Chapter I
Ambient Intelligent (AmI) Systems Development

Simrn Kaur Gill
National University of Ireland Galway, Ireland

Kathryn Cormican
National University of Ireland Galway, Ireland

ABSTRACT

This chapter introduces the concept of ambient intelligence (AmI), a new concept in the area of information and communication technology (ICT), from a systems development perspective in the manufacturing environment. To create an AmI environment, requires the use of a combination of technologies. The AmI environment can be enabled through the use of computers that are embedded into everyday objects and through the use of wireless communication. The interaction between these embedded devices and the human user is improving through advancements in the area of natural interaction. The aim of the chapter is to provide a better understanding of AmI. To this end the following tools are presented, an AmI definition, typology, and taxonomy. The typology solidifies the understanding of AmI by highlighting the elements that need to be considered when developing an AmI system. The taxonomy shows the evolution of technologies towards development of AmI.

INTRODUCTION

The manufacturing environment has changed greatly over the last 20 years and is set to advance even more in the coming years. The Society of Manufacturing Engineers (Koska & Romano, 1988) commissioned a survey in 1988 to consider the changes that would occur in the area of manufacturing in the 21st century. They identified a number of trends. One of these trends was that products would become more sophisticated and the methods used to produce them would become equally as complex. Another was that manufacturing would become more human centred and a shift in manufacturing towards the customer would occur. These changes that were highlighted in the report are at present taking place in the manufacturing environment. This change process is supported by advancements in the area of information communication technology (ICT).

Ambient intelligence (AmI), a new paradigm in the area of ICT allows for user centred developments and adaptability. However, traditional ICT systems are not capable of this level of accommodation, and as a result a user centred approach that provides adaptability and flexibility is needed. AmI is an advancement of ICT that places the human user at the centre of the technology enabled and embedded environment. The user does not have to make an effort to understand the technologies that occupy the environment but rather the embedded technologies need to be able to express themselves in a way that the user can understand (speech, graphical representation, light, music, and heat). In turn, the embedded technologies need to be able to understand the human (gesture, speech, and body language) as well. Therefore, the AmI system in essence caters for the needs and wants of the human user that occupies the AmI environment. To achieve this level of interaction the AmI system has to possess an understanding of the context and information regarding the user and the environment in which it co-exists. To create this environment, the AmI system therefore needs to have knowledge of the user, process, and environment. The need to incorporate all these elements creates a complex system with elements of hardware and software that need to interact together seamlessly. For the AmI system to be achieved requires the advancement of traditional ICT.

No single technology creates an AmI environment, therefore, a combination of different technologies are used to create the AmI environment. Each technology has unique features and characteristics that it brings to the AmI environment. With this level of diversity in technology comes with it a complexity. There are numerous technologies that can be utilized; the challenge lies in which combination of the technology creates the desired AmI environment. AmI has many potential benefits as highlighted in the Information Society Technologies Advisory Group (ISTAG) report *Scenarios for Ambient Intelligence 2010* (Ducatel, Bogdanowicz, Scapolo, Leijten, & Burgelman, 2001). The scenarios cover everything from the social, work and home environments in which AmI will exist. In the area of AmI manufacturing, this will involve products and services becoming human-centred, and users will have far greater involvement in the design and development process. Products will be intelligent and they will be able to interact with other technologies, but the human user will control the level of interaction. AmI will allow for the human worker in the manufacturing environment to come to the centre of the production process. Through accomplishing this it will empower the human worker by giving them greater autonomy over their work and environment. The use of AmI will improve decision-making and utilization of resources to enhance efficiency and effectiveness. Therefore, all aspects of manufacturing will be built around the human user.

The aim and objective of this chapter is to provide a better understanding of the AmI concept and by doing so develop tools that can be used in the assistance of its development. To accomplish this, a review of literature in the area of AmI is provided. This reviews the concept, definitions and technologies that enable developments in the area as well as some of the socio-technical implication of the AmI environment. The findings from the literature review led to the development of typologies that can be used in explaining the concept and can be in developing an AmI system. The example of the manufacturing environment is given. The discussion then moves to the future trends in the area of AmI and the impact that this will have on the research that is imparted. Finally a conclusion of the discussion provides a review of key findings.

AMBIENT INTELLIGENCE

This section will explore the evolution of ICT in relation to the development of the AmI paradigm. The three elements that make up AmI are discussed and examined. This section reviews relevant literature relating to AmI definitions from key authors. This allows for the development of an AmI definition that supports the research that is presented in this chapter. The development of the concept that AmI is built on is discussed. The socio-technical implications of AmI are examined. The key findings and conclusion of the section are presented at the end.

This section will discuss the evolution of ICT and the developments that have been made in the area towards achieving the information society and the AmI paradigm. The evolution of ICT begins with the design of the first computer by Charles Babbage during the 1840s; however, it was never built. The development was based on his vision that the science of numbers could be mastered by mechanisms (Swade, 2000). The design was known as the "analytical engines" it was a general purpose machine capable of being programmed by the user (Swade, 2000) and could execute programs through the use of cards. It was a decimal digital machine and had many similar features to modern computers. However, these ideas lay forgotten for over a century but they did lay the foundation for the evolution of the computer age in the 1960s.

The computer age of the 1960s led to the automation of processes in design and manufacturing and computer aided manufacturing. This evolution in computing has led to advancements of telecommunications, electronic engineering, and computer and control science. These developments have led to a gradual shift away from a focus on the computers, to the user instead. This shift is changing the way people interact with each other. It has led to the emergence of blogs and wikis as the modern way of sharing information. This has involved the meeting and merging of technologies from the areas of telecommunications, electronic engineering, and computer and control science (see Table 1). The area of telecommunications enables the flexibility to communicate through the use of various media from both remote and local locations. Electronic engineering involves the use of sensors and microelectronics. The sensors can provide real-time information regarding the user, process, and environment. The microelectronics enables the integration of technology into everyday objects. In the area of computer and control science the assimilation of information can provide decision support.

Table 1. The emerging ICT trends adapted from Riva (2005)

Technology	**Electronic Engineering**	**Computer & Control Science**	**Telecommunications**
Features	- Sensors - Microelectronics	- Tele-operators - Expert Systems - Computer Vision	- Mobile Communication - Telecommunication Network - Signal Processing

The advancement of telecommunications, electronic engineering, and computer and control science can be viewed in relation to the development of a European information society. A survey conducted by SIBIS (2002), compared the advancements that have been made in Europe and the U.S. toward an information society. Their goal was to create a benchmark for the development of a European information society.

