships and curiosity of individual employees.

These sources of external influence have played pivotal roles in all aspects of corporate innovation (Wolpert 2002). In this respect, the application, adoption and use of ICT in 'non-ICT' manufacturing industries reflects the capacities of managers and staff to envision how people, ideas and objects can contribute to change in processes, products, services and the operation of the business itself. It also depends on their ability to acquire or develop the know-how needed to affect these changes from within or, increasingly, outside the company. In this way, innovation is as much about people as it is about technology.

4.2 ICT and innovation in 'old economy' industries

Recent assessments have pointed to the importance of ICT in innovation outside the so-called new economy industries concerned with knowledge, computing and communications (National Office for the Information Economy 2002, 2004). The concept of the new economy also involves 'old' economy corporations embracing new technologies and enhancing their performance. According to business historian Alfred Chandler, the new economy created, and will continue to sustain for some time, the opportunities and necessities for reconfiguring almost every aspect of the operation of industrial age enterprises (Chandler 2001).

Bonds Clothing

Bonds (part of the Pacific Brands Limited Group) is a highly innovative business unit in what is considered to be an 'old economy' industry. Innovation is enabled by ICT which is used to link and integrate production, marketing and sales. ICT has enabled the company to move from a manufacturing/production orientation to a marketing/customer orientation. Bonds is led by a Group General Manager with a strong marketing background.

ICT underlies the current order fulfilment process. Customer orders are made and processed electronically. The order management system allows stock to be tracked from inventory to invoice using scanning technologies. Bar coding is fully integrated with the inventory management systems of the major retailers. Information is collected weekly from retail point of sale (POS) systems that provide information about stock on hand at stores and which can provide information about stock movements to retailers.

The main ICT driver was the cost of manually handling 18,000 stock keeping units (SKU) – covering seasonal ranges, sizes, colours and retailer marks. ICT allows the order fulfilment process to be expedited, as well as more efficient manufacture and inventory management. This in turn, allows for greater responsiveness and targeting to customer requirements.

The company is looking to implement track and trace technologies for retailers to identify where orders are and monitor progress. It is also looking to automate stock replenishment.

The way in which ICT has the potential to complement, integrate and blend a wide variety of technologies and knowledge areas in a traditional manufacturing environment can be illustrated by reference to food processing – one of the largest manufacturing sectors in Australia and generally regarded as an old economy industry. Each of the activities in the value chain identified in Figure 2 has a strong ICT element that combines with other knowledge domains.

Figure 2: Activities and knowledge/technology areas in food processing

Activity	Technology/Knowledge Area
Selection and preparation of raw materials	Filtering, centrifugal, washing technologies; steaming (thematic treatment) sensorics; molecular biology and micro biology; chemistry and biochemistry
Processing	Process lines (engineering); ICT and informatics; logistics; heating and refrigeration technologies; molecular biology and micro biology; bacteriology; chemistry; biochemistry; gastronomical skills
Preservation and storing	Cooling/freezing technology; vacuum; hermetics and modified atmosphere packing; sterilisation; pasteurisation and homogenisation; biological preservation; biotechnology; biochemistry; bacteriology and microbiology; analytical chemistry
Packing, wrapping and coating	Disposal technology and environmental issues; materials technology; process lines (engineering informatics); design; consumer preferences and marketing; microbiology and bacteriology; biochemistry and analytic chemistry; cooling/freezing technology; vacuum; hermetics and modified atmosphere packing
Hygiene and safety	Microbiology; bacteriology; biochemistry and analytic chemistry
Quality and nutrition	Chemistry; microbiology; additives; texture; sensoric analysis and evaluation
Quality control and documentation	Testing/measurement technology; spectoscopology; sensorics; microbiology and bacteriology; biochemistry and analytic chemistry
Transport and distribution	Logistics; ICTand informatics; general transport technology; cooling/freezing technology; microbiology and bacteriology; biochemistry and analytic chemistry
Trading, marketing, sales	sociology (consumer preferences and trends); economics (price elasticities, etc)

Source: Smith, Keith. 2000.

The business interviews used in this study provide insights into how businesses in the old economy industries have identified, adopted and implemented ICT in business and production processes and in product design. Innovation has also been driven by a need to remain competitive, as well as supporting a strategy of business growth.

The companies consulted for the study indicated that ICT enables innovation in all of the areas most often identified as involving distinctive approaches to innovation:

- Product and service innovation.
- Process innovation.
- Supply chain innovation.
- Business model innovation.

These are addressed briefly in turn.

4.3 Product and service innovation

There are very few categories of industrial machinery or commercial equipment, or associated services, that do not incorporate ICT in some way. Businesses look to ICT to enable product and service innovation.

The difference between what is an ICT product or service and a non-ICT product or service is becoming less clear. For example, medical devices, machine tools and equipment, motor vehicles and even detonators incorporate

ICT in the form of processors and communication capability: ICT is a fundamental part and/or function of the product.

A recent *Business Week* feature on digital convergence argued that ICT manufacturing companies, such as Microsoft, Cisco and Dell, are venturing far from their specialities into consumer and industrial products. Similarly, consumer products manufacturers in Japan and mobile phone manufacturers in Korea are ‘rigging their products with microprocessors and software, racing to turn them into a new generation of digit-gobbling, network ready contraptions’ (Einhorn, Ihlwan, *et al.* 2004).

