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Pervasive Limitations: Innovating with Ambient Intelligence (AmI) Technologies and Restricted Absorptive Capacity in Australian SME Manufacturers

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ABSTRACT *The last 25 years have seen rapid increases in the number and sophistication of technological and process innovations in large manufacturers, producing dramatic improvements in productivity and efficiency. However, smaller manufacturers' adoption of such innovations has been uneven. Ambient Intelligence (AmI) technologies are being positioned as the next performance and productivity enhancing purchase for manufacturers. This paper defines and gives examples of AmI technologies in current use, summarises AmI technologies of potential interest to small and medium enterprise (SME) manufacturers, and identifies potential impacts of restricted absorptive capacity in SMEs on the adoption of AmI technologies. Comparing two SME manufacturers, one from Germany and one from Australia illustrates a potential application of generic AmI technology based business solutions to a range of SME manufacturers.*

Keywords: emerging technologies, innovation, small and medium sized enterprises, manufacturing technology, opportunity identification

INTRODUCTION AND BACKGROUND

The 1980s and 90s saw the operations of many large manufacturers revolutionized by the introduction of process and technological innovations (Gunasekaran & Yusuf, 2002). While there have been uneven adoption rates in smaller businesses and across different nations (Chong & Pervan, 2007; Oyelaran-Oyeyinka & Lal, 2006) it is clear that Electronic Data Interchange, Business Process Re-engineering, Enterprise Resource Planning and robotic automation, amongst other innovations, have played key roles in increasing manufacturing productivity. At the beginning of the twenty first century this transformation continues. Ambient Intelligence (AmI) technologies are being positioned as the next performance and productivity enhancing purchase for manufacturers, and a potential means for manufacturers in developed nations to counter perceived threats from lower labour cost countries (Kuehnle, 2007).

Recently, Brown and Bessant (2003) described the manufacturing environment developing this century as an increasingly competitive landscape, characterised by on-going demands for improved flexibility, delivery speed and innovation. A frequently occurring element in manufacturer's responses to these pressures is the implementation of increasingly sophisticated information and communication technologies (ICTs). The benefits of incorporating ICTs on the responsiveness of a business have been identified as: more effective and efficient information flows; assisting in value-adding improvements for current processes; greater access to efficiency enhancing innovations throughout the value chain (Australian Productivity Commission, 2004); and the ability to access world markets through e-commerce (Kinder, 2002).

ICT has been considered worth the risk, given the competitive pressures placed on business to keep pace with technology. For example, in Australia, the uptake of ICTs has increased dramatically towards the later part of the 90's and into the 21st Century. Reports show that in 1993-94, 50 per cent of firms used computers with 30 per cent having internet access; by 2000-01 these figures had increased to 85 per cent and 70 per cent respectively (Australian Productivity Commission, 2004). One of the latest developments in the application of ICTs to business improvement is that of Ambient Intelligence (AmI) technologies. The objective of AmI is to broaden and improve the interaction between human beings and digital technology through the use of ubiquitous computing devices. By using a wider range of simplified interaction devices, ensuring more effective communication between devices (particularly via wireless networks) and embedding technology into the work environment, AmI provides increased efficiency, more intuitive interaction with technology and improved value and productivity (Maurtua, Perez, Susperregi, Tubio, & Ibarguren, 2006).

Ambient Intelligence Technology

The literature (Kopacsi, Kovacs, Anufriev, & Michelini, 2007; Maurtua et al., 2006; Vasilakos, 2008) points to the co-existence of three features in any AmI technology: ubiquitous computing power, ubiquitous communication and adaptive, human-centric interfaces. Regardless of arguments about terminology and definitions (the terms “pervasive computing” and “ubiquitous computing” are in common use in the US, while “ambient intelligence” is favoured in the EU), these technologies are already commonplace. The beep signalling the automatic deduction of a road toll from your account as your car passes under a toll gate is one aspect of an AmI technology known as Radio-Frequency Identification (RFID). During 2006, in NSW alone, more than 1.2 million head of cattle were automatically tracked from farm to saleyard to abattoir as their RFID ear tags passed through RFID sensor gates (NSW Farmers Association, 2007).

