INNOVATION IN THE 21ST CENTURY SME MANUFACTURING ENVIRONMENT

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ABSTRACT

The environment in which we inhabit is shaped by technology and how as users we use it. This can be seen in the manufacturing SME environment. Manufacturing SMEs are dynamic and flexible but as the business environment is changing at a greater rate than ever before they have to adapt to changes more quickly and efficiently. The ability to adapt to change needs to be reflected in the organisations information management system. The information flows have to be dynamic and flexible to allow for change to occur more efficiently in the organisation not only at management level but throughout the organisation, for the shop floor operator to the managing director. Ambient intelligence (AmI) can assist in the development of more dynamic information flows in the organisation. AmI is a user centred technology concept. In involves including the user, process and environment in the system in a more dynamic way by integrating the various elements to interact together to create an environment that caters to need and requirements of user technologically. This can be achieved by developing an AmI system that can adapt to the different needs and requirements of the users of the system for information related to there specific requirements at any given time. The paper examines the concept of AmI within manufacturing SME. An AmI SME process typology is presented and applied to the manufacturing case study. The solution and implementation are examined through the typology. The business benefits of the system are highlighted.

KEYWORDS: manufacturing, ambient intelligence, AmI, information flow

1. INTRODUCTION

Manufacturing is the foundation on which Ireland's economic development has been based. It has a high multiplier effect in the economy and generates both employment and wealth [1]. However, in recent years there has been a steady decline in traditional manufacturing. In Ireland this is due to the rising cost base, the growth in inflation and higher wage demands. Manufacturing in Ireland needs to innovate to overcome these limitations. Particularly manufacturing SMEs, as they are most susceptible to changes in the business environment, due to their size and customer base [2]. One way to accomplish this is to have an information system that can adapt to change efficiently and effectively to offer high value added customised products and services. To do this manufacturing should focus on information flow and develop processes that are more flexible and dynamic. This will allow them to adapt to changes in customer requirements [3].

There are many solutions to the management of information flow. However many of these are limited by the fact that they are pre-programmed at the development stage, with inflexible and specific application capabilities. Ambient intelligence (AmI) can be utilised to achieve flexibility and adaptability in these systems [4]. AmI embeds user friendly devices such as radio frequency identification (RFID) tags into surrounding devices, to enable the automatic collection and analysis of information, on the movement and location of components, subassemblies and finished products, as well as the utilisation and down time of machinery [5]. Existing systems can be adapted to process the information and to prompt different occurrence, such as maintenance checks on machinery or scheduling changes on the shop floor. This will allow for

better visibility of production and customer demand, through improved lead times and utilisation of resources. This allows SMEs to adapt quickly to changes in customer requirements in relation to the delivery of customised products and services [3].

This paper explores the concept of AmI and the current problems with information flow, and from this an AmI typology is proposed for the manufacturing SMEs sector. The typology is analysed within a case study. The case study analyses the information flows and from this identifies the problems in the organisation. The AmI design solution for the case study is then examined through the implementation and benefits of the solution.

2. INFORMATION MANAGEMENT AND AMI

This paper explores the current problems with information flow and the concept of AmI in alleviating some of these problems. From this an AmI typology is proposed for the manufacturing SMEs sector.

If information is managed properly within an organisation it has the potential to develop into a profitable resource [6]. Orna [6] highlights three core areas with regard to information within an organisation. These include the management of information resources, how these resources are used, and how the resources benefit the objectives of the organisation. The majority of information systems on the market are pre-programmed at the development stage. This creates an end product that is inflexible and capable of specific application. For an information system to be of greatest use it needs to have the ability to be[6]:

- Intuitive and adaptive to the changes in the work environment,
- Sensitive and responsive to changes as that occur for example on the shop floor,
- Omnipresent by having information gathered in real-time for the user, process and environment,
- People centred in the information that it provides to the users for decision support and assistance.

Introducing an AmI element to the existing information systems can allow the system to have the ability to adapt to changes in users needs and requirements. The information required by the system, to enable it to adapt to changes, is gathered through embedded user friendly devices like RFID tags and speech recognition software (SRS) in the surrounding environment [5]. This provides for automatic collection and analysis of information in real-time e.g. location of components, utilisation of machinery and raw materials.