ICT is also embedded in products to collect, store and transmit data that will be used by manufacturers to monitor performance and functionality (and failure), and for subsequent product development and enhancement. Embedded ICT is not only used to improve product performance and contribute to product development, it also enables a change in the relationship between manufacturer and consumer.

Where once a business would have manufactured physical products for a one-time sale to an anonymous consumer, there is now a shift towards building long term relationships with customers and serving their needs around the services provided by a manufactured product. Building this relationship is enabled by the embedded ICT. Moreover, embedded ICT provides opportunities for companies to collect and use information as a way of marketing the service value of a product to new customers – rather than simply merchandising a tangible object.

In this environment, as the design, manufacture, sale and distribution of this equipment has become increasingly knowledge intensive; it requires the input of highly skilled scientists and technologists to support the work of engineers in design and manufacture. Sales and marketing teams also need to understand the technology characteristics and service potential of the products they are selling.

Proteome Systems

Proteome Systems has developed a diverse range of software in-house to run its electrophoresis equipment, the Xcise and the ChIP. However, to integrate the various instruments under the ProteomeIQ banner so that they work as an integrated module, the company developed BioinformatIQ using IBM’s enterprise level IT infrastructure.

BioinformatIQ centralises and records data from the various instruments and serves as a laboratory information management system and electronic notebook that is Web accessible so that users can access and share data from multiple geographic sites. This lies at the heart of the ProteomIQ platform and has been marketed as part of a global strategic alliance with IBM.

The company arranged to embed statistical analysis modules developed by CSIRO within ProteomIQ, as well as improve the graphical user interface.

In commoditising markets, and in order to drive home a commitment to customers, businesses are bundling complementary offerings into their products in order to compete (Gulati 2004). These complementary offerings are often marketed as product enhancements or product service packages. It has been argued that every company has an opportunity to integrate ICT enabled services into its products. These services are seen as part of the ICT hardware, differentiating otherwise commodity products to gain competitive advantage (Tapscott 2004).

The machinery and equipment suppliers consulted for the study, for example, combine hardware, software and value added services such as consultancy and performance information back to their customers. This equipment includes medical devices (Proteome Systems, Vision BioSystems) and mining equipment (Orica Mining Services).

Following on from the idea of capturing revenue from the service value of a product, manufacturers are finding it necessary to provide education and training in product use to their distributors and customers. This goes beyond installation into after sales service and warranties. Consequently, manufacturing companies are finding it necessary to take a much closer interest and involvement in how their products are used.

The interviews indicated that the competitive advantage provided by ICT intensive products is not the ICT *per se*, but the information attributes, properties and customised service offerings that the ICT enables, and which are embodied in the product. In other words, clever use and incorporation of ICT becomes a differentiator.

4.4 Process innovation

Most activities in the manufacturing production process fit somewhere within one of the following business processes:

- Research and development.
- Design and engineering.
- Purchasing and logistics.
- Operations – manufacture/production.
- Marketing.
- Sales and order management.
- Post sale service.
- Product content and design.

Effective ICT systems enable these processes to be performed more efficiently and effectively and also more flexibly. Process innovation involves the review, revision, streamlining and improvement of procedures, systems and tasks to eliminate non-value adding activities and reduce the overall number of transactions or steps in a production process. It often involves instituting an entirely different way of doing things (Davenport 1993). Examples of ICT enabled processes are listed in Figure 3.

Figure 3: ICT enabled processes

Process Category	Examples of ICT enabled processes
Research and development	ICT based modelling and analysis ICT based field trails and data collection Research coordination, development and management systems and collaboration Integrated research database Information distribution and dissemination

Process Category	**Examples of ICT enabled processes**
Design and engineering	ICT aided design and analysis ICT controlled modelling and prototyping Integrated engineering and design database Collaborative design Design for manufacture systems Integrated ICT systems coordinating design, manufacturing and sales ICT–based compliance testing
Purchasing and logistics	Integrated supplier ordering system Inventory storage and retrieval systems Third party shipment and location tracking systems
Operations – manufacture/production	Linkages to sales and design systems (built to order) Real time systems (custom configuration and order processing) Integrated materials ordering and inventory management system Robotics and cell controllers Diagnostic systems (maintenance and repairs) Quality and performance information Health and safety systems
Marketing	Customer relationship management and databases Point of sale systems tied to individual customer purchases Online sales and customer profiling Vendor managed inventory (VMI) systems Expert systems for data and trend analysis Statistical modelling of dynamic market environments
Sales and order management	Prospect tracking and management systems Sales force management systems Online/dialup product database (price, lead times, order variation, status checking) Web enabled 'choosing engines' that match products and services to customer needs Expert systems for configuration, shipping and pricing Sales analysis systems Customer, product and production databases
Post sale service	Online/dialup service and fault analysis Service personnel location monitoring and management Service diagnostic database Software upgrade
Product content and design	Enhanced functionality, control and operation Performance monitoring and management Data collection and integration Networking

Source: Based on Davenport, Thomas. 1993.

Many of these ICT enabled processes are used by companies consulted for this study. Whittley Marine, for example, makes extensive use of ICT embedded in stereolithography equipment used in the design and production testing of motor boats and marine vessels[8]. This technology replaces manual, more time consuming and less accurate techniques for the creation of moulds and shapes.

