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Implementation of an ambient intelligence (AmI) system in a manufacturing SME

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Abstract: SME's are facing greater challenges due to increased labour cost and reduced cycle times. To adapt to these challenges they need systems in place that will enable them to be flexible, effective and efficient. This is the case in the customised product and service manufacturing SME sector. Ambient intelligence (AmI) has the ability to help SME to become more flexible to change and build on their already dynamic nature. The ability of the AmI system to adapt and learn in different situations is the key to maintaining the competitiveness in an organisation. This paper seeks to demonstrate the development and implementation of an AmI system in the manufacturing SME environment. It presents an AmI system in industry reference model that highlights the implicit and explicit interaction between the user, process and environment in an AmI system. The reference model is applied to a case study and the benefits arising from implementation are highlighted and discussed.

Keywords: manufacturing, ambient intelligence, knowledge management, SME,

1. Introduction

Manufacturing is an important part of economic development in Europe. It has a multiplier effect on the economy which has an impact along the value chain [1]. Over recent year it has been in a state of flux due to factors such as reduced cycle times and increased labour costs. Small to medium size manufacturing outlets are especially facing these pressures. Small to medium enterprises (SME) need the ability to adapt to the rapidly changing business environment and to compete in the market place efficiently and effectively [2]. They also need to be more flexible and dynamic in adapting to change in demand from customers [3]. Enhanced flexibility while at the same time promoting efficiently and effectiveness of processes requires knowledge from the surrounding environment to become readily available to the decision maker. The new system should have the ability of controlling the environment or ambience. Ambient intelligence is such a solution.

Ambient intelligence (AmI) is a means of integrating electronic technology such as radio frequency identification (RFID) tags with information technology, multimodal services and semantic web, creating the ability to adapt and learn in the physical environment that encircles the user [4]. AmI can be utilised to achieve flexibility and adaptability in these systems through enhanced human computer interactions [5]. The ambient environment is achieved by embedding user friendly devices such as RFID tags into surrounding environment. This can be achieved in the example of the manufacturing shop floor by placing RFID tags at workstations, subassemblies and components. This will 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 [4]. 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]. AmI is a new and evolving concept which at present has few working applications. The proliferation of ambient situations and the approach for identifying and developing such solutions to ensure accurate and effective results currently does not exist.

The aim of the paper is to demonstrate the development and implementation of an AmI system in the manufacturing SME environment. This is shown by presenting a case example. This case is a manufacturing SME in the west of Ireland that manufactures and fabricates customised emergency vehicles for the domestic market. Their main problems lie in the area of shop floor control in relation to scheduling and materials management. Therefore the paper examines the analysis and development of an AmI system in the areas of scheduling and materials management within a SME case study. To accomplish this, an outline of the concept of ambient intelligence is provided. The review of the concept leads to the development of an AmI in industry reference model. The reference model examines the user in the AmI system with regard to their implicit and explicit interaction with the process and environment. The model outlines the generic requirements of the system in the manufacturing environment. The reference model is discussed further in the paper. The technologies used in developing the AmI system within the case study are examined. A manufacturing SME case study is analysed through the application of the reference model. Problems specific to the SME are identified and overcome using the AmI reference model. The implications of the system developed using the reference model is discussed with regard to the benefits and the issues of implementations.

2. Ambient Intelligence

Ambient intelligence is a user centred concept. It places the human decision maker at the centre of a technology embedded environment. Hence optimising the role and impact of the decision maker is a key objective of such technologies. AmI can provide greater product efficiency by providing improved visibility to the user, process and environment in manufacturing. This visibility can be utilised to make more informed decisions by all users of the AmI system and in turn improve the time frame in which decisions are made. It can also provide the decision maker with the relevant information that they need to make an informed decision. Through accomplishing this it will empower the human worker to make more effective and efficient decisions. Therefore all aspects of manufacturing such as shop floor production processes will be built around them. The following subsections review what ambient intelligence is and some of the technologies that can be used to achieve an AmI system. The third subsection presents the AmI in industry reference model.

2.1 What is ambient intelligence

The concept of ambient intelligence 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 user's environment [11-14]. Ubiquitous communication allows these embedded technology devices to communicate with each other [11, 15]. Intelligent user friendly interface provides the user with ease of interaction and access to the embedded technologies in the environment [4, 11, 15]. Gill and Cormican [7] define ambient intelligence "as a people centred technology that is intuitive to the needs and requirements of the human actor. They are non-intrusive systems that are adaptive and responsive to the needs and wants of different individuals." Technology in the AmI environment moves to the background by becoming embedded in everyday objects like cloths and furniture [8-10]. The AmI system works on the principles of evaluated inputs and outputs from the user, process and environment in which the user inhabits.

