Vladimír Bolek

Ambient Intelligence in Enterprises

Predictors, Barriers and Areas of Implementation



Leges

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AMBIENT INTELLIGENCE IN ENTERPRISES

PREDICTORS, BARRIERS AND AREAS OF IMPLEMENTATION

Vladimír Bolek

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INTRODUCTION

Information and communication technologies are of fundamental importance for sustainable and long-term economic development. The rapid development of information and communication technologies makes it impossible to predict exactly how the information society will change in future. We are also unable to precisely define nature of new smart businesses or how business processes will be modified by innovative technologies. Current trends in this area suggest only a certain possibility of predicting that the key element will be ubiquitous new information and communication technologies communicating via the Internet and the Internet of Things. These technologies are characterised by ubiquity, and in this scientific monograph we will refer to them as innovative pervasive technologies that are capable of self--management, optimization, and replication. Innovative pervasive technologies also function independently, but when they are combined, they integrate physical and virtual worlds, bringing about a very significant synergistic effect. Through their ability to learn, self-regulate, and respond to user requests even without conscious intervention, they create an ambient environment.

The emergence of these technologies was driven by demands of Industry 4.0, and they in turn contribute to its development. Innovative pervasive technologies and the Internet, which have sparked an industrial revolution in society, are becoming hyper-aware systems, representing highly flexible technologies that follow clear algorithms and respond not only to human commands but also to their own perceptions and direction. In literature, in connection with the integration of innovative technologies into business processes, we encounter terms such as data collection and analysis, new ubiquitous technologies, sophisticated sensors, robotics, cloud computing, the Internet of Things, digital manufacturing, autonomy, system interoperability, digitisation, virtualization, artificial intelligence, augmented reality, and ambient intelligence. Implementation of these technologies in business processes creates a new environment that we call ambient business intelligence.

Ambient intelligence represents a new paradigm. This paradigm, anywhere and anytime, is becoming a new challenge for the concept of next-generation information and communication technologies. New technologies, such as Wi-Fi networks and third- and fourth-generation mobile

networks, provide the infrastructure required to design ubiquitous information systems, that is, systems accessible from almost anywhere, at any time, and through almost any electronic device. However, the use of such ubiquitous access to information systems requires new concepts, models, methodologies, and supporting technologies that can fully explore its potential. In this context, mobility introduces new accessibility scenarios and increases the demands on companies providing IT services and products.

Ambient intelligence is a fundamental concept in the normative visions for information technology in the European Union. It also represents a general framework for the European information society and it is its long-term vision.

A review of domestic and international literature indicates that previous studies have not addressed ambient intelligence comprehensively from a business management perspective or examined the interaction among the factors affecting its development. We identified no empirical studies that examined companies across a broad range of size categories and economic sectors. Instead, the existing literature has been predominantly theoretical and has focused on conceptual analyses, future scenarios, expert perspectives, policy recommendations, and national and international strategic frameworks. Most of these studies have therefore adopted a conceptual or visionary rather than an empirical perspective. Application-oriented research has generally examined the implementation of ambient intelligence within specific sectors, such as healthcare and construction. The identification of this research gap was one of the principal motivations for selecting the topic of the research project.

Based on the analysis, dissection, comparison, systematization, and taxonomy of theoretical knowledge about ambient intelligence, integration of information and communication technologies, innovative pervasive technologies, and the current state of corporate practice, we have set the main objective of our research, which is to examine the current state of integration of innovative pervasive technologies in corporate practice in Slovakia and, at the same time, to identify predictors influencing the level of ambient intelligence of a company.

This scientific monograph is structured into five chapters. The first chapter focuses on analysing the current state of issue at home and abroad. The introductory part of this chapter points out the basic conceptual apparatus, applies it to business practice and the fourth industrial revolution. Ambient intelligence is one of the key elements of the fourth industrial revolution.

In this chapter, we define terms innovative pervasive technologies, intelligence, digitisation, virtualisation, augmented reality, and ambient intelligence. The chapter includes a comparison of definitions for ambient intelligence, which we classify into three groups: technologically, multi-faceted, and visionary definitions. With definitions structured in this way, it is possible to clearly identify fundamentals of ambient intelligence and development of the concept over time. In the next subchapter, we focus on areas of interest in ambient intelligence covered by definitions from domestic and foreign authors, which resulted in a synthetic table of areas of interest in ambient intelligence and a proposed definition of ambient intelligence. Subsequently, in the following subchapters, we analyse properties and elements of ambient intelligence and present ambient intelligence platforms, which we have divided from a technological and integration perspective. Scenarios of Ambient Intelligence is a title of next subchapter, where we analyse and compare four scenarios of ambient intelligence that represent the vision of ISTAG (the European Commission's advisory group for the Information Society and Information Technologies Program), contrasting applications that serve to optimize efficiency, whether in business or in companies themselves. ISTAG perceives the concept of ambient intelligence as providing a vision of an information society in which the emphasis is on greater user-friendliness, more effective service support, user empowerment, and support for human interaction. By integrating innovative pervasive technologies, companies achieve financial, customer, and process benefits. This separate subchapter analyses these effects from a theoretical perspective and highlights results of studies. We encounter potential barriers when integrating innovative pervasive technologies and building ambient intelligence. In subchapter 1.7 Barriers to Building Ambient Intelligence in Enterprises, we analyse theoretical foundations of authors who have studied these barriers. It creates a sufficient theoretical basis for the construction of research focused on perception of significance of barriers by companies when building ambient intelligence.

The second chapter sets out main and partial objectives, fulfilment of which predicts achievement of main objective. This chapter includes research questions that are justified by theoretical principles and constructed under certain research assumptions. We have formulated several research hypotheses to be able to answer the individual research questions accurately.

The third chapter contains methodology and research methods used for individual parts of research. This part describes the research object, research model, work procedures, data collection methods, and data sources. We pro-

vide a detailed description of methods used to evaluate and interpret results. We use an extensive set of scientific methods and a wide range of statistical tools in order to obtain the most accurate results possible.

The main part is the fourth chapter – Results of research. It contains evaluation and interpretation of data obtained in relation to the research model. This chapter is structured as follows: integration of innovative pervasive technologies in business processes, predictors influencing the development of ambient intelligence, effects achieved through the integration of innovative pervasive technologies, barriers to the development of ambient intelligence in a company, areas of development of ambient intelligence in a company.

The final chapter is Discussion. It synthesizes findings and compares them with theoretical approaches of domestic and foreign authors. In individual subchapters, we point out conclusions from the research for each part and supplement them with findings from other research studies. The findings and conclusions from the analysis of theoretical principles and evaluation of data obtained formed a basis for the proposal of phases of business transformation leading to creation of an ambient ecosystem. This chapter also includes limitations of research, as every research and study has its limitations. This scientific monograph also presents benefits and recommendations for the scientific research field, business practice, and education. At the end of this chapter, we predict the possible direction of future research in this area.

This scientific monograph attempts to clarify the issue of ambient intelligence, which represents a new approach and concept in the field of information and communication technologies. In this way it contributes to expansion of current knowledge and providing insight into the current state of affairs in this field in companies in the Slovak Republic.

1 THEORETICAL BACKGROUND

Continuous scientific and technical progress in a field of information and communication technologies, miniaturization and integration of information and communication technologies into everyday life, generation of large volumes of data, and information overload have led to the existence of ubiquitous computing power. We are currently in a period of unprecedented change, which we refer to as Industry 4.0, or „The Fourth Industrial Revolution."

Basics of The Fourth Industrial Revolution are created by integration of information and communication technologies, information systems supported by information technologies, and their interconnectivity and communication between them.

Xu, David and Kim (2018) define The Fourth Industrial Revolution as: computer, computer-generated product design, three-dimensional printing. In 2011, Henning Kagermann, head of the German National Academy of Technology (Acatech), used the term Industrie 4.0 to refer to a proposed industry-backed initiative. Industry 4.0 has gained a strong foothold in Germany and has generated major initiatives in the country's industrial enterprises.

Enterprises BASF, Bosch, Daimler, Deutsche Telekom, Klöckner & Co., and TRUMPF are the main integrators of Industry 4.0 technologies, according to The Economist. The initiative is also growing rapidly in other countries, particularly in the US, Japan, China, Scandinavia, and the UK. Global economic leaders such as Siemens and GE, have fully embraced this new technological revolution. The CEOs and managers of both companies have stated that Industry 4.0 and related technologies are now "a key part of their identity" (Gross, 2016).

Given the rapid pace of digitisation in industry, this situation does not seem hyperbolic at all. It is a sweeping change that is transforming many areas of society, not just industry. Industry 4.0 (Geissbauer et al., 2016) focuses on combining several significant innovations in information and communication technologies and digital technologies that can transform almost all sectors of economy. The Fourth Industrial Revolution is changing (Schwab, 2017) the way we interact with each other and even the work we do. It is also changing the way the economy works.

The Fourth Industrial Revolution is characterised by digital transformation of the surrounding world with an obligatory interaction between people, information and communication technologies, and material elements.

Digitisation and new technologies are transforming the world into a digital one, leading to changes in customer behaviour, business models, innovation, ways of working, and even a new generation of „digital natives." Businesses and organisations have to change their corporate culture, which will be marked by these developments.

This digital world is characterised by concepts such as virtuality, mobility, big data, the Internet of Things, etc., which are significant platforms that enable this change. These elements create an increasingly fast-paced and complex environment that requires businesses and organisations to be more agile, better prepared, and able to establish themselves and adapt. They have to be aware of what they are doing, how they are doing it, and be prepared to adopt new working methods.

Stock and Seliger (2016) point out that current globalization faces the challenge of coping with ever-increasing global demand for capital and consumer goods while ensuring the sustainable development of human existence in social, environmental, and economic terms. They emphasize that Industry 4.0, with help of innovative technology integration, provides great opportunities for sustainable production.

In the following subchapters, we point out origins of ambient intelligence, analyse in detail definitions of the conceptual apparatus of ambient intelligence by domestic and foreign authors, and point out heterogeneous and homogeneous elements in these definitions. We classify the authors' definitions of ambient intelligence into three groups (technologically, multi-faceted, and visionary definitions) and arrange them chronologically within these groups to make developments in this area clearer. The dissection of conceptual apparatus has led to the identification of areas of interest in ambient intelligence covered by the definitions of domestic and foreign authors.

In the next section, properties and elements of ambient intelligence are characterised. An important substance of ambient intelligence are its platforms, which we have categorized into two groups, namely from a technological and integration perspective. Several scenarios and contexts for the applicability of ambient intelligence can be identified in the literature; an analysis of the content of selected scenarios is included in the sixth subchapter.

The last subchapter is focused on effects achieved by integrating innovative pervasive technologies that constitute ambient intelligence. We divided these effects into three groups: financial, customer, and process effects.

1.1 Foundations of Ambient Intelligence

Over the last twenty years, we have witnessed a major revolution in information and communication technologies that has affected all areas of economic and social life.

Innovative technologies are important in their own right, but in combination, they integrate physical and virtual worlds, creating a significant synergistic effect (Geissbauer et al., 2016). The Internet and the Internet of Things are important elements that connect these technologies. Authors Geissbauer et al. (2016) in connection with Industry 4.0, and the integration of information and communication technologies, argue that „the technologies and internet networks that have brought about an industrial revolution in society are becoming hyper-aware systems; they are highly flexible technologies that respond not only to human commands but also to their own perceptions and direction, and they operate according to clear algorithms."

Industry 4.0 is currently the subject of extensive academic debate and research. Domestic and foreign authors (Lasi et al., 2014; Brettel et al., 2014; Rüßmann et al., 2015; Geissbauer et al., 2016, Stock & Seliger, 2016; Roblek, Meško & Krapež, 2016; Lu, 2017) use following terms in connection with Industry 4.0 in their scientific and professional publications: digitisation, virtualisation, artificial intelligence, augmented reality, ambient intelligence, information and communication technologies, sophisticated sensors, robotics, cloud computing, the Internet of Things, data collection and analysis, digital manufacturing, software as a service, autonomy, and interoperability. New technologies brought by scientific and technological progress and The Fourth Industrial Revolution are creating ambient intelligence. Ambient intelligence mainly concerns electronic environments that are sensitive and respond to presence of people. This form of intelligence can be described as ambient intelligence.

Ambient intelligence represents a new paradigm. This paradigm, anywhere and anytime, is becoming a new challenge for the concept of next-generation information and communication technologies. New technol-

ogies, such as Wi-Fi networks and third- and fourth-generation mobile networks, provide the infrastructure required to design ubiquitous information systems, that is, systems accessible from almost anywhere, at any time, and through almost any electronic device. However, using such a ubiquitous approach to information systems requires new concepts, models, methodologies, and supporting technologies that can fully explore its potential. In this context, mobility introduces new availability scenarios and increases the demands on companies providing IT services and products.

This paradigm raises new issues, such as enabling users to retain their ability to collaborate when located in different workplaces, a role of context and location in determining collaboration, support for ad-hoc collaboration in situations where fixed network infrastructure is lacking or cannot be used, and others.

Lee (2017) estimates that next ten years will see a revolution in ambient intelligence, with all technologies that comprise it being integrated into businesses, homes, shops, offices, hospitals, agriculture, transport services, etc. Ambient intelligence is one of key elements of The Fourth Industrial Revolution.

Ambient intelligence is the basic concept of normative visions for information technology in the European Union. At the same time, it represents a general framework for the future European information society and is its long-term vision.

1.2 Comparison of Ambient Intelligence Definitions

Ambient intelligence is a concept developed by European Commission's advisory group for the Information Society and Information Technologies Program - EU Information Society Technologies Program Advisory Group - ISTAG (ISTAG, 2001) (ISTAG, 2002). ISTAG (2003) believes it is necessary to take a holistic view of ambient intelligence taking into account not only technology, but the entire innovation supply chain from science to the end user, as well as various elements of academic, industrial, and administrative environments that facilitate or hinder the realization of the vision of ambient intelligence.

Ambient intelligence basic definition (ISTAG, 1999; ISTAG, 2003) can be considered intuitive work with information and communication technologies, which we often refer to as „user friendly." The basic definition of ambient intelligence can be understood as intuitive and user-friendly interaction

with information and communication technologies, supported by intelligent analytical capabilities that enable targeted and flexible system assistance.

The system is configured using various components that are integrated into the user's environment. The user can personalize and customize the system to suit personal requirements. System's adaptive components may vary depending on individual requirements and its important element are components that are not often directly visible but they provide support to surrounding environment, and therefore can be considered pervasive.

Based on a detailed analysis and comparison of theoretical approaches, we classify authors' definitions of ambient intelligence into three groups and arrange them chronologically within each group to make developments in this area clearer:

1. technology-oriented definitions,
2. multi-aspect-oriented definitions,
3. visionary-oriented definitions.

1.2.1 Technology-oriented definitions

Authors' definitions include a description of ambient intelligence from a technological perspective, taking into account the technological aspect, often listing specific technologies that comprise it and pointing out the benefits for society.

Ambient intelligence integrates information technology and a human factor. The emergence of ambient intelligence (Aarts et al., 2001) was prompted by fact that current technological developments enable the integration of information and communication technologies into surrounding environment. In addition, there is a growing desire for a role of information and communication technologies in surrounding environment to be strengthened and not focused solely on increasing productivity.

Ambient intelligence can be defined as convergence of three key technologies: computing, communication, and intelligent user interfaces (Ducatel, 2001).

Shadbolt (2003) adds to the basic ISTAG definition a broader understanding of mobility. Users of mobile technologies can communicate with them and transmit information to relevant systems. In addition, their location and other data from surrounding environment are captured, which allows new contextual information to be obtained.

Ambient intelligence systems can improve user activity, and devices can perform specific tasks based on delegation (Remagnino et al., 2005; Weber et al., 2005).

Ambient intelligence responds to the technological challenge. Its goal is to provide the most consistent contextual information and transform data into knowledge (Aarts et al., 2001; Aarts & Encarnação, 2006; Cook et al., 2009). It is an emerging technology that is increasingly becoming a part of everyday life, sensitive and responsive to our presence (Aarts & Encarnaçao, 2006).

In ambient intelligence environment, people are surrounded by networks and built-in smart devices that can assess the current situation and adapt to users' needs (Vasilakos & Pedrycz, 2006).

Ambient intelligence can be regarded as a digital environment that supports people in their daily lives in a non-intrusive way (Philips Research, 2007).

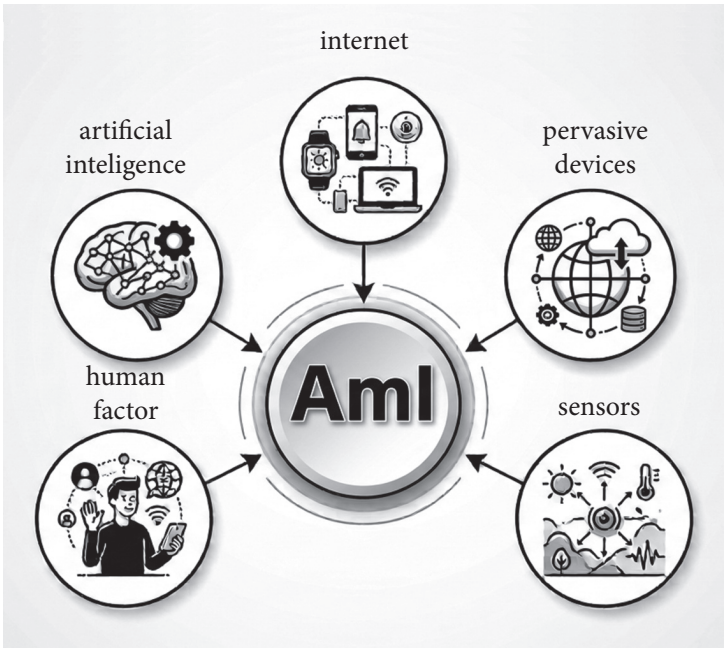


Figure 1.1: Areas forming ambient intelligence
Source: adapted by AI from (Augusto & McCullagh, 2007)

Augusto and McCullagh (2007) define ambient intelligence as an integration of sensors, information technology, network connectivity, ubiquitous computing power, and human interaction.

Ambient intelligence deals with a new world of ubiquitous computing devices, where the physical environment integrates with virtual reality and users (Ramos, Augusto & Shapiro, 2008).

Information and communication technologies should not primarily increase functional complexity, but should also contribute to development of intelligent and simple applicability (Aarts & De Ruyter, 2009).

Ambient intelligence provides a special perspective on ongoing research related to technical areas such as ubiquitous information and communication technologies and ubiquitous and proactive work with information and communication technologies (Veronica et al., 2009).

The paradigm is based on previous visions of mobile devices and smart devices. The significance of ambient lies in the need for widespread implementation of technology so that it becomes an integral part of everyday objects in the surrounding environment (Aarts & De Ruyter, 2009).

This is a shift in computing paradigms. These are transparent, easily accessible, and intelligent technologies. There has been significant progress in technology that has the property of ubiquitous computing power. It is created according to people's requirements in an interactive environment and responds to their various needs (Kleinberger et al., 2007; Van Hoof, 2011; Bravo et al., 2014).

Ambient intelligence represents technologies that communicate autonomously with each other in a value chain. Computer systems monitor physical processes, create a virtual copy of the physical world, and make decentralized decisions based on their own intelligence mechanisms (Smit et al., 2016).

Kaptein (2018) notes that a large part of characteristics and definitions focused on the field of ambient intelligence often do not explicitly focus on importance of data, the development and evaluation of methods for collecting, processing, or estimating data, or the extent of their analysis. This dimension is often overlooked in definitions, and its importance is forgotten. Definitions tend to focus on the development and evaluation of new applications and on user engagement and the social responsibility of such applications. Machine intelligence is taken for granted; it is a useful prerequisite that allows this field to effectively study and justify future emerging technologies and involve users in the design of ambient intelligence applications even before they can be technically implemented. However, from Kaptein's (2018)

point of view, it is appropriate to explicitly assess the impact of the importance of data and the extent of data analysis for the enterprise, as they have a significant impact on the development of the ambient intelligence environment.

Technology-oriented definitions provide a clear overview of what technologies constitute the substance of ambient intelligence and what their purpose is. Authors often list technologies and emphasize their mutual communication and interoperability. These technologies and systems are integrated into the surrounding environment in such a way that the user does not perceive, or at least minimally perceives, their presence.

1.2.2 Multi-faceted definitions

Authors also bring another dimension to characteristics of the concept of ambient intelligence: the human, socio-economic, and social dimensions. Authors do not refer specifically to technologies that make up ambient intelligence, but also mention other aspects that contribute to its essence.

Ambient intelligence responds to technological challenges. Advances in artificial intelligence and ambient intelligence are governed by rules and laws similar to those in the field of information and communication technologies. Many of these principles, such as Moore's Law, are exponential. Despite some indications that progress is slowing down, it is likely that artificial intelligence and ambient intelligence will continue to grow rapidly in the near future.

The holistic approach to the definition of ambient intelligence, which focuses on integration of users for the purpose of its development, is also specific. Ambient intelligence must be driven by humanistic issues that are not technologically determined and must be controllable by ordinary people (Riva, Vatalaro & Davide, 2005).

Ambient intelligence has become a multidisciplinary topic of interest and many areas of research where its positive impact on society can be identified (Augusto & McCullagh, 2007). It is a new vision and concept, bringing together several functions related to integration of information technologies into the environment in collaboration with the user. The entire system has to respond intelligently to user requests. Intelligence refers to the ability to learn and apply knowledge in new situations. The goal of ambient intelligence (Augusto & McCullagh, 2007) is to improve the way people communicate with each other. The ultimate goal of this field is to create the places where we live

and work. Smart Homes is one of the examples of such systems, but the idea can also be applied in hospitals, public transport, factories, and other environments.

Charitos (2008) points to potential of nonverbal and spatial communication interfaces for ambient intelligence design practices in his definition of ambient intelligence. Ambient intelligence design focuses on the human factor, which goes beyond the scope of „intelligent" technology-oriented ubiquitous devices and equipment. This approach is characterised by design goals such as maintaining the human factor in the cycle and as a control mechanism. Streitz (2017), in connection with the combination of the human factor and „smart" devices and spaces, argues that „smart devices and spaces make people smarter."

Ambient intelligence (Augusto & McCullagh, 2007; Aarts & De Ruyter, 2009) represents a shift in perception of information technologies and information systems forward and an improvement in interaction with the human factor in order to promote safety and improve quality of life, economic performance of businesses, and their productivity.

Streitz (2017; 2018) talks about the „smarteverything" paradigm, the resulting compromise between privacy and human control, and its application in smart cities. This author's definitions of ambient intelligence are based on a combination of the Internet of Things and artificial intelligence. The technological perception is missing from his definitions. All elements of life are becoming intelligent, whether software, hardware, specific platforms, or services. Terms such as smart and intelligent require critical reflection and alternative perspectives, especially in combination with increasing automation and autonomous systems. An alternative is an approach that goes beyond „smart" environments towards human and social environments of ambient intelligence. It is rooted in the initial vision of ambient intelligence and requires a redefinition of the „everything intelligent" paradigm (Streitz, 2017). Ambient intelligence must also accept the human and social environment, its rules and frameworks. It cannot be based solely on a purely technological perception. Now is the right time to promote this human and social perspective and adapt it to new constellations. This alternative view by Streitz (2017) is based on compromises between the technical perception and the human and social perspectives on ambient intelligence.

Multi-faceted definitions add a human, socio-economic, and social dimension to technology. They emphasize communication between technology and users, point to changes in contemporary life, the creation of new

ecosystems that take established rules into account, and highlight the need to create new rules and frameworks.

1.2.3 Visionary-oriented definitions

The third group of authors characterises ambient intelligence as a potential future; definitions provide a visionary view of this paradigm, with the authors pointing to an environment that is changing society.