[8] Stereolithography (SL) equipment translates computer aided designs (CAD) into solid objects through a combination of laser, photochemistry and software technologies.

Whittley Marine

Whittley Marine is a Victorian manufacturer of marine pleasure craft. The manufacturing process is based on moulds for the range of fibreglass models. Moulds are re-used subject to the quality of the mould and the demand for the design.

Moulds are designed using sophisticated CAD systems and tested under computer simulated marine conditions. Scale models are generated using stereolithography technology – which provides for greater accuracy, less margin for error and faster results on new design parameters. This results in shorter design timelines and faster time to production of the mould.

As indicated earlier, process related ICT investments will not of themselves deliver an economic return. If nothing changes about the way work is done then the role of ICT is simply to automate an existing process, and the economic benefits are likely to be minimal (Davenport 1993). The interviews provided evidence that successful introduction of ICT enabled production technologies has been accompanied by a fundamental redesign of business processes.

In the factory environment, ICT supplements and in many cases replaces the need for human direction and supervision. In the factory walk throughs undertaken for this study, the absence of production workers and supervisors on the factory floor was startling. Production management and control is enabled by supervisory control and data acquisition (SCADA) systems. In this way, ICT increases by a very substantial amount, the effective management span of control.

Arnott’s Biscuits

ICT has allowed Arnott’s to increase the scale of its plant and take advantage of economies of scale. It has also enabled the company to respond to demand for smaller and more customised orders. In 1985 Arnott’s Biscuits operated eight bakeries, located and managed on a ‘federal’ basis; now there are four. However, production facilities created for large scale production runs are not economic for small production runs and it is difficult for a large plant to operate using just in time (JIT) production techniques. To support operational flexibility, Arnott’s has retained a number of smaller production lines – in addition to its larger ones. ICT has allowed these smaller lines to cater for smaller niche and speciality product markets.

The detailed discussions with companies indicated that ICT allows for increased scale of machinery and higher production through-put. It also allows for a move away from batch manufacture to customised manufacture where each product on the assembly line can be tailored differently to accord with customer preferences.

In companies where marketing and distribution relies on a sales force, ICT has enabled innovation in the order fulfilment process: sales staff are able to digitally design, display and demonstrate a product’s features and functionality (Prowler Proof Doors, B&D Doors). These technologies allow for the customer to be involved in the design process, and for this process to link directly (and electronically) to ordering and through to manufacture.

ICT is also used extensively in the order fulfilment process. However, in only a few cases does an electronic design and order process by-pass sales consultants. The technology still relies on a sales consultant to close the deal. Customer driven design through to order and manufacture may actually make the role of the sales consultant even more important than it has been previously – in terms of interpreting and advising on what is actually desirable, feasible and practical. Motor vehicle manufacturers, for example, still prefer orders to come through dealerships.

Amcor Australasia

Amcor Australasia manufactures paper, plastic, metal and glass based packaging. The main driver for Amcor’s investment in ICT is to optimise supply chain logistics in a ‘mass customisation’ business environment. This is a demand-driven trend in which packaging products are made to order within the cost and lead-time targets normally associated with mass production. This requires close interactions with customers over packaging design.

Seventy five percent of ‘design to production’ work is now handled electronically. This includes a substantial degree of automation as key customers are able to specify what they want and then receive the new design electronically before finalising the order. In addition, substantial amounts of operational data are now generated by the packaging manufacturing machines, and then transferred to the company’s data management systems.

Until the late 1990s Amcor’s ICT focus was on the in-house development of made-to-order ICT applications. This tended to be driven by operational issues and technological opportunities. The emphasis has now shifted to a more strategically driven ‘whole-of-business’ focus. To meet this challenge, ICT operations are now outsourced – except for ICT strategy development, architecture and risk management which are still handled internally. All viable ICT investments must now demonstrate a better return on investment than could be earned on alternative corporate investments.

Moreover, in the monitoring, testing and diagnostic areas of manufacture – adjacent to factory floor operations – equipment is embedded with ICT allowing for greater coverage, accuracy and scope of information.

4.5 Supply chain innovation

ICT also enables supply chain innovation – new forms of collaborative relationships within industry and business supply chains, with suppliers at the beginning of the chain, and with retailers (and increasingly final consumers) at the other.

ICT enables manufacturers to work closely with supply chain integrators who link initial supply with retail outlets. The food processing industry often refers to an integrated ‘paddock to plate’ supply chain. The ability to move data at the same time as physical goods is the essence of an efficient supply chain. Bar codes, radio frequency identification devices (RFIDs) and remote sensors are key ICT enablers in this process.

Supply chain innovation in food processing

Food processing is one of the largest manufacturing industries in the OECD, including Australia where it makes up 23 percent of the manufacturing sector (Australia. Department of Agriculture Fisheries and Forestry, 2004). However, the industry is fragmented; and with many firms operating at each level of the supply chain inter-organisational cooperation is a challenge. The demand by stores for products in bulk and at a relatively low cost, and high transportation costs pose particular challenges for firms in this sector.

A key challenge therefore is logistics management. This ends inside the store, where employees can use ICT (in the form of hand-held units) to improve ordering and even in some stores where customer self-scanning is being introduced. Manufacturers though are more interested in the larger efficiency gains that are possible through collaboration, information sharing and integration with suppliers and transporters outside the store.

Computer assisted ordering and vendor managed inventory are examples of such collaboration.