In essence the move is away from one computer one user to an environment where many computers interact seamlessly with one user [6]. Technology moves into the background in the AmI environment. This can be achieved through the use of radio frequency identification (RFID) tags and speech recognition system (SRS). The use of these technologies provides the user with the ability to interact with technology in a more natural way. 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 shop floor environment.

Different technologies are used in combination to achieve the AmI system. The technologies vary depending the level and type of interaction needed by the user. Three of these enabling technologies are examined below. They included the semantic web, RFID tags and multi-modal services.

2.2 – Enabling technologies

For the AmI system to be achieved requires the advancement of traditional information communication technology (ICT). As such AmI is an advancement of ICT. The technology requirements for achieving an AmI system are “very unobtrusive hardware, seamless mobile or fixed web-based communication infrastructure, dynamic and massively distributed device networks, a natural feeling human interface” and “dependability and security” [4]. In achieving these requirements there needs to be an amalgamation of a number of fundamental developments in the area of ICT which will assist in the development of AmI in the manufacturing sector [4, 5]. These developments are needed to achieve a user centred system that is based on having an omnipresent system that adapts to the users needs and requirements. Three of the technologies that can be used in the developing an AmI system are outlined below. These include semantic web, radio frequency identification and multimodal services.

- The semantic web is the next generation in the development of the web. It is designed to provide meaning to web content. By accomplishing this it allows for more intelligent searches of web content, as well as improved interaction between human and computer. In the manufacturing environment this may lead to an intelligent search of the information stored in the database by the technical staff to assist them on repairing machines on the shop floor in the most efficient manner based on previous repairs and similar machine failures. [16-18]
- Radio frequency identification (RFID) tags are considered to be the next generation of bar-coding. It can be used to track shipments around the world as well as products on the production line. Information related to products can be stored on the tag. This information can be read at different distances depending on the tag. There

are two main types of tags, active and passive. Active tags as their name implies are continuously sending information to the reader. They also are more expensive then passive tags which only respond when read. [19, 20]

- Multi-modal services provide the ability to access and interact with data on a computer through the use of multiple interfaces e.g. both text and speech. This can be accomplished through the use of a keyboard and mouse entry system as well as the speech recognition system (SRS) inputs and outputs. This interaction can also be accomplished through the use of multiple input and output devices e.g. mobile telephone, personal digital assistant (PDA) or computer. In the case of a technician repairing a machine on the shop floor they can access the previous repair history of the machine on their PDA and can through the use of SRS input and also receives information with regard to repairing the machine. [15, 21]

No single technology incorporates the characteristics of the AmI environment. Only when combined seamlessly with other enabling technologies is the concept realised. In developing an AmI system the AmI in industry reference model is outlined below.

2.3 – Modelling AmI

The model attempts to present a structured approach to understanding AmI in the manufacturing setting. The AmI in industry reference model (see Figure 1) was developed based on the findings of the AmI-4-SME project in conjunction with project partners. The models incorporate the user, process and environment within the manufacturing setting. In the case of manufacturing this may involve the tracking of a part for example, from when it is delivered to the company, through incoming inspection, assignment to a work order, assembled as part of a subassembly to the finished product. The location of the part is tracked through the process; the human operators and machinery that the part interacts with are tracked and recorded. The product if found faulty can be tracked back to where the error occurred. The manufacturing process can be modified to reduce the likelihood of an error occurring and the machinery can be monitored more carefully to ensure that it is within expectable parameters. Training can also be tailored to the needs of the human operator to assist in manufacturing process on the shop floor.

The model identifies the information inputs and outputs of the system; it incorporates the user, process and environment within the information and data retrieval, processing and output. This provides for implicit interaction between the human operator and the AmI system. This is accomplished through a network of devices that are embedded into the background and can collect information implicitly. The acquisition of information from the shop floor is processed to incorporate context. To communicate the gathered information requires the need for high intelligence in the system. The system needs to provide information in context for it to be of use, to the users of the AmI system. Therefore the AmI system acts as both an observer and controller as the information is provided to it through the network of embedded devices and it has the ability to process the information and take action. Figure 1 is examined in more detail under the following areas:

1. Ambience environment
    - Ambient environments inputs to the AmI system include information on basic environmental conditions like temperature, humidity and vibration. This information can be gathered by wireless networks of basic ambient sensor like temperature, humidity and vibration sensors.

This may include information on hazardous changes in the environment that are critical for the human operators. In the shop floor environment this may relate to the detection of health and safety issues, for example the detection of a chemical spill that will prove hazardous to the human operators in the area.

- AmI system outputs make changes to environmental conditions that are based on preferences and profiles of the human operators, like the levels of temperature, humidity and light on the shop floor. This is accomplished by the AmI system having control over environmental conditions like air conditioning, heating systems and light. In the shop floor environment this may result in the AmI system modifying the ambient environment to suit the conditions in which the human operator is most productive. Some people may work best at 20^0C while other may work best at 15^0C.