Ambient intelligence represents a potential environment in which we will be surrounded by intelligent technologies that recognize the presence of people and respond to them in an unidentifiable way (I.A. Group, 2001; Ducatel, 2001).

Authors Fabian and Hansen (2006) perceive ambient intelligence in a visionary way. They theorize that ambient intelligence, understood from the perspective of information technology, mobility, and communication, is accepted and embraced by society. Rather, its visionary nature should be emphasized and we should look to the future. This perspective is rarely encountered in the literature.

Ambient intelligence is a vision of future everyday life. It assumes that intelligent technology should enter our environment to make life easier and more enjoyable for people (Crutzen, 2006).

The focus is no longer on hardware, computers, or networks. Intelligence must be provided in everyday environments. We are aware of the pressure towards smart homes, smart vehicles, smart transport systems, smart manufacturing systems, and even smart cities. This is why the concept of ambient intelligence is so important today (Ramos, 2007).

The ambient intelligence paradigm (Aarts & De Ruyter, 2009) builds on previous visions of mobile devices and smart devices. The significance of ambient lies in the need for widespread deployment of technology so that it becomes an integral part of everyday objects in the surrounding environment. Intelligence reflects a digital environment exhibiting specific forms of social interaction, integration of information technologies, and information systems.

Ambient intelligence will create a digital environment that is sensitive, adaptable, and responsive to the presence of people (Philips Research, 2007).

The philosophy of ambient intelligence offers a concept of an environment that will be sensitive and responsive to the presence of people. The idea is based on advanced results of interdisciplinary research. The development

of ambient intelligence applications is a complex task, and all their characteristics and functioning are difficult to predefine or predict due to various emerging or synergistic effects (Bureš et al., 2016).

This group of definitions predicts where ambient intelligence is headed. The authors create a vision of a digital ecosystem that responds intelligently and autonomously to user requests.

1.3 Areas of Ambient Intelligence Interest

Based on a study of literature, it can be identified that authors reject a precisely specified and narrow definition of the term ambient intelligence. There is no clear specification of ambient intelligence. ISTAG has only acknowledged the complexity and rapid development of relevant technologies that comprise it. It has taken a holistic approach and identified areas that need to be worked on in implementation of ambient intelligence in terms of technology, business models, society, and entrepreneurship.

Each author supplements basic key concepts: ubiquitous computing, communication, and mobility (mobile technologies) with more detailed characteristics or expands them with new technologies or environments. According to Mattern (2001), these concepts cannot be understood only on an academic level, but as the basis of the industrial sector concept.

From the perspective of understanding concepts, it is necessary to define the conceptual apparatus that has become the focus of authors' interest and is reflected in definitions of ambient intelligence: ubiquitous computing, communication, mobility, intelligence. We define fundamental differences between individual concepts that are often associated with the concept of ambient intelligence as follows:

- The concept of ubiquitous computing and computing power (Weiser, 1991; Chun & Kai, 2003) refers to a large number of invisible, inconspicuous technologies that connect the virtual world with the real world. Various sensors are embedded in physical objects to collect and transmit data to an information system.
- In their definitions of ambient intelligence, authors frequently use the concept of ubiquitous communication (Ark & Selker, 1999; Hansmann et al, 2001). This communication provides permanent access to data and information, which is secured by remote computers that evaluate it using algorithms. Products are constantly monitored by various sen-

sors, from which data is processed and evaluated. Measures are implemented based on the collected data.

- Mobile applications that form ambient intelligence, taking into account the contextual requirements of users, facilitate the relevant activities and processes, whereby the use of mobile devices is essential (Müller-Veerse, 1999). Device localization is ensured by GPS-enabled mobile devices that can monitor the movement and location of objects.
- Intelligence is the ability to solve problems in circumstances accompanied by uncertainty. It is a basic algorithm used to examine data and find connections, rules, or patterns within it. This means that the system does not need to be explicitly programmed, but rather learns. It can be said that it is an algorithm capable of gradually accumulating new abilities and using them to solve problems.

These innovative intelligent technologies, which can be found all around us, are integrated into the surrounding environment and enable communication. We refer to them as **pervasive technologies.**

Attention in the field of ambient intelligence also focuses on the integration of the human factor and the interaction of innovative pervasive technologies with it. Some authors define it in overly technical terms, while others bring a visionary perspective to their definitions.

Based on a study of theoretical foundations and a comparison of definitions of the conceptual apparatus, we have defined areas of interest in ambient intelligence covered by the definitions of domestic and foreign authors, which we have compared, analysed, and synthesized. We have identified the following areas of interest in ambient intelligence: technology, virtuality, sensitivity, responsiveness, adaptability, transparency, truthfulness, realism, pervasiveness, and intelligence (Table 1.1).

Table 1.1: Areas of Interest in Ambient Intelligence

	technology	virtuality	sensitivity	perception	adaptability	reality	pervasiveness	intelligence
ISTAG, 1999; ISTAG, 2003	×							
I.A. Group, 2001; Ducatel, 2001			×	×		×	×	
Aarts et al., 2001	×							
Ducatel, 2001	×							
Ahola, 2001	×							
I.A. Group, 2001	×			×	×		×	×
Rech & Althoff, 2004						×		×
Remagnino et al, 2005; Weber et al., 2005	×				×			×
Aarts & Encarnaçao, 2006			×	×				
Maeda & Minami, 2006							×	×
Crutzen, 2006				×		×	×	
Vasilakos & Pedrycz, 2006			×		×	×	×	×
Philips Research, 2007			×	×	×			
Philips Research, 2007						×	×	
Augusto & McCullagh, 2007								
Ramos, 2007	×							
Ramos, Augusto & Shapiro, 2008	×	×			×		×	
Aarts et al., 2001; Aarts & Encarnação, 2006; Cook et al., 2009	×					×		
Veronica et al., 2009	×							
Aarts & De Ruyter, 2009	×							
Kleinberger et al., 2007; Van Hoof, 2011; Bravo et al., 2014;	×						×	×
Smit et al., 2016	×	×						×
Bureš et al., 2016			×	×	×		×	×

Source: (ISTAG, 1999; ISTAG, 2003; Ducatel, 2001; Aarts et al., 2001; Aarts & Encarnação, 2006; Cook et al., 2009; Ahola, 2001; Rech & Althoff, 2004; Remagnino et al, 2005; Weber et al., 2005; Maeda & Minami, 2006; Crutzen, 2006; Vasilakos & Pedrycz, 2006; Philips Research, 2007; Augusto & McCullagh, 2007; Ramos, 2007; Veronica et al., 2009; Aarts & De Ruyter, 2009; Smit, 2016; Bravo et al., 2014; Van Hoof, 2011; Kleinberger et al., 2007)

By creating a synthetic table of areas of interest in ambient intelligence covered by authors' definitions, we identified that technology-oriented definitions were more prevalent before 2005. Between 2005 and 2007, authors began to work with concepts of perception, device sensitivity, interoperability, and adaptability, pointing to their pervasiveness. Definitions from 2007 have been a kind of intersection of technologically and visionarily oriented definitions, supplemented by dimension of intelligence. They define intelligence as the ability to learn and respond to user requirements, often pointing out that an ambient system does not need to be constantly adjusted and parameterized, but is capable of learning.

Based on an analysis of theoretical principles, systematization, and generalization, we have defined ambient intelligence. **Ambient intelligence represents a multidisciplinary approach, integrating innovative pervasive technologies and systems that form an ecosystem which, based on collected, transformed, analysed, and evaluated data, intelligently responds to user requirements.**

Ambient intelligence is a multidisciplinary approach that focuses on the integration of innovative pervasive technologies that support user activities through specific ambient services provided with minimal user intervention. Essentially, an ambient intelligence system should be aware of a person's presence, perceive that person's needs, and be able to adapt to the user's needs. Ambient intelligence brings new insights into the environment for software development and implementation, where there are large numbers of different devices and sensors that need to be integrated to create a programmable and auto-configurable information systems infrastructure. The focus is no longer on hardware, computers, or networks. Intelligence must be provided in everyday environment.

1.4 Features and Elements of Ambient Intelligence

From definitions and characteristics of ambient intelligence, we have identified features of ambient intelligence that contribute to its social acceptance and implementation in the surrounding environment.

1.4.1 Features of ambient intelligence

In connection with ambient intelligence, we encounter one of the most important features of ambient intelligence technologies in definitions of domestic and foreign authors, namely ubiquity (pervasiveness).

Pervasive computing power was defined by authors Chun and Kai (2003), who spoke of a new homological computing paradigm. They predicted developments in the field of computing technology that would be characterised by ever closer integration of information and communication technologies and everyday life. The main idea behind ubiquitous computing was to embed computers into the environment or integrate them as human tools in such a way that they would be invisible to users, allowing users to focus on their work and tasks without being aware that they were working with a computer. It was about integrating the physical world with the virtual world into the information space as a whole. We refer to such technologies in the monograph as pervasive technologies.

Aarts and Marzano (2003) summarized five key technological features that characterise an ambient intelligence system:

- integration - network devices are integrated into the environment,
- situational context - the system recognizes people,
- personalization - the system can adapt to people's needs,
- adaptability – the system can change in response to people's requirements,
- predictability - the system predicts without conscious mediation.

The acceptance of ambient intelligence by society is primarily influenced by its characteristics (Riva, Vatalaro & Davide, 2005):

Usability – interaction with ambient intelligence should be unobtrusive, and user-friendly. In practice, we often find that many products, especially technological ones, do not come with detailed operating instructions. According to manufacturers, the technologies will function intuitively as soon as they log into the ambient environment.

Technical feasibility – ambient intelligence must work reliably within the limitations of state-of-the-art technologies. Factors such as accuracy, capacity, and measures to prevent failure of all hardware and software components must be taken into account.

Trustworthiness – Lee (2017) emphasized building trust in ambient intelligence. Users must develop a relationship with it and trust it before it can be widely accepted.

Lynch (2017) expressed his belief that ambient intelligence is a new energy. This idea can be dissected as an energy infrastructure, an Internet of Things infrastructure that provides ambient intelligence services. In order for society to build trust in ambient intelligence, it is important to make risk management, information security, data security, privacy protection, and system reliability top priorities.

Marr (2016) defined four characteristics that a company must have in order to be considered smart and part of the concept of ambient intelligence and Industry 4.0:

- interoperability,
- information transparency,
- technical support,
- decentralized decision-making processes.

The basis is that individual machines and sensors communicate with each other; the system must be able to continuously create a virtual copy of the physical world and provide contextualization of information. Cybernetic systems are also part of this, supporting people in performing work and demanding tasks, while also being able to make basic decisions and be independent and autonomous.

Smit and a team of authors (2016) added the characteristics of virtualisation, real-time changes, and modularity to the requirements for smart enterprises and ambient intelligence.

Gams et al. (2019) pointed to the field of ambient intelligence, which is closely related to pervasive technologies, as well as context awareness and the design of human interaction. The most important features of ambient intelligence systems include:

- embedded: devices are integrated into the environment; they are "invisible";
- contextual: they recognize the user, possibly also the user's current state and situational context,
- personalized: they are often tailored to the user's needs,
- adaptive: ambient intelligence systems change their performance in response to changes in the user's physical or mental state,
- predictive: they can anticipate the user's wishes without conscious mediation,
- Unobtrusive: discreet, providing nothing more than necessary information about the user to other devices and people.

- non-invasive: they do not require any action from the user, but act independently.

1.4.2 Elements of ambient intelligence

Ambient intelligence consists of individual elements that together create an intelligent environment integrating innovative information and communication technologies and pervasive technologies interacting with the human factor. In the following section, we define elements of ambient intelligence from the perspective of several authors.

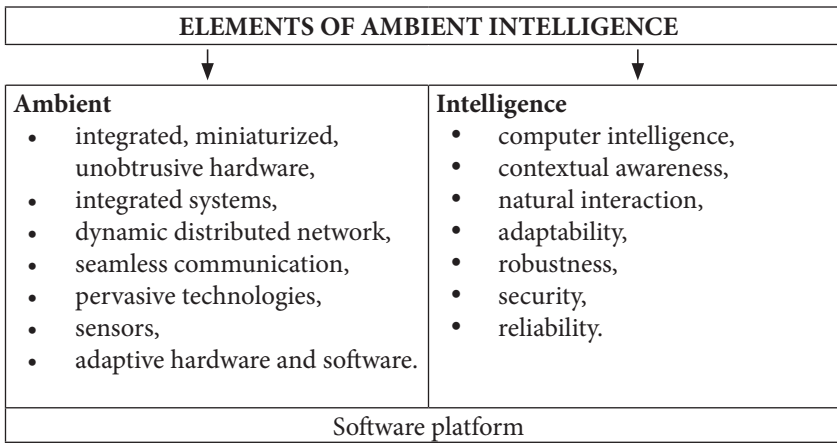


Figure 1.2 : Elements of ambient intelligence
Source: adapted from (Ramos, Augusto & Shapiro, 2008)

Ramos, Augusto, and Shapiro (2008) divided the elements of ambient intelligence into two areas. The ambient area includes sensors, processors, communication, and personalized, adaptive software. All of these tools have made significant technological advances in recent years. The trend can be seen primarily in miniaturization and cost reduction, and according to ISTAG, the future lies in integrating these devices "into everything around us." The second area, system-side intelligence, will determine the success or failure of ambient intelligence implementation. Both of these areas are covered by a software platform, and the core of the ambient intelligence system is human interaction, the user.

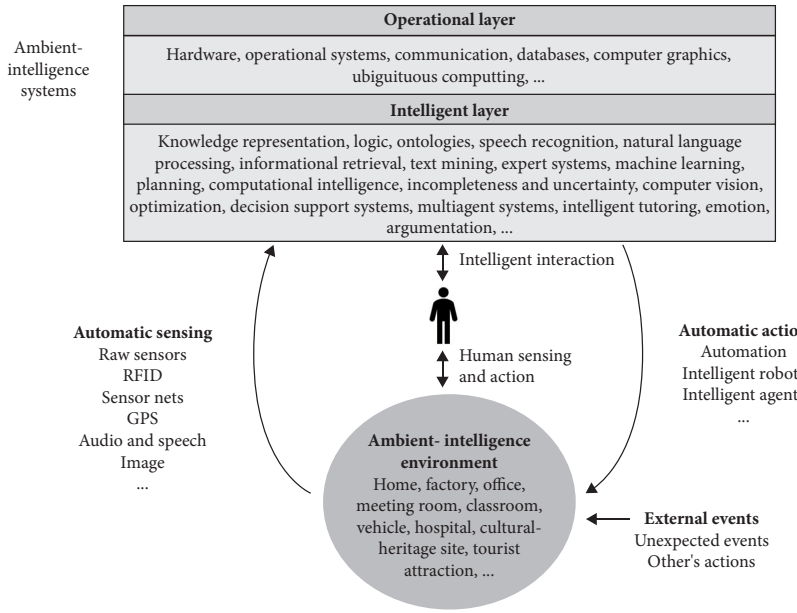


Figure 1.3: Ambient intelligence ecosystem
Source: adapted from (Ramos, Augusto & Shapiro, 2008)

Ambient intelligence uses operating technologies that belong to the operational layer, and we integrate interaction with users into the intelligent layer (Ramos, Augusto & Shapiro, 2008). Interaction with people is very important. Ambient intelligence systems should be integrated with people and know how to work with them. Such interaction requires contextual awareness. Contextual awareness includes factors such as: interface, adaptation to users, situation, learning by observing the user, scalable intelligence. The emotional aspect of the user is also often raised. Ambient intelligence is capable of automatically providing personalized services in anticipation of user needs.

We conclude that ambient intelligence consists of several elements that can be divided into two basic areas: technology and intelligence. The technological area includes elements that represent innovative pervasive technologies and hardware, while the intelligent group consists of contextual awareness and interaction with the human factor.

1.5 Ambient Intelligence Platforms

The foundation of ambient intelligence platform that builds Industry 4.0 is the full integration of information and communication technologies, digitisation, virtualisation, and augmented reality. We perceive ambient intelligence platforms from two perspectives: technological and integrative.

1.5.1 Technological perspective of Ambient Intelligence

Important technologies, hardware, and software tools that build ambient intelligence include sensors, scanners, network tools, technical infrastructure, and application programs. These basic tools and their integration have enabled the emergence of new platforms, domains, subdomains, and models such as Cyber-Physical Systems (CPS), the Internet of Things (IoT), the Internet of Services, Big Data, Cloud Computing, Product Lifecycle Management Systems, Digital Manufacturing, Digital Twin, and many others.

Herrmann (2018) stated that companies should focus on: autonomous devices, which would increase the degree of automation; augmented reality and more intensive analysis of automated data (metadata); the development of software based on artificial intelligence, replacing previous and classic software development with the use of artificial intelligence; digital twins, which will change the business world in the future, allowing companies to map their business processes and optimize them; Empowered Edge - supports data transfer and centralization of computer calculations, i.e., data collection and processing using cloud solutions between different devices in order to minimize the amount of data transferred to the user's end devices, known as network transfer; use of new virtual reality technologies, technologies that interact with other human senses; database systems; intelligent environments that intelligently support everyday activities (smart home devices or smart cities, e.g., Helsinki – Kalasatama); digital ethics, privacy, and information security; quantum computers can process data even faster than conventional computers, and their use is predicted mainly in the automotive and financial sectors.

Due to the scope of this paper, we cannot discuss individual technologies in detail in this scientific monograph. Several of them were also the subject of research conducted at the Department of Information Management, as well as in collaboration with other universities, which resulted in several scientific

articles (Bolek & Romanová, 2014; Bolek et al., 2016; Romanová et al., 2019) and scientific monographs (Bolek, 2016; Látečková & Bolek, 2018).

In the following section, we characterise only selected technologies. Kagermann (2014) and Greengard (2015) listed four key technologies, components of Industry 4.0, which are cybernetic systems (connections between the real and virtual worlds), the Internet of Things, the Internet of Services, and smart products, Machine to Machine (M2M) communication. Machine communication (M2M) and smart products are not considered independent parts. M2M is an activator of the Internet of Things, and smart products are part of cyber-physical systems.

A) Cyber-physical systems (CPS)

Building an information society through increasing informatization in every sector of the economy and industry creates new value. Cyber-physical systems represent the interconnectedness of the virtual (cyber) world and the physical environment through the use of M2M (Machine to Machine) communication. These systems bring about a fundamental interaction between the real world and the virtual world.

The term cyber-physical systems (Baheti & Gill, 2011) refers to a new generation of systems that integrate computational and physical capabilities and interact with humans through new modalities. These systems use computation, communication, and control to extend the capabilities of the physical world.

According to Herčko and Štefánik (2015), cyber-physical systems represent the integration of computational and physical processes, embedded computers, monitors, and control processes with feedback, where physical processes complement computer processes and vice versa. At the same time, they represent an important evolutionary step in the development of industry.

Cyber-physical systems are intelligent, cooperating units that exchange information (Vogel-Heuser et al., 2015).

The development of these systems lies in the early use of independent information and communication technologies. The term cyber-physical systems first appeared about fifteen years ago in the US, where they are referred to as a system consisting of physical entities controlled by computer algorithms.

Currently, cyber-physical systems are finding real-world applications in various areas of social life and industry. They bring radical change beyond

the automation and intelligence of development, production, and distribution. These systems include physical devices with integrated tools for digital data collection, processing, and distribution.

The combination of cyber and physical environments, together with powerful software support, creates significant space for system functionality and brings new smart devices that are growing in popularity. They are characterised by their interconnectedness via the internet and online availability. Cyber-physical systems are currently attracting increasing attention.

The main foundation is technical advances in the field of the internet and data analytics. These systems collect digital data, aggregate it, and provide feedback based on the results of analysis from cyberspace to the real world. This creates a reciprocal relationship between the real and cyber worlds (Kim & Park, 2017).

Cyber-physical systems cannot function effectively in isolation. Other information and communication technologies, chips, network connectivity, the Internet of Things (IoT), and, last but not least, cloud-based technology play an important role.

The implementation of cyber-physical systems entails high initial investment costs for implementation and subsequent maintenance. However, as a result of the diversification and digitisation of every sector and industry, these costs are gradually decreasing (Kim & Park, 2017).

Cyber-physical systems can be divided into:

- Multi-agent systems – these are autonomously behaving agents that do not necessarily have a physical form, but can be software systems. The weakness of these systems is a certain need for standardization and time consumption. Their advantage is their high flexibility and resistance to failures. According to Wooldridge (2002) and Ferber (1999), they are characterised by decentralization and parallel execution of activities based on autonomous entities. According to Wooldridge (2002), these systems replace centralized control with distributed functioning, where interactions between agents lead to the emergence of "intelligent" behaviour, while also being able to respond and adapt to conditional changes.
- Holonic systems – these are also multi-agent systems. Part of the production equipment consists of agents with a control element and software agents. A holonic agent is capable of planning, coordinating, and actively implementing activities . This holonic system can be a sensor

agent, an actor, or even an entire machine, production line, or enterprise.

According to SOVA Digital (2016), the development of cyber-physical systems is characterised by three generations:

1. The first generation consists of identification technologies such as RFID (Radio Frequency Identification) sensors, which are used for unique identification and tracking. This is high-frequency identification, communication that takes place on the basis of radio wave transmission. This technology is a significant shift from the classic barcodes used, for example, in the labelling of goods.
2. The second generation consists of cyber-physical systems equipped with sensors with a limited range of functions.
3. Generation 3 – cyber-physical systems are capable of storing and analysing data, are equipped with sensors, and are connected to the Internet.

According to SOVA Digital (2016), cyber-physical systems are an important element of products, manufacturing, warehousing, robotics, traffic management, logistics services, supply chain management, fleet management, and telemedicine.

Individual physical entities connected to the Internet of Things can communicate with each other, but they do not necessarily have their own control algorithm.

B) Digital data

The volume of processed digital data doubles every two years (analogous to Moore's Law for hardware) (Grantz & Reinsel, 2012). The growth of digital data is not everything; changes in the type of data can also be observed.

The types of data processed can be divided into three main groups (Tyagi, 2012): structured data, semi-structured data, and unstructured data. There is no clear definition of the term „big data." There are many definitions in scientific publications by domestic and foreign authors, each of which is correct but focuses on a different aspect.

The importance of digital data is also growing from an economic and social perspective. The value of data in the European Union economy was more than €285 billion in 2015, representing more than 1.94% of the European Union's GDP. The year-on-year growth of 5.03% in the value of data increased in 2016 to €300 billion, representing 1.99% of the European Union's GDP.

If European Union countries and businesses operating within it support investment in information and communication technologies, favourable political and legislative conditions will be created. According to European Commission estimates, the value of the European data economy could increase to €739 billion by 2020, representing 4% of the European Union's total GDP.

The growing volume of this digital data and information creates volumes that exceed the capacity of conventional database systems. Hurwitz et al. (2013) defined big data as a combination of old and new technology that enables the processing of large amounts of data at an appropriate speed so that the required analyses can be provided at a given moment in time. Author Ohlhorst (2012) provided a more comprehensive definition: „Big data is such an extremely large set of data that traditional data processing is insufficient for the required analysis." Dumbill (2012) defined the term big data more thoroughly: „It is data whose processing exceeds the capacity of conventional database systems. This data is too large, moves too fast, or its structure does not correspond to the existing database architecture. To extract value from such a data set, an alternative processing method must be chosen."

In his research publication, Gartner analyst Doug Laney (2001) used the term big data, which he supplements with the 3V dimension. He defines big data as a set of data whose size is beyond the ability of commonly used software tools to capture, manage, and process data within a reasonable time, with size understood not only in terms of data volume, but comprehensively in a three-dimensional context, which he refers to as 3V (Volume (volume) – expresses the exponentially growing amount of data within a given business area, Variety (variability) – information varies in countless types, sources, formats, structures, encodings, syntaxes, etc., Velocity – the speed at which data is generated and the need to analyse it in real time).