The study looked at the uptake of ICT in Europe during 2002 and compared it to that in the U.S. The findings of the study cover areas from telecommunication and access to e-government. It found that on many of the indictors Europe was behind the U.S., this can be demonstrated by the fact that Europeans are less likely to have Internet access at home about 40% compared to 60% of Americans. This trend continues in the usage of the Internet on a regular basis and the uses made of the Internet. One of the reasons for this is the slow roll out and uptake of faster broadband services. On some indicators the Europeans were ahead of their U.S. counterparts. It was found that the Dutch are more likely to be involved in eWork (at least one day a week) than their American counterparts. Since 2002, there has been an improvement in Internet access. Household Internet access ranges between 23% in Greece to 80% in the Netherlands and nearly "half of the individuals in the 25 EU states used the Internet at least once a week in 2006" (Eurostat, 2006, p. 1).

The developments in the areas of telecommunications, electronic engineering, and computer and control science are furthered in their accessibility by development in three core areas. These areas are in the embedding of computers into everyday objects (ubiquitous computing), allowing for these technologies which are embedded in everyday objects to communicate (ubiquitous communication), and an interface that allows for ease of use and access for the user to interact with these embedded technologies (intelligent user friendly interface). These three elements, ubiquitous computing, ubiquitous communication, and intelligent user-friendly interfaces, are discussed in greater detail in the following subsection.

Ubiquitous Computing

Ubiquitous computing is defined by Alcaniz (2005) as being an "integration of microprocessors into everyday objects like furniture, clothing, white goods, toys even paints" (p. 3). The term ubiquitous computing was coined by Mark Weiser in a 1991 article in Scientific America. Weiser (1993) described ubiquitous computing to have "as its goal the non-intrusive availability of computers throughout the physical environment, virtual, if not effectively, invisible to the user" (p. 71). Therefore ubiquitous computing can be defined as computers embedded into the social, home, and work environments that are invisible to the user. These computers are at the disposal of the users in the specific environment. The computers can perform predetermined action with or without the user having direct interaction with it (Alcaniz, 2005; Sørensen & Gibson, 2004; Weiser, 1993, 1999).

Ubiquitous computing is described as the third wave of computing. The first wave can be described as one computer and many people using it. The second wave is the era of the personal computer and the third wave is one person with many computers interacting with them.

Therefore, for ubiquitous computing to be made a plausible reality "near-zero telecommunications costs and seamless interoperability of devices across networks" (Blackman, 2004, p. 261) is needed. Some examples of ubiquitous computing devices are the Philips TV mirror that can show weather and television reports all in one device and be used as mirror. It can also recognize the user by weight and height if used in a bathroom. The device can present information related to news and weather that is tailored to the preferences of the user. Another device is the ambient orb developed by Ambient. The device can be configured to monitor stocks and shares as well as the weather. It changes color depending on how the stock and shares are moving. The following section describes the area of ubiquitous communication, which provides the ubiquitous computing devices with the ability to communicate with other devices creating a system that is omnipresent.

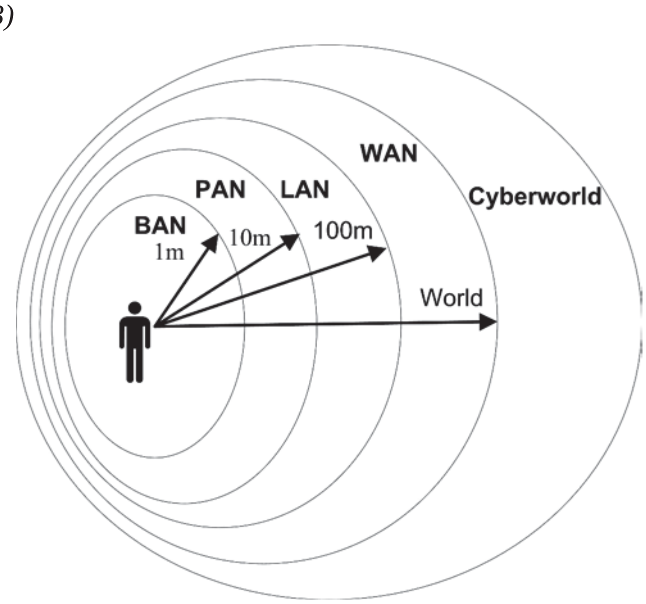
Ubiquitous Communication

Ubiquitous communication allows the ubiquitous computer devices "to communicate with each other and the user by means of ad-hoc and wireless networking" (Alcaniz, 2005, p. 3). There are various different types of communications and technology networks, which depend on the type of communication that is necessary. The communications and technology network is best described in Figure 1 (Friedewald & Da Costa, 2003), which shows the communications networks that surround the user in a ubiquitous computing environment. This communication network provides the ability for different technology devices to communicate with each other over varying distances depending on the communication technology that they operate on. The spheres of communication distance are discussed below.

The five spheres surrounding the user are:

- **Body area network (BAN):** BAN provides the link between the user and the technology (Ducatel et al., 2001). The BAN may be used in mobile telephones that can both send and receive telephone calls as well as transmitting physiological data to the system to monitor heart rate for example. It will communicate over a distance of 1 to 2 metres (Friedewald et al., 2003).
- **Personal area network (PAN):** Wireless PAN is in use at present as Bluetooth. It is used at present in mobile telephones and PDA's (Personal Digital Assistant) (Friedewald et al., 2003). The range is up to 10 metres. New Bluetooth versions are being developed that will allow for increased data transfer rates (Raisinghani et al., 2004). Only when Bluetooth capable devices come into

Figure 1. Multi sphere reference model of communication and network technologies adapted from (Friedewald et al., 2003)



range of one another do they communicate either exchanging data or one controls the other. Due to this fact it is well suited to various technologies (Diegel, Bright, & Potgieter, 2004).