2. Ambience process

- Ambience process inputs to the AmI system provide information assessment of the status of process, plant, machines, products and materials. This can be enabled through the use of wireless networks of basic ambient sensors. Information on location and movement of a device, products and materials can be gathered through the used of RFID tags. The information that is gathered through the use of this sensory network can be used to provide real-time information to the manager and supervisors on the shop floor.

- AmI system outputs to the ambience process involve control inputs to process plant and machines for task execution. The reconfiguration of production systems can be outputted and changes to the schedule and production plans can be provided. The information can be used to assist in scheduling of tasks on the shop floor to allow for better utilisation of resources and improved efficiency.

3. AmI system: Observer and controller part

    - The AmI system may act as an observer. This allows for the gathering of information and the development of knowledge on the human operator, process and environment. The observations can develop into intelligence regarding the production and planning system of the shop floor. This can be accomplished through the use of a sensory network that monitors the users, process and environment on the shop floor and stores this information semantically by providing meaning to the information that is stored. This is done so that when the information is needed it can be used to provide intelligence for the AmI system regarding the shop floor. This can be viewed on the shop floor by providing tailored information related to the needs of the user in relation the process and environment.
    - The AmI system may operate as a controller. This may be control over a process or the environment. This may manifest as control over certain business processes, for example the AmI system may be a new AmI based process control system. This control may also develop into ambience, for example a system for controlling the environment in

which the human operator is occupying. The control may also provide information regarding, control of actions to obtain requested information.

4. Human operator inputs and outputs
    - Interaction between the human operators (shop floor worker, manager, supervisor and technician) and the AmI system are made implicitly through the use of multimodality which may include mobile or embedded computers in the AmI environment. Based on this implicit interaction the AmI system may take action with regard to the process and environment without informing the human operator in areas related to reliability and safety. In the shop floor setting this may include the AmI system adapting automatically to the specific needs and requirements of the human operators once they are detected by the system. This can include the case of the shop floor worker where the AmI system can provide information related to the task they are about to undertake that is tailored to their skills level and skill set.

In the case of a machine losing calibration and slowing down production the AmI system can notify a technician of the problem immediately so that there will be less of an impact on the production schedule. The AmI system can also assist the scheduler by providing them with real-time information from the shop floor so that production can be adapted to take account of the machine that requires calibration and testing.

3. Methodology

In developing a research methodology that reflects the research to be conducted one must consider answering two critical questions put forward by Grayling [23]“What is knowledge?” and “ What are the best and most secure way of acquiring knowledge?”. Therefore the question is how to demonstrate that the research that was conducted and is presented in this paper is knowledge and that it was gathered in the most suitable manner for collation and presentation. Due to the exploratory nature of the topic of the research chosen, for discussion and development it is important to choose a methodology that reflects the unique combination of human and technology.

The research strategy is to test the theories that are presented in this paper. The approach taken is one of an exploratory nature and given the research topics presented as well as the required outcome a naturalism method is undertaken [24]. 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. The researchers believed that the investigation being undertaken would lead to the building of theory as this was the aim of the research. To necessitate this more emphasis was paid to the naturalist approach rather than to the analysis of data and this includes a case study. Within this qualitative philosophy the case study approach is chosen from grounding theory, ethnographic, phenomenological research and narrative research. The 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. A single case study approach is undertaken.

The case study approach was chosen as it assumes that the human is the variable in the situation and is in a state of flux and in AmI the user is placed at the centre of the system [4, 24]. A case study was used in this case as there was little understanding of the AmI concept except through definitions. The case study examines the AmI requirements analysis in its natural setting. It involves a single case study. The researcher is required to investigate the whole system and look for similarities and find explanations [25]. 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 [26, 27]. The research case study that has been undertaken is primarily concerned with the meticulous and impartial presentation of the empirical data that has been gathered. A number of different methods have been used to collect the data. These include observation, interviews and surveys. The majority of the data collection took place during a two week period when the researcher was stationed at the company. Any remaining queries and information were gathered during follow up visits.

The case study is based on a shop floor manufacturing environment. There are a number of users (managers. supervisors, technicians, and 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. As part of the case study, the requirements of the company were gathered, and an analysis of the current situation was conducted. The weak points from the analysis were categorised and further analysed. This resulted in the identification of the problems effecting the organisation. The problems that would be covered in the solution were then selected. The solution was developed using the AmI in industry reference model and implemented in the case study. The reference model was validated through the case study and the findings were analysed with regard to the benefits and drawbacks of the solution. [24, 26, 27]

4. Business Case Description

The approach outlined in the previous section is validated in the implementation of a case study. Company A is a SME located in the West of Ireland and employs twenty-eight people. They currently are in the business of manufacturing and fabricating customised emergency vehicles for the Irish domestic market. The company not only produces emergency vehicles but also services them as well. The main competitive advantage of the company lies in their flexibility to adapt to customer requirements at any time during the design and production process.