2.1 Ambient Intelligence

The concept of ambient intelligence (AmI) developed from advancements in three technology areas, ubiquitous computing, ubiquitous communication and intelligent user friendly interfaces. Ubiquitous computing involves the embedding of technology devices into everyday objects within the users environment [7-10]. Ubiquitous communication allows these embedded technology devices to communicate with each other [7, 11]. Intelligent user friendly interface provides the user with ease of interaction and access to the embedded technologies in the environment [5, 7, 11].

In the AmI environment technology moves into the background through the use of embedded radio frequency identification (RFID) tags and speech recognition system (SRS) which results in a more natural interaction between the user and the technology that surrounds them. The use of speech and gestures to communicate with technology creates a more dynamic and flexible surroundings in manufacturing, particularly on the shop floor. Therefore AmI is an adaptive and flexible technology that caters to the needs and wants of the user by modifying its responses inline with the changing manufacturing environment.

Ambient intelligence is defined by numerous authors [12-14] but the most comprehensive definition is provided by ISTAG in their report 'Scenarios for Ambient Intelligence in 2010' which defines ambient intelligence as being a "seamless environment of computing, advanced network technology and specific interfaces"[5]. The envisioned interaction with the user is outlined as the environment is, "aware of the specific characteristics of human presence and personalities, taking care of needs and is capable of responding intelligently to spoken or gestured indications of desire, and even can engage in intelligent dialogue". ISTAG articulates an environment in which technology will be, "unobtrusive, often invisible; everywhere and yet in our consciousness – nowhere unless we need it". The interactions with the users "should be relaxing and enjoyable for the citizen, and not involve a steep learning curve" [5].

2.2 AmI SME Process Typology

Ambient intelligence is a user centred concept, in that all the technologies in the environment are built around the user, this is demonstrated in the figure 1 below. The AmI SME process typology is presented here to assist developers of an AmI system in developing a system that adheres to the concept of AmI. Ambient can be described as the environment that surrounds the user, where the physical environment becomes the users interface with technology. Intelligence is the ability to adapt to different situations and to be capable of taking advantage of them. The technologies cater to the needs, habits, gestures, emotions and the context awareness of the users interactions with the environment, by tailoring its responses to the user. The responses are provided due to the technologies embedded in the environment being people centred and having the ability to be intuitive and adapt to changes in the environment. The environment is sensitive and responsive to the changes in the user. The environment has the ability to adapt to these changes due to its omnipresent nature. AmI is a system composed of technologies that have the ability to adapt and learn in the physical environment that encircles the user.
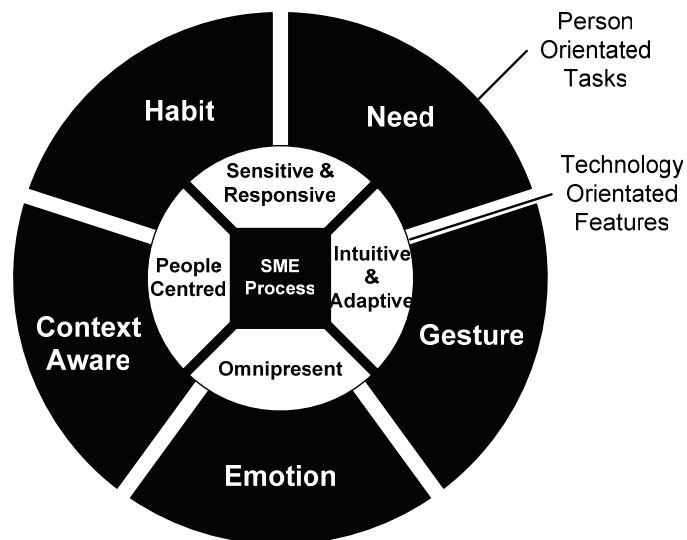

Figure 1 AmI SME process typology adapted from Gill and Comican [15]

The AmI SME process typology is used to adapt existing systems to process information and prompt different occurrences e.g. maintenance checks. The typology highlights the areas that need to be considered during the development process from a holistic viewpoint for the user, process and environment.

The person orientated tasks in relation to the solution are examined below:

- Needs – The users of the system differ and their requirements for the system are different. For example the manager in the system needs to be informed of any issues on the shop floor i.e. any tasks that require his attention. The shop floor operator needs to be informed of the tasks that need to be performed during the shift.
- Habits – The users interact with system in different ways. Manager may use SRS to input data or query the system.
- Context awareness – The type of information required by each user differs. This can be the information required by the shop floor operator to complete his task.
- Gestures – Information on the movement of subassemblies around the shop floor can be gathered to update the schedule to the readiness of the product for shipping to the customer.