- **Local area network (LAN):** Wireless LAN or WiFi as it is more commonly known is commercially available at present. WiFi can be extended over entire building or production floors through the introduction of multiple access points (Friedewald et al., 2003; Raisinghani et al., 2004). It can be used to allow for the seamless interaction of devices that are located in opposite ends of a production floor, which are of distance less than 100m.
- **Wide area network (WAN):** Wireless metropolitan area networks (WMAN) are commercially available but it is still undergoing further development and will be used more extensively in the future. (Friedewald et al., 2003; Raisinghani et al., 2004). WAN has the ability to span the world and can be used by intelligent agents to search databases that are dispersed across continents for information that is pertinent to the user.
- **Cyber world:** Cyber world is the seamless interaction into cyberspace. To facilitate seamless interaction and the adoption of more interoperable technologies the Internet is changing too. The Internet Protocol version 4 (IPv4) is being replaced by IPv6 (Friedewald et al., 2003). With the development of the semantic Web, the Web will be given meaning in that it will be capable of accommodating smarter search engines and providing information to the user that is more tailored to their specific requirements.

Ubiquitous communication is the enabler of the ubiquitous computing. It is also the concept that transforms intelligent user friendly interfaces to allow for seamless interaction between computer to human and vice versa.

Intelligent User Friendly Interface

Intelligent users friendly interface "enables the inhabitants of the ………environment to control and interact with the environment in a natural (voice, gesture) and personalized way (preference, context)" (Alcaniz, 2005, p. 3). In essence this is done to provide an improved level of communication between the human and computer and visa versa. To achieve this, the interface adds increased functionality by making the system more intuitive, efficient, and secure. This allows the system to have a greater awareness about the user i.e. the situation, environment, and context that the user is in (Raisinghani et al., 2004). This is accomplished through the characteristics of the interface (Alcaniz, 2005; Friedewald et al., 2003; Raisinghani et al., 2004):

- Ease of use
- Ability to personalize
- Adapts automatically to user behavior
- Adapts automatically to different situations

This level of adaptation is achieved in developments in three areas that are discussed by Friedewald et al. (2003), multilingualism, multisensorial, and multi-modality.

- **Multilingualism** will provide the user with the language that they prefer to be used when they interact with the system. This creates a number of challenges for multilingualism. An example of this is an application that operates using multilingual text input or speech interpretation (Alcaniz, 2005; Ducatel et al., 2001; Friedewald et al., 2003).
- **Multi-sensorial** (sight, hearing, touch) is the concept that numerous sensors can be used to collect input from the user in the environment. These sensors collect information that is used by the system to adapt to the needs and wants of the user. This is an example

of collecting information implicitly from the environment that the user occupies to allow the system to adapt. This is related to context awareness (Alcaniz, 2005; Ducatel et al., 2001; Friedewald et al., 2003).

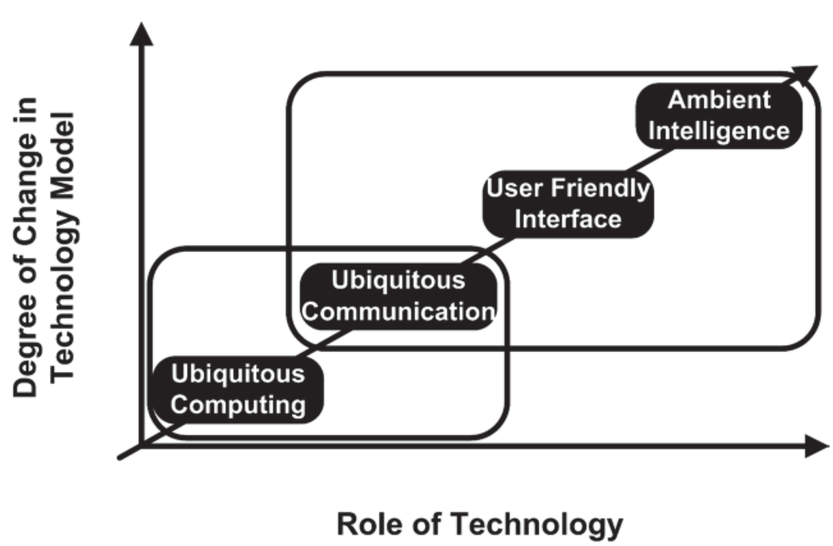
- **Multi-modality** (speech, touch, expression, gesture) interfaces need to use multiple modals to take advantage of the fact that humans communicate in numerous ways at the same time. Human users can use gestures, body language, and speech for example to express and communicate ideas and thoughts. By having a system that takes advantage of this level of interaction improves the natural interaction element of the system (Alcaniz, 2005; Ducatel et al., 2001; Friedewald et al., 2003).

Intelligent user-friendly interfaces have the potential to create a more natural interaction between humans and computers. It will also allow for complex tasks to be completed quickly and with ease. The system also manages the information and knowledge that it provides to the user. This may be accomplished through the use of tailored information being provided to the user. This information can be presented in the most efficient way for each user. In the example of a maintenance technician who needs his or her hands free to complete the task, the system may present the information in spoken format. This accomplishes a more user friendly environment where the user does not feel out of place and instead it will improve the satisfaction that user has for the system.

The Next Evolution

The integration of the three elements, ubiquitous computing, ubiquitous communication, and intelligent user friendly interface has led to the development of the AmI paradigm. Emiliani and Stephanidis (2005) describe the paradigm as being developed on the principles of invisible computing and intelligent mobile devices. The integration of these elements in the users environment will have a profound effect on the "type, content, and functionality of emerging products and services, as well as on the way people will interact with them, bringing about multiple new requirements

Figure 2. AmI evolution



for the development of information technologies" (Emiliani et al., 2005, p. 605). ISTAG (Ducatel et al., 2001) explains the usage of the technology in relation to the vision statement of AmI "on convergence humans will be surrounded by intelligent interfaces supported by computing and networking technology which is everywhere, embedded in everyday objects such as furniture, clothes, vehicles, roads and smart materials even particles of decorative substances like paint" (p. 11). The convergence of these technologies is demonstrated in Figure 2. The x-axis represents the role of technology as an enabler and a transformer. The enabler technologies facilitate the advancement of technology at a technical level. The transformer technologies permit the advancement of the technology at a more human centric level. The y-axis represents the degree of change in the technology model as tactical and strategic. The tactical change represents the approach taken to overcome a specific problem. The strategic change is a part of a long-term plan that will achieve the overall goals. They have been built on each other and enhance the technology further. This provides us with an appreciation of where it came from and what it is built on.