The overall processes in company A consists of four key phases, see Figure 2. It begins with a tendering phase. This involves local authorities submitting technical specifications documents for the manufacturing of a fire engine. This is an iterative process and may repeat itself many times until a final specification is agreed upon. Once a contract is agreed, it enters the planning phase. The planning phase deals with the ordering and forecasting of the shop floor activities and tasks, and material management. A production plan is prepared and sent to the shop floor or production execution phase where it is implemented and the product is made according to the tendering specifications. The production schedule consists of assembly tasks and material specifications. The production execution phase is completed with testing and shipping. The final phase is service of the product in the field of operation. Any feedback which is provided is inputted back into the tendering phase for new contracts.

With constant variations in customer demands and the high level of customisation within company A for customer requirements and their involvement throughout the entire life span of the product, one of the central processes in the production execution phase is a reconfigurable manufacturing assembly system. The reconfiguration process is stimulated by customer orders which come as a result of the tendering phase. On receipt of orders the production plan is drawn up in the planning phase. The planner considers all the factors such as cost and availability of raw material, deadlines and skill level of the employees to draw up the initial production plan that includes task lists and materials requirements. This production plan then drives the entire production process on the shop floor. Materials are ordered according to the plan and the current stock levels. The current materials management system operates on a Kanban system on the shop floor and the reorder levels for components are ordered according to the Kanban level. However, for larger materials this operates directly off the production plan so as to reduce the holding cost of the stock in the case of the chassis. Once the materials are received into stores, the customer orders are sent into production. The shop floor has a cellular and fixed layout and hosts a number of functions from the fabrication of parts to the assembly of the final product. Once the product is initially complete a number of tests are conducted with inputs from the customer which may result in further changes or modifications and reconfiguration of the manufacturing assembly process. After initial testing is completed any rework is rescheduled and the final truck is tested and delivered to the customer.

As the activity on the production floor is being executed material records are regularly updated as appropriate and material and Kanban reorders take place. Materials and customers orders are recorded on the legacy systems. The information on this database can support the production planning, materials management and execution on the shop floor providing all the information is kept up to date.

In order to successfully compete in the market place the key objectives of the overall manufacturing process is to make products efficiently. Due to various stoppages and other inefficiencies it takes on average fourteen weeks to complete one fire engine. The optimal time frame would be to reduce this to eight weeks. This is primarily due to stoppages at workstations due to the lack of availability of supervisors to instruct the shop floor personnel on what tasks to do next and also due to the unavailability of materials. This also has the added complexity of billing the labour costs accurately to the individual product costs as it becomes difficult to assess the level of activity for each product on the shop floor. Furthermore many savings could be made by reducing the holding cost of the stock if the lead time is reduced by improving the overall scheduling on the shop floor.

The company used a database system to manage all resource planning and scheduling. The database system was designed in house by a member of the engineering staff. The database system evolved with the ever evolving user requirement of manufacturing operations. This created an environment where only the employees that had been at the company from the beginning of the deployment of the system had a full understanding of the system and used it to its full potential. New members of staff were more hesitant to use the system and information in the database became no longer accurate. Particularly in critical areas of raw materials usage, as work orders were sent to the shop floor and only during production were material deficiencies found. On the shop floor the level of traceability was low. It was not always known how many components were used in the production or if they were assembled in the correct manner. Due to this the lead time for products was greater than their competitors.

The weak points in the process are examined in greater detail below:

- Weak point 1:

    - Material shortages are a main cause of time delay in the process. This problem results in the delaying of the product being made and extending the lead time, while the problem itself sounds trivial. However the result is increasing the holding cost of the products which in many parts of the assembly are extremely expensive and reduces the cash flow of the organisation.
- Weak point 2:
    - Increased lead time is caused due to redundancy of information on the schedule. The schedule itself is subject to an extreme amount of variation on a daily basis due to changes in customer requests, material shortages, absenteeism, etc. However, the schedule is only produced once a week and can quickly become redundant and unusable by the workers on the shop floor. This causes further delays and inefficiency to the activities on the shop floor.
- Weak point 3:
    - Production progress is often unknown due to lack of information status on the shop floor. Information is dependant on end of shift or end of the working week updates and delayed decisions result. Poor real time information is available to update schedule.
- Weak point 4:
    - There is poor traceability regarding the activity of each individual worker and the tasks carried out on the shop floor which makes the costing of the jobs inaccurate and complex.