In addition to increasing process speed and efficiency, AmI has the potential, intended or otherwise, to dramatically increase employee surveillance and monitor consumer activity over the entire product life cycle. This potential raises important ethical issues. Proposals to use RFID tags to track sufferers of Alzheimer's disease (Caprio, 2005) and children provide examples of the ethical dilemmas AmI technologies can present. While these issues are beyond the scope of this paper, we suggest Cochran et al (2007) for a review of ethical challenges associated with RFID. Many other applications of AmI technologies are appearing as technologists extend the concept into areas such as "wearable technology" (clothing that incorporates sensors and interface devices) more intuitive home space designs and shopping assistance; and the creation of seamless interfaces between work, home and leisure activities. While many of these applications currently seem unrelated to improving business productivity, it is clear that the applications for business can only grow as the technologies become more sophisticated and less expensive. As Rao and Zimmerman (2005, p.3) state "there is a gap in the scholarly discussion addressing the business issues related to it, and the role of pervasive computing in driving business innovation".

Ambient Intelligence Technology in Manufacturing

AmI technology is much more than RFID inventory control systems. Wireless, multi-modal services and speech recognition systems have the potential to increase manufacturing flexibility by supporting dynamic reconfiguration of process and assembly lines, and improving human-machine interfaces to reduce process times (Maurtua et al., 2006). Also, maintenance processes may be improved by linking common mobile wireless devices, such as mobile phones, Personal Digital Assistants (PDAs) or even pagers to production alert systems (Stokic, Kirchhoff, & Sundmaeker, 2006).

Small and Medium Manufacturers in Australia

Organisations with between 20 and 199 workers employ 56% of Australia's workforce (Wiesner, McDonald, & Banham, 2007). The Australian Bureau of Statistics (ABS) defines a small business as employing less than 20 people, and a medium enterprise as between 20 and 200 employees (ABS, 2001). The most recent ABS figures available (2007) indicate that there are around 47,000 manufacturing firms employing between 1 and 20 people, around 10,000 employing between 20 and 200 people, and only 873 employing over 200 people. In turnover terms, around 29,000 manufacturing firms reported annual turnover between $500,000 and $10 million, while only 3,300 firms reported turnover of $10 million or above. It is clear that the bulk of manufacturing in Australia occurs in small-to medium firms. While SME firms employ the majority of manufacturing workers their expenditure on R&D notably lags behind that of large manufacturers. Within the manufacturing industry companies with more than 200 employees were responsible for 73% of total industry R&D expenditure, with only 27% being contributed by the SME sector (ABS, 2007).

In addition, while Australia's manufacturing output has quadrupled since the mid 1950s, the Australian Government Productivity Commission (2003) states that overall, it has not grown at the same rate as the service sector. The Productivity Commission also describes Australia's manufacturing sector as having "missed out on the productivity surge" of the mid 1990s while noting signs of improved manufacturing productivity in 2002 and 2003. Given the significance of SMEs in Australian employment and the perceived need to increase manufacturing productivity, potential improvements available through the systemic application of AmI technology to SME manufacturers form an important topic for research and government policy.

Absorptive Capacity

This paper applies the concept of *absorptive capacity* to manufacturing SMEs. We argue that SMEs can benefit from AmI technologies, using specialised intermediary organisations to overcome the "absorptive capacity" limitations evident in a great many SME organisations. Cohen and Levinthal (1990) proposed that internal Research & Development activities serve two purposes: to generate innovations, and to provide the ability to absorb relevant knowledge appearing in the external environment. The absorptive capacity of a firm is comprised of these two categories of activity. Their foundational paper conceptualised absorptive capacity in the context of large U.S. manufacturers, as evidenced by their survey of identifiable "R&D lab managers" (Cohen & Levinthal, 1990, p. 142) and their discussion of “communication inefficiencies” between business units. But what of small and medium manufacturers? Does the notion of absorptive capacity have relevance to SMEs outside narrow, industry-segment specific technologies? If so, can external intermediaries assist SMEs to overcome absorptive capacity limitations regarding ambient technological innovations? This paper examines the potential impact of restricted absorptive capacity on the adoption of AmI technologies in two manufacturing SMEs, one Australian and the other German.