Emotions are not applicable in this case at present and are not included in the solution.

Technology orientated features are explained below in relation to their interaction with the user of the system:

- Omnipresent – Through the use of RFID tags the system can keep track of the how the manufacturing process is progressing in real-time and modify the schedule to accommodate any delays that arise.
- People centred – The technology surrounds the users and adapts to meet each users specific requirements
- Sensitive and responsive – The system has the ability to inform relevant personnel of change and issues as they arise. For example if a machine breaks down on the shop floor the system can inform the technician and scheduler of the incident and assist in taking relevant action.
- Intuitive and adaptive – The system can change seamlessly to different situations as they arise on the shop floor. For example a delay in production may arise in the schedule being updated to allow for the delay to be managed to ensure that the final product is delivered to the customer on schedule.

These technology oriented features represent the AmI characteristics that the technology must have to interact with the user. The typology is examined with in a case study and the implementation of the typology is used to validate it in the manufacturing setting.

3.   RESEARCH METHODOLOGY.

A qualitative research approach is taken to validate the findings of this research in this case as the topic being investigated could not be explored experimentally as it is a new area of research and is not very well documented in literature. To necessitate this more emphasis was paid to the deductive approach rather than to the analysis of data. Case study research, as Yin [16] describes, is used when the "focus is on a contemporary phenomenon within some real-life context". In the research that is presented in this paper there will be a focus on an exploratory case study that develops the "how and why" factor. With regard to how and why AmI systems can be of use in manufacturing to improve information flow [17, 18]. Therefore a case study approach was chosen due to the research question and the type of research that was conducted and the need for validating the findings in a structured scientific manner. The case study examines the AmI requirements analysis in its natural setting. It involves a single case study which will involve the development of an exploratory case study. The motivation for the choice of an exploratory case study is that AmI is a new area of research. The application of this new concept is still in its infancy and is not well documented at present [17, 18].

4. CASE STUDY

The case study analyses the information flows and from this identifies the problems in the organisation. The AmI design solution for the case study is then examined through the implementation and benefits of the solution.

The organisation, which is examined in this study, is an Irish company. Company A manufactures customised fabricated emergency vehicles for the Irish domestic market. The case study will be viewed in relation to assisting the information flows in the dynamic reconfiguration of distributed assembly and manufacturing processes for shop floor control. The competitive advantage of the company over its counterparts is its ability to adapt to customer requirements at any time during the design and production process.
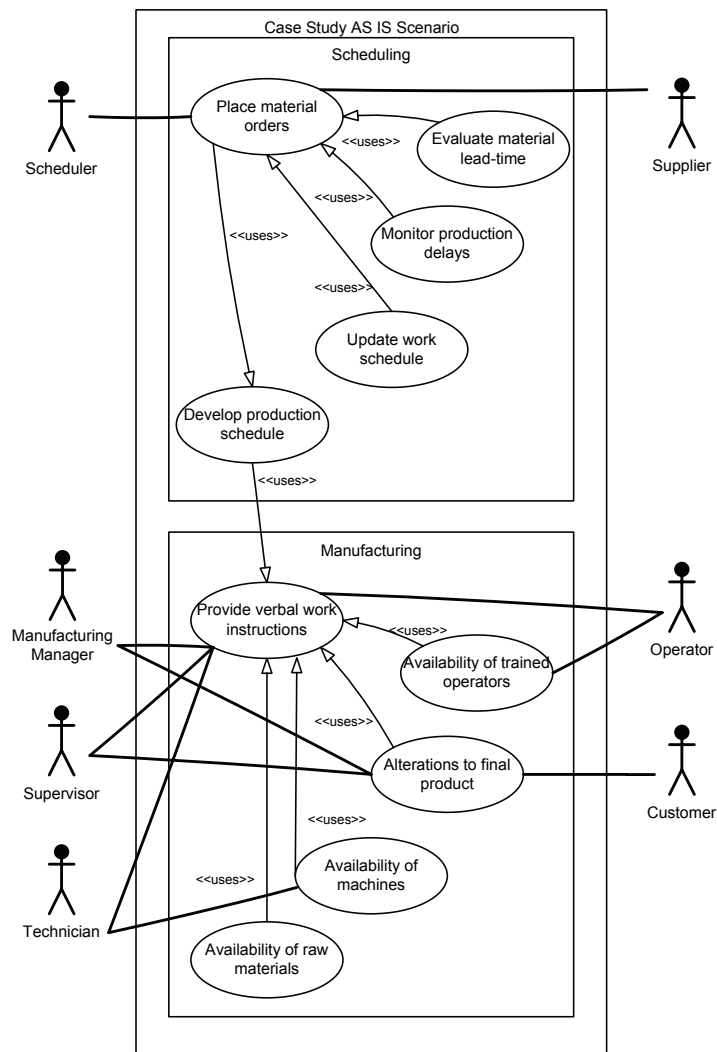
Figure 2 SME Information flow