The objective of the requirements gathering and development of the conceptual model of AmI in the case study, is to incorporate the classical approach within the shop floor but primarily to focus on human orientated aspects of this problem. In order to do this all the actors on this process have been identified. They include:

- Shop Floor Operator:
    - These are a number of trades people with different skills and aptitudes such as welding, fabricating, etc.
- Shop floor Supervisor/Manager
    - He/She is responsible for translating the customer orders into the schedule and making decisions on a day to day basis to keep the shop floor continually operating.

There were three options available to the SME with regard to possible solution. The first is to buy an off the shelf information management system, the second is to design a new in house AmI system that caters to their specific requirement and can be adapted to deal with future changes. The third option is to combine the first two, 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. This would help to ensure that they maintain their competitive advantage of being able to adapt to customer requirements at any time during the design and production processes. In this case study the third option was chosen.

4.1 – Decision information production algorithm

The product which is developed is a system that enables integration between electronic hardware and software to develop an AmI system. It occurs in three parts:

- A set of information technology services are provided by the vendors which expands the functionality of the core technologies to allow the system to be integrated in the SME manufacturing environment.
- Vendors provide for the expansion of existing hardware and middleware. This is accomplished through the development of services that are available for download to provide middleware for integration of legacy systems.
- Developers are provided for implementation of the ambient system. The ambient consultants will guide the implementation and integration of both the technology vendors and service providers.

For these solutions to be successfully available all three stakeholders must play a role.

The solution was developed in relation to the users, process and technology, and applied to two areas, scheduling and materials management, see Figure 3. 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.

Each of the parts of the AmI system, see Figure 3 are examined in further detail below:

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, see Figure 4. 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 for example it can provide a detailed break down of the task to be performed for a less experienced operator or just the specifics of the task for a more highly skilled operator. Not in all but in some areas of the shop floor the operator can interact with the AmI system through SRS.

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 PDA's with SRS into the AmI

system network, see Figure 5. 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. The materials manager can then ensure that there is adequate availability of materials for production on the shop floor. This is to ensure that production is not delayed due to lack of raw materials, see Figure 6 the work order tacking in real-time is shown.

5. Business Benefits and Implications

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 intelligent 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.
    - Through greater visibility of the shop floor, the downtime on machines due to maintenance, lack of materials and trained operators can be

reduced. This is accomplished due to constant updates to the schedule to accommodate changes as they occur on the shop floor. This is done to ensure that production is not disrupted greatly which results in reduced downtime.

- System collects real-time information from the shop floor and uses it to update the existing schedule.
    - The embedding of RFID tags in the environment provides for information to be gathered in real-time from the users, processes, and environment. This information is then used by the scheduler and AmI system to update the production schedule. This provides greater visibility over production allowing for more flexibility in the schedule as it is required.
- Providing decision support to the scheduler,
    - Due to the real-time information that is provided by the AmI system the scheduler has far greater visibility over the production processes and can better manage changes. These changes can vary from customers design changes to the breakdown of machinery on the shop floor. The information that is now available to the scheduler allows for a reduction in downtime and better resource management.
- Tracking any and all problems that occur on the shop floor and updating the schedule to reflect them.
    - Through improved visibility across the shop floor issues that arise are logged and dealt with in real time. The scheduler can view problems that have occurred on the shop floor during the production process and take

action to rectify them and modify the production schedule to ensure that he final product is delivery to the customer on time.

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

- Providing real-time update of production progress information to operators, supervisors and managers,
    - The use of a real time updated production schedule all stakeholders in the production process are kept up to date on the aspects of the production schedule that affect them specifically. Operators can view the task that they have to perform. The managers are given an overview of the production operations and are notified of any problems as they arise so action can be taken.
- Providing the information required by shop floor personnel to complete their assigned tasks.
    - The information that is provided to shop floor personnel is tailored to their skills level and competency on specific machinery.

In the case study the production schedule was improved by providing real-time updates on production progress information by operators and reducing downtime with improved time and resource management. Materials management benefited from the material in the warehouse being tracked on the shop floor, so keeping accurate records of stocks and its utilisation. The holding cost of stock could be reduced by reducing the lead time as well as improving the accuracy due to traceability of materials and work being conducted on the shop floor. As a result, the manager now has greater visibility over the shop floor, the traceability of raw materials usage in production and utilisation of personnel is improved. This resulted in lead time reduction from 14 to 8 weeks through improved decision making

In the implementation of the AmI system in the case study a number of lessons were learned in relation to system development. Some of these are outline below:

- The AmI environment is about breaking down boundaries and making information and knowledge accessible to all. This idea is wonderful in theory but in practice boundaries are an essential part of every day life. Particularly in businesses, boundaries to access to sensitive information, work and personal time are needed, as within the AmI environment users are accessible at all time.
- Training needs to be provided to all personnel interacting with the system. If the users are not comfortable with the technology their fears and hesitations need to be alleviated prior to the deployment of the new system.
- Consultation with users in the development and implementation phases is important to ensure a smooth introduction of the new system
- Thorough testing of system before deployment is critically important.
- In designing and implementing an AmI system that caters to the needs of the user, the requirements of the user need to be gathered. This gathering of information gives the system analyst a better understanding of the present environment in which the user operates and the type of AmI environment that will meet the needs of the user. This will require the user to be involved in a collaborative process with the systems analyst and developer of the system with regard to both technical and knowledge of the system. The benefits of developing an AmI system need to be outlined to the user as well as the drawback of introduction.