Regulation and compliance at various points in the value chain (such as health inspection and customs clearance) is also enabled through ICT. The concept of the virtual corporation is probably the pinnacle of supply chain efficiency where fulfilling customer demand is used to focus and drive the close management of supply chain relationships, service agreements and outsourcing.

In the clothing industry the influence of effective supply chain management (SCM) in the short term can be significant, with large savings and profit increases. Firms without excellent supply chain management capabilities will fail to be competitive. The underlying problem that SCM will solve is matching supply and demand, but tremendous demand uncertainty remains.

Successful retailers and their apparel and textile suppliers have taken advantage of huge changes wrought by ICT and which have made traditional manufacturing practices largely ineffective. In an increasingly fashion-oriented world, companies have had to respond to the practice of lean retailing – the effective management of inventory based on accurate and timely information (Abernathy, Dunlop, *et al.* 2000). That is:

- The retail, apparel and textile sectors are increasingly linked as a channel through information and distribution relationships. Thus, the channel, rather than the firm, becomes the basis for competition.
- Supply chain management is the key to success for textile and apparel manufacturers. It enables them to use sophisticated information links, forecasting capabilities and management systems. Companies that do this well tend to be successful.
- The factory can provide competitive benefits only if other, more fundamental, changes in supply chain management have been introduced. Unless firms change their distribution practices, there is no change to the bottom line.
- As retailers and manufacturers respond more quickly to consumers' demands, clothes will take on the characteristics of a perishable commodity. To stay successful, companies will need to adjust their manufacturing paradigm in response to these flow on effects.

Bonds Clothing has demonstrated success in these areas.

Through the aggressive integration of multiple companies, supply chain speed and flexibility can be achieved while, at the same time, providing a higher quality of products and services to a broader spectrum of customers in a dynamic marketplace. ICT has been and will continue to be a critical enabler in this evolving production and market environment.

Inclusion in ICT enabled supply chains requires manufacturers to have an ongoing commitment to quality, consistency, reliability and product integrity. For example, food retailers and supply chain integrators have developed quality systems and other forms of accreditation and certification that provide the basis for manufacturers to enter into, and remain within, industry supply chains (Australia. Department of Agriculture Fisheries and Forestry 2001, 2002; Howard and Higham 2002).

ICT not only provides for monitoring of manufacturer performance in industry supply chains, it also provides for feedback and the basis for corrective strategies – and exclusion where standards are not being met.

4.6 Business model innovation

Finally, ICT enables business model innovation – radically new ways of doing business that are reflected in the structures of an organisation and its relationships.

ICT allows reductions in transaction and interaction costs, which make partnering and strategic alliances more cost effective, and facilitates unbundling of the vertically integrated corporation to enable it to concentrate on what it does best and acquire other capabilities from specialist suppliers.

Prowler Proof Doors

The way in which ICT has been used to fully automate the order fulfilment process (see section 3.4) has created a greater span of control for the company whilst also improving productivity (mainly by replacing labour with machinery). The company is no longer dependent on wholesalers and distributors for orders, whilst also avoiding dependence on the suppliers of pre-cut aluminium for its basic components.

In the increasingly commoditised industries such as food and clothing, ICT has been influential in permeating business boundaries and linking industry supply chains to generate competitive advantage and profit potential.

Returns have been captured by existing, but often new, businesses that see the opportunities in redesigning business models and supply and distribution processes through the adoption, application and use of the communication and information processing capabilities of ICT (Chesbrough 2003b; Christensen 1997; Christensen and Raynor 2003). Again, it is not the technology that delivers the benefits: it is the way it is used by creative and talented managers and entrepreneurs.

In established companies, enterprise resource planning (ERP) systems now play key roles in production, logistics and purchasing. In more advanced stages of integration, individual companies and suppliers may have applications that enable Internet links not only at the borders between companies, but also within specific internal processes.

For many companies, the traditional transaction and information handling is now carried out by a Web-enabled supply chain, which coordinates activities and simultaneous global planning between multiple businesses, both internally and externally. In the food industry, new companies have been created to perform the role of business integrators.

The Internet and e-business affect every step of the process and offer a cost-reduction opportunity. In speed and efficiency of communication and planning, steps that happened in sequence now happen concurrently and collaboratively. Final configuration happens with the customer, and there is reduced inventory, process time and cost.

4.7 Conclusion

The role of ICT in enabling innovation has been canvassed extensively in the management, technology and public policy literature (Briggs 2004; Fitzgerald and Wynn 2004; Matthews and Frater 2003; National Academy of Sciences 2003b; OECD 2000). Much of this material takes a generic view of technology and technological change and has a focus on economy wide and industry level concerns. At the enterprise level, the focus tends to be on the opportunities and possibilities captured through the acquisition of ICT hardware, systems and services – rather than on the situations and circumstances where investment decisions are made at the firm, or enterprise level.

In most of the companies interviewed for this study, investors, CEOs and business unit managers could envision how ICT could be used to innovate in all major areas of business activity – in product development, production, process design and supply chain management. They were also aware of the possibilities of relating to suppliers and customers in new ways through new business relationships.

The interviews made clear, however, that existence and availability of technological advances (and novelty) does not necessarily mean that boards and senior management will commit to adoption through an innovation strategy: acquisition, adoption and use of technology will reflect a business decision, based on a wide variety of strategic and environmental considerations.