This case study examines the scheduling and manufacturing processes in Company A, see figure 2. The company used a database system to manage all information with regard to parts, work orders, scheduling and use of resources. The system was not kept current due the complexity of the system as it had grown exponentials since its inception to deal with changing information requirements in the company. The newer employees that needed to directly interact with the system were not adequately trained in using the traditional system. All information was

sent in one direction and feedback was not provided. This led to problems in scheduling and production, which led to lack of productivity and competitiveness due to

- Material shortages due to poor traceability
- Increased lead-time due to schedule redundancy
- Production progress unknown
- Poor traceability of individual worker

The above problems resulted in product lead times becoming greater than their competitors. The optimum lead time to make a product is six weeks. Due to the delays it took an average of nine weeks to complete a product.

There were three options available to Company A to deal with these problems. They included:

1. Buy an off the shelf information management system
2. Design a new in house AmI system that caters to their specific requirement and can be adapted to deal with future changes.
3. Use the off the shelf system to manage the resource planning and scheduling, and create an in house AmI system that, is interoperable, can interact with the information management system and make it more adaptive and flexible to the needs of the SME.

In this case study the third option was chosen as it would help to maintain Company A's competitive advantage of being able to adapt to customer requirements at any time during the design and production processes. The solution and implementation are discussed in the subsection below.

4.1 Solution and Implementation

The solution was developed in relation to the users, process and technology, and applied to two areas, scheduling and materials management. There are a number of users (managers. supervisors, technicians, shop floor operators), process (cutting, folding, welding, assembly, etc.) and environmental requirements that need to be gathered and analysed as part of the case. The case study involves a dynamic and flexible manufacturing process that is adapted to the specific requirements of the customer. Within the new system all users, subassemblies and machines have been tagged with passive RFID tags. RFID readers have been mounted at workstations. The RFID readers send the collected information back to the AmI system.

1. The new process begins by the AmI system having all the scheduling and work instructions finalised with the scheduler. This means that the AmI system is ready to execute the work orders on the shop floor and has ensured that all materials for completing the orders will be available for production as they are required.
2. When the operator arrives in the morning or after completing a work task goes to the LCD monitor to interact with the AmI system. The AmI system recognises the operator from his/her RFID tag and can provide the operator with a new work assignment in relation to their skills level competence in that specific area, log a problem, or adapt the work assignment instructions to the operators specific skill requirements
3. If the AmI system detects a problem or is notified of one it will inform all relevant personnel. For example a technician can be notified of a machine malfunction or rejects being generated by a specific machine.
4. All the manager and supervisors are contactable and can view and update shop floor operations in real-time, due to the integration of personal digital assistant (PDA) with speech recognition software (SRS) into the AmI system network. This allows them to track problems and solution on the shop floor as they happen.

5. Materials usage and availability can also be tracked in real-time. To ensure that there is adequate availability of materials for production on the shop floor so that production is not delayed due to lack of raw materials.

The benefits of the AmI system are discussed in the following section.

4.2 Benefits

The business benefits are discussed in relation to the problems outlined in the case study with the results of the implementation of the AmI system in the case study. The problems examined lie in the areas of production scheduling and manufacturing in a constantly changing environment. The environment is one in which customer requirements can change at any time during the production process. Therefore the scheduling and manufacturing departments need to be able to adapt to these changes seamlessly to prevent delays in delivery of final products to customers. These problems can be solved by developing an information management system that is intelligence and can adapt to the changes as they occur on the shop floor. The problems related to material shortages due to poor traceability, increased lead-time due to schedule redundancy, production progress unknown and poor traceability of individual worker.