In his publication, Kaptein (2018) pointed out the need to consider new categories of data and big data, such as „future data," and the role of uncertainty in designing the next generation of ambient intelligence. From a digital data perspective, ambient intelligence needs:

- data and information that describe the current state of the world for the devices operating in it,
- data processing, either through explicit human-coded rules or, more implicitly, machine-learned relationships,
- estimates of the results of activities.

In conclusion, digital data and information are a fundamental source of economic growth, competitiveness, innovation, job creation, and social progress, and their role in ambient intelligence is indispensable.

C) Internet of Things

The speed of change in information technology and scientific and technical progress is the most significant factor influencing the use of the Internet of Things. The Internet of Things is penetrating almost all areas of social and economic life, but the pace varies. The Internet of Things is the basic layer of Industry 4.0, which is designed for the collection, distribution, and archiving of data. It is the cornerstone of Industry 4.0, and most Industry 4.0 applications are implemented in this environment.

The current monitoring and measuring sensors that companies use to collect data are being replaced by more efficient, technically advanced solutions based on mobile networks. Communication protocols and specialized networks enable the operation and communication of low-power devices. Technologies that enable communication between different sensors and devices, as well as their low-cost wireless connection for the purpose of automation, streamlining, and acceleration of processes, can be referred to as the Internet of Things.

The term Internet of Things was first used by Kevin Ashton in 1999. Kevin Ashton worked on emerging sensing technologies called radio frequency identification (RFID). This is a relatively new paradigm that is rapidly establishing itself in the modern wireless communications and telecommunications landscape.

The basic idea (Giusto et al., 2010) behind this concept is the ubiquitous communication of various things or objects, including radio frequency identification. Through unique addressing schemes, these objects are able to communicate with each other, interact with their surroundings, and achieve common goals.

According to Weber (2010), the Internet of Things represents a global technical architecture based on the principle of the Internet. It facilitates the exchange of goods and services in global supply networks and has a significant impact on the privacy and security of the parties involved.

The emergence of the Internet of Things can therefore be linked to RFID technology. Technological advances and miniaturization have led to the emergence of new, more sophisticated devices and new, less expensive sensor technologies. These technologies have been connected to the Internet.

Their penetration has expanded to such an extent that they are no longer the domain of large enterprises, but also of households and ordinary users. At present, two main development trends can therefore be observed:

- the Internet of Things, which is provided as a service for ordinary users,
- industrial deployment of the Internet of Things (IIoT).

The Internet of Things and cyber-physical systems are closely linked because they use physical objects, RFID sensors, and mobile devices. In this way, they connect the virtual world with the real environment (Wolf, 2009).

Kopetz (2011) provided a very clear definition of the Internet of Things. According to the author, it is the connection of physical things to the Internet, which allows access to remote data via sensors. The captured and collected data bring a synergistic effect that the system can provide. The platform is based on RFID technology, which represents ubiquitous optical barcodes and the Internet.

According to Chandrakanth et al. (2014), the Internet of Things represents a complex of three models:

1. web model (middleware),
2. a model based on things (sensors),
3. a semantic model based on knowledge.

The overall effectiveness of the Internet of Things is only achieved when these three models intersect in the area of applications. The Internet of Things represents an intelligent environment that uses information and communication technologies that find their application in industry, management, education, and various sectors of the economy. The platform itself is built on hardware, middleware, and presentation. The hardware consists of sensors or built-in communication hardware. Middleware consists of tools for data storage and data analysis. Presentation includes visualization and interpretation.

A UN report states that an era of ubiquity is coming, where humans can only become generators and receivers, integrating the human factor (Botterman, 2009). We agree with the view (Atzori et al., 2010) that perceives the Internet of Things as an intersection of a material, communication (Internet), and semantically oriented vision.

The object-oriented vision of the Internet of Things is based on the principle of sensors that are in direct contact with devices and the environment, transmitting data via a radio network to servers, where it is transformed into an IoT platform that ensures data storage and decoding.

Data collection is primarily provided by sensors, RFID, NFC, and other technologies that are part of everyday objects. Middleware (Emmerich, 2010; Capra et al., 2001), software that connects software components, enables the activity of multiple processes. According to Presser (2009), RFID is constantly at the forefront and will continue to play a leading role due to its low cost and strong support from the business community. This technology ensures interoperability to support the transition to distributed architectures. It is an integral part of modern information technologies and systems based on web services and service-oriented architecture.

Data is made available to individual applications for evaluation, and the outputs are exported to a presentation format. The vision is focused on „things" that are necessary for full deployment and implementation of the Internet of Things. These are not just sensors equipped with wireless communication capabilities and memory, but also processing capabilities and new potential.

It is often also about autonomy, proactive behaviour, and the application of contextual awareness. Based on the above, the International Telecommunications Union (2005) defines the Internet of Things as „anytime, anywhere, for anyone, connectivity of everything."

The communication and internet-oriented vision consists primarily of the internet as a communication tool and protocols and technologies related to it. The basis is the internet protocol as a network technology for connecting smart objects around the world. Data collected from the object-oriented part, sensors, and sensors communicate via communication modules using data transmission via a communication network, the Internet. Smart semantic middleware connects individual components for the purpose of multiple processes.

Semantic-oriented vision deals with questions of how to store, connect, search, organize, and present generated information. It constantly points to the complexity of these processes. In this context, semantic technologies play a key role. In fact, they use appropriate modelling solutions for generated data, facts, and information. They are the underlying asset for decision-making and subsequently taking a position and implementing measures and activities. The paradigm of the semantic understanding of the Internet of Things is the subject of several definitions and studies (Wahlster, 2008; Katasonov et al., 2008; Toma et al., 2009; Vázquez, 2009).

The interconnection of individual visions creates a functional concept of the Internet of Things. This concept can be simply summarized in three

processes: 1. acquisition, data collection, 2. transmission and distribution, 3. evaluation, execution of activity. The process can also be in reverse flow when it comes to active elements. Based on the collected data that is evaluated, the data is sent to perform the activity, and smart devices perform the given activity (an example is smart thermostatic heads).

From a theoretical point of view, it can be said that the principle of this technology is based on the connectivity of individual smart devices via the internet. The connection of devices with internet connectivity is primarily based on wireless technology. Communication uses wireless Wi-Fi networks, GSM networks, low-energy Bluetooth, NFC, or RFID.

Mutual communication and data transfer generate large amounts of data that can be analysed using big data technology. The connection (not only via mobile networks) of these devices brings new possibilities for interaction, control, monitoring, and security of advanced services between individual systems.

Global coverage by communication networks is constantly growing, but there are still areas without this communication option. According to the 4G Americas association, there were 7.1 billion mobile connections worldwide at the end of 2014, of which approximately 2 billion subscribers had access to 3G or 4G mobile broadband and 498 million users surfed on LTE networks. However, significant gaps in mobile network coverage remained in sparsely populated and geographically remote regions.

Technological developments are shifting the 3G and 4G network types to 5G with multi-layer communication. This type of network already includes several communication layers, including a layer for car-to-car (D2D) communication and the Internet of Things. Communication between devices is based on the M2M (machine-to-machine) principle.

The Internet of Things is gradually penetrating industry, where individual industrial machines and robots communicate via the Internet. Significant benefits are expected in the improvement of production machinery and equipment technology, which, thanks to improved communication, measurements, sensors, and records, will enable high-quality, prompt, detailed monitoring and fault detection. Technicians will receive better records for each device (even where this was not previously technically possible or affordable).

The technologies that make up the Internet of Things must be designed with economic feasibility vs. technological feasibility in mind. The portfolio

of devices that enter the Internet of Things can be divided into the following categories according to how the device communicates with the application:

- Passive – this group includes sensors that work on the principle of a code (EAN, QR code) or RFID chip. From a physical point of view, RFID is a small microchip connected to an antenna, often in the form of a self-adhesive sticker (Jules, 2006). Scientific and technical progress has also brought about semi-passive RFIDs, which are battery-powered. Information from these devices is read by a scanner or reader. Their widespread use in industry can be seen primarily in logistics.
- Active – most sensors that communicate in only one direction are called active devices. They are a source of data that can be sent continuously or at the user's request. These are mostly various motion and door sensors, detectors, meters, cameras, etc. In all these cases, the priority direction of communication is from the device to the application.
- Controlled – these are devices that, in addition to collecting data and sending data based on an algorithm, can receive controlled instructions. These include lighting, thermostatic heads, security cameras (positioning, focusing), sound systems, and many others. Such devices send data to the control application. The application can then change the behaviour of the device based on the program or user requirements.

Data from special sensors, scanners, detectors, or other devices is sent via the Internet to the service provider. This data is then normalized in the IoT Input/Output Interface module. Data from different devices thus acquires a uniform format so that it can be stored in the database. Normalization depends on the type of connected devices and the range of services offered.

Over last decade, the services sector has become the largest and fastest growing business sector in the world. More and more people are employed in it. For this growth to continue, services should become more accessible. The intelligent use of information technology can contribute significantly to achieving this goal. The provision of services must also bring added value and increased productivity. This new and revised vision for next-generation services provided over the Internet is known as the Internet of Services. The Internet of Services is an area that cuts across all areas of Industry 4.0.

Internet services represent an infrastructure that uses the Internet as a medium for offering and selling services. As a result, services become a tradable commodity. It provides a commercial and technical basis for advanced business models focused on the provision and use of services. It includes the interconnection of individual information systems and their modules in or-

der to provide better services to consumers. Internet services have stimulated the emergence of new distribution channels for services and completely new business models.

D) Digital manufacturing

Over the past decade, digital manufacturing has been considered a highly developing area of information technology. The global manufacturing era continues. Digital manufacturing is one of the main strategies of the European vision of manufacturing and the strategic agenda towards knowledge-based production. It is driven by the application and standardization of information and communication technologies and the increasing demand for operational efficiency in global networks (Westkämper, 2007).

The manufacturing environment is turbulent and requires constant adaptation of production systems. Manufacturing engineering covers a wide range from networks to processes and from real time to long-term operations. The tools of future engineering and manufacturing management are digital and distributed.

Chryssolouris et al. (2009) pointed to the integration of information and communication technologies in manufacturing, which can significantly reduce production time, lower costs, reduce product development costs, improve product quality, and enable faster market response.

Digital manufacturing cannot do without information technology, data collection, data analysis, simulations, virtual reality, process automation, and ultimately e-commerce.

The introduction of three-dimensional printers and direct digital manufacturing brings a new paradigm, direct digital manufacturing (Chen et al., 2015), with a significant impact on society. The direct aspects of the sustainability of digital manufacturing are closely related to social, economic, and environmental dimensions. Direct digital manufacturing combines the advantages of other manufacturing paradigms and has a positive impact on sustainable development, but there are a number of technical and societal challenges to overcome. Digital manufacturing is mainly used for prototyping. Currently, its integration into new types of assembly lines can already be observed, and a high level of specification is becoming the norm.

Important social aspects of digital manufacturing include lifestyle changes, changes in the labour market, the working environment, waste management, and others. The integration of information and communication technologies, virtualisation, and the development of ambient intelligence are

giving rise to various paradigms and subdomains in the field of digital manufacturing.

E) Cloud-based design manufacturing

Cloud-based design manufacturing is a new concept that has emerged from the integration of information and communication technologies and virtualisation (Wu et al., 2015) and is a network model of product development.

Customers are able to configure, select, and use customized tools and services to configure products. This subdomain of digital manufacturing ranges from software engineering to reconfigurable manufacturing systems. There are still many unanswered questions that are the subject of academic and economic discussions on key characteristics, computer architectures, communication processes, crowdsourcing, information and communication infrastructure, programming models, etc.

In their articles, researchers often discuss whether cloud manufacturing is truly a new subdomain of digital manufacturing, a new platform, or just „old wine in new bottles," as Wu and his team of authors (2015) put it.

The essence of this production is based on the cloud platform. Cloud design manufacturing is an idealized system that needs to be compared to more traditional collaborative, distributed manufacturing systems, agent-based manufacturing systems.

However, we can say with certainty that it supports digital manufacturing and innovation in the field of design.

1.5.2 Integrative Aspect of Ambient Intelligence

The integration of ambient intelligence within a company can be divided into four basic forms (Čierny, 2016):

1. **Vertical integration**

   This represents functional integration across the entire hierarchy. Vertical integration includes the integration of information technology, analysis and data management, cloud solutions, and operational efficiency.

   The essence lies in the information interconnection of all systems across the entire structure of the enterprise. It is possible to interconnect all production systems, plants, workplaces, products, logistics systems, but also areas such as supply, production, marketing, human re-

sources, financial management, and all management functions and areas. The personalization of technologies and information systems also plays an important role in this integration.

2. **Horizontal integration**

   This is a relatively new generation of extensive interconnection of individual aspects of the business chain, building a network of partners and customers. The essence lies in the interconnection of individual parts of the business chain. Integration is created across the entire supply chain from customer – manufacturer – supplier. Integration also includes end distribution to the customer and subsequent service.

   Horizontal integration helps optimize the business model and builds a smart supply chain and logistics. An important area in horizontal integration is communication, data and information transfer between individual entities, and information security management, which has an irreplaceable position.

   The risks of computer infiltration are increasing, and consequences of information security breaches can be severe. New taxation models can also be observed within this form of integration.

   Geissbauer, Vedsø, and Scharauf (2016) cited inventory management systems that connect retailers, distribution centers, carriers, manufacturers, and suppliers as an example of horizontal integration in their case study. Each of them receives data on the status of deliveries, places and executes orders automatically. As part of this cycle, they monitor the communication process, check it, balance it, and eliminate possible interruptions. The authors cite flexible production equipment and programmable robots as a more sophisticated example of the integration of information and communication technologies. The authors describe the virtualisation of the physical world. Simulating a new design, product, or production equipment allows for testing, eliminating deficiencies, and thus preventing deviations that can cause significant increases in costs and expenses.

3. **Integration of engineering processes**

   The result of the business transformation process is a product or service. As part of the integration of engineering processes, individual processes throughout the entire life cycle are integrated.

   It focuses on the integration of individual parts from planning, development, implementation, testing, evaluation, control, feedback, to sales services. The integration of engineering processes helps to build

new models of innovation efficiency and effective product management.

4. **Acceleration through exponential technologies**
   This form includes existing technologies that have previously worked separately. Through integration and utilization, they become more usable, bring synergistic effects, and their main role is to utilize individual solutions, increase flexibility, and save costs throughout the process of building ambient intelligence and industrial revolution.
   Acceleration through exponential technologies creates space for new business models, and the organisation of education is also an interesting area. The issue thus affects not only the economic sector, but also the social and public sectors.

We note that the full digitisation of business processes and vertical and horizontal integration are important. Communication, possibilities, and forms of data, information, and communication transfer play a significant role in the various forms of integration.

1.6 Scenarios of Ambient Intelligence

According to the European Union's Information Society Program, the goal of ambient intelligence is convergence of information technologies and information systems into social areas and integration with users. The concept of ambient intelligence provides a vision of an information society in which the emphasis is on greater user-friendliness, more effective service support, empowerment of users, and support for human interaction. The application of ambient intelligence can be identified in almost every area of social life. In addition to traditional application areas such as industry, sales and distribution, manufacturing, materials management, agriculture, healthcare, etc., it can also support pervasive technologies and environments, knowledge sharing, and education (Bick et al., 2007).

The concept of ambient intelligence (Ducatel et al., 2010) provides a vision of an information society in which the emphasis is on greater user-friendliness, more effective service support, user empowerment, and support for human interaction. We are currently surrounded by intelligent, intuitive interfaces that are incorporated into all kinds of objects and environments, capable of recognizing and responding to the presence of various objects in often subtle and invisible ways.

Several scenarios and contexts for the applicability of ambient intelligence can be identified in the literature. These contexts represent ontological considerations of ambient intelligence. The scenarios they describe are not traditional extrapolations from the present, but offer provocative views of the future that may (but need not) be realized. Each scenario has a script that is used to create a key to the development of technologies, society, economy, and markets necessary to achieve that scenario. Based on the available literature, we conducted a detailed analysis of these concepts, taking into account the criteria for comparison and proposed taxonomy according to Viterbo et al. (2008):

1. Context type – what types of information are collected, processed, and distributed by the system, location, physical context... This information provides an idea of the frameworks of usefulness, scalability, and practical feasibility.
2. Ontology – what is the main purpose of using the information, what are the relationships between them. This criterion evaluates expressiveness and flexibility.
3. Technique of conclusions, justifications – what kind of justification is supported. This factor determines performance, reliability, completeness, and practical use.
4. Knowledge management – what is the knowledge base (static, dynamic), the system works with decentralized heterogeneous knowledge bases, knowledge models are developed, or heterogeneity is supported. The suitability of the ambient intelligence system for solving naturally dynamic, decentralized, unpredictable events is monitored.
5. Architecture – system architectures (centralized, decentralized, hybrid).

Viterbo et al. (2008) also pointed out that there may be several ways to classify contextual systems. The authors believe that the following aspects are the most important:

1. Centralized vs. decentralized knowledge base.
2. Static vs. dynamic knowledge base.
3. Reliability of information.
4. Means of processing knowledge bases.

An important element of the scenarios (Figure 1.4) is the environment and users who use services and applications supported by new innovative pervasive technologies and intelligent user interfaces, which form the essence of the scenarios. Four scenarios depict the ISTAG vision (Ducatel et

al., 2001), contrasting applications that serve to optimize efficiency, whether in business or in the enterprises themselves.

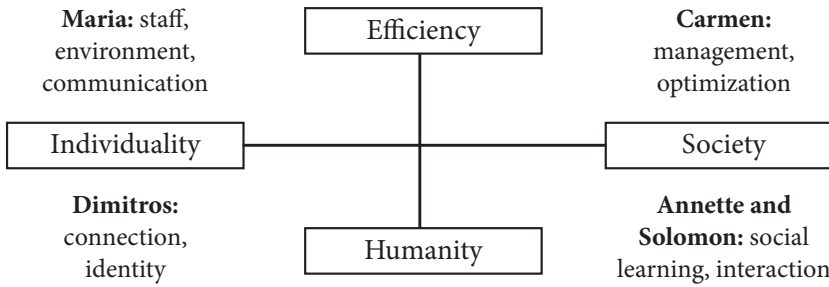


Figure 1.4: Ambient intelligence scenarios
Source: adapted from Ducatel et al. (2001)

Maria presents a visionary scenario. Technological and socio-economic changes are a relative addition to the development of existing approaches. The key barriers are the creation of interoperable agent hierarchies. Ambient intelligence is determined by the requirements of the business sector and focuses on commercial markets (which tend to be more efficiency-oriented and less price-sensitive). No significant changes in behaviour are expected.

Dimitrios is a more specific scenario, the emergence of which can be observed in this period. It offers an alternative way of using a customized, more modular environment. The emphasis is on play and social interaction rather than "efficiency." Ambient intelligence focuses on the market segment of the younger generation (Generation Z). Behavioural changes mainly concern the willingness to reveal (or mask) one's personality online. This is an approach that would allow the development of one's own and the creation of new applications based on the requirements of acquaintances, colleagues at work, and friends.

Carmen is another part of two "individual" scenarios resulting from infrastructure development (i.e., highly developed networks of interoperable sensor systems and dynamic database management systems). It also brings significant assumptions about changes in public behaviour, such as the acceptance of traffic management actions and systems.

Annette and Solomon's scenario is probably the most demanding in terms of time, as it has high technological and socio-economic requirements. It involves significant technical developments, such as shared presence and visualization technologies, or a breakthrough in computer-assisted learning techniques. In addition, the scenario presents a challenging social vision of an ambient society in order to promote social life through shared interests. The basis is to understand the education system and fulfill its potential. Qualified personnel contribute to the competitiveness of a company, and the skills of employees bring growing opportunities. From the perspective of this scenario, it is necessary to recognize the importance of educational institutions and strengthen their position.

1.7 Barriers to Building Ambient Intelligence in Enterprises

The integration of innovative pervasive technologies into business processes and the building of ambient intelligence in a company is determined by the existence of internal and external barriers, which we have identified on the basis of theoretical principles (Abascal, 2004; Punie, 2005; Friedewald et al., 2005; Ducatel, 2010; Jaschinski & Allouch, 2015, PwC, 2016) and consultations with companies that integrate innovative pervasive technologies, implement elements of digitisation and virtualisation into business processes, and create ambient intelligence in the enterprise. Consultations with companies that are mentors in the field of building ambient intelligence in companies were an important source of information.

Abascal (2004) dealt primarily with technical barriers in his studies. Punie (2005) also pointed to technical barriers, but at the same time examines barriers from the socio-economic environment and the internal environment of the enterprise, the acceptance of new technologies, social acceptance, new skills, and digital literacy.

Ducatel (2010) pointed to ambient intelligence barriers as part of ambient intelligence scenarios (Maria, Dimitrios, Carmen, Annette, and Solomon's). He pointed to several types of barriers: corporate resources, new technologies, technological barriers, social barriers, individuality, communication barriers, but also examines barriers from the company's environment.

A comprehensive study on barriers to the integration of innovative technologies was conducted by Jaschinski and Allouch (2015), who identified the following significant barriers: usability, lack of human interaction, technological factors, costs, privacy concerns, and information security.

The document Analysis of the Impact of Digital Transformation on Entrepreneurs (MPSVaR SR, 2017) in the private and public sectors pointed to poor preparedness of small and medium-sized enterprises in particular in terms of a lack of resources to invest in innovative pervasive technologies.

A global survey by PwC (2016) identified that a very significant barrier to the integration of innovative pervasive technologies into business processes and the development of ambient intelligence in a company is the internal environment of the company, in particular the skills of employees in working with technologies. This is the area of digital literacy. The level of digital and information literacy as a barrier is highlighted in the research of Friedewald et al. (2005).

Bureš et al. (2016) pointed to the barrier of insufficient information literacy in their study and highlighted the need for education in the field of ambient intelligence and the integration of ambient intelligence into education. The main reason for their research stemmed from the existence of different generations of students, employees, managers, and business owners. The varying levels of digital literacy among employees, which are sometimes insufficient, are a significant barrier to the integration of innovative technologies into business processes.

Ambient intelligence can develop many areas and contribute to making life more efficient, but users must be sufficiently skilled in working with these technologies (Friedewald et al., 2005).

1.8 Summary of Theoretical Background

Ambient intelligence is a fundamental concept in normative visions for information technology in the European Union. It represents a general framework for the future European information society and is its long-term vision. Ambient intelligence has become a multidisciplinary topic of interest and many areas of research where its positive impact on society can be identified (Augusto & McCullagh, 2007). The basic characteristic of ambient intelligence (ISTAG, 1999; ISTAG, 2003) can be considered to be intuitive work with information and communication technologies, which we often refer to as "user friendly."

Ambient intelligence is a concept developed by the European Commission's advisory group for the Information Society and Information Technologies program (ISTAG, 2001; ISTAG, 2002). ISTAG (2003) believes that it is necessary to take a holistic view of ambient intelligence, taking into account

not only technology, but the entire innovation supply chain from science to the end user, as well as various elements of the academic, industrial, and administrative environments that facilitate or hinder the realization of the vision of ambient intelligence. ISTAG has recognized the complexity and rapid development of the relevant technologies that comprise it. It has taken a holistic approach and identified areas that need to be addressed in the implementation of ambient intelligence in terms of technology, business models, society, and entrepreneurship.

Scientific and technological progress and the advent of the fourth industrial revolution have stimulated the emergence of ambient intelligence. The concept of next-generation information and communication technologies has created a basis for the construction of a new paradigm of ambient intelligence. Based on the analysis and comparison of theoretical starting points and the identification of homogeneous and heterogeneous features, we classify the authors' definitions of ambient intelligence into three groups (technologically, multi-faceted, and visionary definitions), based on the content of each definition. Within these three groups, we presented the definitions chronologically to make the development and shift of the paradigm in this area clearer. Based on a study of the literature, it can be identified that authors reject a precisely specified and narrow definition of the concept of ambient intelligence. Authors most often work with the concepts of innovative pervasive technologies, communication, mobility, virtualisation, and human interaction. These concepts, which authors work with in their definitions, cannot be understood only on a theoretical level, but also as the basis of the concept of the industrial sector.

