AmI Technologies Based Business Improvement in Manufacturing SMEs

Uwe KIRCHHOFF, Dragan STOKIC, Harald SUNDMAEKER
ATB- Institute for Applied Systems Technology
Wiener Strasse 1, 28359 Bremen, Germany
Tel: +49 421 220 92 0, Fax: +49 421 220 92 10,
kirchhoff@atb-bremen.de / dragan@atb-bremen.de / sundmaeker@atb-bremen.de

Abstract:
AmI technologies are likely to play a key role in respect to the innovation of industrial collaborative working environments. The paper presents a new approach how to bring AmI technologies to the industrial sector of manufacturing SMEs and how to develop and validate business processes innovations based on "Ambient Intelligence" philosophy. Thus, manufacturing SMEs will be enabled to actively take part in this revolution. The paper presents an approach, tailored to the needs of SMEs, how to plan, implement and validate AmI based business processes innovations for the optimisation of a shop-floor control in an EE environment.

1. Introduction

Modern SMEs (Small and Medium sized Enterprise) have to meet the challenges of the increasing product variants and service content of products by radically innovating their business processes. To achieve this objective, the usage of Ambient Intelligence (AmI) technologies is promising to enable the realisation of new paradigms, focusing upon the main actor in industry: the human actor. This will allow a key improvement of collaborative working environments, also in the manufacturing industry [1].

Currently, AmI technologies (e.g. wireless multi-media, wearable IT, wireless sensor networks, agent technologies etc.) are attracting a high interest in the research domain [2, 3, 4], where their applications in manufacturing industry are still in an initial phase. Particular in manufacturing SMEs, constraints like limited investment potentials and investment risks, limited staff quantity and qualification to drive business process innovations often create a strong reluctance to innovations. Therefore, SMEs need specific approaches how to address the successful utilisation of these new technologies to create measurable business benefits on short to medium term, enabling SMEs to keep pace with the innovation speed at large companies.

The strategic objective of the presented research results is to enable SMEs to actively take part in this revolution, by proposing a new scheme for systemic innovation of industrial working environments in SMEs by applying AmI technology. The basic approach, presented below, targets to enable SMEs to make decisions on the following key topics:

- To what extent AmI technologies can create innovation potentials – innovation by technology.
- In which of their business processes technology need to be introduced and organisation of work to be changed – innovation by a human centric process reorganisation.

To achieve these objectives as a basic approach, for a systematic assessment of AmI technology innovation potentials, a reference model for AmI in manufacturing industry is

introduced. Furthermore, in respect to this reference model an AmI feature concept is presented, indicating a systematics of solution independent formulation of specific AmI technology potentials relevant for the interaction of a human operator with the ambience and expressed in a form understandable by non-experts.

Based on this basic approach it will be presented, that the goal oriented efficient optimisation of business processes taking advantages of AmI potentials, can be achieved by the extension of well known business improvement methodologies [5, 6], bringing together the human centric as well as the business process optimisation dimension in manufacturing SMEs. Thereby, the focussed application scenarios address new manufacturing concepts based on advanced AmI technology in two key business areas within SME driven Extended Enterprise context: shop-floor control and maintenance process. A business case for shop-floor control in an Extended Enterprise environment will serve as example for demonstration of methodology application and presentation of achieved results.

The results presented in this paper are elaborated in the scope of the EU-funded project "Revolution in Industrial Environment: Ambient Intelligence Technology for Systemic Innovation in Manufacturing SMEs", contract nr.-017120 (AMI-4-SME) [7].

2. The AmI Approach

The current approach of implementing the AmI concept is oriented to surround people with electronic environments, sensitive and responsive to their wishes [8]. AmI based solutions are expected to combine concepts of ubiquitous computing and intelligent systems putting humans in the centre of technological developments. However, in spite of intensive research activities on specific AmI technologies, besides such generic formulation on AmI, there are no wide spread accepted definitions of AmI systems in manufacturing industry.

Based on a definition of AmI in manufacturing industry in [9] in the following chapter, a related AmI feature concept will be presented, aiming to contribute to a common understanding of the AmI technology domain and AmI related terms for the manufacturing sector.