Some of the risks with development and implementation of an AmI system are will the user use the system, accuracy of information and continual maintenance. Financial investment by SME's must be made. However, the solution will depend on the accuracy and availability of the legacy data, also the willingness of users to adopt the solution. The SME solution needs to be one that promotes efficiency, effectiveness, flexibility and can only be delivered through such ambient solutions. AmI is an inspiring concept and with its introduction will change the way that we work and live our lives.

6. Conclusions

SME are facing greater challenges due to the faster changing business environment. To adapt to this change more effectively and efficiently they need systems in place that adapt to change easily and seamlessly. This is the case in the customise product and service manufacturing SME sector. AmI has the ability to help SME to become more flexible to change and build on their already dynamic nature. The ability of the AmI system to adapt and learn in different situations is the key to maintaining the competitiveness in an organisation. This paper examines the implementation of an ambient intelligence (AmI) system in a manufacturing SME. To achieve this, an AmI in Industry reference model is applied in a SME manufacturing case study. To create an AmI environment, requires the use of a combination of technologies as well as an understanding of the need and requirements of the user, process and environment in which the AmI system is to be implemented. The aim of the paper is to demonstrate the development and implementation of an AmI system in the customise product and service manufacturing SME environment. To achieve this, the case study is analysed with regard to the weak points to be improved through the development of an AmI system. The AmI in industry reference model is used to assist in developing the system as it shows the user, process, environment and AmI system as well as the interaction between these elements. The solution is discussed with regard to business benefits and issues in implementation.

Further research needs to be carried out with regard to the enabling technologies that are used together to create an AmI system. These technologies require further development to enable the development of an AmI system so they can be integrated into the background more easily. For example RFID tags cannot place on metal objects directly unless and buffer is placed between the tag and the metal object.

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Vitae

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Figure Captions

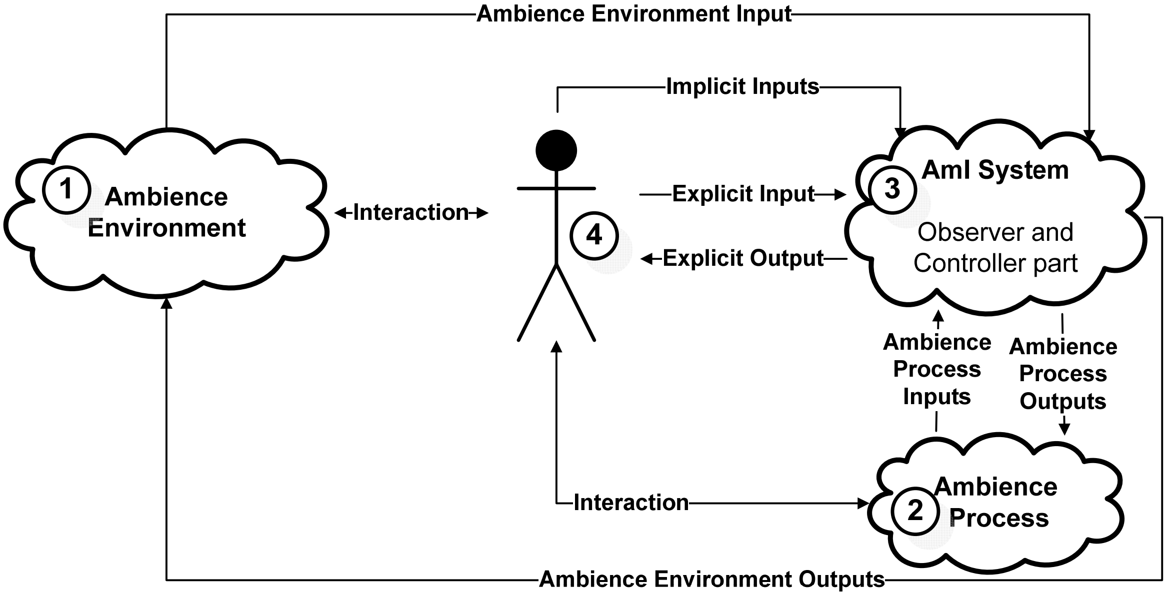

Figure 1 AmI in Industry Reference Model adapted from Stokic et al[22].