This diagram also shows two groupings of the technology. The first is ubiquitous computing and communication. These two technologies are linked together as they are symbiotic. Computers can be integrated in everyday objects, but if they cannot communicate with each other and with the humans that occupy the environment, they are of no real benefit as lone independent systems in the modern world in which we live. The second grouping is ubiquitous communication, user-friendly interface, and ambient intelligence. These three technologies are transformers; they create an easily accessible and navigateable environment that will benefit the user. The user will not require the ability to understand the intricate detail as to how the technology works in the background. The user only needs to know that the system caters to their needs as it comes into contact with the user. In the ideal scenario, the user may be interacting with twenty or more devices embedded into their environment without realising it. The AmI concept and definitions are examined further in the following section.

Concept of Ambient Intelligence

This section will explore the concept of AmI. A review of relevant literature relating to AmI definitions from key authors is presented. This allows for the development of an AmI definition that supports the research that is presented in the following sections.

The easiest way to convey the concept of AmI is through the use of an example:

An executive vice president in her office in Dublin could ask for an up to the minute efficiency report from one of their facilities in Chile for her board meeting. If she also requested that the efficiency report should be added to her presentation for the board meeting in five minutes. That would seem completely normal. Except that she was talking not to her secretary but to her mobile phone.

This could be one of the plausible scenarios for AmI in the years to come. The mobile phone has evolved from what we know it to be today and has become somewhat of a hybrid. It can interact with many other computing devices within 10 meters of it. It also works like a PDA in that it will allow the user to access for example, Microsoft documents wirelessly within a secure environment. It also contains all the relevant information on the individual, for example, it may monitor their health. By containing advanced speech recognition software (SRS) it now has the ability to process the information that it receives. All the information in the electronic devices is written in a format, which allows for the use of intelligent agents in this case searching the servers for the relevant information to the request and then presenting the information in an appropriate format for the presentation. This is accomplished by the fact that the AmI has learned how the vice president presents her work and will format the presentation to comply with this request (Ducatel et al., 2001; Friedewald et al., 2003).

Defining

The previous scenario describes an AmI environment which humans inhabit. The AmI concept that was presented in the previous section will be further developed in this section with a focus on the definitions of AmI from key authors in the area. Various definitions are outlined and the important aspects of AmI are summarized. A definition of AmI is presented that aligns with the research in this chapter.

Definitions are fundamental to the understanding of AmI as they illustrate the properties of AmI and they explain the term in relation to related terms. They lay the foundation of our understanding of this new concept.

The concept of ambient intelligence is made up of two words "ambient" and "intelligence." Ambient is described as the environment in which we inhabit. Morville (2005) defines ambient as being an "encircling" and "completely enveloping" (p. 6) environment. In essence the physical ambient environment becomes the user's interface in a digital world. Providing only the necessary information that the user requires tailored to the users specific needs and level of knowledge.

Intelligence is more elusive, Hofstadter (1980) suggests that certain characteristics denote intelligence. He represents intelligence as the ability:

- "To respond to situations very flexibly.
- To take advantage of fortuitous circumstances.
- To make sense out of ambiguous or contradictory messages.
- To recognize the relative importance of different elements of a situation.
- To find similarities between situations despite differences which may separate them.
- To draw distinctions between situations despite similarities which may link them.
- To synthesize new concepts by taking old concepts and putting them together in new ways.
- To come up with ideas which are novel" (p. 26).

The descriptions of ambient and intelligence that are presented create an environment where technology is all encompassing and has the ability to adapt and learn. This leaves the task of programming intelligence into a computer. Computers by their nature are inflexible and rule following. They also lack the desire to show initiative. The characteristics above describe intelligence and the description of ambience illustrates the environmental interaction that is needed to achieve ambient intelligence. A number of definitions of ambient intelligence have been put forward over the last few years. A selection of these definitions are discussed and analyzed.

Ambient intelligence is lauded to be "a digital environment that is aware of" human "presence and context and is sensitive, adaptive, and responsive to their needs, habits, gestures, and emotions" (ITEA, 2003, para. 1). Ambient intelligence is a pervasive and proactive technology that is omnipresent. Horvath (2002) develops the definition further in practical terms, "this means we will be surrounded by intelligent interfaces embedded in everyday objects such as furniture, clothes, vehicles, and roads" (para. 2). He also highlights the fact that the technology will be omnipresent and learn "these interfaces register our presence, automatically carry out certain tasks based on given criteria, and learn from our behavior in order to anticipate our needs" (para. 2). Lindwer et al (2003) delves more into the human actors interactions with the AmI system and defines it as a technology that is "invisible, embedded in our natural surroundings, present whenever we need it," the technology is easily "enabled by simple and effortless interactions," that are "attuned to all our senses, adaptive to users and context and autonomously acting" (p. 10). The ISTAG (Ducatel et al., 2001) definition is the most comprehensive for ambient intelligence as it describes the "seamless environment of computing, advanced network technology, and specific interfaces" (p. 11). It also communicates the interaction that is envisioned with the user, "aware of the specific characteristics of human presence and personalities, taken care of needs and is capable of responding intelligently to spoken or gestured indications of desire, and even can engage in intelligence dialogue" (p. 11). ISTAG further articulates the environment in which the technology will exude, "unobtrusive, often invisible; everywhere and yet in our consciousness - nowhere unless we need it" (p. 11). The interactions with the users "should be relaxing and enjoyable for the citizen, and not involve a steep learning curve" (p. 11).

For the purposes of this discussion, the author defines 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.

The following section reviews some of the socio-technical implications of ambient intelligence on the human user.

Socio-Technical Implications of Ambient Intelligence

AmI by its very nature that has been discussed in earlier sections is centred on the user. Due to this fact, it has socio-technical implications. The following subsection will discuss the implication of AmI with regard to monitoring of users which highlights issues regarding trust, safety, security, and privacy. The next subsection will review the impact that an AmI environment could possibly have on the knowledge worker. With Europe moving towards an information society the knowledge worker becomes more prevalent on the landscape and their use of the AmI environment is crucial to the success of the paradigm.