The theoretical contexts we have analysed represent ontological considerations of ambient intelligence, in some cases suggesting a view of the future, and the authors' definitions appear visionary. We conclude that ambient intelligence is a new concept and vision, bringing together several functions related to the integration of innovative pervasive information and communication technologies into the environment in collaboration with the user.

The analysis of the conceptual apparatus has led to the identification of areas of interest in ambient intelligence covered by the definitions of domestic and foreign authors, which we have presented in a summary table. The genesis of developments in the field of definitions of ambient intelligence ranges from a technological orientation to visionary definitions. In the period of the creation of ambient intelligence, authors point to the technologies that constitute it. In subsequent periods, they gradually integrate human, social,

and economic aspects. Current definitions and views of authors point to the building of an ecosystem with innovative intelligent pervasive technologies that are capable of responding to user requirements and learning.

Based on an analysis of theoretical foundations, systematization, and generalization, we have defined ambient intelligence.

Ambient intelligence represents a multidisciplinary approach, integrating innovative pervasive technologies and systems forming an ecosystem that intelligently responds to user requirements based on collected, transformed, analysed, and evaluated data.

Ambient intelligence is a multidisciplinary approach that focuses on the integration of innovative pervasive technologies that support user activities through specific ambient services provided with minimal user intervention. Essentially, an ambient intelligence system should be aware of a person's presence, perceive that person's needs, and be able to adapt to the user's needs. Ambient intelligence brings new insights into the environment for software development and implementation, where there are large numbers of different devices and sensors that need to be integrated to build a programmable and auto-configurable information systems infrastructure. The focus is no longer on hardware, computers, or networks. Intelligence must be provided in everyday environments.

The most important features of ambient intelligence include pervasiveness, integration, mobility, adaptability, and personalization. We note that ambient intelligence consists of several elements that can be classified into the ambient domain and elements that constitute the intelligence of the system. The ambient domain includes elements that represent innovative pervasive technologies, while hardware and intelligence form contextual awareness and interaction with the human factor.

An important part of ambient intelligence is its platforms, which we have categorized into two groups based on technological and integration aspects. Individual platforms are functional and autonomous, but their interaction forms ambient intelligence.

Several scenarios and contexts for the applicability of ambient intelligence can be identified in the literature. The scenarios we describe are not traditional extrapolations from the present, but offer provocative views of the future that can be realized. Each scenario has a script that is used to create a key for the development of technologies, society, economy, and markets necessary to achieve that scenario. Some scenarios seem visionary and are a

question of the future, while others are more specific and focus on a selected group of users.

The integration of innovative pervasive technologies brings several effects for businesses that can help them succeed in competition, simplify work, and effectively exploit opportunities, as well as identify potential threats. Based on an analysis of theoretical principles, we have divided effects into three groups: financial, customer, and process effects.

Achieving effects of integrating innovative pervasive technologies into business processes, as well as the integration itself and building ambient intelligence, can be influenced by several internal and external barriers. The most significant of these are financial capital, financial demands, and the level of information literacy of parties involved.

2 OBJECTIVE OF RESEARCH

Based on the analysis, dissection, comparison, systematization, and taxonomy of theoretical knowledge about ambient intelligence and the current state of business practice, we have set the main objective.

The main objective is to examine the current state of integration of ambient intelligence elements in business practice in Slovakia and to identify predictors influencing the level of ambient intelligence of a company.

To achieve the main objective, we have set several partial objectives for the work:

- Analyse, dissect, and compare theoretical foundations.
- Identify areas of interest in ambient intelligence.
- To examine the current state of integration of innovative pervasive technologies and the level of ambient intelligence in companies in the Slovak Republic.
- Identify predictors influencing the development of ambient intelligence.
- Identify significant barriers to building ambient intelligence in a company.
- Verify research hypotheses and formulate research conclusions.
- Define significant areas for the creation of ambient intelligence in business practice.
- Confront research results with theoretical foundations.
- Propose recommendations for scientific research and business practice.

Research Hypotheses

For the purpose of accuracy and rigor in scientific research in the subject area and to expand the current state of knowledge, we have established several research hypotheses based on an analysis of scientific theories, studies, surveys, and knowledge from business practice.

I. Predictors influencing the development of ambient intelligence

Based on our findings, we conclude that some authors define ambient intelligence in their studies in overly technical terms, characterizing individual technologies (Augusto & McCullagh, 2007), pointing to the importance of data and the extent of its analysis (Kaptein, 2018), the level of digitalisation

(Aarts et al., 2001), the level of virtualisation (Ramos, Augusto & Shapiro, 2008; Smit et al., 2016), and the level of augmented reality implementation (Kleinberger et al., 2007; Van Hoof, 2011; Bravo et al., 2014). In several of the theoretical frameworks analysed (Riva, Vatalaro & Davide, 2005; Kleinberger et al., 2007; Augusto & McCullagh, 2007; Charitos, 2008; Ramos, Augusto & Shapiro, 2008; Aarts & De Ruyter, 2009; Veronica et al., 2009; Van Hoof, 2011; Bravo et al., 2014), it is also possible to identify the significant influence of the human factor, i.e., the attitude of company management towards the integration of innovative pervasive technologies into business processes. Based on the above theoretical starting points, we have established a research hypothesis and research question.

Research hypothesis

In setting the research question, we assume that activities resulting from the integration of innovative pervasive technologies into business processes and the attitude of company management towards these technologies have a significant impact on the level of ambient intelligence achieved by the company.

Research question

How do selected activities influence the level of ambient intelligence achieved by a company: data analysis, digitisation, virtualisation of business processes, implementation of augmented reality, and the attitude of company management towards data (the importance of data) and innovative pervasive technologies?

Hypothesis No. 1 a)

H_0 : The importance of data does not have a statistically significant impact, measured by linear regression, on the achieved level of ambient intelligence of the company.

H_1 : The significance of data has a statistically significant impact, measured by linear regression, on the level of ambient intelligence achieved by a company.

Hypothesis No. 1 b)

H_0 : The degree of data analysis has no statistically significant impact, measured by linear regression, on the achieved level of ambient intelligence of the company.

H_1 : The degree of data analysis has a statistically significant impact, measured by linear regression, on the level of ambient intelligence achieved by the company.

Hypothesis No. 1 c)
H_0 : The level of digitisation of business processes has no statistically significant impact, measured by linear regression, on the achieved level of ambient intelligence of the company.
H_1 : The level of digitisation of business processes has a statistically significant impact, measured by linear regression, on the achieved level of ambient intelligence of the company.

Hypothesis No. 1 d)
H_0 : The level of virtualisation of business processes has no statistically significant impact, measured by linear regression, on the achieved level of ambient intelligence of the enterprise.
H_1 : The level of virtualisation of business processes has a statistically significant impact, measured by linear regression, on the achieved level of ambient intelligence of the enterprise.

Hypothesis No. 1 e)
H_0 : The level of implementation of augmented reality elements into business processes has no statistically significant impact, measured by linear regression, on the achieved level of ambient intelligence of the enterprise.
H_1 : The level of implementation of augmented reality elements into business processes has a statistically significant impact, measured by linear regression, on the achieved level of ambient intelligence of the company.

Hypothesis No. 1 f)
H_0 : Management's attitude towards the integration of innovative pervasive technologies into business processes has no statistically significant impact, as measured by linear regression, on the level of ambient intelligence achieved by the company.
H_1 : Management's attitude towards the integration of innovative pervasive technologies into business processes has a statistically significant impact, measured by linear regression, on the achieved level of ambient intelligence in the company.

II. Barriers to building ambient intelligence

The integration of innovative pervasive technologies into business processes and the building of ambient intelligence in a company is determined by the existence of internal and external barriers, which we have identified on the basis of theoretical starting points (Abascal, 2004; Punie, 2005; Friedewald et al., 2005; Ducatel, 2010; Jaschinski & Allouch, 2015, PwC, 2016) and consultations with companies that integrate innovative pervasive technologies, implement elements of digitisation and virtualisation into business processes, and build or would like to build ambient intelligence in their companies.

In our research, we examine the barriers we have identified in the theoretical framework, but we also build on our previous research. These theoretical foundations and facts formed the basis for the formulation of a hypothesis focused on examining the barriers to ambient intelligence. Based on the above theoretical foundations, we established a research assumption and a research question.

Research assumption

We assume that companies do not differ in their perception of barriers depending on their size (micro, small, medium, large) and activity (non-manufacturing, manufacturing).

Research question

Which internal and external barriers most significantly prevent companies from building ambient intelligence?

Hypothesis No. 2 a)

H_0 : Depending on their size, companies differ statistically significantly in their perception of very significant barriers.

H_1 : Companies do not differ statistically significantly in their perception of very significant barriers depending on their size.

Hypothesis No. 2 b)

H_0 : Companies differ statistically significantly in their perception of very significant barriers depending on their activity.

H_1 : Businesses do not differ statistically significantly in their perception of very significant barriers depending on their activity.

The results of the work, analysis, verification of research hypotheses, formulation of answers to research questions, and conclusions that fulfill the individual partial objectives and the main objective are presented in Chapter 4, Results of the research.

3 METHODOLOGY AND RESEARCH METHODS

In our research, we used a whole set of general and specific scientific methods, which enabled us to achieve partial objectives and the main objective of the work. The scientific methods we used provided us with answers to research questions, which we used to verify research hypotheses, resulting in the formulation of conclusions. The following section describes the research object, the research procedures, and the scientific methods applied in the study. Results of the application of general and specific methods are presented in Chapter 4, Results of the research.

3.1 Characteristics of the Research Object

The object of the study was companies in the Slovak Republic. There were 206 relevant respondents whose answers were included in the analysis. The structure of the survey sample consisted of 79% commercial companies, 6% self-employed persons, and 15% other companies. The representativeness of the sample was ensured by regional balance, with the sample coming from all Slovak regions. The structure of the sample (Table 3.1) by sector approximates the distribution of companies in the national economy (statistical classification of economic activities – SK NACE).

Table 3.1 : Structure of the research sample by sector

Sector	Percentage representation of respondents
A Agriculture...	5.34
C Industrial production	24.27
D Electricity supply...	0.49
E Water supply...	0.49
F Construction	9.71
G Wholesale and retail trade...	12.14
I Accommodation and food services...	5.34
J Information and communication	6.31
K Financial and insurance activities	8.25
L Real estate activities	0.49
M Professional, scientific and technical activities	3.88
N Administrative and support services	3.40
O Public administration and defense....	0.97
P Education	3.40
Q Healthcare	2.43
R Arts, entertainment, and recreation	0.49
S Other activities	12.62
Total	**100.00**

Source: own processing

The most represented were industrial manufacturing companies (24%), other activities (13%) and wholesale and retail trade (12%). Companies were also segmented according to manufacturing/non-manufacturing activities. The survey sample of companies segmented by activity consisted of 40% manufacturing and 60% non-manufacturing companies. We segmented the companies by size (Table 3.2) based on the recommendation of European

Commission 2003/361/EC, based on the number of employees (micro 1-9, small 10-49, medium 50-249, large company >=250).

Table 3 .2 : Structure of the research sample by size

Enterprise size	Number
Micro	17.48
Small	19.42
Medium	24.76
Large	38.35
Total	100.00

Source: own processing

3.2 Work Procedures

Literary sources were drawn primarily from citation and reference databases such as Web of Science, Scopus, EBSCO, and others. Sources were analysed and compared in detail and systematically. By decomposing individual parts, we gained a deeper insight into the research problem. We meticulously analysed individual literary sources, definitions, and authors' approaches, searching for their essence and homogeneous and heterogeneous features, which resulted in a summary table that highlights areas of interest in ambient intelligence captured by the authors' definitions. In it, we point out the occurrence of terms representing ambient intelligence: technology, virtuality, sensitivity, responsiveness, adaptability, transparency, truthfulness, realism, pervasiveness, and intelligence.

Formulation of the research problem is based on a literature review in which authors associate ambient intelligence with the integration of information and communication technologies, innovative pervasive technologies, digitisation, virtualisation, and augmented reality into business processes.

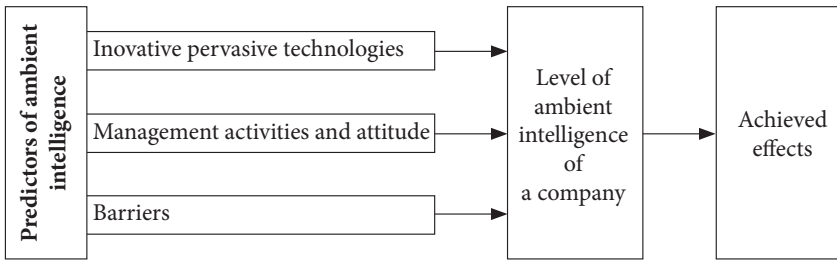
As part of the work process, we compiled a questionnaire based on a detailed analysis of literary sources, knowledge of the current state of business management and information and communication technologies, and case studies, semi-structured and structured interviews with companies cooper-

ating in the scientific research activities of the faculty and department, and mentors in the field of building ambient intelligence in companies.

We conclude that the measuring instrument (questionnaire) had sufficient construct validity. The measuring construct empirically shows relationships with other variables as predicted by theory (Pelikán, 2011). Induction, deduction, and abstraction are the methods we used to compile a questionnaire focused on ambient intelligence.

We then conducted a questionnaire survey among companies in the Slovak Republic using random sampling. After obtaining the data, we measured the internal consistency of the questionnaire. We subjected the data obtained from the questionnaire survey to detailed statistical analysis using MS Excel and IBM SPSS. We examined the structure of the data set, the relationships and strength of the relationship between variables, and predicted the strength of the dependence. In some cases, we examined and quantified the functional and predictive relationship between variables using linear regression analysis.

Figure 3.1: Research model



Source: own processing

We analysed and examined in detail the individual areas of research in the structure presented in the research model (Figure 3.1). The results are systematically presented in the following fourth chapter.

The output of solution (in accordance with the set partial objectives and the main objective of the work) was the formulation of conclusions from the statistical survey, verification (acceptance/rejection) of hypotheses and their confrontation with theoretical principles, and the formulation of answers to research questions.

Through generalization and interpretation, we formulated recommendations for the scientific research field, business practice, and the field of edu-

cation. At the same time, we also outlined new areas of research direction in the subject matter.

3.3 Methods of Data Collection and Their Sources

Literary sources were drawn primarily from citation and reference databases such as Web of Science, Scopus, EBSCO, and others. These formed the basis for the construction of the content of the first chapter, Current Status of the Issue at Home and Abroad. We obtained valuable information directly from company managers through personal meetings, structured and semi-structured interviews, and interviews with representatives of companies that are mentors in the field of building ambient intelligence in companies.

The data that formed the basis for the statistical survey to determine the current state of ambient intelligence in companies in the Slovak Republic and to verify research hypotheses was obtained through a questionnaire survey conducted by random selection in companies in the Slovak Republic.

During questionnaire distribution, attention was paid to regional balance and to ensuring that the sectoral composition of the sample broadly reflected the structure of enterprises in the Slovak economy.

Individual questions and variables were formulated on the basis of induction, deduction, and a certain degree of abstraction. The questionnaire (which met conditions of validity and reliability) contained open-ended and closed-ended questions that were measured using nominal, ordinal, and interval variables. A Likert scale of 0 (insignificant) to 6 (very significant) was used. We also used secondary statistical data to verify our conclusions.

3.4 Methods of Evaluation and Interpretation of Results

We meticulously analysed, compared, and contrasted individual theoretical approaches of domestic and foreign authors, pointing out homogeneous and heterogeneous features, and we carried out a taxonomy of conceptual apparatus.

We use an extensive set of mathematical and statistical methods to evaluate the data obtained from the questionnaire survey. We measure the accuracy and reliability of this research tool using Cronbach's Alpha reliability, because the items that make up the questionnaire are not dichotomous but have a wider range (Likert scale). We analysed the reliability of the scales used in the groups that were the subject of the survey in relation to the in-

dividual parts of the results of the work. The results of Cronbach's Alpha are shown in Table 3.3 below.

Table 3.3 : Reliability of the research tool

Scales used for survey groups	Cronbach's Alpha
Platforms building ambient intelligence	0.843
Factors influencing the building of ambient intelligence	0.830
Achieving effects from the integration of innovative pervasive technologies	0.975
Significance of barriers	0.903
Significance of the area of implementation of ambient intelligence	0.928

Source: own processing

The reliability of the scale of platforms building ambient intelligence in the enterprise is α = 0.843. The reliability of individual questions ranged from α = 0.796 to α = 0.853. The reliability of the scale of factors influencing the building of ambient intelligence in the enterprise is α = 0.830. The reliability of individual questions ranged from α = 0.810 to α = 0.840. The reliability of the scale of achieving individual effects through the integration of innovative pervasive technologies is α = 0.975. The reliability of individual questions ranged from α = 0.974 to α = 0.975. The reliability of the scale for the significance of barriers that prevent or slow down the development of ambient intelligence in a company is α = 0.903. The reliability of the significance of individual barriers ranged from α = 0.895 to α = 0.908. The reliability of the scale for determining the significance of the area of implementation of ambient intelligence and its tools is α = 0.928. The reliability of the significance of individual areas ranged from α = 0.923 to α = 0.927.

Field and Hole (2002) state that a Cronbach's alpha level above 0.8 is acceptable, while a lower value indicates a relatively unreliable scale. Author Anýžová (2015) works with a Cronbach's alpha value of 0.7, which she refers to as the lower limit of reliability.

From the analysis of the reliability of the research tool, we conclude that the scales were designed at an excellent level and the results of the statistical analysis of the questionnaire survey are sufficiently reliable and easily in-

terpretable. The questionnaire can be considered sufficiently reliable and, as stated in section 3.2 Working Procedures, sufficiently valid.

In the individual analytical sections of the scientific monograph in Chapter 4 Results of the Work, we use descriptive statistics to analyse the current state of integration of pervasive technologies, factors influencing the development of ambient intelligence, the effects achieved from the integration of innovative pervasive technologies, barriers, and areas of development of ambient intelligence.

Each area covered by the questionnaire survey—the current state of the integration of pervasive technologies, factors influencing the development of ambient intelligence, effects achieved through the integration of innovative pervasive technologies, barriers to building ambient intelligence, and areas of ambient intelligence development—was analysed in detail and evaluated using three groups of indicators (Hanák, 2016):

1. central tendency,
2. variability,
3. distribution shape.

The individual tools of these three groups provide us with sufficiently relevant data for evaluation, commentary, and taking a position on the issue. We present the partial results of the statistical survey in the individual subchapters of the fourth chapter, Results of the Work.

In selected subdomains of the questionnaire, we examine causality, the mutual relationships between individual variables.

Before conducting more in-depth statistical analyses, we verify two assumptions for the variables (Mareš, Rabušic & Soukup, 2015):

1. **normality of data distribution** – assumption of normal data distribution using the Kolmogorov-Smirnov test. In all cases of testing, the condition of a threshold number of over 30 units in the set as the minimum lower limit is met (Hanák, 2016).
   We compare the distribution of the sample with a normally distributed sample that has the same mean and standard deviation. Based on the results of this testing, we then apply parametric or non-parametric tests.
2. **homoscedasticity** – the correctness of the results from parametric tests depends on the variances in the individual groups under investigation.

At the same time, we also verify the assumption of sphericity, which requires that the variances in all possible measurement differences within individual units in the set be identical.

Homoscedasticity and sphericity will be verified using Levene's test, the results of which (p, or Sig.) will determine whether a parametric or non-parametric test is applied.

Based on the verification of the above assumptions, we will apply the following parametric tests: the two-sample t-test for two different groups and ANOVA with Bonferroni correction for more than two groups.

If the data are not normally distributed, we apply non-parametric tests: Mann-Whitney U test for two groups (equivalent to t-test) and Kruskal-Wallis test (equivalent to ANOVA) for more than two groups.

Using the above methods of testing mean values for individual research hypotheses and variables, we identify differences between groups and examine whether these differences are systematic and not just random.

Among the variables, we will examine not only the difference in mean values and the systematic nature of the difference, but we will also determine and quantify the degree of linear dependence between the variables. We will use correlation, measured by the correlation coefficient, which can take values from -1 (absolute indirect dependence) to 0 (no dependence, no linear dependence) or from 0 to +1 (absolute direct dependence).

For normally distributed variables, we use Pearson's correlation coefficient, and if the data are not normally distributed, we apply Spearman's correlation test.

To interpret the strength of mutual dependence measured by the correlation coefficient, we use the recommendations of Cohen (1988), Rimančík (2007), and Hanák (2016). However, we do not always use Pearson's or Spearman's correlation coefficient; the choice of method will depend on the level of measurement.

Our choice of a specific statistical method for examining interrelationships is determined by the overview of authors Mareš, Rabušic, and Soukup (2015). For example, when examining the relationship between company size (micro, small, medium, large) and the use of sensors for data collection in the company, we use the Eta coefficient as these are nominal and interval variables.

We will measure the indication of a certain possibility of predicting the level of ambient intelligence achieved by a company through individual fac-

tors in section 4.2 Factors influencing the development of ambient intelligence using Kendall's tau c and Spearman's rho.

For the section on predictors influencing the development of ambient intelligence, a research assumption, research question, and research hypothesis have been established. The work procedure consists of two phases: in the first phase, we use correlation analysis to examine the dependence between the variables (factors) affecting the development of ambient intelligence in a company. The second phase consists of examining the functional and predictive relationship between the variables and quantifying it precisely using linear regression analysis.

We examine the predictors influencing the development of ambient intelligence in a company using correlation analysis and multiple linear regression. We use correlation to quantify the degree of linear dependence between variables. In order to construct the results and answer the research question, we quantify the existence of a specific relationship between variables to verify the hypotheses.

Statistical significance is measured at a significance level of $p = 0.05$, marked as *. In some cases, the model and individual predictors show statistical significance at a significance level of $p = 0.01$, marked as **. For individual models, we monitor the significance of the model, individual predictors, model variance measured by the R^2 indicator, and its variability.

We assume that individual predictors have a statistically significant independent influence on the achieved level of ambient intelligence, but that their influence on the achieved level of ambient intelligence begins to diminish when they interact with each other.

In order to quantify the variables, i.e., the predictors that influence the level of ambient intelligence of a company, as accurately as possible, we apply multiple linear regression. We will construct this model in such a way that the statistical significance of individual variables, as well as the entire model, is maintained at a significance level of $p = 0.05$. When compiling the equation for the level of ambient intelligence - AMI (y), we start from the general equation $Y = b(_0) + b(_1)_x$.

The analysis of barriers to building ambient intelligence will include a quantification of the significance of individual barriers.

A research question was set for this part of the research. The working procedure for addressing this question consists of analysing the significance of individual barriers using descriptive statistics and systematically classify-

ing the barriers into three groups based on the standard deviation method (Hanák, 2016).

We define the boundaries of individual groups based on the calculated average value and standard deviation $\pm$. By adding the standard deviation to the average, individual vaiables (barriers) belong to very significant areas. Thus, all units in the set that have this and higher values are one extreme group, which is a very significant group. By subtracting the standard deviation from the average and all values lower than the obtained value, they belong to the less significant ones. A variable (barrier) that reaches a value of 0 is considered insignificant, but there are no such variables in the given set.

4 RESULTS OF THE RESEARCH

The integration of innovative pervasive technologies into business processes is unstoppable and desirable in today's digital society and the fourth industrial revolution. The biggest challenge for companies in the industrial sector in building ambient intelligence is not only new technologies, but also the integration of the human factor. In the following chapter, we analyse in detail, evaluate the data obtained from the questionnaire survey, and formulate conclusions from the analysis of the results for each partial section. The evaluation and presentation of the results of the work is based on the research model.