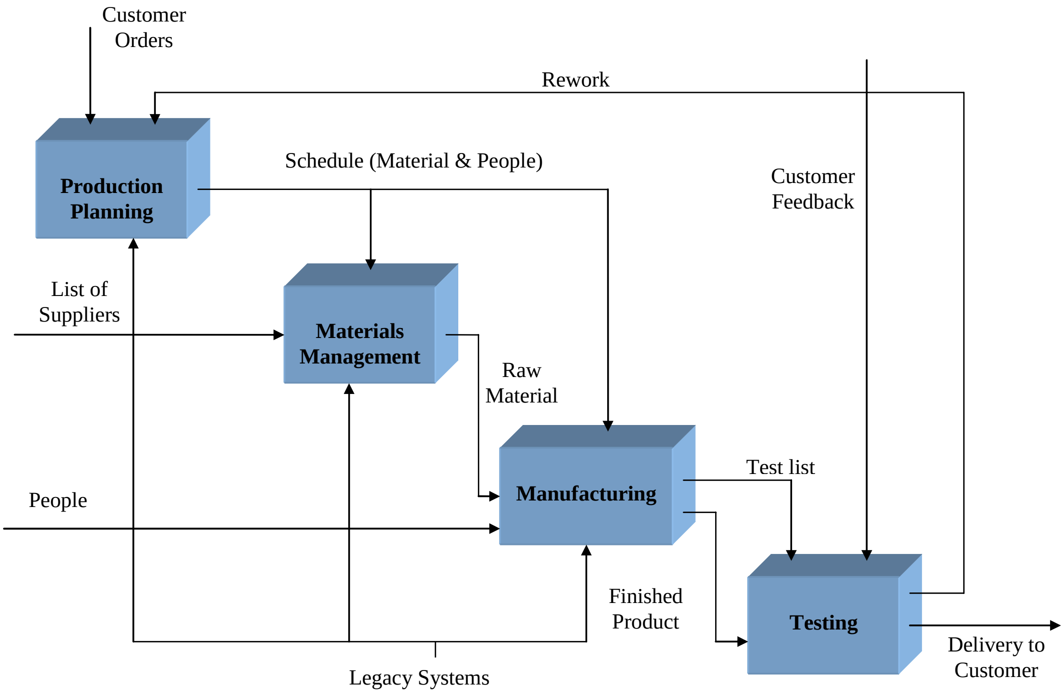

Figure 2 Reconfigurable Manufacturing System

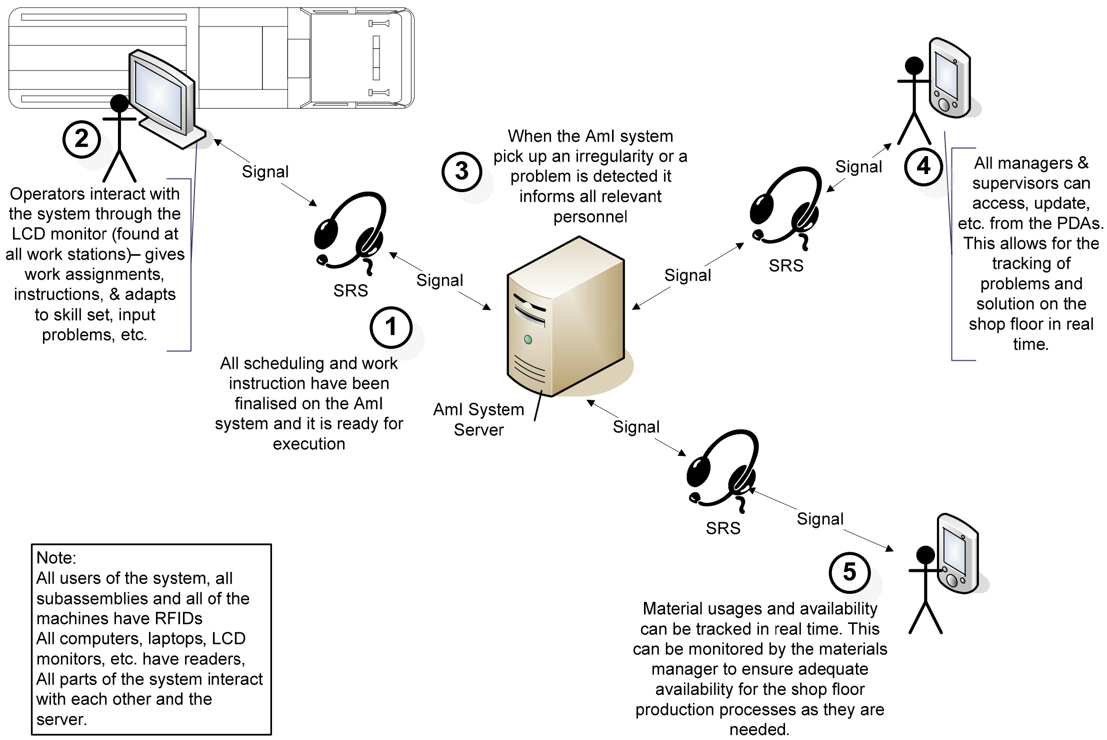

Figure 3 AmI system

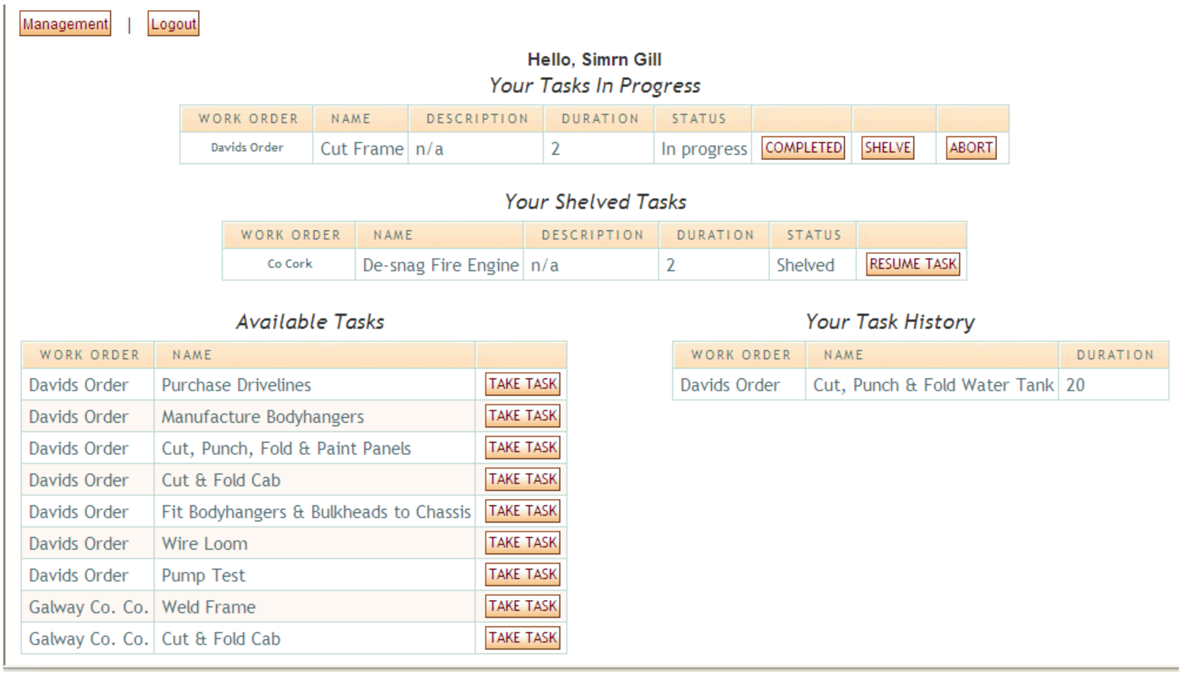