Monitoring: Trust, Safety, Security, Privacy

Aarts (2004) states "The opportunities of ambient intelligence also comes with threats" (p.18). One of the key factors to ensuring the successful integration of AmI into the environment is the trust of the user in the system. The core function of AmI is to monitor the environment which the user occupies waiting for the right moment to assist the user. A number of concerns are raised with regards to such an environment, the safety and security of users. Some of these include Casal, Burgelman, and Bohlin (2004), Raisinghani et al. (2004), and Wright (2005):

- Such an open system could be susceptible to influences by outsiders (i.e., hackers or viruses).
- The system will be storing large amounts of personal information, which could threaten privacy and security.
- The personal response that the system will give to each user requires the recording of the user behavior, which leads to privacy issues.
- The users will co-exist in an environment that contains technologies that are capable of making autonomous decisions.
- If these technologies become uncontrollable this could create a serious concern.

Some of these concerns are prevalent today; radio frequency identification (RFID) technology is causing unease among customers who buy products that contain RFID tags. RFID is the successor to bar coding. This technology can provide information on location and movements. It is made up of a small tag, which contains an integrated circuit chip and an antenna. The chip and the antenna give the tag the ability to recognize and respond to radio waves which are transmitted from a RFID reader (Kiritsis, Bufardi, & Xirouchakis, 2003; Potter, 2005). If the tags are not disabled, they are capable of being used to track customers. A RFID tag that is designed to be read up to 30cm away, could be read by an invader approximately 30m away. The invader could also manipulate the data on the tag. To subjugate this problem some retailers replace the information of the tag to random data when it is sold. With random data stored in the tags it is no longer linked to information in the retailers database (Potter, 2005). Another method that is discussed by Potter (2005) is the KILL command. This command when received by the RFID stops it responding to RFID readers.

Concerns regarding trust, safety, security, privacy of personal users of the AmI environment are crucial to a successful introduction of the system and the acceptance of the users of the system. If the users do not have faith in the system and use it, the system will become redundant and the development will have been a waste of time, effort, and expense.

Ambient Intelligence and the Knowledge Worker

The technologies that enable AmI will have a dramatic increase with regard to the availability and ease of access that knowledge workers will have to data and computing facilities. Davis (2002) described knowledge work as being "cognitive rather than physical" (p.68). The knowledge worker is for example a professional, an accountant, manager, programmer, or lawyer. They output evaluations, instructions, or arguments. This is all based on the mental capabilities of the worker to develop information and knowledge from training they received, or data that they have been given. In completing this form of work the knowledge worker accesses the data and computing facilities. With the introduction of the AmI environment the knowledge worker will have far greater access to the information at any time and at any location. This will be accomplished thought availability of embedded devices in the surrounding environment. The knowledge worker will be released from their office environment and from fixed working hours.

The benefits and the drawbacks of knowledge workers having access to computing facilities at all times and at any location are discussed by Davis (2002), Drury and Farhoomand (1999), and Kidd (1994). This discussion leads to the possible benefits, the first being the elimination of constraints on communication. The location, time, and environment in which the knowledge worker inhabits in AmI will not constrain the ability of the knowledge worker to communicate. The AmI environment can provide information and data in a timely manner that is tailored to the user's particular requirements. The second is the ability of the knowledge worker to work in conditions and at times that they are most productive. An example of this could be an engineer who has an idea in the middle of the night of how to solve the productivity problem on an assembly line and has access to the information so that the problem can be solved from home before production starts at 8 o'clock in the morning. The third is an improvement in the knowledge with regard to the location of people. As the knowledge worker has access to information and analysis at anytime, the result is more prudent responses to requests and critical information being exchanged more efficiently among key stakeholders. The final benefit is for example the improvement in the information that is gathered regarding the company. This may include the availability of real-time information from the shop floor in relation to production or quality. This allows managers to access information and solves problems as they arise (Davis, 2002; Kidd, 1994).

The possible drawbacks are discussed, first being the management of the individual. The level of distractions that enter the realm of the knowledge worker will increase. The knowledge worker will require guidelines and training with regard to how best to manage their time. This can be demonstrated by the use of e-mail; the norm is now to respond to all e-mails immediately, which takes away from productivity. The second is a possible reduction in boundaries between personal and work life. As the knowledge worker is always contactable there may occur an invasion of the knowledge workers private space. Finally the access to unlimited information may result in decisions being made in haste without an adequate level of thought been exerted on the problem resulting in a quick fix. This may lead to a larger problems in the long term. The information that is provided needs to be filtered and analysed prior to action being taken. (Davis, 2002; Drury et al., 1999)

Discussed above are only possibilities, it is not known how the users will react to the AmI environment. It is important to consider the benefits and the drawbacks of such an environment in the development of an AmI system. This needs to be facilitated so that some of these issues can be solved and considered in the design, which is the least costly phase to make changes to a system and also the least complex.

Summary of Key Findings

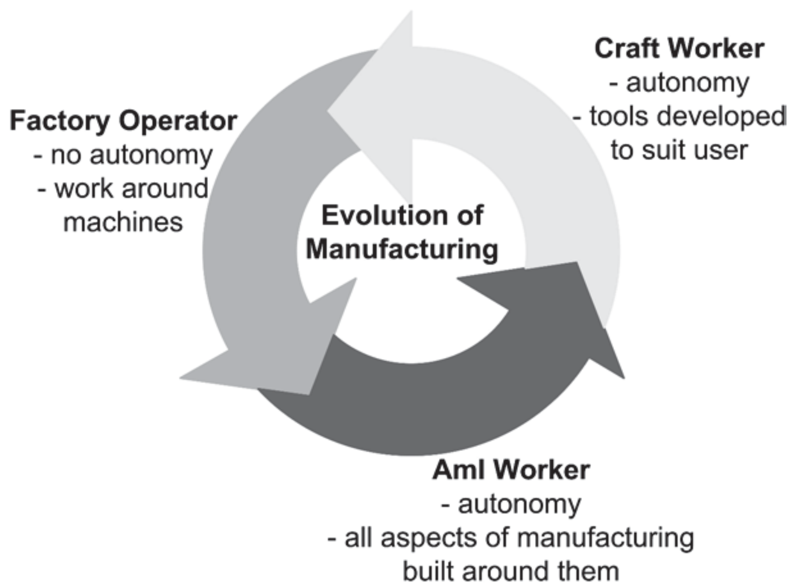
The concept of AmI is obscure. The AmI concept involves a complex combination of elements that together create the AmI environment. Each definition that was presented in the literature review highlights slightly different aspects of the concept as being of greater importance than others. Therefore a comprehensive definition and explanation to support the concept is needed. 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.