The question in this part of survey was aimed at summarizing and obtaining respondents' opinions on whether they are building an organisation that implements innovative pervasive technologies.

Table 4.1: Interest of companies in building ambient intelligence of the company

Status/size of the company	Micro	Small	Medium	Large	Σ
Not feasible	25.00	30.00	11.76	8.86	16.50
We only know in theory	19.44	2.50	15.69	2.53	8.74
We have considered it, but are not implementing it yet	11.11	12.50	7.84	8.86	9.71
We will implement	8.33	12.50	9.80	7.59	9.22
We have already taken the first steps	8.33	17.50	7.84	7.59	9.71
We are gradually introducing	11.11	17.50	31.37	20.25	20.87
Implemented	16.67	7.50	15.69	44.30	25.24
Σ	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Source: own processing

Analysed companies in the Slovak Republic are interested in building businesses with innovative pervasive technologies. The interest of companies in building ambient intelligence (Table 4.1) reaches a value of M= 3.50, SD = 2.21. We consider it positive that two-thirds of the analysed companies are already trying to do so. Twenty-five percent of companies consider themselves to be such organisations, 40% are trying to build such a company, and

35% of companies are not yet attempting to integrate innovative pervasive technologies and build ambient intelligence.

Almost half of large companies consider themselves to be organisations that have already integrated innovative pervasive technologies, while medium-sized companies are working hardest to become such organisations. However, we can positively assess the direction of development, as all types of companies are working to build ambient intelligence in their companies.

Manufacturing companies are still lagging behind in building an organisation that represents the pervasiveness of innovative technologies, with only 8% of them rating themselves as already being such an organisation, compared to 17% of non-manufacturing companies. However, we consider it positive that as many as 48% of manufacturing companies are trying to build such an organisation and have already taken the first steps, compared to 28 % of non-manufacturing companies.

4.1 Predictors Influencing the Development of Ambient Intelligence

In the previous section, we analysed in detail the current state of use and companies' intentions to implement selected pervasive technologies that build ambient intelligence.

Based on theoretical principles, we established a research hypothesis and research question.

Research hypothesis

In setting the research question, we assume that activities resulting from the integration of innovative pervasive technologies into business processes and the attitude of business management towards these technologies have a significant impact on the level of ambient intelligence achieved by the business.

Research question

How do selected activities influence the level of ambient intelligence achieved by a company: data analysis, digitisation, virtualisation of business processes, implementation of augmented reality, and the attitude of company management towards data (the importance of data) and innovative pervasive technologies?

Verification of hypotheses

In order to answer this research question accurately, we constructed hypotheses 1. a) – f), which can be tested empirically.

Hypothesis verification is divided into two phases: in the first phase, we use correlation analysis to examine the dependence between variables (predictors) influencing the development of ambient intelligence in a company. The second phase consists of examining the functional and predictive relationship between the variables and quantifying it precisely using linear regression analysis.

In the following section of partial analyses and construction of conclusions for the purpose of constructing an answer to the research question, we examine the dependence between variables predictors influencing the development of a company's ambient intelligence (AMI level), thereby indicating a certain possibility of prediction on a general level.

Table 4.2: Correlation between selected predictors and the level of ambient intelligence of a company

Variable	Coefficient	AMI level
Degree of data analysis	Kendall's tau-c	0.392**
	Spearman Correlation	0.499
Significance of data	Kendall's tau-c	0.286
	Spearman Correlation	0.385
Digitisation	Kendall's tau-c	0.371
	Spearman Correlation	0.470
Virtualisation	Kendall's tau-c	0.407
	Spearman Correlation	0.523
Augmented reality	Kendall's tau-c	0.255
	Spearman Correlation	0.334
Management's attitude towards technology integration	Kendall's tau-c	0.385
	Spearman Correlation	0.483

*Note: * $p = 0.05$, ** $p = 0.01$*
Source: own processing

Building ambient intelligence in a company largely depends (Table 4.2) on the introduction of virtualisation elements that the company integrates into its business processes Kendall's tau – c = 0.407, $p < 0.05$; Spearman r = 0.523, $p < 0.05$ and the extent to which companies analyse and evaluate data Kendall's tau – c = 0.392, $p < 0.05$; Spearman r = 0.499, $p < 0.05$. The average strength of the mutual relationship between the achieved level of ambient intelligence of a company can be identified in the management's attitude towards integrating innovative pervasive technologies into business processes Kendall's tau – c = 0.385, $p < 0.05$; Spearman Correlation = 0.483, $p < 0.05$, introduction of elements of digitisation Kendall's tau – c = 0.371, $p < 0.05$; Spearman r = 0.470, $p < 0.05$. We found a low level of correlation in the relationship between the achieved level of ambient intelligence of the company and the importance that the company attaches to the data obtained Kendall's tau – c = 0.286, $p < 0.05$; Spearman r = 0.385, $p < 0.05$ and the introduction of augmented reality elements Kendall's tau – c = 0.255, $p < 0.05$; Spearman r = 0.334, $p < 0.05$.

We conclude that building ambient intelligence in a company **largely** depends on the level of virtualisation of business processes and the extent to which companies analyse and evaluate data. The level of building ambient intelligence in a company depends to **a moderate extent** on the attitude of company management towards innovative pervasive technologies and their integration into business processes, as well as the level of digitisation of business processes. There is **a low degree** of dependence between the level of building ambient intelligence in a company and the importance that company management attaches to the data obtained and the level of implementation of augmented reality elements into business processes.

Through correlation, we calculated the degree of mutual linear dependence between the variables, but we cannot quantify the specific relationship between the variables. In the following section, we therefore examine the functional and predictive relationship between the variables and quantify it precisely using linear regression analysis.

The aim is to determine the magnitude of the influence and the expected values that the dependent variable (the level of ambient intelligence of the company) will acquire, which is influenced by predictors (the importance of data and the degree of its analysis, the level of digitisation, virtualisation of business processes, and the level of implementation of augmented reality into business processes).

Hypothesis No. 1 a)

H_0: The importance of data does not have a statistically significant impact, measured by linear regression, on the achieved level of ambient intelligence of the company.

H_1: The significance of data has a statistically significant impact, measured by linear regression, on the level of ambient intelligence achieved by a company.

Table 4.3: Verification of Hypothesis No. 1 a)

Explanatory variable	*B*	*SE B*	*β*
Significance of data	0.314	0.044	0.445
Adjusted R^2		0.194	
F (1, 204)		50.285	
N		206	

*Note: * p = 0.05, ** p = 0.01*
Source: own processing

The importance of data for business management (very low – strategic, very significant) is a statistically significant factor in the level of ambient intelligence achieved by a company. The level of ambient intelligence achieved by a company is predicted by the importance of data attributed to it by company management: standardized $\beta = 0.445$, $t(1, 204) = 7.091$, $p < 0.001$, explains a small part of the variance $R^2 = 0.194$, $F(1, 204) = 50.285$, $p < 0.001$. From the results of the analysis, we conclude that the model is significant $p < 0.001$ at a significance level of $\alpha = 0.05$ and explains 19.40% of the variability ($R^2 = 0.194$).

Based on the above, we conclude that: the importance of data attributed to it by company management has a statistically significant impact, measured by linear regression, on the level of ambient intelligence achieved by the company. We reject hypothesis H_0 and accept hypothesis H_1.

Hypothesis No. 1 b)

Another factor analysed is the extent to which companies analyse data. The data obtained should not be passively collected in a data warehouse, but

should be analysed to provide the most relevant information for company management decision-making.

H_0 : The degree of data analysis has no statistically significant impact, measured by linear regression, on the level of ambient intelligence achieved by the company.

H_1 : The degree of data analysis has a statistically significant impact, measured by linear regression, on the level of ambient intelligence achieved by the company.

Table 4.4: Verification of hypothesis No. 1 b)

Explanatory variable	***B***	***SE B***	***β***
Data analysis rate	0.338	0.039	0.515
Adjusted R^2			0.261
F (1, 204)			73.513
N			206

*Note: * p = 0.05, ** p = 0.01*
Source: own processing

The extent to which companies analyse data (very low – very high) is a statistically significant factor in the level of ambient intelligence achieved by a company. The level of ambient intelligence achieved by a company is predicted by the extent to which companies analyse data: standardized $\beta = 0.515$, $t(1, 204) = 8.574$, $p < 0.001$, explains a small part of the variance $R^2 = 0.261$, $F(1, 204) = 73.513$, $p < 0.001$. From the results of the analysis, we conclude that the model is significant $p < 0.001$ at a significance level of $\alpha = 0.05$ and explains 26.10% of the variability ($R^2 = 0.261$).

Based on the above, we conclude that: the extent to which companies analyse data has a statistically significant impact, measured by linear regression, on the level of ambient intelligence achieved by the company. We reject hypothesis H_0 and accept hypothesis H_1 .

Hypothesis No. 1 c)

In the next step, we tested the impact of another factor, namely the level of digitisation of business processes.

H_0: The level of digitisation of business processes does not have a statistically significant impact, measured by linear regression, on the achieved level of ambient intelligence of the company.
H_1: The level of digitisation of business processes has a statistically significant impact, measured by linear regression, on the achieved level of ambient intelligence of the company.

Table 4.5: Verification of hypothesis No. 1 c)

Explanatory variable	*B*	*SE B*	*β*
Level of digitisation	0.437	0.047	0.543
Adjusted R^2			0.291
F (1, 204)			85.193
N			206

*Note: * p = 0.05, ** p = 0.01*
Source: own processing

The level of digitisation of business processes (very low – very high) is a statistically significant factor in the level of ambient intelligence achieved by a company.

The level of ambient intelligence achieved by a company is predicted by the level of digitisation of business processes: standardized $\beta = 0.543$, $t(1, 204) = 9.230$, $p < 0.001$, explains a small part of the variance $R^2 = 0.291$, $F(1, 204) = 85.193$, $p < 0.001$. From the results of the analysis, we conclude that the model is significant $p < 0.001$ at a significance level of $\alpha = 0.05$ and explains 29.10% of the variability ($R^2 = 0.291$).

Based on the above, we conclude that: the level of digitisation of business processes measured by linear regression has a statistically significant impact on the achieved level of ambient intelligence of the company. We reject hypothesis H_0 and accept hypothesis H_1.

Hypothesis No. 1 d)

The level of virtualisation of business processes is another of the tested predictors.

H_0: The level of virtualisation of business processes does not have a statistically significant impact, measured by linear regression, on the achieved level of ambient intelligence of the enterprise.
H_1: The level of business process virtualisation has a statistically significant impact, measured by linear regression, on the level of ambient intelligence achieved by the company.

Table 4.6: Verification of hypothesis No. 1 d)

Explanatory variable	*B*	*SE B*	*β*
Virtualisation	0.340	0.038	0.533
Adjusted R^2		0.280	
F (1, 204)		80.782	
N		206	

*Note: * p = 0.05, ** p = 0.01*
Source: own processing

The level of business process virtualisation (very low – very high) is a statistically significant factor in the level of ambient intelligence achieved by a company. The level of ambient intelligence achieved by a company is predicted by the level of business process virtualisation: standardized $\beta = 0.533$, $t(1, 204) = 8.988$, $p < 0.001$, explains a small part of the variance $R^2 = 0.280$, $F(1, 204) = 80.782$, $p < 0.001$. From the results of the analysis, we conclude that the model is significant $p < 0.001$ at a significance level of $\alpha = 0.05$ and explains 28.00% of the variability ($R^2 = 0.280$).

Based on the above, we conclude that: the level of business process virtualisation measured by linear regression has a statistically significant impact on the achieved level of ambient intelligence of the enterprise. We reject hypothesis H_0 and accept hypothesis H_1 .

Hypothesis No. 1 e)

Another of the tested factors of the achieved level of ambient intelligence is the level of implementation of augmented reality into business processes.

H_0 : The level of implementation of augmented reality elements into business processes does not have a statistically significant impact,

measured by linear regression, on the achieved level of ambient intelligence of the company.

H_1 : The level of implementation of augmented reality elements into business processes has a statistically significant impact, measured by linear regression, on the achieved level of ambient intelligence of the company.

Table 4.7: Verification of hypothesis No. 1 e)

Explanatory variable	*B*	*SE B*	*β*
Augmented reality	0.246	0.046	0.349
Adjusted R^2		0.118	
F (1, 204)		28.373	
N		206	

*Note: * p = 0.05, ** p = 0.01*
Source: own processing

The level of augmented reality implementation in business processes (very low – very high) is a statistically significant factor in the level of ambient intelligence achieved by a company. The level of ambient intelligence achieved by a company is predicted by the level of implementation of augmented reality into business processes: standardized $\beta = 0.349$, $t(1, 204) = 5.327$, $p < 0.001$, explains a small part of the variance $R^2 = 0.118$, $F(1, 204) = 28.373$, $p < 0.001$. From the results of the analysis, we conclude that the model is significant $p < 0.001$ at a significance level of $\alpha = 0.05$ and explains only 11.80% of the variability ($R^2 = 0.118$).

Based on the above, we conclude that: the level of implementation of augmented reality into business processes measured by linear regression has a statistically significant impact on the achieved level of ambient intelligence of the company. We reject hypothesis H_0 and accept hypothesis H_1 .

Hypothesis No. 1 f)

The human factor and its integration with innovative pervasive technologies can very often be identified in definitions of ambient intelligence. The integration of the human factor is conditioned by the attitude of the man-

ager and the company's management towards information and communication technologies.

H_0 : The attitude of management towards the integration of innovative pervasive technologies into business processes has no statistically significant impact, measured by linear regression, on the level of ambient intelligence achieved by the company.

H_1 : Management's attitude towards the integration of innovative pervasive technologies into business processes has a statistically significant impact, measured by linear regression, on the level of ambient intelligence achieved by the company.

Table 4.8: Verification of hypothesis No. 1 f)

Explanatory variable	***B***	***SE B***	***β***
Management attitude	0.441	0.047	0.549
Adjusted R^2			0.298
F (1, 204)			88.001
N			206

*Note: * p = 0.05, ** p = 0.01*
Source: own processing

The attitude of company management towards the integration of innovative pervasive technologies into business processes (very low, lax – very high, strategic) is a statistically significant factor in the level of ambient intelligence achieved by the company. The level of ambient intelligence achieved by a company is predicted by the attitude of company management towards the integration of innovative pervasive technologies into business processes: standardized $\beta = 0.549$, $t(1, 204) = 9.381$, $p < 0.001$, explains a small part of the variance $R^2 = 0.298$, $F(1, 204) = 88.001$, $p < 0.001$. From the results of the analysis, we conclude that the model is significant $p < 0.001$ at a significance level of $\alpha = 0.05$ and explains 29.80% of the variability ($R^2 = 0.298$).

Based on the above, we conclude that: the attitude of company management towards the integration of innovative pervasive technologies into business processes, measured by linear regression , has a statistically significant impact on the level of ambient intelligence achieved by the company. We reject hypothesis H_0 and accept hypothesis H_1 .

Before constructing the research question, a research assumption was established. We assumed that individual predictors (activities and attitudes) have a statistically significant independent impact on the achieved level of ambient intelligence. The results of the verification of hypotheses 1) a) to 1) f) showed that individual predictors have an autonomous statistically significant impact on the achieved level of ambient intelligence.

By comparing the interviews conducted with experts from business practice, it can be said that these individual activities and attitudes do not act autonomously in a company, but interact with each other, which was the subject of further research and verification. We assume that in mutual interaction, the influence of individual predictors on the achieved level of ambient intelligence begins to diminish.

In order to quantify the variables that influence the level of ambient intelligence in a company as accurately as possible, we applied multiple linear regression. We included all analysed predictors in the model (Table 4.9).

Table 4.9: Linear regression model

Explanatory variable	***B***	***SE B***	***β***
Significance of data	0.037	0.049	0.052
Data analysis rate	0.129	0.046	0.196
Management attitude	0.170	0.065	0.212
Digitalisation	0.075	0.069	0.093
Virtualisation	0.134	0.048	0.210**
Augmented reality	0.060	0.044	0.085
Adjusted R^2		0.416	
F (6, 199)		25.310	
N		206	

*Note: * p = 0.05, ** p = 0.01*
Source: own processing

From the results of multiple linear regression, we conclude that the model is statistically significant $R^2 = 0.416$, $F(6, 199) = 25.310$, $p < 0.001$ and explains up to 41.60% of the variability, but the individual predictors in mutual

interaction are not statistically significant (significance of data, digitisation, augmented reality).

We removed these statistically insignificant predictors from the multiple linear regression model and compiled a new model.

The conclusions of the statistical survey showed that the level of ambient intelligence achieved by a company is predicted by the extent to which the company analyses data that forms the basis for decision-making standardized $\beta = 0.222$, $t(3, 202) = 3.304$, $p = 0.001$, the attitude of company management towards the integration of innovative pervasive technologies into company processes: standardized $\beta = 0.279$, $t(3, 202) = 4.063$, $p < 0.001$ and the level of virtualisation of business processes standardized $\beta = 0.287$, $t(3, 202) = 4.452$, $p < 0.001$. The model explains a significant part of the variance $R^2 = 0.411$, $F(3, 202) = 48.779$, $p < 0.001$ and explains up to 41.10% of the variability. From multiple linear regression, the equation can be written as:

$$\textit{AMI level } (y) = 1.408 + 0.146 * \textit{Data analysis } (x_1) + 0.224 * \textit{Management attitude } (x_2) + 0.183 * \textit{Virtualisation } (x_3)$$

The interpretation can be derived from the previous equation: If the level of analysis of the acquired data increases by one unit, the level of ambient intelligence achieved increases by 0.146 points. If the attitude of company management towards innovative pervasive technologies improves, the level of ambient intelligence of the company will increase by an average of 0.224 points. By increasing the level of virtualisation of business processes by 1 point, the level of ambient intelligence will increase by 0.183 points.

Summary

Based on the research assumption that activities resulting from the integration of innovative pervasive technologies into business processes and the attitude of company management towards these technologies have a significant impact on the level of ambient intelligence achieved by the company, we formulate an answer to the research question.

Evaluation of the research question

How do selected activities influence the level of ambient intelligence achieved by a company: data analysis, digitisation, virtualisation of business processes, implementation of augmented reality, and the attitude of company management towards data (the importance of data) and innovative pervasive technologies?

The separately examined impact of selected activities and the attitude of company management towards data and innovative pervasive technologies statistically significantly influences the achievement of the level of ambient intelligence of a company, but their effect begins to disappear in mutual interaction. In mutual interaction, two activities influence the achievement of a company's ambient intelligence level , namely the extent to which the company analyses data and virtualizes business processes, and the attitude of company management towards innovative pervasive technologies.

The level of ambient intelligence development in a company largely depends on the level of virtualisation of business processes and the extent to which companies analyse and evaluate data. The level of ambient intelligence development in a company depends to a moderate extent on the attitude of company management towards innovative pervasive technologies and their integration into business processes, as well as the level of digitisation of business processes. There is a low degree of dependence between the level of building ambient intelligence in a company and the importance that company management attaches to the data obtained and the level of implementation of augmented reality.

At the same time, we note that if the level of analysis of the data obtained increases by one unit, the level of ambient intelligence achieved increases by 0.146 points. If the attitude of company management towards innovative pervasive technologies improves, the level of ambient intelligence of the company will increase by an average of 0.224 points. By increasing the level of virtualisation of business processes by 1 point, the level of ambient intelligence will increase by 0.183 points.

As companies increase their level of data analysis, the level of virtualisation of business processes, and strengthen management's attitude towards the integration of innovative pervasive technologies, the level of ambient intelligence of the company also increases.

4.2 Barriers to Building Ambient Intelligence in Enterprises

After analysing the state of use of ambient intelligence elements, its level in companies in the Slovak Republic, and identifying predictors influencing the building of ambient intelligence and the effects achieved from the integration of innovative pervasive technologies, we examined the barriers that prevent or slow down the building of ambient intelligence in companies.

Research assumption

We assume that companies do not differ in their perception of barriers depending on their size (micro, small, medium, large) and activity (non-manufacturing, manufacturing).

Research question

Which internal and external barriers most significantly prevent companies from building ambient intelligence?

Hypothesis No. 2 a)

H_0 : Depending on their size, companies differ statistically significantly in their perception of very significant barriers.

H_1 : Companies do not differ statistically significantly in their perception of very significant barriers depending on their size.

Hypothesis No. 2 b)

H_0 : Companies differ statistically significantly in their perception of very significant barriers depending on their activity.

H_1 : Businesses do not differ statistically significantly in their perception of very significant barriers depending on their activity.

Verification of hypotheses

To address this research question, we analyse the significance of individual barriers using descriptive statistics and systematically classify barriers into three groups based on the standard deviation method. We then test for statistically significant differences in the perception of individual barriers by companies depending on the size and activity of the company.

I. Analysis of the significance of barriers

Companies determined the significance of barriers (Table 4.10) on a scale of 0 insignificant to 100 very significant. We then segmented the barriers into three groups based on the standard deviation method:

1. $0 < H \leq 47.45$ = less significant barrier
2. $47.45 < H < 65.95$ = significant barrier
3. $65.95 \leq H \leq 100.00$ = very significant barrier

Table 4.10: Significance of barriers

Barrier	Value	Significance
B1 - Time	60.68	significant
B2 - Personnel	63.06	significant
B3 - ICT skills, digital and information literacy	68.70	very significant
B4 - Finance	73.18	very significant
B5 - Business management	58.07	significant
B6 - Legislation	47.52	significant
B7 - Technical equipment	63.53	significant
B8 - Nature of business	56.64	significant
B9 - Information security	63.84	significant
B10 - Lack of information on how to become a smart enterprise	51.15	significant
B11 - Lack of companies that could mentor others on how to build a smart enterprise	44.51	less significant
B12 - Hardware costs	58.07	significant
B13 - Installation and configuration costs	55.27	significant
B14 - Operating and maintenance costs	54.10	significant
B15 - Costs of integrating new systems with existing systems	59.27	significant
B16 - Lack of information strategy	55.50	significant
B17 - Heterogeneity of current equipment and its incompatibility with new equipment	55.25	significant
B18 - We do not see the benefits of building a smart enterprise	32.23	less significant

Source: own processing

From results of the descriptive characteristics (Table 4.11), we identified two very significant barriers, fourteen significant barriers, and two less significant barriers. In the following section, we comment on the results of the indicators of central tendency, quantiles, variability, and distribution shape.

Table 4.11: Results of descriptive statistics for individual barriers

Barrier	Mean	Median	Mode	Std. Dev.	Skew.	Std. Error of Skew.	Kurt.	Std. Error of Kurt.	Min	Max	Percentiles		
											25	50	75
Time	60.68	61.50	50	27.146	-.418	.169	-.647	.337	0	100	50.00	61.50	80.00
Personnel	63.06	70.00	80	27.818	-.632	.169	-.520	.337	0	100	50.00	70.00	80
ICT skills	68.70	75	80	25.105	-.695	.169	-.330	.337	0	100	50.00	75.00	90.00
Finance	73.18	80	100	25.550	-.953	.169	.314	.337	0	100	60.00	80.00	100.00
Company management	58.07	60	80	31.475	-.380	.169	-1.029	.337	0	100	30.00	60.00	80.00
Legislation	47.52	50	30	31.416	.149	.169	-1.170	.337	0	100	20.00	50.00	76.25
Technical equipment	63.53	70.00	80	27.656	-.418	.169	-.919	.337	0	100	40.00	70.00	90.00
Nature of business	56.64	55	50	31.705	-.263	.169	-1.067	.337	0	100	30.00	55.00	90.00
Information security	63.84	70	100	30.649	-.506	.169	-.835	.337	0	100	43.75	70.00	90.00
Lack of information	51.15	50	50	31.999	.020	.169	-1.203	.337	0	100	20.00	50.00	80
Absence of mentors	44.51	50	50	29.65	.201	.169	-.967	.337	0	100	20.00	50.00	70.00
Hardware costs	58.07	60	50	27.040	-.184	.169	-.753	.337	0	100	40.00	60.00	80.00
Installation and configuration costs	55.27	50	50	27.240	-.142	.169	-.733	.337	0	100	40.00	50.00	80.00
Operating and maintenance costs	54.10	50	50	26.752	-.085	.169	-.787	.337	0	100	30.00	50.00	76.25
Costs of integrating new systems with existing systems	59.27	60.00	50	26.011	-.362	.169	-.520	.337	0	100	50.00	60.00	80
Lack of information strategy	55.55	60	5	28.849	-.223	.169	-.874	.337	0	100	30.00	60.00	80.00
Heterogeneity of current devices and their incompatibility with new devices	55.25	50	50	29.89	-.181	.169	-.959	.337	0	100	30.00	50.00	80.00
We do not see the benefits of building a smart enterprise	32.23	20	0	34.498	.745	.169	-.809	.337	0	100	0	20.00	50.00

Source: own processing

Managers consider the lack of funds and the financial demands (N = 206, M = 73.18, STDEV = 25.550) necessary for the implementation and development of ambient intelligence to be a **very significant** barrier. The most frequently cited significance value by respondents was 100, and more than 50% of companies rated the significance of this barrier above 80. The percentile values are also significant, showing that only 25% of respondents rated the significance of the barrier below 60, with the remaining values above this level. At the same time, the skewness indicator (SKEW = -0.953) suggests that the distribution is negatively skewed, indicating that responses were concentrated towards the higher end of the scale.