Innovation, Manufacturers, SMEs and Government Policy

One study (Philips, 1997), identifies innovative Australian manufacturers as having substantially higher sales growth compared to non-innovating firms. In addition, the impact of innovation is considered to be cumulative (Chapman, Toner, Sloan, Caddy, & Turpin, 2008) with some level of innovative behaviour or research and development being required to equip a firm to identify, assess and adopt technologies. The innovativeness and absorptive capacity of SMEs is a matter of concern for other nations besides Australia. For example, in its 2008 budget, the UK government signalled its intention to set a goal for innovative SMEs to win 30% of its £150 billion public procurement spending (Kable's Government Computing, 2008), equating to A$98 billion Australian of incentives to encourage UK SMEs to innovate. While similar incentives are yet to appear in Australia, there are clear signs of government interest in the ability of SMEs to innovate (Department of Innovation Industry Science and Research, 2008).

There is a growing body of work in the innovation literature on the limited absorptive capacity of SMEs to identify relevant innovations, understand and appreciate possible applications, and finally adapt and implement innovation in their organisations (Beckett, 2008; Liao, Welsch, & Stoica, 2003; Muscio, 2008). Many points concerning "constraining factors" and "implementation challenges" support the notion that SMEs can experience organisational absorptive capacity limitations. Beckett (2008) identifies knowledge and resource constraints that impede the ability of SMEs to develop absorptive capacity, but also provides an example of how absorptive capacity is built when the outlays of time and money required match the SME’s resources.

While the benefits of AmI technologies are already accruing in large organisations (Angeles, 2005) if manufacturing SMEs are to benefit from AmI technologies, one challenge requiring attention will be that of their limited absorptive capacity. Thus, the research question addressed by this research is "Can external intermediaries overcome absorptive capacity limitations in Australian SMEs seeking to improve business operations through technological innovation, with specific reference to AmI technologies."

METHODOLOGY

This paper describes findings from the Australian section of an international study of Ambient Intelligence Technology for Systemic Innovation in Manufacturing SMEs (AmI-4-SME). The EU AmI-4-SME project involves six SMEs, three research partners and three Information and Communications Technology (ICT) providers located in Germany, Ireland, Spain and Poland. The Australian AmI-4-SME project consists of six SMEs, two research partners (University of Melbourne and University of Western Sydney) and two ICT providers. Six SMEs were selected from those responding to a request for expressions of interest in participating in the study. Using the Australian Bureau of Statistics (2001) metrics, all are classified as medium sized manufacturers and all are privately owned.

The EU AmI-4-SME project aims to design and develop coordinated methodology, ICT "building blocks" and a software platform to support the improvement of manufacturing processes in SMEs. These improvements will be achieved by re-engineering processes and introducing appropriate ICT tools. The method used to analyse and re-engineer business processes is an extension of the COST-WORTH methodology (ATB Institute for Applied Systems Technology Bremen GmbH, 2004) and has three main phases: Analysis and Conception, Selection and Specification and Implementation. The Australian Ami-4-SME project is performing Analysis and Conception, but not Specification and Design or Implementation phases. The links between these phases are shown in Figure 1.

[Insert Figure 1 here]

The Analysis and Conception phase produces a rough implementation plan for the proposed AmI solution. Analyses of each SME's business processes and bottlenecks form the majority of this phase which concludes with presentation of a business re-engineering recommendation and a Return on Investment Analysis (Kirchhoff, Stokic, & Sundmaeker, 2006).