The study has highlighted the importance of close and effective working relationships between ICT staff, business unit staff and suppliers/customers in realising innovation potential in all aspects of business. The practice-based literature and commentary on innovation establishes that it is a collective, social learning and evolutionary process – not a one-off technical exercise. However, the business profiles undertaken for this study indicate that senior executives have had a key role in driving the innovation process, drawing on and ‘pulling through’ available information and communication technologies.

The study found that companies in specialised and high technology manufacturing areas, such as medical equipment, have developed their own ICT solutions that are incorporated directly into products that deliver higher levels of value to customers. These solutions may be developed within companies’ own research and development (R&D) business units and/or in collaboration with research organisations. However, companies generally outsource ICT maintenance and support functions to specialised ICT developers, providers and service contractors.

On the other hand, for companies, particularly SMEs, that purchase solutions directly from third party vendors, the study identified a risk that poor project specification, inappropriate software selection and missed opportunities to integrate ICT with other aspects of the business operation may adversely impact on the ability of ICT to contribute to business performance. However, in situations where owners and senior managers are skilled in ICT applications and development ICT has been developed, applied and used economically and efficiently.

The study has demonstrated, through the interviews, that ICT-based technological advances will be adopted, applied and used when there is a likelihood that they will result in increased profitability and demonstrated return on investment. In a highly competitive environment where profit margins are thin, managers may have to invest in ICT simply to stay in business.

The study found that it is only when innovations remain unique to a company that it is possible to capture sustained profits. For an innovation to be unique a company will rely on context dependent, tacit and location specific knowledge embedded or manifested in its people, business processes, organisation structures, culture and human behaviour. These are the hardest aspects of an innovation to replicate – not the technology.

5 Complementary support for manufacturing ICT

The purpose of this section is to examine issues relating to the way in which ICT adoption is supported in a manufacturing environment, by canvassing issues relating to sources of ICT capability and skills and capabilities in software development.

5.1 Sourcing ICT capability

The interviews indicated that manufacturing businesses sourced ICT enabled machinery and equipment in a number of ways. The following approaches were identified:

- Engage other businesses normally considered to be part of the ICT sector to design and manufacture computer hardware and software which is then installed and linked to production equipment.
- Purchase production machinery and equipment with computer control hardware embedded. Software is then developed in-house, or more commonly outsourced to a software developer and services provider.
- Specify to machinery and equipment suppliers the functionality required and allow them the opportunity to innovate. Machinery and equipment providers are not generally regarded as ICT manufacturers.
- Design and development of ICT enabled and embedded machinery and equipment undertaken in house, while ICT components are sourced ,and manufacturing undertaken by, specialist companies.

Proteome Systems

Proteome Systems is, in effect, a re-seller of IBM equipment – as part of bundled/integrated service offerings. This includes sales of medium to large p-series computers to anywhere in the world. These laboratory machines use IBM "middleware" – databases, storage products. This fits well with the IBM strategy not to sell applications and compete with individual software vendors – the enabling technologies that make products successful.

The study found that for large manufacturing equipment installations, businesses, plant designers, equipment suppliers, software vendors, programmable logic control (PLC) programmers, engineering consultants, etc, often work in a collaborative arrangement. At Arnott's Biscuits for example, the equipment was purpose built for a new plant.

Such large capital investments are not regarded internally or externally as an ICT purchase, even if it was possible to separately identify the ICT component. As indicated above, they are regarded as capital investments, and subject to appraisal on the basis of expected contribution to the bottom line over the longer term. They also have to compete with other investment proposals and are considered in a corporate capital expenditure decision making and resource allocation process. That is a decision is made on the project as a whole, not its technology component parts.

The interviews suggest that most companies acquire their ICT software capability from external service providers. With the exception of high technology industries, such as medical equipment, ICT adaptation and application to specific business uses is undertaken by software service providers and consultants. The global hardware and software suppliers are increasingly incorporating services into their own business strategies.

The study suggests that very few manufacturing companies maintain and develop software in-house – except where this is core business or has significant security ramifications relating to matters such as access to intellectual property protected through confidentiality and secrecy. Further, the suppliers of manufacturing machinery and equipment are becoming major players in the manufacturing software and services market.

5.2 Software developers and service providers

The development of software for the manufacturing environment involves a very large number of businesses occupying niche positions in various aspects of the production system. Much of this software is developed by consultants and service providers as they imitate and adapt software to suit specific manufacturing process elements.

Many newly established and specialised software companies have very short lives, as they fail to become profitable or are taken over by larger companies: many are set up to be ‘harvested’ (Howard 2004c).

Australian manufacturing companies rely on local software developers and service providers to develop and apply applications that meet the specific needs of the Australian and global markets in which industry currently operates and sees opportunities. With free trade, the regulatory environment is becoming more rules driven requiring greater levels of accountability and traceability. In the food industry, which accounts for over 20 percent of Australia’s exports, there are growing demands for quality, safety, traceability and documentation.

There are indications that the software sector is rationalising as manufacturing companies look for greater integration and inter-operability of systems within the production environment and between production and corporate systems. Large software vendors are also looking for greater levels of integration between their corporate and smaller scale production systems (Malone, Laubacher, *et al.* 2003). But, as the study indicates, many of these larger and integrated systems are too expensive for Australia’s predominantly SME manufacturing sector to afford.