From results of the analysis, we conclude that digital and information literacy (N = 206, M = 68.70, STDEV = 25.105) is also a very significant barrier that prevents or hinders the introduction of ambient intelligence elements into a company. This is not only about skills in working with individual information and communication technologies, but also about the attitude towards working with them and the willingness and ability to learn something new. Respondents most often reported a significance level of 80. As in the case of the financial cost of implementing ambient intelligence elements, in this case too, companies mainly reported higher values for the importance of barriers (SKEW = -0.695), with 25% of companies reporting a barrier importance value below 50 and 75% of companies reporting a value below 90.

The second group of **significant** barriers includes: information security, technical equipment, personnel, time, costs of integrating new systems with existing systems, company management, hardware costs, nature of business, lack of information strategy, installation and configuration costs, heterogeneity of current equipment and its incompatibility with new equipment, operating and maintenance costs, and lack of information on how to become a smart enterprise.

Businesses consider information security, infiltration, and security breaches to be a significant barrier (N = 206, M = 63.84, STDEV = 30.649), the most frequently occurring significance value was 100, half of the companies consider this barrier to be very significant, as they reported a value above 70, higher values prevail in the significance assessment (SKEW = -0.506), and 75% of respondents indicated a significance value of 90. The introduction of ambient intelligence into business processes naturally also brings risks for companies associated with information security breaches, and the impact of infiltrations can be very high.

The second significant barrier slowing down the development of ambient intelligence is the current technical equipment of the company (N = 206, M = 63.53, STDEV = 27.656). Some companies are not ready to build ambient intelligence, a smart company, due to the technical obsolescence of their hardware equipment. The introduction of intelligence elements also entails the modernization of technical equipment for reasons of compatibility and device communication capabilities. The most common significance value was 80, and the median of the set is 70. When assessing the significance of this barrier among companies, higher significance values prevailed (SKEW = -0.418), and 75% of respondents rated the significance of this barrier at 90.

The third significant barrier is personnel. The human capital of a company, as a valuable resource for building the development of an organisation, is also an integral part of ambient intelligence. Its integration is more than necessary. The absence or unwillingness of personnel (N = 206, M = 63.06, STDEV = 27.818) to engage in the changes brought about by ambient intelligence is a significant barrier. Companies most often rated this barrier at a significance level of 80, thus considering it significant. Up to 50% of respondents gave a significance value higher than 70, and higher significance values prevailed in the evaluation (SKEW = -0.632); only 25% of respondents consider this barrier to be less significant, as they gave a significance value of 50. The results of descriptive statistics on the significance of barriers that belong to the group of significant barriers are shown in Table 4.11.

We draw attention to the last of the group of significant barriers, namely the lack of information on how to become a smart enterprise (N = 206, M = 51.15, STDEV = 31.999). Enterprises most often reported a significance value of 50, and this significance value was seen by up to 50% of enterprises. The significance values reported by companies were approximately symmetrically distributed (SKEW = 0.020). The results of this analysis show that half of the companies surveyed consider this barrier to be significant, while the other half consider it to be less significant, which means that they have almost enough information on how to build an ambient business.

The third group of barriers**,** segmented into three groups based on significance**,** are **less significant barriers** that achieved a significance value (determined by companies) of less than 47.45 (H ≤ 47.45). Companies do not consider the lack of companies that would be mentors in building ambient intelligence and smart companies to be a very significant or significant barrier (N = 206, M = 44.51, STDEV = 29.650). This barrier is closely related to the availability of information on which elements of integration build ambi-

ent intelligence. Companies often assigned lower significance values to this barrier (SKEW = 0.201), with up to 25% of companies assigning a value of less than 20 to the significance of this barrier.

The least significant barrier from the perspective of companies in building ambient intelligence is the lack of awareness among companies and the fact that companies do not see the benefits of building ambient intelligence (N = 206, M = 32.23, STDEV = 34.498) and do not identify with its development. We consider it positive that companies have a positive attitude towards building ambient intelligence and integrating innovative pervasive technologies. We can conclude that they see the benefits of building it, are willing to build it, and are interested in integrating innovative pervasive technologies, digitisation, and virtualisation of business processes. When determining the significance of this barrier, companies reported low values, with the distribution positively skewed (SKEW = 0.745), indicating that responses were concentrated towards the lower end of the scale.

II. Testing differences in the perception of barriers between companies

We tested the assessment of the perceived significance of individual barriers depending on the size of the company (micro, small, medium, large) and the company's activity (manufacturing, non-manufacturing).

a) Testing statistical significance depending on company size

For the part of the analysis of barriers depending on the size of the enterprise, the following hypothesis was formulated:

Hypothesis No. 2 a)

H_0 : Businesses differ statistically significantly in their perception of very significant barriers depending on their size.

H_1 : Businesses do not differ statistically significantly in their perception of very significant barriers depending on their size.

In order to verify the hypothesis, we first tested the normality of data distribution, homoscedasticity, and sphericity. The results of statistical analysis and testing of differences in mean values are presented in Table 4.12 below.

Table 4.12: Significance of barriers depending on company size

		Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Parametric/non-parametric test	
					Lower Bound	Upper Bound		
B1	Micro	61.33	30.043	5.007	51.17	71.50	**Anova**	
	Small	61.83	27.304	4.317	53.09	70.56	**F**	**p**
	Medium	63.43	22.505	3.151	57.10	69.76	0.451	0.717
	Large	58.04	28.660	3.225	51.62	64.46		
	Total	60.68	27,146	1.891	56.96	64.41		
B2	Micro	58.69	31.029	5.171	48.20	69.19	**Kruskal-Wallis**	
	Small	64.48	27.675	4.376	55.62	73.33	χ^2	**p**
	Average	67.61	23.105	3.235	61.11	74.11	1.395	0.707
	Large	61.41	29.162	3,281	54.87	67.94		
	Total	63.06	27,818	1.938	59.24	66.88		
B3	Micro	65.39	26.452	4.409	56.44	74.34	**Kruskal-Wallis**	
	Small	69.45	27,490	4,347	60.66	78.24	χ^2	**p**
	Median	72.90	22.206	3.109	66.66	79.15	2.250	0.522
	Large	67.13	25.084	2,822	61.51	72.75		
	Total	68.70	25,105	1.749	65.26	72.15		
B4	Micro	74.89	23.204	3.867	67.04	82.74	**Kruskal-Wallis**	
	Small	71.60	22.990	3.635	64.25	78.95	χ^2	**p**
	Average	71.92	26.622	3.728	64.43	79.41	1.302	0.729
	Large	74.01	27.406	3,083	67.87	80.15		
	Total	73.18	25,550	1,780	69.67	76.69		
B5	Micro	60.44	31.259	5.210	49.87	71.02	**Anova**	
	Small	55.48	30.823	4.874	45.62	65.33	**F**	**p**
	Medium	54.02	33.511	4.693	44.59	63.44	0.654	0.582
	Large	60.92	30.745	3.459	54.04	67.81		
	Total	58.07	31,475	2.193	53.75	62.40		
B6	Micro	47.33	31.920	5.320	36.53	58.13	**Anova**	
	Small	50.95	30.135	4.765	41.31	60.59	**F**	**p**
	Medium	46.27	32.060	4.489	37.26	55.29	0.202	0.895
	Large	46.68	31.876	3.586	39.54	53.82		
	Total	47.52	31,416	2.189	43.21	51.84		
B7	Micro	59.19	27.551	4.592	49.87	68.52	**Anova**	
	Small	68.63	25.037	3.959	60.62	76.63	**F**	**p**
	Medium	60.16	30.982	4.338	51.44	68.87	1.087	0.356
	Large	65.10	26.625	2,996	59.14	71.06		
	Total	63.53	27,656	1.927	59.73	67.33		
B8	Micro	63.50	30.135	5.023	53.30	73.70	**Anova**	
	Small	60.50	31.821	5.031	50.32	70.68	**F**	**p**
	Medium	52.02	31.557	4.419	43.14	60.90	1,241	0.296
	Large	54.53	32.279	3,632	47.30	61.76		
	Total	56.64	31,705	2.209	52.28	60.99		
B9	Micro	67.67	27.103	4.517	58.50	76.84	**Kruskal-Wallis**	
	Small	57.10	30.238	4.781	47.43	66.77	χ^2	**p**
	Medium	62.06	30.466	4.266	53.49	70.63	4.227	0.238
	Large	66.67	32.356	3,640	59.42	73.92		
	Total	63.84	30,649	2.135	59.63	68.05		

B10	Micro	60.50	31.832	5.305	49.73	71.27	**Anova**	
	Small	62.93	32.712	5.172	52.46	73.39	**F**	**p**
	Medium	48.20	28.910	4.048	40.07	56.33	5.039	0.002
	Large	42.82	31.278	3,519	35.82	49.83		
	Total	51.15	31,999	2.230	46.75	55.54		
B11	Micro	45.64	31.645	5.274	34.93	56.35	**Kruskal-Wallis**	
	Small	55.85	30.490	4.821	46.10	65.60	χ^2	**p**
	Average	41.92	27.359	3.831	34.23	49.62	6.892	0.075
	Large	39.92	28.711	3,230	33.49	46.35		
	Total	44.51	29,650	2.066	40.44	48.58		
B12	Micro	57.17	23.136	3.856	49.34	64.99	**Anova**	
	Small	58.00	27.545	4,355	49.19	66.81	**F**	**p**
	Medium	54.90	26.410	3,698	47.47	62.33	0.468	0.705
	Large	60.57	29.011	3.264	54.07	67.07		
	Total	58.07	27,040	1,884	54.36	61.79		
B13	Micro	52.47	20.943	3.490	45.39	59.56	**Kruskal-Wallis**	
	Small	55.13	28.295	4.474	46.08	64.17	χ^2	**p**
	Average	53.71	27.199	3.809	46.06	61.36	1.278	0.734
	Large	57.63	29.460	3,315	51.03	64.23		
	Total	55.27	27,240	1.898	51.53	59.01		
B14	Micro	49.06	25.430	4.238	40.45	57.66	**Anova**	
	Small	52.83	25.550	4.040	44.65	61.00	**F**	**p**
	Medium	53.25	28.102	3.935	45.35	61.16	0.919	0.433
	Large	57.58	27.070	3.046	51.52	63.65		
	Total	54.10	26,752	1.864	50.42	57.77		
B15	Micro	54.11	26.702	4.450	45.08	63.15	**Anova**	
	Small	59.33	25.395	4.015	51.20	67.45	**F**	**p**
	Medium	54.43	24.696	3.458	47.49	61.38	2.258	0.083
	Large	64.72	26.214	2.949	58.85	70.59		
	Total	59.27	26,011	1.812	55.70	62.84		
B16	Micro	53.69	28.996	4.833	43.88	63.51	**Anova**	
	Small	59.33	28.011	4.429	50.37	68.28	**F**	**p**
	Medium	54.78	27.600	3.865	47.02	62.55	0.297	0.828
	Large	54.99	30.330	3.412	48.19	61.78		
	Total	55.55	28,849	2.010	51.59	59.52		
B17	Micro	54.58	28.570	4.762	44.92	64.25	**Anova**	
	Small	55.50	32.337	5.113	45.16	65.84	**F**	**p**
	Medium	53.88	29.565	4.140	45.57	62.20	0.074	0.974
	Large	56.30	29.945	3.369	49.60	63.01		
	Total	55.25	29,894	2,083	51.14	59.35		
B18	Micro	32.78	30.786	5.131	22.36	43.19	**Kruskal-Wallis**	
	Small	39.65	36.036	5.698	28.13	51.17	χ^2	**p**
	Average	34.80	35.916	5.029	24.70	44.91	4.721	0.193
	Large	26.57	34.078	3,834	18.94	34.20		
	Total	32.23	34.498	2.404	27.49	36.97		

Note: n = 206; p = 0.05; df = 3, 202
Source: own processing

Table 4.12 shows results of comparing the mean values depending on the size of the enterprise (micro, small, medium, and large enterprises). Only for barrier B10 – Lack of information on how to become a smart enterprise did we identify a significant difference in the mean values.

We conclude that significance of barrier B10 – Lack of information on how to integrate innovative pervasive technologies, digitize and virtualize business processes, become a smart enterprise, and build ambient intelligence in the enterprise (N = 206, M = 51.15, STDEV = 31.999) differs significantly p = 0.002 at a significance level of p = 0.05 depending on the size of the enterprise (micro, small, medium, large enterprise).

Groups of enterprises do not have equal access to information; some (especially micro and small enterprises) feel a greater lack of information on how to build ambient intelligence, integrate innovative pervasive technologies, and digitize and virtualize business processes. Large enterprises have the greatest access to information.

Test results showed that enterprises do not differ in their perception of very significant barriers depending on their size. We reject hypothesis H_0 and accept hypothesis H_1: Enterprises do not differ statistically significantly in their perception of very significant barriers depending on their size.

b) Testing the statistical significance of barriers depending on the activity of the company

In the following section, we tested the statistical significance of barriers depending on the activity of the company in relation to the hypothesis:

Hypothesis No. 2 b)

H_0 : Businesses differ statistically significantly in their perception of very significant barriers depending on their activity.

H_1 : Companies do not differ statistically significantly in their perception of very significant barriers depending on their activity.

In the first step, we tested the normality of the data distribution, homoscedasticity, and sphericity. In the commentary below Table 4.13, we only list those barriers in which companies differ significantly in their perception of significance.

Table 4.13: Significance of barriers depending on the activity of the company

		Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Parametric/non-parametric test	
					Lower Bound	Upper Bound		
B1	Non-manufacturing	59.11	29,346	2,646	53.88	64.35	**Mann-Whitney**	
	Production	63.01	23.490	2.578	57.88	68.14	**Z**	**p**
	Total	60.68	27.146	1,891	56.96	64.41	-0.621	0.535
B2	Non-manufacturing	62.84	29.019	2.617	57.66	68.02	**Mann-Whitney**	
	Production	63.40	26.105	2.865	57.70	69.10	**Z**	**p**
	Total	63.06	27.818	1,938	59.24	66.88	-0.121	0.904
B3	Non-manufacturing	69.51	25.409	2,291	64.98	74.05	**Mann-Whitney**	
	Production	67.51	24.753	2.717	62.10	72.91	**Z**	**p**
	Total	68.70	25.105	1,749	65.26	72.15	-0.709	0.478
B4	Non-manufacturing	74.62	26.188	2.361	69.94	79.29	**Mann-Whitney**	
	Production	71.05	24.575	2.697	65.68	76.41	**Z**	**p**
	Total	73.18	25.550	1,780	69.67	76.69	-1.434	0.152
B5	Non-manufacturing	59.91	31.239	2.817	54.33	65.49	**Mann-Whitney**	
	Production	55.35	31.815	3.492	48.40	62.30	**Z**	**p**
	Total	58.07	31.475	2.193	53.75	62.40	-1.052	0.293
B6	Non-manufacturing	51.84	31.363	2.828	46.24	57.44	**Mann-Whitney**	
	Production	41.13	30.574	3.356	34.46	47.81	**Z**	**p**
	Total	47.52	31.416	2.189	43.21	51.84	-2.438	0.015
B7	Non-manufacturing	65.01	27.814	2.508	60.04	69.97	**Mann-Whitney**	
	Production	61.34	27.441	3.012	55.35	67.33	**Z**	**p**
	Total	63.53	27.656	1.927	59.73	67.33	-0.957	0.339
B8	Non-manufacturing	59.42	31.473	2.838	53.81	65.04	**Mann-Whitney**	
	Production	52.51	31.787	3.489	45.57	59.45	**Z**	**p**
	Total	56.64	31.705	2.209	52.28	60.99	-1.562	0.118
B9	Non-manufacturing	68.20	29.039	2.618	63.02	73.39	**Mann-Whitney**	
	Production	57.39	31.987	3.511	50.40	64.37	**Z**	**p**
	Total	63.84	30.649	2.135	59.63	68.05	-2.439	0.015
B10	Non-manufacturing	52.31	33.147	2.989	46.39	58.23	**T-test**	
	Production	49.42	30.334	3.330	42.80	56.05	**t**	**p**
	Total	51.15	31.999	2,230	46.75	55.54	0.634	0.527
B11	Non-manufacturing	45.38	30.401	2.741	39.96	50.81	**T-test**	
	Production	43.22	28.635	3.143	36.96	49.47	**t**	**p**
	Total	44.51	29.650	2,066	40.44	48.58	0.513	0.608

B12	Non-manufacturing	57.95	28.082	2.532	52.94	62.96	**Mann-Whitney**	
	Production	58.25	25.584	2.808	52.67	63.84	**Z**	**p**
	Total	58.07	27.040	1,884	54.36	61.79	-0.305	0.761
B13	Non-manufacturing	54.65	28.667	2.585	49.53	59.77	**T-test**	
	Production	56.19	25.118	2.757	50.71	61.68	**t**	**p**
	Total	55.27	27.240	1,898	51.53	59.01	-0.398	0.691
B14	Non-manufacturing	53.91	28.286	2,550	48.86	58.96	**T-test**	
	Production	54.37	24.468	2.686	49.03	59.72	**t**	**p**
	Total	54.10	26.752	1,864	50.42	57.77	-0.122	0.903
B15	Non-manufacturing	59.10	27.033	2,438	54.27	63.92	**Mann-Whitney**	
	Production	59.53	24.578	2.698	54.16	64.90	**Z**	**p**
	Total	59.27	26.011	1,812	55.70	62.84	-0.096	0.924
B16	Non-manufacturing	55.53	29.296	2,641	50.30	60.76	**T-test**	
	Production	55.59	28.351	3.112	49.40	61.78	**t**	**p**
	Total	55.55	28.849	2,010	51.59	59.52	-0.015	0.988
B17	Non-manufacturing	55.93	30.809	2.778	50.43	61.43	**T-test**	
	Production	54.24	28.639	3.144	47.99	60.49	**t**	**p**
	Total	55.25	29.894	2,083	51.14	59.35	0.396	0.692
B18	Non-manufacturing	28.58	33.232	2,996	22.65	34.51	**Mann-Whitney**	
	Production	37.65	35.812	3.931	29.83	45.47	**Z**	**p**
	Total	32.23	34.498	2,404	27.49	36.97	-2.079	0.038

Note: n = 206, p = 0.05
Source: own processing

Based on statistical testing of the differences in mean values, we conclude that companies segmented into two categories based on activity (non-manufacturing, manufacturing) differ statistically significantly in the significance of three barriers: B6 – Legislation, B9 – Nature of business, B18 – Companies do not see the benefits of building ambient intelligence.

Non-manufacturing companies consider legislation to be a statistically more significant barrier than manufacturing companies. It is precisely in legislation that they see a greater obstacle and limitation to building ambient intelligence in their companies. Manufacturing companies consider this barrier to be significant, but not to the same extent as non-manufacturing companies. Manufacturing companies integrate innovative pervasive technologies primarily into production processes and technical equipment, which leads to increased efficiency. Non-manufacturing companies are introducing

elements of digitisation and virtualisation of data and processes, which are also regulated to a greater extent by a certain legal framework.

Manufacturing companies see greater opportunities for integrating innovative pervasive technologies, digitisation, and virtualisation into their business activities than non-manufacturing companies, which consider this to be a more significant barrier than manufacturing companies.

The last barrier where we identified statistical significance is B18 – Companies do not see the benefits of building ambient intelligence. On the contrary, manufacturing companies achieve a higher level of significance in perceiving this attitude as a barrier. Companies claim that some manufacturing processes are set up in such a way that they are functional, and management does not yet see the benefits of building ambient intelligence. Non-manufacturing companies are often forced by the nature of their business to implement elements of ambient intelligence in order to increase their competitiveness. However, we cannot generalize this statement, nor do we consider it very significant, as this barrier is identified by companies as the least significant barrier (N = 206, M = 32.23, STDEV = 34.498). When determining the significance of this barrier, companies reported low values, with the distribution positively skewed (SKEW = 0.745), indicating that responses were concentrated towards the lower end of the scale. Therefore, we can conclude that companies have a positive attitude towards building ambient intelligence, understand the benefits of its development, are willing to implement it, and are interested in integrating innovative pervasive technologies, digitisation, and virtualisation of business processes.

In other cases of the significance of barriers as perceived by companies based on their activities (non-manufacturing, manufacturing), we did not identify any statistically significant differences.

From the verification of the hypothesis, we reject hypothesis H_0 and accept hypothesis H_1: Depending on their activity, companies do not differ statistically significantly in their perception of very significant barriers.

Summary

We accept the conclusion on the verification of the hypothesis based on the results of statistical testing in two parts:

I. **Analysis of the significance of barriers,** where we identified two barriers as **very significant**:

a) Availability of financial capital, financial demands necessary for the introduction and development of ambient intelligence.

Companies and managers consider the lack of finances and the financial demands (N = 206, M = 73.18, STDEV = 25.550) required for the implementation and development of ambient intelligence to be a very significant barrier. The most frequently cited significance value by respondents was 100, and more than 50% of companies rated the significance of this barrier above 80. The percentile values are also significant, showing that only 25% of respondents rated the significance of the barrier below 60, with the remaining values above this level. At the same time, the skewness indicator (SKEW = -0.953) suggests that the distribution is negatively skewed, indicating that responses were concentrated towards the higher end of the scale.

b) Level of information literacy of company employees.
The results of the analysis show that digital and information literacy (N = 206, M = 68.70, STDEV = 25.105) is also a very significant barrier that prevents or hinders the introduction of ambient intelligence elements into the company. This is not only about skills in working with individual information and communication technologies, but also about the attitude towards working with them, the willingness and ability to learn something new. Respondents most often reported a significance level of 80. As in the case of the financial demands of implementing ambient intelligence elements, in this case too, companies primarily reported higher values for the importance of barriers (SKEW = -0.695), with 25% of companies reporting a barrier importance value below 50 and 75% of companies reporting a value below 90.