2.1 Reference Model for AmI in Industry

In [9], based on the definition of AmI systems relevant for manufacturing industry, a reference model is presented starting from the main assumption that the AmI systems in industry can be considered as control systems of Automation & Robotics and processes, which include human operators in control loop. The elaborated reference model indicates, where AmI technologies offer potentials to optimise the interaction of human operators within their working environment.

The reference model indicates the different areas of required AmI based solutions to enable a human centred interaction of the worker with his ambience. Thereby, the ambience is split up in a manufacturing related ambience, covering process, plant, machines etc. and an ambience representing a wider human operator environment, not directly (however indirectly) related to the manufacturing process. The intelligence of interaction of the human operator with the environment is managed by the AmI system (see Figure 1).

As presented in Figure 1 the reference model covers the input and output areas of the human operator with the AmI system comprising implicit (1.1) and explicit (1.2) inputs from human operator to the AmI system and the explicit outputs of the AmI system to the human operator (1.3). Additionally input/output areas address the interaction of the different ambiences (environment (2) and process (3)) with the AmI system.

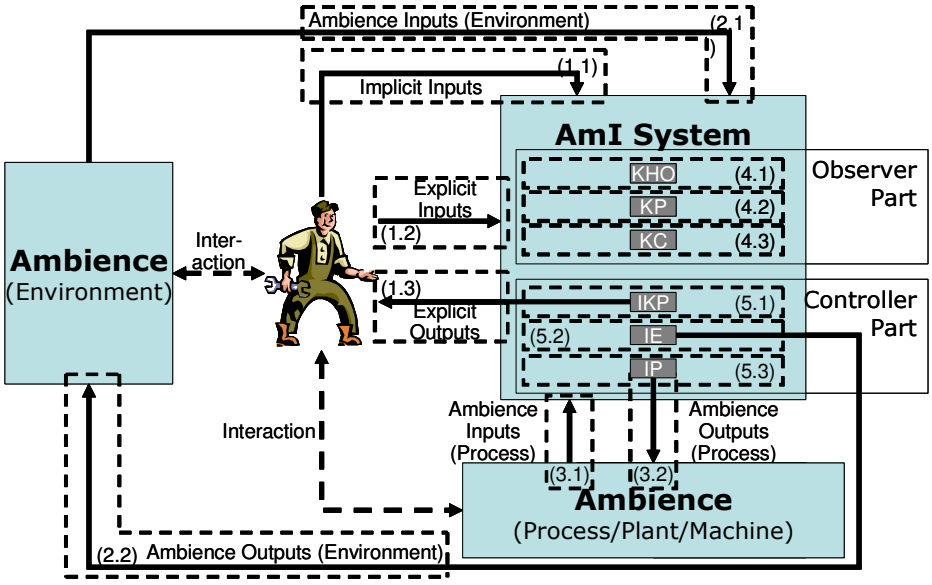

Figure 1: Reference model for AmI in manufacturing industry.

Based on the control engineering approach in [9], the AmI system is separated in an observer and a controller part. The observer part is creating, based on input information and other existing knowledge and information, the knowledge about human operator (4.1), the knowledge about ambiences (4.2), covering process, environment and interactions, as well as the knowledge on context (4.3), based on knowledge and information provided by the mentioned two observer modules and other systems.

Based on knowledge and information provided by the observer part, the controller part of the AmI systems covers the information/knowledge provision to human operator (5.1 - IKP), the intelligent interaction with ambience (environment) (5.2 - IE) and the intelligent interaction with ambience (process) (5.3 - IP).

2.2 The AmI Features Concept

The objective must be to enable SME end-user, representing "non-experts in AmI technology", to identify most appropriate AmI technologies for a human centred business improvement, not requiring any expertise on AmI technologies. This statement implies a contradiction.

To overcome this contradiction: the concept of "AmI features" is introduced. AmI features represent a solution independent formulation of AmI technology potentials offered to the human operator when interacting with the ambience. These AmI features must be expressed in a form understandable by non-expert and must posses the following characteristics:

- It must be technology independent,
- It must indicate the functional and/or non-functional requirement(s) relevant for the user which can be provided by AmI technology and
- It must correspond to one or more SPECIFIC characteristics of AmI according to the above definition of reference Model of the AmI systems.