The study indicates that Australia’s manufacturing sector needs a manufacturing software capability that is suited to its needs. A number of research organisations, such as the CSIRO, CRCs and rural R&D corporations are working in this area, but the company studies covered in this study, and in a parallel study being undertaken (Howard 2004c) do not indicate that the SME base is adequately representing its needs and requirements.

According to data provided by the Australian Computer Society which are based on analysis of ABS unpublished data, there were 340,700 ICT jobs in Australia in November 2000 (Houghton 2001). A significant proportion of these, 27,400 or 8.0 percent, were in manufacturing. However, these people represent only around 2.5 percent of all manufacturing employees. This can be compared to the ICT manufacturing industry where only 16 percent of employees are designated as ICT people (ABS Cat No. 8162.0).

This lower level of direct ICT employment in manufacturing is consistent with our findings from discussions and consultations with manufacturing companies that they rely on the ICT knowledge, skills and experience of people whose primary job classification and qualification is something else – particularly engineering in relation to production systems and management accounting in relation to corporate systems.

Moreover, as companies do not see ICT as core business, they source capability externally and rely on hardware and software service providers, consultants and contractors to meet their ICT needs and requirements. Indeed, an analysis undertaken of ICT enterprises indicates that a substantial number of ICT firms are essentially contractors and service providers (Howard 2004c).

Some of the ICT service providers engaged by the case study companies in servicing manufacturing companies are quite small and specialised, but there are a number of substantial service businesses, operating as systems integrators and as contractors providing a full range of ICT services to manufacturing companies. Some of the case study companies have outsourced their entire ICT functions to global service providers such as EDS, CSC and IBM[9].

The following table provides an illustration of the number of developers in various functional areas.

Table 1: Australian Manufacturing Software Developers

Functionality	Number
CAD & visualisation	77
Control & automation software	58
Electronic procurement	31
ERP / supply chain software	125
Graphical programming	16
Maintenance – software & systems	77
Production software	66
Software development	71
Warehousing software	60

Source: http://www.electronicsnews.com.au/browse_section.asp?catcode=02. Accessed 18 October 2004.

The sheer number of providers makes it difficult for manufacturing companies, particularly small to medium businesses, to satisfy themselves that they are acquiring software and services with the appropriate levels of functionality, quality and integrity. To this end, it is important that manufacturing companies seek to develop effective business relationships with developers and providers with whom they can trust and have confidence. As with other professions, industry certification, standards and accreditation assist in developing these relationships.

Corporate and production software used in manufacturing is developed and marketed by global software companies as well as by small innovative businesses catering for niche markets and specific industry requirements and characteristics. This diversity is important for Australian manufacturing where businesses and business units are relatively small in comparison with North American, European and Asian corporations.

[9] IBM has an objective of becoming a service provider ; it is moving out of some aspects of software development. See *Fortune* June 2004.

Australian companies need to be able to access software developed for a global market and adapt it to local conditions, as well as being able to access locally developed solutions to meet specific and unique needs. Few Australian manufacturing companies are of sufficient size to support the cost of large ICT implementation and management teams. The interviews undertaken for this study point to very small in-house ICT capability in manufacturing businesses – with a preference for acquiring capability through consulting and contracting.

5.3 ICT skills and capabilities

The manufacturing ICT environment now demands skills and capabilities related to intelligent manufacturing systems, manufacturing and process execution systems and process control together with an understanding of business strategy. These skills are based in emerging engineering fields (mechatronics, for example) and business studies. Businesses consulted during this study indicated that courses and programs are required not only at the undergraduate but also at the post graduate level.

A major finding of the study is that non-ICT manufacturing companies require people with knowledge of ICT and its application in industrial contexts. As ICT use in these companies is often 'hidden', new employees do not necessarily come equipped with technical knowledge of how to extract, assemble and organise the vast amounts of data that are generated as a by-product of machine processing.

A number of companies consulted pointed out that ICT is rebalancing skills requirements, from those of 'doing' on the shop floor to the intelligence skills required to monitor and control automated processes. There is also a need for ICT personnel who have commercial acumen, sound interpersonal skills and a capacity to work as brokers matching business needs and technology.

Staff need to have a good understanding of the way in which ICT works and, importantly, an understanding of the potential for ICT adoption and application. They also need to understand how massive amounts of process data can be leveraged into knowledge about production processes and as a basis for business improvement and enhanced competitiveness.

Companies consulted for the study also identified a skills shortage resulting from rapidly changing technologies. There was a perception that graduates from academic institutions lack the skills to apply ICT solutions to business needs. Institutions are seen to be educating people with only a theoretical understanding of ICT, that is, good at knowing how to do it but not what to do with ICT in a business environment.

In the metal products area, the study identified the need for sales forces to also have skills in using ICT in their sales and marketing responsibilities. Sales staff are often employed in their own businesses by distributors who do not have an employment relationship with a manufacturer.

There is a clear message from a number of the companies profiled that potential employees could benefit from more education about ICT industrial applications whilst studying at university or TAFE. It is open for industry associations and industry training boards should take a lead role in this area.

5.4 Contribution of universities and research organisations

In the current manufacturing environment, there is a growing trend for companies to work more closely with universities and public research organisations in collaborative and cooperative research and development (Howard 2004a). This is reflected in industry–university research centres and institutes, including centres of excellence and cooperative research centres. A number of state governments have made significant investments in research facilities that support academic–industry research collaboration[10].