II. Testing differences in the perception of barriers. We found that, depending on their size and activities, companies **do not differ** in their perception of these two very significant barriers**.**

a) Availability of financial capital, financial demands necessary for the introduction and development of ambient intelligence.
Through statistical testing, we found that companies do not differ in their perception of these two very significant barriers depending on their size: micro-enterprises (M = 74.89, STDEV = 23.204), small enterprises (M = 71.60, STDEV = 22.990), medium-sized enterprises (M = 71.92, STDEV = 26.622) and large enterprises (M = 74.01, STDEV = 27.406) do not differ statistically significantly χ^2 (3) = 1.302, p = 0.729 in their perception of the significance of this barrier.
Enterprises do not differ statistically significantly in their perception of this barrier depending on the activity of the enterprise: Non-man-

ufacturing enterprises (M = 74.62, STDEV = 26.188) do not differ statistically significantly Z = - 1.434, p = 0.152 from manufacturing companies (M = 71.05, STDEV = 24.575) in their perception of the significance of this barrier.

b) Level of information literacy of company employees.
Statistical testing confirms that, depending on their size, micro-enterprises (M = 65.39, STDEV = 26.452), small enterprises (M = 69.45, STDEV = 27.490), medium-sized enterprises (M = 72.90, STDEV = 22.206) and large enterprises (M = 67.13, STDEV = 25.084) do not differ statistically significantly χ^2 (3) = 2.250, p = 0.522 in their perception of the significance of this barrier.
Companies do not differ statistically significantly in their perception of this barrier depending on the activity of the company: Non-manufacturing companies (M = 69.51, STDEV = 25.409) do not differ statistically significantly Z = - 0.709, p = 0.478 from manufacturing companies (M = 67.51, STDEV = 24.753) in their perception of the significance of this barrier.

From the above, we conclude that, depending on the size and activity of the enterprise, enterprises do not differ statistically significantly in their perception of very significant barriers.

Evaluation of the research question

Which barriers from the internal or external environment most significantly prevent companies from building ambient intelligence?

Companies consider the most significant barriers to the integration of innovative pervasive technologies and the development of ambient intelligence to be the insufficient availability of financial capital related to the financial demands of implementing and developing ambient intelligence and the insufficient level of information literacy of company employees.

Companies do not differ in their perception of these most significant barriers depending on their size (micro, small, medium, large) and activity (non-manufacturing, manufacturing).

4.3 Areas of Building Ambient Intelligence in Enterprises

In the survey, we asked companies which areas could be improved by integrating innovative pervasive technologies.

Significance was rated by companies on a scale of 0 (insignificant) to 100 (very significant). The survey results are presented in Table 4.14 below. Individual areas were segmented into three groups based on the standard deviation method:

1. $0 < H \leq 44.49$ = less significant area
2. $44.49 < H < 64.77$ = significant area
3. $64.77 \leq H \leq 100.00$ = very significant area

Table 4.14: Significance of areas for building ambient intelligence in a company

Area	Mean	Std. Deviation	Skewness		Kurtosis		Group
			Statistic	Std. Error	Statistic	Std. Error	
O1 - Logistics	56.05	35.486	-.272	.169	-1.300	.337	2
O2 - Supply	51.46	34.613	-.089	.169	-1.277	.337	2
O3 - Manufacturing	41.54	37.063	.241	.169	-1.414	.337	1
O4 - Standardization	45.29	32.399	.084	.169	-1.150	.337	2
O5 - Control	64.00	29.897	-.590	.169	-.587	.337	2
O6 - Supervision of production facilities	42.40	37.057	.157	.169	-1.482	.337	1
O7 - Maintenance	43.06	32.224	.090	.169	-1.298	.337	1
O8 - Energy optimization and monitoring	50.94	32.948	-.165	.169	-1.237	.337	2
O9 - Intelligent manufacturing systems	41.98	36.891	.201	.169	-1.479	.337	1
O10 - Data processing	73.02	28.899	-1.003	.169	.042	.337	3
O11 - Customer behaviour analysis	58.59	32.813	-.417	.169	-1.037	.337	2
O12 - Decision-making processes	58.58	30.555	-.372	.169	-.839	.337	2
O13 - Financial processes	60.86	30.595	-.467	.169	-.838	.337	2
O14 - Occupational safety	44.97	32.511	.226	.169	-1.165	.337	2
O15 - Communications	68.28	28.888	-.797	.169	-.272	.337	3
O16 - Information security	68.21	29.842	-.772	.169	-.405	.337	3
O17 - Physical security	52.21	33.167	-.173	.169	-1.217	.337	2
O18 - Education	61.86	30.023	-.547	.169	-.694	.337	2

Note: N = 206, Min = 0, Max = 100
Source: own processing

The **most important areas** for development and building of ambient intelligence in a company through its tools and the integration of innovative pervasive technologies are data processing (M = 73.02, SD = 28.899), communication (M = 68.28, SD = 28.888), and information security (M = 68.21, SD = 29.842).

Data processing is the most important area for the development of the integration of innovative pervasive technologies. The results of the survey we conducted among companies confirmed that data is a valuable resource, the most important building block of ambient intelligence.

From a theoretical point of view, it is clear that other technical elements are also an essential part, but especially those involved in data collection and processing. We analysed these in the previous sections (RFID, barcodes, QR codes, sensors, collection, transformation, processing, data significance). The creation, collection, and processing of data are the foundation of ambient intelligence. The importance of data processing and analysis in achieving a level of ambient intelligence is a significant factor $\beta = 0.222$, $t(3, 202) = 3.304$, $p = 0.001$, which resulted from multiple linear regression and the compilation of a statistically significant model of the level of ambient intelligence of a company $p < 0.001$.

The second very important area of development of a company's ambient intelligence is communication (M = 68.28, SD = 28.888), the use of elements of ambient intelligence in a company, and the integration of innovative pervasive technologies into business processes, streamlines communication not only between individual devices, but also between other subdomains of communication within a company. Innovative pervasive technologies enable interactive communication between individual devices and information systems. Ambient intelligence modernizes, streamlines, and accelerates communication through the pervasiveness of technologies. It often offers new ways of communication, and from the statements of companies, we learn that they consider the provision of information in real time or with minimal response time to be the most important.

Information security (M = 68.21, SD = 29.842) is the last area from the group of very important areas that companies consider to be a significantly developing area due to the integration of innovative pervasive technologies and the introduction of elements of ambient intelligence. Methods of protection against infiltration, monitoring, and removal of infiltrations are improving and becoming more effective, resulting in better protection against further possible leaks. Progress in this area is very important because the pace of

progress and development in cybercrime is enormous, and businesses cannot underestimate the consequences of falling behind in information security, as the consequences of a breach can have a major impact not only on a company's financial results.

The second group of areas in terms of importance are **significant areas** of building ambient intelligence in a company. The highest importance score in this group is achieved by the area of control and control mechanisms (M = 64.00, SD = 29.897). By integrating innovative pervasive technologies and building ambient intelligence, companies can introduce automated control mechanisms into their business processes, enabling individual processes to be controlled automatically with minimal error rates.

Innovative pervasive technologies are applied in almost all industries and areas of business. We draw attention to the results of the survey, which showed that the second most important area for process development and improvement is education (M = 61.86, SD = 30.023). Foreign theoretical sources already show the introduction of elements of ambient intelligence in educational models, especially those focused on information and communication technologies, innovative pervasive technologies, and information literacy. We compare views and indicate the direction of this area in Section 5 Discussion.

The third important area is financial processes (M = 60.86, SD = 30.595). The introduction of innovative pervasive technologies and ambient intelligence accelerates and streamlines financial processes, which can be seen in the growing integration of innovative pervasive technologies in this area and the use of information systems in corporate financial management.

In conclusion, we can state that none of areas examined was considered **insignificant** by respondents. The minimum significance value was at the level of (M = 41.54, SD = 37.063) in the area of production improvement. This is more an area of improvement of current production through the integration of innovative pervasive technologies. The pace of improvement is not enormously high, or in very significant areas where companies see great room for improvement through the integration of ambient intelligence elements. However, we consider the significance value of M = 41.54 to be very high, and based on SKEW = 0.241, we can even say that the distribution was slightly positively skewed (SKEW = 0.241), although the deviation from symmetry was relatively small.

We also focused in detail on perception of importance of the development of individual areas through the integration of innovative pervasive technolo-

gies by companies, depending on the size of the company (micro, small, medium, and large) and its activity (manufacturing, non-manufacturing).

The results of descriptive statistics and testing of the differences in mean values are presented in Table 4.15 below.

Table 4.15: Significance of areas depending on the size of the enterprise

Area		Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Parametric/ non-parametric test	
					Lower Bound	Upper Bound		
O1	micro	41.56	37.324	6.221	28.93	54.18	**Anova**	
	small	58.10	33.263	5.259	47.46	68.74	**F**	**p**
	medium	59.80	35.099	4.915	49.93	69.68	2,498	0.061
	large	59.20	34.972	3.935	51.37	67.04		
	Total	56.05	35.486	2.472	51.18	60.93		
O2	micro	36.94	35.942	5.990	24.78	49.11	**Anova**	
	small	50.68	35.072	5.545	39.46	61.89	**F**	**p**
	medium	54.31	31.496	4.410	45.46	63.17	2.90	0.036
	large	56.63	34.469	3,878	48.91	64.35		
	Total	51.46	34,613	2.412	46.71	56.22		
O3	micro	19.64	24.620	4.103	11.31	27.97	**Kruskal-Wallis**	
	small	39.00	32.976	5.214	28.45	49.55	χ^2	**p**
	medium	50.98	39.459	5.525	39.88	62.08	15.518	0.001
	large	46.71	38.555	4.338	38.07	55.34		
	Total	41.54	37,063	2.582	36.45	46.63		
O4	micro	33.36	33.396	5.566	22.06	44.66	**Kruskal-Wallis**	
	small	41.13	27.257	4.310	32.41	49.84	χ^2	**p**
	medium	46.76	34.144	4.781	37.16	56.37	9.111	0.028
	large	51.89	31.929	3.592	44.73	59.04		
	Total	45.29	32.399	2,257	40.84	49.74		
O5	micro	58.08	28.152	4.692	48.56	67.61	**Kruskal-Wallis**	
	small	62.18	30.684	4.852	52.36	71.99	χ^2	**p**
	medium	64.31	30.936	4.332	55.61	73.01	3.308	0.346
	large	67.43	29.656	3,337	60.79	74.07		
	Total	64.00	29,897	2.083	59.90	68.11		

O6	micro	25.44	31.861	5.310	14.66	36.22	**Kruskal-Wallis**	
	small	37.08	33.134	5.239	26.48	47.67	χ^2	**p**
	medium	45.43	38.754	5.427	34.53	56.33	12.297	0.006
	large	50.86	37.631	4.234	42.43	59.29		
	Total	42.40	37,057	2.582	37.31	47.49		
O7	micro	23.33	25.248	4.208	14.79	31.88	**Anova**	
	small	37.50	30.822	4.873	27.64	47.36	**F**	**p**
	medium	47.96	30.303	4.243	39.44	56.48	7,904	0.00
	large	51.70	33.056	3,719	44.29	59.10		
	Total	43.06	32,224	2.245	38.63	47.48		
O8	micro	34.19	31.153	5.192	23.65	44.74	**Anova**	
	small	48.55	31.627	5.001	38.44	58.66	**F**	**p**
	medium	52.78	31.745	4.445	43.86	61.71	4.905	0.003
	large	58.58	32.829	3.694	51.23	65.94		
	Total	50.94	32,948	2.296	46.41	55.46		
O9	micro	21.44	29.120	4.853	11.59	31.30	**Kruskal-Wallis**	
	small	38.38	34.239	5.414	27.42	49.33	χ^2	**p**
	medium	41.98	33.082	4.632	32.68	51.28	17.688	0.001
	large	53.15	39.760	4,473	44.25	62.06		
	Total	41.98	36,891	2.570	36.91	47.04		
O10	micro	62.25	33.818	5.636	50.81	73.69	**Kruskal-Wallis**	
	small	70.00	27.245	4.308	61.29	78.71	χ^2	**p**
	medium	74.20	26.638	3.730	66.70	81.69	8,244	0.041
	large	78.70	27.641	3,110	72.50	84.89		
	Total	73.02	28,899	2.013	69.05	76.99		
O11	micro	54.03	31.437	5,240	43.39	64.66	**Anova**	
	small	56.93	33.572	5.308	46.19	67.66	**F**	**p**
	medium	55.00	31.016	4,343	46.28	63.72	1,145	0.332
	large	63.84	34.041	3,830	56.21	71.46		
	Total	58.59	32,813	2.286	54.08	63.10		
O12	micro	45.36	32.342	5.390	34.42	56.30	**Anova**	
	small	52.83	29.031	4.590	43.54	62.11	**F**	**p**
	medium	65.20	28.160	3.943	57.28	73.12	4.330	0.006
	large	63.24	30.106	3,387	56.50	69.98		
	Total	58.58	30,555	2,129	54.38	62.77		
O13	micro	52.25	30.373	5.062	41.97	62.53	**Kruskal-Wallis**	
	small	62.38	26.311	4.160	53.96	70.79	χ^2	**p**
	medium	61.08	31.358	4.391	52.26	69.90	4,350	0.226
	large	63.89	32.017	3,602	56.71	71.06		
	Total	60.86	30,595	2.132	56.66	65.07		
O14	micro	32.00	29.90	4,983	21.88	42.12	**Anova**	
	small	42.93	33.302	5.266	32.27	53.58	**F**	**p**
	medium	45.20	31.511	4.412	36.33	54.06	3.217	0.024
	large	51.77	32.542	3.661	44.48	59.06		
	Total	44.97	32,511	2.265	40.50	49.44		

O15	micro	65.67	32.187	5.364	54.78	76.56	**Kruskal-Wallis**	
	small	61.10	27.159	4.294	52.41	69.79	χ^2	**p**
	medium	67.41	27.155	3.802	59.77	75.05	7.796	0.050
	large	73.67	28.764	3,236	67.23	80.11		
	Total	68.28	28,888	2.013	64.31	72.25		
O16	micro	61.36	33.766	5.628	49.94	72.79	**Kruskal-Wallis**	
	small	64.35	27.099	4.285	55.68	73.02	χ^2	**p**
	medium	66.47	27.318	3.825	58.79	74.15	8.554	0.036
	large	74.42	30.217	3,400	67.65	81.19		
	Total	68.21	29,842	2.079	64.11	72.31		
O17	micro	39.64	34.930	5.822	27.82	51.46	**Anova**	
	small	53.48	34.369	5.434	42.48	64.47	**F**	**p**
	medium	52.25	31.453	4.404	43.41	61.10	2.407	0.068
	large	57.28	31.923	3,592	50.13	64.43		
	Total	52.21	33,167	2.311	47.66	56.77		
O18	micro	58.64	33.668	5.611	47.25	70.03	**Anova**	
	small	64.13	29.459	4.658	54.70	73.55	**F**	**p**
	medium	59.94	28.057	3.929	52.05	67.83	0.351	0.788
	large	63.42	30.159	3.393	56.66	70.17		
	Total	61.86	30,023	2.092	57.74	65.98		

Note: N = 206, p = 0.05; df = 3, 202
Source: own processing

Test results show that companies differ statistically significantly depending on their size in their perception of the importance of integrating innovative pervasive technologies and ambient intelligence elements to improve processes in the following areas:

- Supply – large companies consider the integration of innovative technologies in this area to be important (M = 56.63, SD = 34.469). It is precisely the implementation of these technologies that significantly streamlines individual logistics processes, starting with the procurement of raw materials, materials, etc.
- Production – medium-sized companies in particular reported a higher value (M = 50.98, SD = 39.459) for the importance of developing this area through the integration of innovative pervasive technologies.
- Standardization – companies confirm the importance of integration and the role of these technologies in this area as well. Innovative pervasive technologies contribute to interdependent activities and measures that lead to the effective unification of repetitive solutions.
- Supervision of production facilities – we agree with the respondents that the integration of innovative pervasive technologies can better

monitor production facilities, collect data, analyse it, and subsequently provide relevant information for control and decision-making in production and management processes. This importance is particularly recognized by large enterprises (M = 50.85, SD = 37.631), which differ significantly from other groups.

- Maintenance – large companies once again see greater benefits of ambient intelligence in the area of maintenance, indicating the need for maintenance and its performance.
- Business process optimization – companies consider the integration of innovative pervasive technologies to be important in the area of business process optimization. Large and medium-sized enterprises are most aware of this importance. These enterprises report that they implement new technologies for the purpose of automating and optimizing business processes, eliminating bottlenecks, and ensuring high-quality reporting.
- Manufacturing systems – large enterprises (M = 53.15, SD = 39.760) see the greatest benefit in this area, as they strive to fully automate manufacturing systems and related processes.
- Data processing – this is the most important area. Companies consider it to be the area that can be most significantly improved and streamlined by the introduction of innovative pervasive technologies and ambient intelligence. In general, companies reported high significance values.
- Decision-making processes – innovative pervasive technologies can prepare suitable bases for decision-making, but ambient systems can make autonomous decisions, which speeds up the decision-making process. User intervention is required in rare cases.
- Work safety – large companies in particular consider this area to be more important. The integration of these technologies also modifies this important area, which has recently been receiving greater attention.
- Communication – in the area of communication, interactive communication between devices and systems, the integration of innovative technologies can significantly streamline communication processes. Companies consider this area to be very important (M = 68.28, SD = 28.888), and in testing for differences, the p-value is on the borderline of significance p = 0.05, which indicates that this area is considered very important by all groups of companies.

- Enterprise information security – companies reported high significance values (M = 68.21, SD = 29.842), and we conclude that this is a very important area of the enterprise that can be improved and developed by introducing elements of ambient intelligence. Innovative pervasive technologies enable the integration of new security techniques and tools against possible infiltrations. A breach of information security can also have devastating consequences for a company.

We also examined the importance of integrating innovative pervasive technologies and elements of ambient intelligence in individual business areas depending on the type of business (non-manufacturing, manufacturing). Descriptive statistics and the results of testing the differences in mean values are presented in Table 4.16 below.

Table 4.16: Significance of areas depending on the company's activity

Area		Mean	STDEV	Std. Error	95% Confidence Interval for Mean		Parametric/ nonparametric test	
					Lower Bound	Upper Bound		
O1	Non-manufacturing	51.33	37.727	3.402	44.59	58.06	**Mann-Whitney**	
	Production	63.06	30.776	3.378	56.34	69.78	**Z**	**p**
	Total	56.05	35.486	2.472	51.18	60.93	-2.270	0.023
O2	Non-manufacturing	46.23	37.832	3.411	39.47	52.98	**Mann-Whitney**	
	Production	59.22	27.635	3.033	53.18	65.25	**Z**	**p**
	Total	51.46	34.613	2.412	46.71	56.22	-2.508	0.012
O3	Non-manufacturing	26.24	35.104	3.165	19.97	32.50	**Mann-Whitney**	
	Production	64.22	26.999	2.964	58.32	70.11	**Z**	**p**
	Total	41.54	37.063	2.582	36.45	46.63	-7.445	0
O4	Non-manufacturing	43.82	35.610	3.211	37.46	50.18	**Mann-Whitney**	
	Production	47.47	27.009	2.965	41.57	53.37	**Z**	**p**
	Total	45.29	32.399	2.257	40.84	49.74	-0.927	0.354
O5	Non-manufacturing	63.46	31.986	2.884	57.75	69.16	**Mann-Whitney**	
	Production	64.82	26.669	2.927	59.00	70.64	**Z**	**p**
	Total	64.00	29.897	2.083	59.90	68.11	-0.170	0.865
O6	Non-manufacturing	27.84	35.550	3.205	21.49	34.18	**Mann-Whitney**	
	Production	63.98	27.629	3.033	57.94	70.01	**Z**	**p**
	Total	42.40	37.057	2.582	37.31	47.49	-7.016	0

O7	Non-manufacturing	37.19	33.403	3.012	31.22	43.15	**Mann-Whitney**	
	Production	51.76	28.417	3.119	45.55	57.96	**Z**	**p**
	Total	43.06	32.224	2.245	38.63	47.48	-3.277	0.001
O8	Non-manufacturing	45.25	34.799	3.138	39.04	51.46	**Mann-Whitney**	
	Production	59.36	28.141	3.089	53.22	65.51	**Z**	**p**
	Total	50.94	32.948	2.296	46.41	55.46	-2.850	0.004
O9	Non-manufacturing	31.63	37.524	3.383	24.94	38.33	**Mann-Whitney**	
	Production	57.30	30.152	3.310	50.72	63.89	**Z**	**p**
	Total	41.98	36.891	2.570	36.91	47.04	-5.321	0.00
O10	Non-manufacturing	72.67	31.262	2.819	67.09	78.25	**Mann-Whitney**	
	Production	73.54	25.166	2.762	68.05	79.04	**Z**	**p**
	Total	73.02	28.899	2.013	69.05	76.99	-0.742	0.458
O11	Non-manufacturing	62.57	35.050	3.160	56.31	68.83	**Mann-Whitney**	
	Production	52.70	28.375	3.115	46.50	58.89	**Z**	**p**
	Total	58.59	32.813	2.286	54.08	63.10	-2.659	0.008
O12	Non-manufacturing	58.15	32.657	2.945	52.32	63.98	**Mann-Whitney**	
	Production	59.22	27.325	2.999	53.25	65.18	**Z**	**p**
	Total	58.58	30.555	2.129	54.38	62.77	-0.216	0.829
O13	Non-manufacturing	62.14	32.049	2.890	56.42	67.86	**Mann-Whitney**	
	Production	58.98	28.389	3.116	52.78	65.17	**Z**	**p**
	Total	60.86	30.595	2.132	56.66	65.07	-1.085	0.278
O14	Non-manufacturing	42.03	34.302	3.093	35.91	48.16	**Mann-Whitney**	
	Production	49.33	29.319	3.218	42.92	55.73	**Z**	**p**
	Total	44.97	32.511	2.265	40.50	49.44	-1.884	0.060
O15	Non-manufacturing	68.49	30.048	2.709	63.12	73.85	**Mann-Whitney**	
	Production	67.98	27.254	2.992	62.02	73.93	**Z**	**p**
	Total	68.28	28.888	2.013	64.31	72.25	-0.504	0.615
O16	Non-manufacturing	70.31	30.426	2.743	64.88	75.74	**Mann-Whitney**	
	Production	65.11	28.856	3.167	58.81	71.41	**Z**	**p**
	Total	68.21	29.842	2.079	64.11	72.31	-1.651	0.099
O17	Non-manufacturing	47.62	34.095	3.074	41.53	53.70	**T-test**	
	Production	59.02	30.692	3.369	52.32	65.73	**t**	**p**
	Total	52.21	33.167	2.311	47.66	56.77	-2.450	0.015
O18	Non-manufacturing	63.42	30.951	2.791	57.90	68.95	**T-test**	
	Production	59.54	28.620	3.141	53.29	65.79	**t**	**p**
	Total	61.86	30.023	2.092	57.74	65.98	0.910	0.364

Source: own processing

Depending on their activities (manufacturing, non-manufacturing), companies differ statistically significantly in their perception of the importance of integrating innovative pervasive technologies and elements of ambient intelligence for the purpose of possible process improvement in the following areas: logistics, supply, production, production equipment, supervision of production equipment, maintenance, energy optimization and monitoring, development, implementation of intelligent production systems, physical security, and protection of buildings and equipment.

In above-mentioned areas, we identified statistically significant differences between manufacturing and non-manufacturing companies in their perception of importance of integrating innovative pervasive technologies and applying elements of ambient intelligence to improve and streamline processes in the analysed area. In all these significant cases, higher values of importance were attributed to individual areas by manufacturing companies, which, due to nature of their activities and the experience of their managers, see greater opportunities and possibilities for streamlining and improving processes in the given area.

Non-manufacturing companies reported higher significance values than manufacturing companies in some areas, but not all of them were statistically significant. We identified only one area for which non-manufacturing companies reported higher significance values and the mean values differed statistically significantly, namely in the area of customer behaviour analysis.

5 DISCUSSION

Ambient intelligence has become a multidisciplinary topic of interest in many areas of research where its positive impact on society can be identified (Augusto & McCullagh, 2007). The basic characteristic of ambient intelligence (ISTAG, 1999; ISTAG, 2003) can be considered to be intuitive work with information and communication technologies, which we often refer to as "user friendly." Ambient intelligence is a concept developed by the European Commission's advisory group for the information society and information technology program (ISTAG, 2001; ISTAG, 2002).