There are numerous technologies that can be used in combination to create an AmI environment. No single technology incorporates the characteristics of the AmI environment. Only when combined seamlessly with other enabling technologies is the concept realized. In designing and implementing an ambient intelligence system that caters to the needs of the user, the requirements of the user need to be gathered. This gathering of information gives the designer 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 designers and developers 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 drawbacks. To create the environment requires cross-functional involvement by multidisciplinary team in the development process. In the following section a typology and taxonomy are presented that support the development of an AmI system. AmI is an inspiring concept and with its introduction will change the way that we work and live our lives.

TOWARDS A FRAMEWORK FOR AMBIENT INTELLIGENCE

This section examines the need for a structure to help developers of AmI systems develop systems that are AmI and user centred, it incorporates the research that is presented in the previous sections. In doing so it presents various elements of research, a typology, and a taxonomy that help to further the developers understanding of interacting elements of an AmI system. The typologies

Figure 3. Evolution of manufacturing



that are presented have been developed by Gill and Cormican (2006). The first element is a typology for AmI that incorporates the tasks and skills that the system needs to be cognisant of. The second element is the taxonomy that reflects the development of technologies in the AmI environment. The elements outlined are interrelated and this relationship is highlighted with AmI system development structure. The manufacturing environment is used to demonstrate the implications of the typology and taxonomy.

Over the last 200 years, the manufacturing environment has come full circle (Figure 3). Prior to the industrial revolution, there were craft workers who through the use of their skills had autonomy over their work and conditions. The tools that they used were developed and tailored to their specific needs. They were entrepreneurs and mainly sole traders who passed on the skills to their children. During the industrial revolutions machines became the driving force of evolution and development. In the earlier years, they were crude, but over time developed into high precise pieces of machinery. The production process no longer revolved around the human; instead, the human was required to meet the needs of the machines. As the machines became more efficient, the human was in many cases designed out of the system and their role was taken by robots and other machines during the automation of production processes. AmI reverses the trend and gives the human more autonomy by creating an environment where all aspects of manufacturing are built around him.

Ambient Intelligence System

Typologies and taxonomies are classification techniques. Classification is the act for placing order on units to form groups and classes purely on the basis of similarity (Bailey, 1973, 1994; Rich, 1992). It lays the foundation for language, speech, mathematics, statistics, data analysis, and conceptualizations (Bailey, 1973, 1994; Rich, 1992). In essence it is both the process and the end result. A typology can better facilitate an understanding and communication of the AmI concepts and philosophy. A typology may also be known as a taxonomy or classification. The Oxford English Dictionary (2005) defines a typology as "classification according to general type… the study and interpretation of types and symbols" (para. 1). Typologies are therefore groupings of models, which describe different aspects of the same characteristics. There are as with any technique advantages and disadvantages to its use and later interpretation (Bailey, 1973, 1994). The advantages and disadvantages of classification in relation to typologies and taxonomies are discussed by Bailey (1994), they are summarized in the following:

Advantages (Bailey, 1994):

- It is the foremost descriptive tool. A good classification provides the user with an extensive array of types.
- It helps to reduce complexity by providing a very frugal explanation of the concept being demonstrated.
- It allows for the grouping and identification of similarities.
- It allows for the difference within cases to be identified.
- Typologies and taxonomies need to show all the types and dimensions that are possible. They also necessitate the inclusion of the relationship between both the types and dimensions.
- It allows for use as a quick reference and for quick comparison between types.
- It provides the research with the tools needed to know the position of any type and to also know which types are in use for analysis.
- Typologies may be used not only for describing but also in some cases to explain the relationships between cases.

Disadvantages (Bailey, 1994):

- Typologies are not mutually exclusive and exhaustive. They are only as useful as the information and research that was used to develop them.
- They should not be seen as an ends in themselves. The typologies are used as a tool to achieve the aim or objective.
- Some typologies are not concise enough for their area of use.
- Some typologies are based on subjective and random criteria.
- Typologies are fixed or static. They only represent the information that was used to develop them. As such they are not dynamic.
- Typologies are categorized by mainly their differences rather than their similarities.
- Typologies can at times be treated as objects rather than as concepts.
- Typologies tend to be more descriptive rather than explanatory or predictive.

In literature many models and theories can be found, some examples of these are Hellenschmidt and Kirste (2004) developed a topology for AmI middleware and Riva et al. (2005) presents the development of the technology that has led to AmI. These models and theories however do not take a combined view of the characteristic of what an AmI system should include. They look at the technological areas that AmI has evolved from and the technologies that can be used to initiate an AmI system. With regard to this the typology that is presented will help in outlining; what constitutes an AmI system, what are the unique characteristics and how it differs from other technologies and if not AmI what characteristics it must have to achieve AmI. The typologies below have been developed to assist in the understanding and the development of an AmI system. In particular to help to remove the ambiguity around what constitutes AmI. The first is an AmI system typology and the second is AmI taxonomy. The AmI system typology illustrates the tasks and the skills that an AmI system must have. The AmI taxonomy shows the evolution of the technology in relation to three areas: mobility, pervasive intelligence, and human and computer interactions in comparison to technology complexity and the development of higher value products for the end user.