The benefits to the system lie in areas of scheduling and manufacturing. In the area of scheduling this includes:

- Reduced downtime with improved time and resource management,
- System collects real-time information from the shop floor and uses it to update the existing schedule,
- Providing decision support to the scheduler,
- Tracking any and all problems that occur on the shop floor and updating the schedule to reflect them.

In the area of manufacturing the benefits to the system and users included:

- Providing real-time update of production progress information to operators, supervisors and managers,
- Providing the information required by shop floor personnel to complete their assigned tasks.

AmI is an inspiring concept and when it is fully realised will help to change the way that we live and work.

5. CONCLUSIONS

Manufacturing SMEs are dynamic and flexible but as the business environment is changing at a greater rate than ever before they have to adapt to changes more quickly and efficiently. The ability to adapt to change needs to be reflected in the organisations information management system. The information flows needs to be dynamic and flexible to allow for changes to occur more efficiently in the organisation not only at management level but throughout the organisation, for the shop floor operator to the managing director. AmI can assist in the development of more dynamic information flows within the organisation. This can be achieved by developing an AmI system that can adapt to the different needs and requirements of the users of the system for information related to there specific requirements at any given time. The paper examined the concept of AmI within the information flows of a manufacturing SME. An AmI SME process typology is developed from literature and applied in an SME manufacturing company. The solution and implementation are examined through the typology. The business benefits of the system are highlighted.

References

[1] MANUFUTURE, A vision for 2020: Assuring the future of manufacturing in Europe, (2004).

[2] D. J. Storey, Understanding the Small Business Sector. London: Routledge, (1995).

[3] D. K. Koska and J. D. Romano, Profile 21 Issues and Implications, Countdown to the Future: The Manufacturing Engineer in the 21st Century, Society of Manufacturing Engineers, Dearborn, Michigan, US (1988).

[4] ISTAG, Recommendations of the IST Advisory Group for Workprogramme 2001 and beyond "implementing the vision", ISTAG (2000).

[5] K. Ducatel, M. Bogdanowicz, F. Scapolo, J. Leijten, and J.-C. Burgelman, Scenarios for Ambient Intelligence in 2010 (ISTAG 2001 Final Report), ISTAG, IPTS, Seville (2001).

[6] E. Orna, Practical information policies: How to manage information flow in organizations: Gower Publishing Company Limited, (1990).

[7] M. Alcaniz, New Technologies for Ambient Intelligence, in Ambient Intelligence: the evolution of technology, communication and cognition towards the future of human-computer interaction, G. Riva, F. Vatalaro, F. Davide, and M. Alcaniz, Eds.: IOS Press, (2005).

[8] C. Sørensen and D. Gibson, Ubiquitous visions and opaque realities: professionals talking about mobile technologies Info, Vol. 6, (2004), 188-196.

[9] M. Weiser, Ubiquitous computing, in IEEE Computer, Ronald D. Williams ed: IEEE, (1993), 71-72.

[10] M. Weiser, How computers will be used differently in the next twenty years, in Symposium on Security and Privacy Oakland, CA, USA, 1999, 234-235.

[11] M. Friedewald and O. Da Costa, Science and Technology Roadmapping: Ambient intelligence in Everyday Life (AmI@Life), JRC-IPTS/ESTO, Seville, Spain (2003).

[12] J. Horvath, Making friends with Big Brother?, in Telepolis http://www.heise.de/tp/r4/artikel/12/12112/1.html, (2002).

[13] ITEA, The Ambience Project (2003).

[14] M. Lindwer, D. Marculescu, T. Basten, R. Zimmermann, R. Marculescu, S. Jung, and E. Cantatore, Ambient Intelligence Vision and Achievement: Linking Abstract Ideas to Real-World Concepts, in Design, Automation and Test in Europe Conference and Exhibition, 2003, 10-15.

[15] S. K. Gill and K. Cormican, Ambience Intelligence (AmI) Systems Development, in Information Technology Entrepreneurship and Innovation, F. Zhao, Ed.: Idea Group, (2008), 1-22.

[16] R. K. Yin, Case Study Research: Design and Methods, Second ed. Vol. 5. Thousand Oaks: Sage Publications, (1994).

[17] I. Benbasat, D. K. Goldstein, and M. Mead, The Case Research Strategy in Studies of Information Systems MIS Quarterly, Vol. 11, (1987), 369-386.

[18] P. Darke, G. Shanks, and M. Broadbent, Successfully completing case study research: combining rigour, relevance and pragmatism, Information Systems Journal, Vol. 8, (1998), 273-289.