One challenge of working with SMEs is to gather sufficient information without intruding to the extent that the organisation is adversely affected. On-site interviews and observation, questionnaires (these were developed as a part of the precursor COSTWORTH project, see Nousala, Ifandoudas, Terziovski and Chapman, 2008), video recordings, a visit to a SME already using wireless, wearable and voice technologies in its warehouse and joint creation of process maps where they did not previously exist were used to collect data and minimise disruption to the SMEs. Interview and questionnaire data were used to select important, problematic processes for each SME. On-site observations and video recordings were analysed to create "as-is" maps of the process selected for improvement, and identify key limitations of each process. AmI technologies with potential to improve the selected business process were selected and the likely costs and benefits reviewed with the SME executive managers.

A strength and simultaneous limitation of this approach, is that the time spent at each SME site is not extended or intensive. However, given the objectives of the analysis and conception phase of the AmI-4-SME project, and the need to minimise disruption to the operation of the manufacturing businesses, the methods are appropriate.

RESULTS

This section discusses and compares findings from one Australian SME and a German SME participating in the AmI-4-SMEs project.

Analysis and Conception Results: German SME (Pseudonym: Truckbody GmbH)

Truckbody GmbH claims market leadership for EU manufacture of truck swap bodies (steel framed transport containers, and the legs on which they stand while waiting transfer from truck to truck, or truck to rail) primarily intended for the EU domestic market. A key competence is the manufacture and powder coating of large structures, up to 15m long, such as bus frames. The company employs 330 people, which places it in the EU classification of SME organisations. Truckbody's production system is characterized by strong interdependencies between different task groups; a delay in one step impacts many other groups further down the production line.

To reduce production delays the EU Ami-4-SME project research and technology partners identified a need for automatic production alerts that interfaced to the company's planning system. The ATB Institute for Applied Systems Technology, based in Bremen, Germany is the project leader of the EU AmI-4-SME project, and is currently finalising the implementation of a rule engine and user interfaces on mobile devices. When problems occur in Truckbody's production, employees who need to know about the disruption, such as the shift supervisor and the person with the skill to solve the problem, receive an automatically generated alert message. The alerts are based on user profiles (e.g. manager, foreman), the current location of the user (e.g. meeting, office, home) and the severity of the situation (e.g. deviation threshold, breakdown, loss). Use of a multi-modal user interface, (specifically a wireless message sent to a mobile phone or PDA) leverages the capability of AmI technologies to provide timely alerts that are "pushed" to relevant employees regardless of their location. In this manner, the AmI technology provides immediate and mobile access to production information, warns of delays to the production line, and so supports reallocation of work and staff. Prototypes have been developed as part of the Selection and Specification phase of the study.

Analysis and Conception Results: Australian SME (Pseudonym: Bottletop Pty Ltd)

Bottletop produces a very different product from that of Truckbody GmbH. Bottletop manufactures specialty packaging, with particular strengths in the personal care, pharmaceutical, health foods, chemical, cleaning, food, beverage and cosmetics markets. Operating for sixty years from its single Sydney manufacturing site, it has built a strong sense of loyalty among its 97 employees, and has extensive links to international fastening manufacturers.

Although plastic manufacturing accounts for around 7% of all Australian manufacturing activity, the industry is quite mature (McCaffrey, 2006), and is shrinking at around 4% per year, mainly due to increased purchases from foreign injection moulding companies. Bottletop is growing in this shrinking market, winning market share from its competitors by focussing on quality, service, technology and relationships within and outside the organisation. The company plans to more than double its revenue by 2011/12. While the revenue goal is ambitious, Bottletop's revenue grew by 12% in 2006 even after allowing for a 5% reduction in revenue from its existing customer base due to some customers moving their business to off-shore suppliers.

Discussions with Bottletop's Production Management team identified the following AmI technology scenario as an attractive business concept: Bottletop's moulding and assembly machines have in-built Programmable Logic Controllers (PLCs) which can monitor the six key variables that control the formation of the plastic closure. If a software program collects and monitors the PLC data, when any of these six parameters move outside pre-set limits an SMS alert to a mobile phone, or pager message could be automatically generated and sent to on-site maintenance personnel. This provides several potential business benefits, including minimization of machine downtime, reduction of defective, scrapped product and reduced need for visual inspection. Currently all the plastic fasteners are inspected by a human operator as they leave the machine.