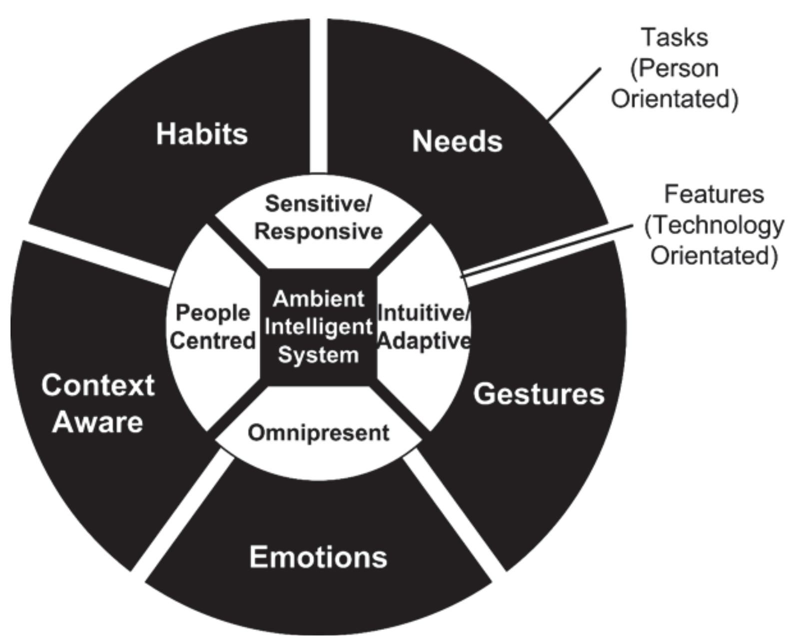
Ambient Intelligence System Typology

AmI is centred on the human actors, because of this there are two main areas that together define what is and what is not an AmI system. The outer ring of Figure 4 represents the tasks that the AmI system needs to respond to and the inner ring has the skills that AmI system should contain. The tasks are person orientated, in that they represent the human characteristics that the AmI has to be aware of, in other words they represent the human characteristics that the system needs to recognize and needs to respond to. The skills are technology orientated, in that they represent AmI characteristics that the technology must have to interact with the human actors. They represent what the technology must innately accomplish as its aptitudes. Both are inseparable, interlinked and interdependent, the link between them is shown in Figure 4.

The tasks are:

- **Habits:** A habit is something that we do often. The AmI system should recognize the users' habits and adapt to suit them. These habits may include the customs, routines, practices, traditions, conventions, patterns, tendencies, inclinations, likes, and preferences of a person.
- **Needs:** A need is something that humans have to have to survive. The AmI system in a home may learn that one of the occupants is allergic to nuts and if food was brought into the home that contains nuts, it would inform the occupants. As such, it could

Figure 4. Ambient intelligence system (Gill et al., 2006)



recognize requirements, wants, necessities, the things we cannot do without, our must haves, essentials, and prerequisites.

- **Gestures:** This is the movement of body parts to convey feelings. AmI systems will be able to sense changes in humans from their body language and learn to adapt and respond to it. The gestures could be for example a motion, wave, shrug or a nod.
- **Emotions:** Emotions are feelings that one has. These feelings could be sadness, joy, boredom, etc. The AmI technology should be able to recognize the outward manifestations of the various emotions that humans experience.
- **Context aware:** The AmI is required to recognize the difference between, for example crying for joy and crying for sadness. The two would require a completely different response from an AmI system. This could be achieved through a combination of speech recognition software (SRS) and sensors that recognize differences in the human reactions, the AmI system should be able to recognize the context in which the human actor is communicating.

The skills are:

- **Sensitive/responsive:** The system needs to be tactful and sympathetic in relation to the feelings of the human actor, has to react quickly, strongly, or favorably to the various situations it encounters. In particular, it needs to respond and be sensitive to a suggestion or proposal. As such, it needs to be responsive, receptive, aware, perceptive, insightful, precise, delicate, and most importantly finely tuned to the requirements of the human actor and quick to respond.
- **Intuitive/adaptive:** AmI needs to be able to adapt to the human actor directly and instinctively. This should be accomplished without being discovered or consciously perceived therefore it needs to be accomplished instinctively (i.e., able to be adjusted for use in different conditions). The characteristics it is required to show are spontaneity, sensitivity, discerning, insightful, and at times shrewd.
- **People centred:** AmI's most basic requirement is that it must be focused on the human actor. If a systems focal point is not the human actor then it is not an AmI system.
- **Omnipresent:** The AmI will have to be seemingly present all the time and everywhere. As such, it will have to be ubiquitous.

Now that we have reviewed the elements of the AmI system we will discuss in detail the application of these principles to the manufacturing industry

AmI is human centred therefore the AmI system in the manufacturing industry can only exist in its interaction with the human user. In this case, it is the human operator. In reviewing the information that is presented in the earlier section a deduction is made of what the AmI concept is and how it can be manifested. The system in the manufacturing industry environment needs to possess a minimum of three of the following characteristics:

- Ease of interaction through an appropriate level of multimodality with the human operator, this may include both or just one, explicit and implicit (inputs and outputs) interaction.
- Information and knowledge of the manufacturing environment and the human operator based on models which provides prior knowledge or history and sensory observations to collect information on the ambience environment and ease of interaction with the human operator. The collection of dynamic knowledge on the following:

   - Human operators (e.g., location, context, her/his intensions, etc.)
   - Process environment in which the human operator is working and interaction among the human operators and process environment
   - The system itself and its interaction with the environment, which provides a level of context surrounding its use.
- Providing support to the human operator with regard to processes, this may include supplying a tailored task execution list to each human operators requirements. The functionality can be imparted by using the systems intelligence. This can be based on the knowledge on the ambience environment related to each unique human operator that is involved in the business processes.
- The implicit actions in processes, these actions are not visible to the human operator.
- The implicit actions in ambience, these actions are not visible to the human operator. They involve the system adapting to the needs of the human operator.

There are some addition characteristics that are identified by the DG Information Society (2004) and include following:

- The ability of the system to develop its own rules on how best to interact with near by systems and the human operator. At the same time continuously trying to progress the development of its own tasks and the interaction, which it has with the environment.
- The system needs to have the ability to be dynamic. It should have the ability to configure and reconfigure under varying and even unpredictable conditions.
- It is essential that the system be resilient and able to recover from events that may cause some of its parts to malfunction.
- The system is required to be trustworthy as to handle issues of safety, security and privacy.
- The system should be traceable.

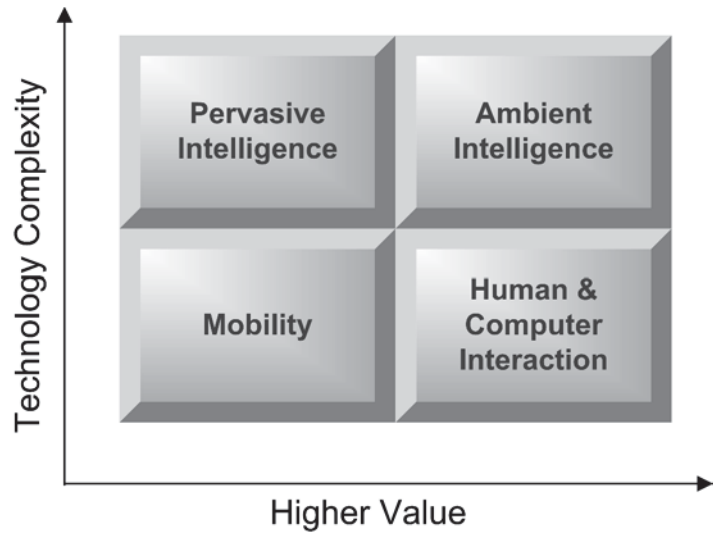
These conclusions are used in the refinement of the taxonomy that is presented in the following subsection.