Therefore, a feature defines WHAT an AmI system may offer, but not HOW it may achieve.

The grouping of the AmI Features in respect to the structure of the AmI Reference Model (see Figure 1) represents the key approach to bridge the gap between identification of processes to be improved, identification of the required AmI potentials and the AmI technology required to create an AmI based solution realising the intended improvements. For each of the five areas of the AmI reference model one or more AmI features are

defined, formulating specific AmI characteristics in this area. However, the proposed classification represents a structure which is open for further extensions and/or refinements. In Table 1 the elaborated AmI features and related AmI technologies required for the implementation of these features are presented for the explicit input of the human operator (HO).

Table 1: Example for the relation between AmI features and technologies.

AmI Features	Related Technologies & Functions of Supporting Applications
(1) Human Operator I/O	
(1.2) Explicit inputs from HO to the AmI system • Natural HO inputs: i.e. spoken language, handwriting, touch screen, gesture, gaze to forward unstructured information and observation to the AmI system • Simultaneous exchange of information over multiple channels at different levels of abstraction, e.g. speech, gesture, animation, non-speech audio. • Provision of observations and experiences of the HO on the status and problems in process and environment to the AmI system • Request for data without knowing specific file names, location or format. • Automated user identification and authentication and authorisation. • Forwarding unstructured communication needs with collaborating partners • Mobile or nomadic access • ...	• Digital pen, touch screen, handwriting recognition, speech recognition technologies. • Wireless handheld devices like PDAs, tablet PC or mobile phones. • Wearable input devices like e.g. key boards sewed in cloth, data glove etc. • Biometric authentication and authorisation technologies • Video conference technologies • Mobile communication and interoperability technologies (Bluetooth, WLAN, GPRS, UMTS etc.) • Collaborative working environment – core services • Network interoperability and ubiquitous communication • ….

3. Basic Methodology Approach

To bring AmI technologies to the industrial sector of manufacturing SMEs, an SME tailored methodology is essential. As the technology innovation in the past exemplifies, such methodologies are indispensable for SMEs to keep pace with the innovation speed of the utilisation of new technologies at large companies. The methodology to be developed has to support SMEs to identify to what extent AmI technologies can create innovation potentials in their business processes. However, SME constraints like limited investment potential, limited staff quantity and qualification often create a strong reluctance to innovation. Therefore, SMEs will not go for a general experimentation of new technologies. They are looking for innovative solutions which can be put into daily operation on a short-term, creating measurable business benefits. Furthermore, a methodology must be able to handle the typical characteristics of SMEs:

- Business process execution by the human operator in SMEs is often individually and experience driven. Therefore in respect to Quality/Cost/Schedule (QCS)-optimisation, structured and reproducible new methods of work for the execution of the business processes has to be introduced, also representing a pre-requisite for any efficient ICT (Information & Communication Technology) support.
- Quite often an insufficient integrated ICT infrastructure exists (computer islands, break of media etc.), therefore in a first step such a basic integrated ICT infrastructure supporting the business process execution has to be introduced, which is also representing the prerequisite for the introduction of any AmI based solution.

- AmI in a variety of business processes may heavily depend on the extent to which AmI complements rather than replaces existing methods of work and the extent to which it requires fundamental changes to organisational structures.

Therefore, the methodology can not focus straight forward on the introduction of AmI technologies, but has also to cover the redesign of the existing (individual driven) process execution and the introduction of a basic integrated ICT infrastructure, as prerequisite for the introduction of AmI solutions.

To mange this complex interdependency and to create a systematic methodological approach, applicable by SMEs and tailored to their needs, the overall problem of the business innovation process is separated in two different projections as presented in Figure 2.

- The **"process dimension",** targeting the QCS-optimisation of the execution of the business processes, supported by an advanced and integrated company wide ICT system, open for its integration in an Extended Enterprise ICT environment.
- The "**human centric dimension**", targeting the creation of a context sensitive intelligent ICT environment for the human operators involved in the different business processes of the company, based on the potentials of the application of AmI technologies.