Previous attempts to use computers coupled to cameras to replace human visual inspection of parts leaving the injection moulding machines were not successful due to the camera's inability to cope with reflective foil routinely used in Bottletop's products. It is important to note that the company's HR practices are likely to support the introduction of the proposed AmI solution. A bonus scheme rewarding operators for reducing the amount of defective caps produced from each machine has been enthusiastically embraced; operators have been heard to comment, "That's my money on the floor" when the speed of the machine is set too fast and fasteners overshoot the hopper.

The preceding comparison demonstrates that despite operating in unrelated industries in different countries, some SME manufacturing processes have sufficient commonality to permit the development of generic AmI solutions. Furthermore, the appearance of the same requirement in different manufacturing contexts shows that AmI technologies have the potential to be "general purpose" production enablers in diverse SME manufacturing settings. This in turn suggests the possibility that affordable "turn-key" AmI solutions may become available from technology providers. The next section considers the possibility of third party technology providers tailoring generic AmI solutions to the specific requirements of each SME, thus overcoming the absorptive capacity limitations inherent in SMEs.

DISCUSSION AND DIRECTIONS FOR FUTURE RESEARCH

In Australian manufacturing SMEs, there is a very low likelihood of in-house R&D being used to build absorptive capacity to investigate AmI technologies. SMEs prefer to buy new technology when it is already embedded in an industry specific product rather than master the details of the underlying innovation (Oyelaran-Oyeyinka & Lal, 2006). Instead, we propose that SMEs are more likely to use industry or informal networks to become aware of potentially useful innovations, and then “buy” the innovation embedded in capital equipment or consulting services as a means to ‘recognise the value of new information, assimilate it, and apply it to commercial ends’ (Cohen & Levinthal, 1990, p.128).

However, Cohen and Levinthal (1990) question the effectiveness of “buying” absorptive capacity in the form of consulting services or through acquisitions when the knowledge is to be integrated with existing business systems. They state “To integrate certain classes of complex and sophisticated technological knowledge successfully into the firm's activities, the firm requires an existing internal staff of technologists and scientists who are both competent in their fields and are familiar with the firm's idiosyncratic needs, organizational procedures, routines, complementary capabilities, and extramural relationships” (Cohen & Levinthal, 1990, p. 135).

On the other hand, advances in the development of ICT industry standards, and the proliferation of software and support for the Windows/Intel platform since Cohen and Levinthal’s 1990 paper have brought technology to SMEs without the need for bespoke development. Furthermore, Cohen and Levinthal appear to assume that investments in absorptive capacity only exist in the form of R&D spending, rather than networking with other organisations to use “connect and develop” models typical of Open Innovation (Chesbrough, Vanhaverbeke, & West, 2006). In contrast, the results from the EU and Australian AmI-4-SME projects suggest that SMEs can use "external research sub-units" in the form of experiences reported by members of their industry network and trade associations, and solutions proposed by research and technology providers, to offset internal absorptive capacity limitations.

Out-sourcing of deep absorptive capacity to equipment and software vendors able to provide “turn-key” solutions that match industry requirements seems to be a way for manufacturing SMEs to gain the commercial benefits of AmI technologies despite the resource and time constraints that prevent them building absorptive capacity in any area other than their core business competence. Similar requirements appear in two very different SMEs on two continents. The potential for the same AmI technology solution components to address these requirements, albeit tailored to the specifics of equipment in use at each site, suggests that SMEs can benefit from AmI technologies by using specialised intermediary organisations to provide the “absorptive capacity” on their behalf. This finding points to potential links between absorptive capacity and “make vs. buy” decision-making, and to “broad” or “deep” versions of absorptive capacity (Henard & McFadyen, 2006) as avenues for future research. In addition, an opportunity exists to track the spread of AmI technologies in SME Australian manufacturers and in doing so contribute to the diffusion of innovation literature.