Figure 4 Shop floor Operator Interface

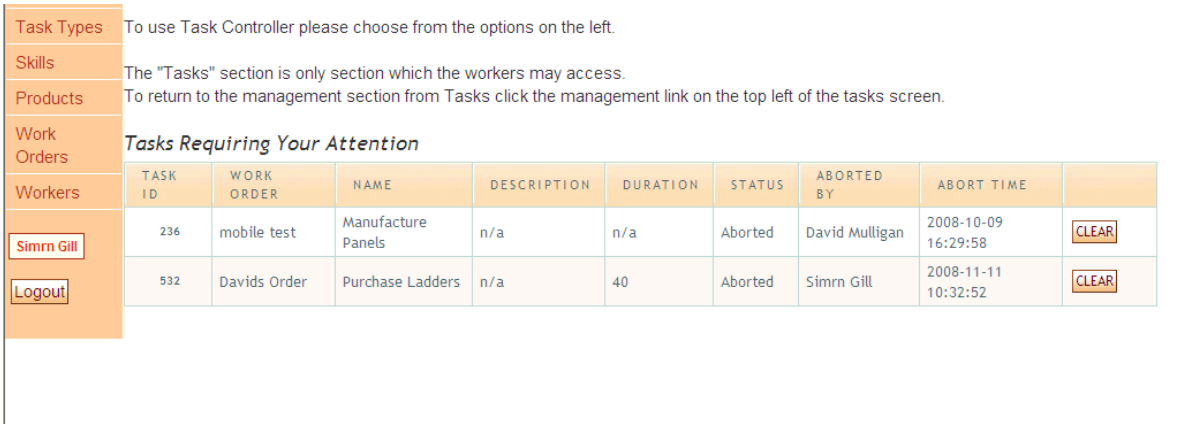

Figure 5 Managers/Supervisors interface

Figure 6 Work order tracking in real time