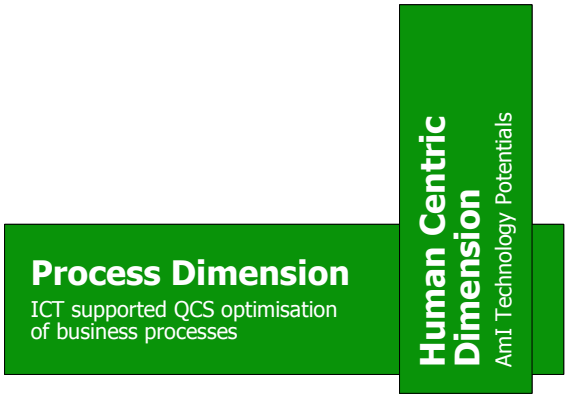

Figure 2: The two optimisation dimensions.

Against this background a methodology has to merge these two dimensions to manage this complex process of an AmI based business process optimisation. Therefore, the key approach of the methodology is driven by a superposition of the two optimisation dimensions. The resulting two step optimisation process starts with the process optimisation as a prerequisite and basis for the human centric optimisation aspects.

For the process dimension well experienced and international recognised methodology solutions already exist [10]. One of these methodological approaches (BEP2-Method) covers the process dimension for an ICT supported business improvement. The life-cycle phases and activities to be executed in the scope of the improvement process are presented in Figure 3.

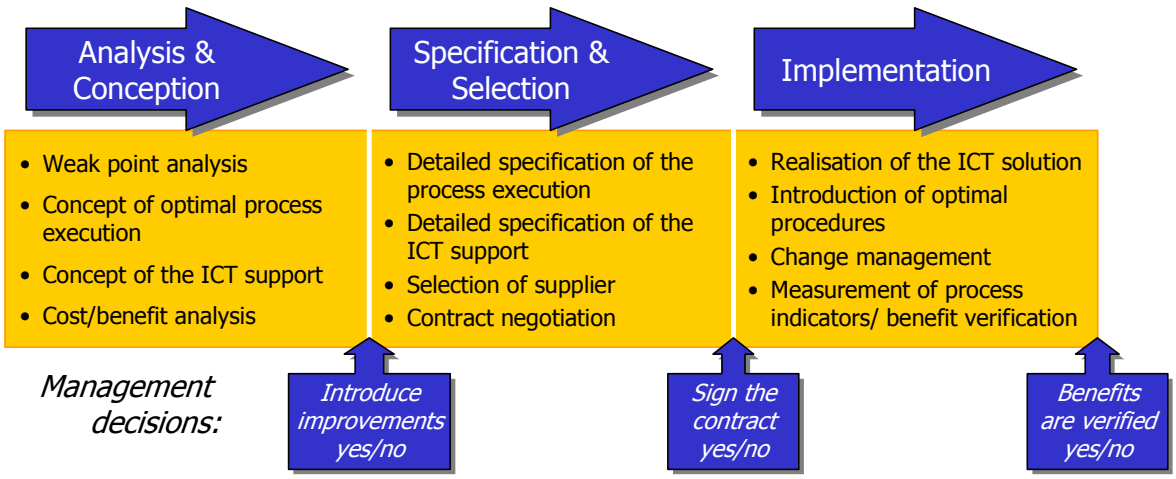

Figure 3: Life-cycle structure of the BEP2-Method.

This method is used as basic methodology skeleton to be extended for the human centric dimension, where the major extensions were required in the Analysis & Conception Phase. This approach results in the following basic methodology concept:

- Identification of competition critical weak points in the actual execution of the business processes, jeopardising the achievement of the stated company's objectives.
- Process dimension: To eliminate weak points, specification of the concept for organisational measures and a related integrated ICT concept (required basic ICT infrastructure based on classical ICTs) optimally supporting the identified new methods of work.
- Human centric dimension: Supported by an AmI feature model, identification of an intelligent human operator interaction within the redesigned business processes, targeting at an AmI based system solution to become an integral part of the specified operational concept and basic ICT infrastructure.