Additionally, AmI implementation challenges for Australian SME manufacturers extend beyond the boundaries of their own organisations. Large ICT manufacturers use a channels marketing approach to sell their products to the SME market segment. The channels may include retail and direct sales forces, but frequently hardware is “bundled” with service and software offerings from business partners, specialising in a particular industry segment, such as manufacturing. While intermediary business partners may supply specialised knowledge and generic AmI solutions to compensate for limited SME absorptive capacity, the organisations that partner with large ICT providers are often SMEs themselves. The ability and willingness of these business partners to gain AmI skills may in turn be a limiting factor in the adoption of AmI technologies by Australian Manufacturing SMEs. Absorptive capacity limitations of SME organisations can potentially affect uptake of AmI technologies at two points: within the manufacturing SME and within the SME technology partner. Low levels of in-house AmI skills and heavy level reliance on SME Australian technology providers suggest there may be an argument for the provision of government subsidies to encourage the adoption of AmI technologies in

Australian manufacturing. A precedent exists in that subsidies have been provided for the purchase of RFID scanners for NSW meat producers (NSW Farmers Association, 2007). Without some form of government encouragement, the task of integrating AmI systems with existing ICT investments and the concomitant diversion from core manufacturing activities, may be enough to prevent the adoption of AmI technologies and, therefore, achievement of the elusive "productivity surge" in Australian manufacturing SMEs.

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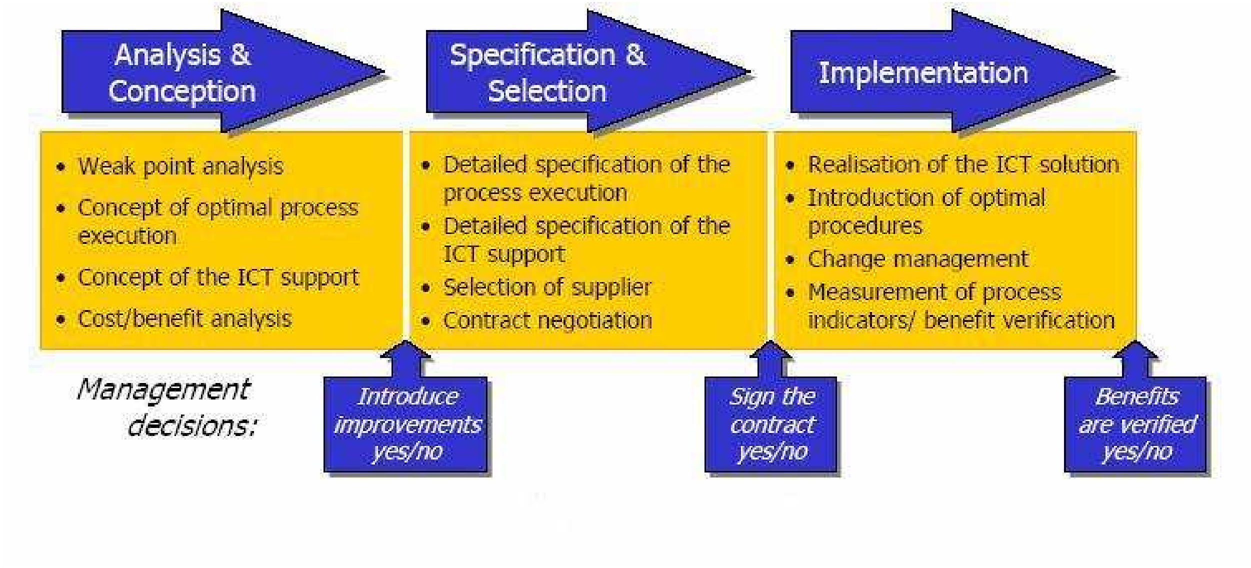
Figure 1: Representation of the Three Phase AmI-4-SME Methodology



Source: (Kirchhoff et al., 2006)