ICT is a key factor in many of these collaborative efforts. For example, the research programs of Australian Government funded cooperative research centres (CRCs) in the manufacturing sector provide a high level of commitment to applicable research relating to photonic and digital sensors and signalling, and radio frequency identification (RFID) technologies. CRCs in agriculture, the environment and mining also have research programs that have ICT–related outcomes. The development and application of software is a major aspect of innovation oriented projects and ventures in cooperative and collaborative research.

Bluescope Steel

Bluescopes's Seamguard™ technology was developed in collaboration with the CRC for Welded Structures at the University of Wollongong. The Seamguard™ technology detects faulty welds as soon as they are made. The technology prevents potentially costly weld breaks in the production line. Operators are forewarned that a weld is faulty, allowing defective welds to be cut out.

The technology, through in-line monitoring, allows independent assessment of welds – that is, independent of operator, maintenance or calibration. When work on the project first commenced there was an average of 19 breaks per year. Current performance now stands at four.

Overall, in 2002-03 the Australian and state governments contributed $60m directly to a total of $200m for manufacturing related research undertaken in higher education institutions. Governments also contributed $184m of a total of $233m in manufacturing research undertaken in public research organisations. A substantial proportion of this research is ICT related (Australian Bureau of Statistics 2004a, 2004b).

The CSIRO, through the Division of Manufacturing & Infrastructure Technology, has assisted and supported a number of companies with ICT enabled process and product improvement[11]. Zuster Furniture is one such company.

Zuster Furniture

Zuster Furniture has been working with CSIRO in a project to use ICT as a basis for shifting from a craft-based manufacturing model to an ICT-influenced model that still retains the best elements of craft production. This involves changing the ways in which the existing production process is used rather than the technologies and tools in the production process itself. In this skilled craft-based environment, ICT is used to collect data on the status of all the jobs under production in order to drive team-based productivity improvement efforts. Simply by identifying what is going right and wrong, team-based efforts are able to address these problems.

[10] For example, the Victorian STI Initiative and the Queensland Smart State Research Facilities Fund.
[11] http://www.ffp.csiro.au/RC-FlooringFurnitureWindows.asp#FurnitureIndustry

5.5 Conclusion

The study indicates that few companies maintain a significant ICT capability in-house. Australian manufacturing relies on a strong ICT services sector that is capable of implementing, customising and developing software in the Australian industry and business contexts. It follows therefore, that the ability of manufacturing companies to capture the benefits of ICT enabled innovation will depend to a large degree on the performance of the ICT sector.

Recent studies have indicated that Australia is developing a strong global position in medical devices and equipment and precision manufacturing equipment. These industries are characterised by small to medium enterprises (Howard and Johnston 2001). As the study indicates, a significant aspect of that position relies on the quality of the manufacturing software that is embedded in that equipment.

Australian developed software applications must also be able to incorporate international, national and state regulatory and compliance regimes of an industry or industry sub sector – such as meat processing and export. Moreover, Australia's predominantly small to medium enterprise (SME) sector relies on external software suppliers and service providers to meet manufacturing needs. Few of these companies are in a position to develop their own software solutions. Even larger companies prefer to acquire, install and maintain ICT from external sources.

From a business perspective, external sourcing from specialised developers and providers makes good commercial sense. But it relies on an ICT sector that is in a position to meet the unique requirements of Australia's manufacturing sector.

It is also apparent from the interviews that education and training institutions must provide and continually update courses and programs that are relevant to Australian manufacturing. This requirement relates not only to ICT specific education and training but also to areas of science, engineering and technology that are applied in manufacturing environments. The study found that many manufacturing companies rely on employees in non-ICT jobs for their ICT knowledge, skills and expertise. Education and training undertaken in a cooperative and collaborative research environment will work towards achieving these ends.

6 Concluding comment

In the modern knowledge economy, manufacturing and ICT are closely intertwined. In many respects, ICT is like other technologies used in manufacturing, but in a number of important respects it differs. These differences relate to the capacity of the technology to:

- enhance the service potential of manufactured products;
- generate useful and applicable knowledge from ICT embedded in products, processes; and
- build business relationships with other companies, suppliers and customers.

The application and use of this information in a business context is a major source of performance improvement.

The capacity to extract and use information generated from manufactured products and manufacturing processes relies on the capacity of businesses to adopt, apply and use ICT in a business and commercial context. This relies to a large extent on the quality of the ICT – and particularly the software production and enhancement capabilities of Australian suppliers and the ability of Australian service providers to adapt internationally sourced software to Australian manufacturing situations and circumstances.

The companies consulted for the study indicated that important software developments and enhancements are quite often undertaken by service providers, consulting companies and advisers. It follows that manufacturing companies must have deep, trust-based and secure relationships with such companies. Computer manufacturers, global software houses and service providers are positioning themselves for this role.

This study commenced by seeking to understand the importance of the 'hidden' use of ICT within manufacturing as a basis for company-specific competitive advantage. On the basis of both company profiles and a literature review, it concludes that effective use of ICT provides the logical means for realising knowledge-based competitive advantages through design, product development, manufacture and relationships with customers and suppliers.