The targeted AmI based solution concept might have consequences on the results of the process optimisation step. Therefore, iterations between the human centric optimisation step and the process optimisation step will be required.

4. Business Case

The developed methodology is verified in 5 business cases of 6 manufacturing SME in 4 European countries. Based on the application of the developed methodology the elaborated results for an AmI based improvement process is presented in the following for one of the business cases.

The company A and company B are co-operatively producing in relatively small batches special, customised, chassis and change over platforms for lorries, where company B is responsible for all welding activities. There is normally a high variation in volume of different product variants. The delivery time is currently 5 days, and the main business objectives is on one side to cut the delivery time to less than 4 days, and, on the other hand, to increase number of variants, i.e. achieve higher customisation following the total Built-To-Order philosophy. Furthermore, quite often a rescheduling of orders on customer demand is required. As an additional QCS-objective an increase of the overall productivity in the co-operation is targeted, as well as a decrease of wasted materials.

Based on the company objectives, the analysis of the business processes indicated the following most critical weak points to be eliminated with highest priority.

- **Production Operations Management:**
  - Delayed update of the production progress information by foremen.
  - Production problems and delays are sometimes detected too late, reducing the reaction time for problem elimination.
  - The coordinated rescheduling of the production order sequence and related reconfiguration of the assembly lines are too slow.
- **Materials Management:**
  - Semi-finished products are not delivered order related to the welding areas, causing sometimes missing material or waste of material.

In the scope of the elaboration of the solution concept for the optimisation of the process dimension the targeted changes in the execution of the business activities were identified, as well as an envisaged extension of existing legacy systems, as presented in Table 2.

Table 2: Results of the optimisation of the process dimension.

Sub-process	Activity Execution	ICT Support of Activity Execution
Production Operations Management	• Organisational measures for production status control to be applied strictly • A defined procedure for production rescheduling and line reconfiguration to be followed.	• Installed PC (Personal Computer) based software for production status control to be extended for the support of the rescheduling and reconfiguration activities.
Materials Management	• Order related delivery of commissioned semi-finished materials by company A to the welding area of company B. • Delivery event to be recorded as part of the production status control.	• Software support for the order related commissioning of semi-finished materials. • Installed PC based software for production status control to be extended to manage delivery events.

In respect to the human centric optimisation dimension an "AmI vision" is created targeting, in reference to the AmI features scheme, at the identification of required intelligent AmI System Services to overcome the identified weak points in the different business processes (see column 2 of Table 3). This will be realised for all actors in the company involved in different processes. Furthermore, to operate intelligent AmI system services the targeted interaction and sensor technologies to manage the specified interaction between Human Operator, Ambience and AmI system have to be identified, representing an essential design dimension of an AmI system for AmI based Input/Output services.

As presented in column 3 of Table 3, this covers the identification of the required AmI technologies, as well as their interaction with the existing and planned ICT infrastructure, identified in the scope of the previous process oriented optimisation step.

Table 3: Results of the optimisation of the human centric dimension.

Sub-process	AmI System Services	AmI based Input/Output Services
Production Operations Management	• Based on an access to the ERP (Enterprise Resource Planning), supervision and automatic identification of critical production delays. • Rescheduling and reconfiguration of the production from any place at any time possible. • Automatic generation of optimal re-scheduling proposals.	• Automatic mobile information of the production managers in case of a delay at any time at any place. • Automatic information of the foreman on rescheduling at any time at any place. • Mobile multi-modal information access (visually and via voice information) to production data. • RFID (Radio Frequency Identification) technologies for automatic recording of truck chassis production status; forwarding info to status control software to disburden foreman.
Materials Management	• Intelligent guidance of the worker, executing the order related picking process.	• Mobile multi-modal support of the worker (visually and via voice I/O) for order picking. • RFID technologies for the automatic recording of delivered transport units leaving the storage area and forwarding info to status control software.