Ambient Intelligence Taxonomy

The AmI taxonomy (Figure 5) shows the evolution of the technology in relation to three areas; mobility, pervasive intelligence and human and computer interactions in comparison to technology complexity and the development of higher value products for the end user. The taxonomy for example can be viewed in respect to the evolution of mobile communications. The x-axis represents the technology complexity and the y-axis the higher value of the technology to the user. The technology complexity can be explained as the evolution of the technology; it becomes more complex as we continue to add on more options, requirements, applications, etc. The higher value of the technology refers to the user friendliness and improved usability of the technology or system, which increases the value of the product in the eyes of the end user. The elements of the taxonomy are as follows:

- **Mobility:** At a basic level, for example a pager that gives only mobility; there is no nice user interface.
- **Pervasive intelligence:** Mobile phones for example that can interact seamlessly and invasively with technologies around them are an example of pervasive intelligence. This could be a mobile phone with Bluetooth technology that can interact with other mobile phones and with other technologies that have Bluetooth. The technology therefore begins to encompass and envelop the human actor and by doing so becomes omnipresent.

Figure 5. AmI Taxonomy (Gill et al., 2006)



- **Human and computer interactions:** A mobile phone that has a user-friendly interface and which allows one to track personal goals and as such has all the functions of a PDA. It can make connections and exchange data on your behalf.
- **Ambient intelligence:** A combination of both the human and computer interactions that makes the technology user friendly and feel safe in the customers hands. The pervasive intelligence allows the technology to work unobtrusively in the background.

The definition, typology, and taxonomy that have been previously presented are tools to be used in the development of an AmI system. They have been designed to incorporate a holistic approach to the development of the system. The typologies that are presented will help in outlining, what an AmI system is and what characteristics are needed to achieve an AmI system. They are not a means to an end in themselves but are tools to assist developers, analysts, and potential user in their understanding of the concept.

FUTURE TRENDS

AmI is an evolving concept and research in the area covers numerous areas. AmI is built on the research and work in the areas of ubiquitous computing, ubiquitous communication and intelligent user-friendly interface. These areas are developing from theories in the laboratory to real world applications.

The real question is whether or not AmI will be adopted out side of Europe. For an AmI society to emerge certain developments need to be in place. These include some technology requirements. These technology requirements for achieving an AmI system are listed in the ISTAG report 'Scenarios for Ambient Intelligence in 2010' (Ducatel et al., 2001) are:

- "Very unobtrusive hardware.
- A seamless mobile or fixed Web-based communication infrastructure.
- Dynamic and massively distributed device networks.

- A natural feeling human interface.
- Dependability and security" (p. 9).

In achieving these requirements there needs to be an amalgamation of the fundamental developments in the area of ICT which will assist in the development of AmI. These developments include (Ducatel et al., 2001; Friedewald et al., 2003; ISTAG, 2000):

- Human Machine Interface (HMI) which may involve humans commanding machines and an improvement in robotic usability;
- The introduction of networked products through the use of wireless technology in the monitoring of product lifecycles; advancements of adaptability and reconfigurable production lines allowing for mass customisation and wireless shop floor configuration;
- The enhanced modelling of supply chain process and the long term monitoring of the behavior of products in their working life;
- Supporting knowledge creation and development by reducing the factors that hinder the transfer of knowledge across teams and organisations;
- The ability to develop integrated and co-operative design of products, processes and services with suppliers, end users and strategic partners;
- The ability of equipment software to become context aware through the use of sensors and actuators to grow into becoming self-correcting and the raise of research into nano-technology.

These developments in the area of ICT are fuelled by the need for advanced ICT services. It is not clear yet how the AmI environment will be created, but Emiliani et al. (2005) and Ducatel et al. (2001) discuss the evolution being based on the present development trends. This will involve:

- Services becoming dynamic and reconfigurable to suite the needs of users.
- Use of multiple devices to communicate and interact with various systems that occupy the user environment.
- Interaction in the system is multimodal and is completed on a more graphical basis.
- Problem solving may occur between human users in a more dynamic way due to increase in resources or between agents that have been granted a specific level of trust.
- Communication is spread to encompass social groups and not just person to person communication.

These developments in ICT and service trends can utilize the typologies that have been presented in the chapter to choose enabling technologies. Technologies that compliment each other and that provide the key characteristics that create an AmI environment for the user.

The typologies that have been developed and presented can be used in the alignment of these developments with the AmI paradigm. They will need to evolve and adapt to encompass new research in the area of AmI.

CONCLUSION

To survive the changing business environment, companies must be able to innovate and become more flexible. Companies need to be able to change and innovate more effectively and efficiently. To adapt to the fluctuating business environment, business's need to have an ICT system that is flexible and adaptive to their changing needs and requirements. This will involve developing real-time information systems that can adapt to changing technical, manufacturing and organisational structures. AmI can be used as a conduit to achieve this.

To create an AmI environment, requires the use of a combination of technologies. The AmI environment can be enabled through the use of computers that are embedded into everyday objects and through the use of wireless communication. The interaction between these embedded devices and the human user is improving through advancements in the area of natural interaction. As with all new developments there are some negative aspects that need to be considered and discussed with all potential users. These aspects relate to the omnipresent nature of the technology and the level of data collected by the system. These aspects of the system may inadvertently collect and record information that may violate the privacy of the individuals that are interacting with the system. If this data is recorded and stored it must be secure and only accessible to authorized users of the system.

AmI is 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. The typologies presented facilitate an understanding and communication of the AmI concepts and philosophy. These typologies should assist the developers, by having an improved understanding of the AmI paradigm. It will allow for the development of enhanced AmI systems. The typologies are new models as they are based on the human side of the AmI, as previous models in literature concentrated on the technologies that enable the AmI system. The typologies are not panaceas. They will only assist in the development of AmI systems. The typologies will also help in defining what AmI is and what it is not.

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