Attachment 1: Approach to the study

Research for the study commenced with a desktop review of the Australian and overseas literature on ICT utilisation and innovation in manufacturing, and its impacts on business performance, business transformation and production processes. This was followed by a series of interviews with non-ICT manufacturing companies that examined:

- the scope of ICT use in the firm in business processes, production processes and through incorporation in products and services.
- the extent to which ICT technologies, components (including software) and services are being developed for sale and/or for incorporation in the company's core product and service offerings, or in production processes.
- how, and the extent to which, ICT has facilitated productivity improvements.
- how ICT has transformed the company's product and service offerings, and production processes.
- the impact of the ICT-induced transformation on the firm’s competitive advantage.
- the key factors that either drive or inhibit manufacturers to incorporate ICT into their products or production processes (eg the adequacy of infrastructure and ICT skills).
- the relationships between the firm and its Australian and overseas suppliers of ICT and the contribution of these relationships to facilitating and developing the above ICT-related activities.
- the relationships between the firm and its key Australian and overseas customers and the contribution of these relationships to facilitating and developing the above ICT-related activities.

The interviews formed the basis for preparation of company profiles.

The industry sectors and manufacturing firms consulted during the study are listed below. Profiles of ICT in many of these companies were prepared for use in the study. Some of the companies have agreed that the study notes may be made available on request to the Department of Communications, Information Technology and the Arts or from Dr John Howard from Howard Partners.

Sector	Company	Type of business
Food, beverages and tobacco	Arnott’s Biscuits	Biscuit manufacture
	Australian Meat Holdings	Meat packer and exporter
	Fosters Brewing	Manufacture and distribution of alcoholic beverages
	Simplot	Manufacture and sale of frozen and canned food products
Textiles, clothing, footwear	Bonds Clothing	Clothing manufacture and distribution
Wood and paper products	Amcor Australasia	Container and fibre packaging

Sector	Company	Type of business
Printing publishing and recorded media	Fairfax Business Media	Business publications
	Snap Printing	Print production
Chemicals and petroleum products	Orica Mining Services	Initiating systems, ammonium nitrate, bulk explosives, packaged explosives, blasting services
	Orica Chemicals	Manufacture, import and marketing of a large range of chemicals
	Orica Consumer Products	Decorative coatings, wood care and powder coatings
Metal products	B&D Doors	Manufacture of electronically operated and controlled doors
	Bluescope Steel	Fully integrated steel making manufacture
	Prowler Proof Doors	Manufacture of security screen doors
Machinery and Equipment	Boeing Hawker de Havilland	Manufacture of aircraft components with expertise in carbon fibre composites
	Whittley Marine	Fibreglass power boat building
	Robert Bosch Australia	Manufacture and distribution of a wide range of automotive and consumer products
Machinery and equipment – Medical	Proteome Systems	Technology; discovery and diagnostics
	Vision BioSystems	Manufacture of invitro diagnostic equipment and reagents – mainly for export
Other manufacturing.	Coringle Furniture	Furniture manufacture
	Zuster Furniture	Specialised design furniture manufacture
	Olex Cables	Cable Manufacture

In addition to the companies listed above, discussions and consultations were held with a number of industry associations and organisations. These included

Australian Chamber of Commerce and Industry
Australian Electrical and Electronic Manufacturing Association
Australian Industrial Research Group
Australian Industry Group
Australian Information Industries Association
CITECT
CRC for Intelligent Manufacturing
CRC for Welded Structures
CSIRO ICT Centre
CSIRO Manufacturing & Infrastructure Technology
Intelligent Manufacturing Systems (IMS) Secretariat
Meat and Livestock Australia
QMI Solutions (formerly The Queensland Manufacturing Institute)
Software Engineering Australia (National) Limited
Warren Centre for Advanced Engineering
Welding Technology Institute of Australia.

These organisations provided valuable insights into the adoption, application and use of ICT in Australian manufacturing industry.

The study team also contacted software suppliers and services providers to the manufacturing sector. In addition, Australian and state government departments and agencies with an involvement and/or interest in manufacturing were also consulted.

The study also involved review of policy development, research papers, reports and monographs on ICT in manufacturing. These reports are included in the bibliography in Attachments 2.

Attachment 2: List of Abbreviations

Abbreviations used in the Study are listed below.

ABS:	Australian Bureau of Statistics
PDA:	Personal digital assistant
PLMS:	Product lifecycle management systems
CAD/CAM:	Computer assisted design and manufacture
CEO:	Chief executive officer
CNC:	Computer numerical control
CRC:	Cooperative research centre
CRM:	Customer relationship management
CSIRO:	Commonwealth Scientific and Industrial Research Organisation
ERP:	Enterprise resource planning
GDP:	Gross domestic product
ICT:	Information and communication technology
IP:	Internet Protocol
IS:	Information services
IT:	Information technology
LAN:	Local area networks
MES:	Manufacturing execution systems
MIS:	Management information systems
MIT:	Massachusetts Institute of Technology
MMUs:	Mobile manufacturing units
MNCs:	Multi-national companies
NOIE:	National Office for the Information Economy
OECD:	Organisation for Economic Cooperation and Development
PLC:	Programmable logic controllers
POS:	Point of sale
R&D:	Research and development
RFID:	Radio frequency identification device
SCADA:	Supervisory control and data acquisition
SCM:	Supply chain management
SKU:	Stock keeping unit
SMEs:	Small to medium enterprises
TAFE:	Technical and Further Education

Attachment 3: Bibliography

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