The identified intelligent AmI System Services and AmI based Input/Output Services (speech recognition systems, RFIDs, wireless LAN (Local Area Network) and multimedia), interoperating with existing Enterprise Resource Planning (ERP) systems will support quick responses to different problems in the shop-floor, including possible order rescheduling, assembly line re-configuration in case of problems. This will allow an optimal co-ordination of work of two assembly lines and their optimal reconfiguration in both SMEs. The benefits expected include considerable reduction of efforts and time needed to reconfigure the lines, enabling faster manufacturing/assembly of different product variants and effective smoothing of the manufacturing processes in both companies.

The identified human centred system solution provides a highly intelligent production status control and decision support system to assure an efficient collaboration of human operators in both companies in charge of the reconfiguration and rescheduling process. In the next development step, in co-operation with the research partners and the technology vendor partners (providing the basic required enabling technologies for speech recognition, RFID and mobile communication) the identified solution concept will be implemented and verified in the real production environment.

5. Conclusions

The paper presented an approach how to implement business process innovations based on "Ambient Intelligence" philosophy, tailored to the needs of SMEs. The developed approach is tested with 6 SMEs from different European countries. Lessons learnt from the methodology application explicitly indicate that the presented approach enables SMEs to achieve a good understanding on how AmI philosophy and technology can contribute to achieve significant business benefits. This obviously leads to a reduction of initial reluctance of SMEs to introduce such technologies in their companies. Therefore, such approaches significantly contribute to open up the huge market potentials for technology vendors in the difficult SME market domain.

To further push this approach, AmI technology vendors are exploiting the identified SME needs on AmI based ICT solutions, to develop sets of AmI technology Building Blocks (BB) enabling a fast and cost efficient realisation of such solutions. As key BB domains the vendors address mobile multimodal services (wireless multimedia), RFID-solutions and speech recognition systems. This innovative BB approach represents a further exploitation strategy to open up the SME market.

Future research activities have to address the proof of concept and extension of the methodology and BB-concept for all manufacturing processes (not only those focused in the project) also in different industrial sectors. Furthermore, it should be assessed to what extent such an approach (methodology and BBs) is also valid for other non industrial collaborative working environments, i.e. government und health care domain, to push business innovations based on Ami philosophy also in these areas and to open further market potentials for AmI technology vendors.

References

[1] Maurtua, Unceta, de Vallejo: Ambient Intelligence in Manufacturing: Organisational Implications, 1st International Workshop on Social Implications of Ubiquitous Computing, April 2005, Portland.

[2] ISTAG: Scenarios for Ambient Intelligence in 2010, ISTAG Report, February 2001.

[3] Boronowsky, Herzog, Knackfuß, Lawo: wearIT@work–Empowering the Mobile Worker by Wearable Computing, In Proceedings of the Marc Pallot, Kulwant S. Pawar (eds.), 1st AMI@Work Communities Forum Day, pp. 38-45, 2005.

[4] Lindwer, Menno; Marculescu, Diana; Basten, Twan; Zimmermann, Rainer; Marculescu, Radu; Jung, Stefan; Cantatore, Eugenio; Ambient Intelligence Visions and Achievements: Linking Abstract Ideas to Real-World Concepts. Proc. Design Automation & Test in Europe (DATE), March, 2003.

[5] U. Kirchhoff et al.: How to Speed-up the IMSS Related Innovation in Manufacturing SMEs, Proceedings of the International IMS forum 2004, Como.

[6] International Organisation for Standardisation; ISO 15704:2000: Industrial automation systems – Requirements for enterprise-reference architectures and methodologies. Geneva, ISO, 2000.

[7] www.ami4sme.org: Project description AMI-4-SME - Revolution in Industrial Environment:Ambient Intelligence Technology for Systemic Innovation in Manufacturing SMEs.

[8] ISTAG: "Involving Users in the Development of Ambient Intelligence", ISTAG Report on Experience and Application Research, September 2004.

[9] Stokic et. al : Ambient Intelligence in Manufacturing Industry: Control System Point of View, IACTED, Conference on Control and Applications, Montreal, 2006

[10] **www.cost-worth.net,** descriptions of 5 business improvement methodologies and support material, accessible free of charge, results of the EU funded COST-WORTH project.