5.1 Evaluation of Theoretical Background

From the analysis of theoretical foundations, we conclude that authors' views on ambient intelligence vary. In their definitions, authors most often work with terms innovative pervasive technologies, communication, mobility, virtualisation, and human interaction. These concepts are the focus of scientific research, professional studies, and also form the basis of the industrial sector concept. We have classified the authors' definitions of ambient intelligence into three groups based on the conceptual apparatus used: technologically, multi-faceted, and visionary definitions.

Technologically oriented definitions provide a clear overview of the technologies that constitute the substance of ambient intelligence and their purpose. Authors often list technologies and emphasize their mutual communication, pervasiveness, interoperability, and intelligence. These technologies and systems are integrated into the surrounding environment in such a way that the user does not perceive, or at least minimally perceives, their presence. Authors (Aarts et al., 2001; Ducatel, 2001; Shadbolt, 2003; Remagninino et al., 2005; Weber et al., 2005) defined technologies that create ambient intelligence and point out benefits for society. Augusto and McCullagh (2007) characterised specific technologies that interact with the user and thus create ambient intelligence. Ramos, Augusto, and Shapiro (2008) considered the integration of the physical environment with virtual reality and users to be the basis of ambient intelligence. We agree that such an environment creates a digital ecosystem that supports users in their daily lives in a non-intrusive way.

When comparing the definitions of authors who perceive ambient intelligence primarily from a technological perspective, we generally do not find a human, socio-economic, or social dimension. **The multi-faceted orientations** of authors (Riva, Vatalaro & Davide, 2005; Charitos, 2008; Streitz, 2017) emphasized the communication between technologies and users, point to the change in the of contemporary life, the creation of new ecosystems taking into account established rules, or point to the need to create new rules and frameworks. We agree with Streitz (2017), who, in connection with the combination of the human factor and smart devices and spaces, argueed that „smart devices and spaces make people smarter." Although this statement could be understood in terms of dependence on these devices and a certain degree of reliance on these technologies. However, from the perspective of integration into business processes, such smart devices and spaces create a set of new data, a basis for decision-making and discovering new dimensions and relationships.

The last group consists of **visionary definitions** by authors. In the theoretical foundations, we present visionary ideas chronologically so that it is possible to recognize how visions of ambient intelligence have developed over time. Ducatel (2001) only worked with the idea that the ambient environment would recognize the presence of people and respond to them. It was Fabian and Hansen (2006) who emphasized the visionary nature of ambient intelligence. Crutzen (2006) added to ambient intelligence a vision of future everyday life. The focus of these definitions is not on technology, but on intelligence, i.e., the ability to learn and respond to user requests. Aarts and De Ruyter (2009) predicted the extensive integration of technologies into everyday objects in the surrounding environment. Subsequent definitions work with the concepts of smart devices and refer to a digital environment that exhibits specific forms of social interaction. Such an environment is sensitive, adaptable, and responsive to the presence of people. Current definitions (Bureš et al., 2016) predictes new developments in this area very cautiously, pointing to the need for interdisciplinary research, the development of complex applications, and the emergence of synergistic effects.

In the theoretical foundations, we identified several areas of interest in ambient intelligence, namely perception, device sensitivity, interoperability, adaptability, pervasiveness of innovative technologies, and the intelligence of these devices. The theoretical contexts we analysed represent ontological considerations of ambient intelligence; in some cases, they outline a vision of the future, and the authors' definitions seem visionary. Ambient intelligence

is a new vision and concept, bringing together several functions related to the integration of innovative pervasive technologies into the environment in collaboration with the user. However, the entire system must be intelligent, i.e., capable of learning and responding to user requests. Such a system creates a new digital ecosystem.

Based on analysis, systematization, and generalization of knowledge, we have created a definition of ambient intelligence that represents a multidisciplinary approach, integrating innovative pervasive technologies and systems that form an ecosystem that intelligently responds to user requests based on collected, transformed, analysed, and evaluated data.

From the perspective of ambient intelligence, multidisciplinary approach focuses on the integration of innovative pervasive technologies that support user activities through specific services in the surrounding environment. These innovative technology services are provided with minimal user intervention. Essentially, an ambient intelligence system should be aware of a person's presence, perceive that person's needs, and be able to adapt to the needs of users. Ambient intelligence consists of several elements that can be divided into the areas of technology and intelligence. The technological area includes elements that represent innovative pervasive technologies, while intelligence consists of contextual awareness, the ability to learn, and interaction with the human factor.

Ambient intelligence brings new insights into the environment for software development and implementation, where there are large numbers of different devices and sensors that need to be integrated to create a programmable and auto-configurable information systems infrastructure. Intelligence must be provided in everyday environments.

Several scenarios and contexts for applicability of ambient intelligence can be identified in the literature. These scenarios (Maria, Dimitrios, Carmen, Annette, and Solomon) represent ontological considerations of ambient intelligence. We believe that individual scenarios are not traditional extrapolations from the present, but offer provocative views of future that may (but may not) be realized. Each scenario has a script that is used to develop key technologies, society, economy, and markets needed to achieve that scenario. Some scenarios are visionary and are a question of the future, while others are more specific and focus on a selected group of users.

5.2 Assessment of the Level of Ambient Intelligence in Enterprises

Attention in the field of ambient intelligence focuses on innovative pervasive technologies and the integration of the human factor. In connection with the analysis of the prediction of the level of ambient intelligence, we compared the approaches of individual authors to ambient intelligence and innovative pervasive technologies. We defined activities related to the integration of innovative pervasive technologies: data analysis, but also attitudes towards data, digitisation, virtualisation of business processes, and implementation of augmented reality. In several of the theoretical approaches analysed, it is also possible to identify the significant influence of the human factor, the attitude of company management towards the integration of innovative pervasive technologies into business processes.

We assumed that activities resulting from the integration of innovative pervasive technologies into business processes and the attitude of company management towards these technologies have a significant impact on the level of ambient intelligence achieved by the company. Based on this assumption, we formulated a research question.

How do selected activities influence the level of ambient intelligence achieved by a company: data analysis, digitisation, virtualisation of business processes, implementation of augmented reality, and the attitude of company management towards data (the importance of data) and innovative pervasive technologies?

By verifying research hypotheses, we found that the **independently** examined impact of selected activities and the attitude of company management towards data and innovative pervasive technologies statistically significantly influences the achievement of the level of ambient intelligence of a company, but their effect begins to disappear **in mutual interaction**. In mutual interaction, two activities influence the achievement of a company's level of ambient intelligence, namely the extent to which the company analyses data and virtualizes business processes, and the attitude of company management towards innovative pervasive technologies.

The level of ambient intelligence development in a company largely depends on the extent to which companies analyse and evaluate data and the level of virtualisation of business processes. The level of building ambient intelligence in a company depends to a moderate extent on the attitude of company management towards innovative pervasive technologies and their integration into business processes, as well as the level of digitisation of business

processes. There is a low degree of dependence between the level of building ambient intelligence in a company and the importance that company management attaches to the data obtained and the level of implementation of augmented reality in business processes.

At the same time, we note that if the level of analysis of data obtained increases by one unit, the level of ambient intelligence achieved increases by 0.146 points. If the attitude of company management towards innovative pervasive technologies improves ( ), the level of ambient intelligence of the company will increase by an average of 0.224 points. By increasing the level of virtualisation of business processes by 1 point, the level of ambient intelligence will increase by 0.183 points.

As companies increase their level of data analysis, the level of virtualisation of business processes, and strengthen management's attitude towards the integration of innovative pervasive technologies, the level of ambient intelligence of the company also increases.

Through discussion and confrontation of theoretical knowledge, we confirm that the findings are consistent with authors who, in their definitions of ambient intelligence, point to the need for and role of data analysis (Kaptein, 2018), emphasized the human factor, and highlight the attitude of company management towards innovative pervasive technologies (Riva, Vatalaro & Davide, 2005; Kleinberger et al., 2007; Augusto & McCullagh, 2007; Charitos, 2008; Ramos, Augusto & Shapiro, 2008; Aarts & De Ruyter, 2009; Veronica et al., 2009; Van Hoof, 2011; Bravo et al., 2014) and pointed to virtualisation of business processes (Weiser, 1991; Chun & Kai, 2003; Ramos, Augusto & Shapiro, 2008; Geissbauer et al., 2016; Smit et al., 2016;). The authors appropriately integrated these concepts into the characteristics of ambient intelligence. These factors, even in mutual interaction, influence the development of a company's ambient intelligence. At the same time, we argue that individual activities independently build a company's ambient intelligence, but a higher degree of ambient intelligence is achieved directly through the interaction of a combination of these predictors.

5.2.1 Barriers to Building Ambient Intelligence in Enterprises

After analysing the state of use of ambient intelligence platforms and the factors influencing the achievement of ambient intelligence in companies, we examined the barriers that prevent its development. The integration of innovative pervasive technologies into business processes and the development of

a company's ambient intelligence are determined by the existence of internal and external barriers.

Based on the research results detailed in section 4.4 Barriers to building ambient intelligence in a company, we have formulated a conclusion to the research question, stating that companies consider **the most significant barriers** to the integration of innovative pervasive technologies and the development of ambient intelligence in companies to be the insufficient availability of financial capital related to the financial demands necessary for the implementation and development of ambient intelligence and the insufficient level of information literacy of employees in the company. Companies do not differ in their perception of these most significant barriers depending on their size (micro, small, medium, large) and activity (non-manufacturing, manufacturing).

We present the most significant barriers to building ambient intelligence in companies identified in accordance with the results of the study and compare them with theoretical principles.

Companies consider **the lack of funds and the financial demands** (N = 206, M = 73.18, STDEV = 25.550) necessary for the implementation and development of ambient intelligence to be a very significant barrier. The most frequently cited significance value by respondents was 100, and more than 50% of companies rated the significance of this barrier above 80. The percentile values are also significant, showing that only 25% of respondents rated the significance of the barrier below 60, with the remaining values above this level. At the same time, the skewness indicator (SKEW = -0.953) suggests that the distribution is negatively skewed, indicating that responses were concentrated towards the higher end of the scale.

The findings of the research are in line with the statements of the Ministry of Labor, Social Affairs and Family of the Slovak Republic and the European Union, which in the document Analysis of the Impact of Digital Transformation on Entrepreneurs in the Private and Public Sectors (2017) note a lack of preparedness, especially among small and medium-sized enterprises, in terms of insufficient resources to invest in innovative pervasive technologies.

The financial burden also lies in the fact that innovative pervasive technologies often come from different manufacturers, and therefore it is financially demanding to connect them, as incompatible technologies cannot communicate correctly with each other and it is difficult to set up compatibility (Forstner & Dűmmler, 2014).

Schrőder (2016) stated that small and medium-sized enterprises often do not have an IT department to make decisions and manage information and communication technologies. Decisions on building ambient intelligence and smart enterprises are often made by managers with a lower level of technological sophistication and less understanding of the business potential of these sophisticated solutions.

Horizontal and vertical integration is also financially demanding. Small and medium-sized enterprises may have smaller financial reserves and resources for this purpose compared to large enterprises (Wischmann, Wangler & Botthof, 2015).

Another very significant barrier that prevents or hinders the introduction of ambient intelligence elements into a company is **digital and information literacy** (N = 206, M = 68.70, STDEV = 25.105). This is not only about skills in working with individual information and communication technologies, but also about attitudes towards them, willingness and ability to learn something new. Respondents most often reported a significance level of 80. As in the case of the financial cost of implementing ambient intelligence elements, companies also reported higher values for the importance of barriers (SKEW = -0.695), with 25% of companies reporting a barrier importance value below 50 and 75% reporting a value below 90.

Similar findings are also reported in a global survey by PwC (2015). The internal environment of a company, particularly the skills of its employees in working with technology, which can be described as digital literacy, is considered a significant barrier to the integration of innovative pervasive technologies into business processes and the development of ambient intelligence within a company. The company also notes that while information and communication technologies are becoming a commodity, the success of a company depends to a large extent on its digital IQ, especially on how the company's management defines, communicates, and manages this transformation to smart and the building of ambient intelligence. The keys to success are knowledge and digital trust. A common problem in building a smart enterprise is a lack of expertise among employees and a lack of support at the highest levels of management. In its findings, the company states that in business practice, they often encounter the problem that company management reinforces what has long been known, which is why it is difficult to perform analytics and integrate new innovative pervasive technologies, for example. When predictive analytics is used to support real-time quality management and maintenance, it contributes to savings by balancing opera-

tions and reducing failures, but sufficient knowledge and digital literacy are required.

Bureš et al. (2016) pointed out in their study the barrier of insufficient information literacy and the need for education in the field of ambient intelligence and the integration of ambient intelligence into education. The main reason for their research stemmed from the existence of different generations of students, employees, managers, and business owners. The varying levels of digital literacy among employees, which are sometimes insufficient, are a significant barrier to the integration of innovative technologies into business processes.

User experience with operating systems has improved in recent years, and employees tend to be more productive with Industry 4.0 when they use their knowledge and skills in the field of information technology. Employees' IT skills should be a strategic priority for businesses (Rosenzweig, 2016). Employees with sufficient IT literacy reduce a company's training, support, and employee turnover costs and increase operational speed.

Between 2016 and 2018, during our scientific work and activities at the Department of Information Management of the Faculty of Business Management at the University of Economics in Bratislava, we conducted research in the field of digital and information literacy of managers. We perceive digital literacy as an integral part of information literacy (Bolek, 2016). We conducted an extensive survey and proposed a quantitative and qualitative model of information literacy among managers, which resulted in the publication of a foreign scientific monograph (Bolek, 2016) and an impactful scientific article (Bolek et al., 2018). Information literacy is also perceived as one of the most significant barriers to building ambient intelligence in a company.

Users will need to acquire knowledge and skills that enable the development of „digital thinking" in order to manage this process of digitisation, virtualisation, and integration of innovative pervasive technologies in a new way.

Digital skills (Härtel et al., 2018) are the abilities of the digital world, including procedural and technological knowledge related to digitisation. In addition, it is important to know the potential opportunities and risks of technology, but also its limitations. Employees will also need greater autonomy, increased digital literacy, and the ability to make independent decisions (Scheer, 2012).

In the following section of the discussion, we would like to focus on the results of research focused on a group of significant barriers, namely the barrier of a lack of information on how to become a smart enterprise.

In the case of this barrier (N = 206, M = 51.15, STDEV = 31.999), companies most often reported a significance value of 50, with up to 50% of companies reporting this significance value. The significance values reported by companies were approximately symmetrically distributed (SKEW = 0.020).

We conclude that half of the companies surveyed consider this barrier to be significant, while the other half consider it to be less significant, which means that some have sufficient information on how to build an ambient business, while others do not.

From results of comparing the mean values depending on the size of the company (micro, small, medium, and large), we identified a significant difference in the mean values only for this barrier, Lack of information on how to become a smart company. We conclude that the significance of the barrier Lack of information on how to integrate innovative pervasive technologies, digitize and virtualize business processes (N = 206, M = 51.15, STDEV = 31.999) differs significantly between companies depending on their size p = 0.002.

Business groups do not have equal access to information, with some (especially micro and small enterprises) experiencing a greater lack of information on how to build ambient intelligence, integrate innovative pervasive technologies, and digitize and virtualize business processes.

Large enterprises have the greatest access to information. It is therefore important to raise awareness in this area among small and medium-sized enterprises, which constitute a significant group of enterprises in the Slovak Republic.

In line with the findings of research and several studies (MPSVaR SR, 2016; CEEMET, 2016; Schröder, 2016), it can be deduced that there is currently a lack of information available to business management, especially in small and medium-sized enterprises, on building ambient intelligence in businesses and a methodological approach to solving and implementing integrated pervasive technologies.

There are several national concepts in EU countries that help to integrate innovative pervasive technologies and build ambient intelligence in companies. Each concept has its own specific features (MPSVaR, 2017; SBA, 2019):

- Germany – Industrie 4.0 (preparing industry for the fourth industrial revolution) deals with horizontal and vertical integration, normalization and standardization, logistics, and labour markets.
- Belgium – Make different (preparing industry for future development) is about parameterizing production at a global level. It addresses issues of digital industry, user-focused industry, connected industry, and ecological, smart production.
- The Netherlands – Smart Industry (raising awareness of Industry 4.0 and creating infrastructure). The goal is to create infrastructure to support Industry 4.0. Investments are made in platforms, laboratories, training for entrepreneurs and employees, and support for education in the field of information literacy.
- Sweden – Produktion 2030 (to increase the competitiveness of Swedish industry). It deals with research and innovation projects, training for small and medium-sized enterprises, and employees in the field of information literacy.
- Czech Republic – Industry 4.0 (providing know-how for the development of more specific strategies and plans). This involves support for scientific and research centers that will promote key areas of Industry 4.0.

The methods of implementing these programs vary: advisory activities, consultations, education, research programs, grant schemes, and financing through companies.

5.2.2 Corporate Areas of Building Ambient Intelligence

Among the most important areas for the development and building of ambient intelligence in a company are data processing and information security. The most important area is data processing.

Our research results have confirmed that data is a valuable resource, the most important building block of ambient intelligence (Geissbauer, Vedsø & Scharauf, 2016; Stuchlý & Látečková, 2017; Maulen, 2017; Kaptein, 2018). From a theoretical point of view, it is clear that other technical elements are also an essential part, but especially those involved in data collection and processing.

The second very important area of development of ambient intelligence in a company is communication, as stated in studies by Kagermann (2014), Greengard (2015), and Hope (2019). The use of elements of ambient intelli-

gence in business and integration of innovative pervasive technologies into business processes streamline communication not only between individual devices but also between other subdomains of the business.

Ambient intelligence modernizes, streamlines, and accelerates communication between individual technologies and information systems through the pervasiveness of technologies. It often offers new ways of communication, and from the statements of companies, we learn that they consider the provision of information in real time or with minimal response time to be the most important.

Information security is the last area from a group of very important areas that companies consider to be a rapidly developing area due to the integration of innovative pervasive technologies and the introduction of elements of ambient intelligence. Permanent monitoring improves and streamlines the management of corporate information security, modifies the method of protection against infiltration, and improves security against further possible infiltration. Progress in this area is very important because the pace of progress and development in computer crime is enormous, and companies cannot underestimate the lag in information security , as the consequences of its disruption can have a major impact not only on the economic performance of the company.

The application of innovative pervasive technologies and the development of ambient intelligence is present in almost all sectors and areas of business. We draw attention to the results of research which showed that the second important area for development and improvement of processes is education.

A detailed analysis of results shows that none of areas examined is insignificant. The minimum significance value was at the level of (M = 41.54, SD = 37.063) in the area of production improvement. This is more about improving current production by integrating new innovative pervasive technologies. We consider the significance value to be relatively high. The distribution was slightly positively skewed (SKEW = 0.241), although the deviation from symmetry was relatively small.

Foreign theoretical sources already show the introduction of elements of ambient intelligence into educational models (Ducatel et al., 2001; Friedewald et al., 2005; Bick et al., 2007; Rosenzweig, 2016; Bureš et al., 2016).

The need to integrate ambient intelligence into the educational process and increase requirements for the level of information literacy of students and graduates is the subject of research studies by Moreira, Ferreira, and Cardosa (2018), who emphasize the important role of schools in this area.

The educational process is the first step and prerequisite for better performance and results for every manager. Achieving a higher level of education increases the likelihood of successful results for managers in business management (Mesároš et al., 2017). Education in the field of information and communication technologies and information literacy will become increasingly important for graduates of economics-focused schools, as they bear a certain degree of responsibility for their implementation and integration (Härtel et al., 2018).

In their study, Wieczorek, Dorčák and Markovič (2019) recommended integrating digital competencies into the profiles of graduates of economics-focused schools and point to the integration of digital skills into individual subjects taught in schools.

Rosenzweig (2016) focused on the need for education and the integration of ambient intelligence in the field of lifelong learning. Bureš et al. (2016) also integrated ambient intelligence into higher education.

5.3 Proposal for Phases of Business Transformation Leading to the Creation of an Ambient Ecosystem

The information literacy of managers and employees is essential for progress in creating ambient intelligence. Development in this area requires time and considerable focus; a gradual process and caution are necessary.

Based on the previous sections of the scientific monograph, we have defined the creation of an ambient enterprise ecosystem in the following phases to reflect our findings:

I. Business intention – the creation of an ambient business ecosystem is based on the vision of the business management. The business management has a general and conceptual idea of the future direction and position of the business. The vision should make it clear where the company is headed, where it wants to go, and what it wants to achieve. It is desirable for the company to have a conceptual framework and a view of ambient intelligence in place at this stage so that it can exploit its potential. It is important for company management to send a clear signal downwards and support digital culture. Company management and employees must also be willing to experiment in this area to a certain extent and adapt their daily processes accordingly.
II. Analysis of the company's digital maturity – the company must assess its digital maturity, resources, and opportunities in comparison

with where it currently stands and where it is headed. It must prioritize goals and take measures that will benefit the company. All goals must be in line with the company's strategy, identified with by the company's management, and in harmony with the company culture, which includes the company's employees.

III. Defining the target state – the company must define the steps to achieve its goals and create a plan for implementing innovative pervasive technologies into business processes. The plan and concept must be based on the technological capabilities, agility, and functionality of the company's IT infrastructure. In this section, the company must set a timetable and allocate financial resources and human resources.

IV. Key and partial projects – the concept of creating an ambient ecosystem must demonstrate added value for individual business processes. Every organisation and business is learning, so not every project will be successful. At this stage, the business will assess the scope of the project and consider dividing it into partial projects, which it must prioritize.

V. Activities leading to transformation – this phase involves the implementation of innovative pervasive technologies based on the setting up of processes based on virtual data analytics. Another area of activity is ensuring mutual communication between all necessary devices, including the implementation of an Internet of Things platform. Developments in this area bring new analytical, creative, and more efficient ways of collecting, transforming, analysing, and evaluating data.

VI. Achieving an ambient enterprise ecosystem – by implementing transformation activities and integrating ambient intelligence platforms, the enterprise will achieve a functional ambient system. Harnessing the full potential of ambient intelligence means radical changes in established processes, attitudes, and practices for the enterprise. At this stage, it is important to realize that the change the enterprise has undergone is not over. It must continue to move forward, discover new capabilities, and thus strengthen its competitiveness.

VII. The prospect of an ambient ecosystem – a functional ecosystem supported by innovative pervasive technologies – offers new opportunities in all areas of business. However, it is up to the company's management to identify and make appropriate use of them. It is necessary for the company to approach individual ambient intelligence platforms with the aim of maintaining them and further developing this ecosystem. At this stage, it is very important for the company to actively and fully

exploit the potential of ambient intelligence and identify new development opportunities, thereby strengthening its performance and competitiveness.

In constructing the phases of business transformation leading to the creation of an ambient ecosystem, we drew on the conclusions of our research and the recommendations of Uhl and Gollien (2016), who argued that the adoption of ambient intelligence is a technological change focused on four areas: cloud, mobility, big data analytics, and socialization. At the same time, in agreement with the authors Al-Ruithe, Benkhelif, and Hameed (2018), we note that building an ambient ecosystem is a fundamental change during which companies discover new areas.

The digital transformation of a business leading to ambient intelligence requires a new dynamic from businesses. The transformation can also have an unpredictable effect on the company, so it is very important that the integration of innovative pervasive technologies and the building of ambient intelligence are carried out by sufficiently skilled personnel and that employees are digitally literate. In this context, we also draw attention to the results of the latest research by Moreira, Ferreira, and Cardoso (2018), who, in connection with the digital transformation of a company and the building of ambient intelligence, emphasized the important role of education and the position of educational institutions, which must prepare sufficiently information-literate graduates.

We agree with the views of several authors (Al-Ruithe, Benkhelifa & Hameed, 2018; Moreira, Ferreira & Cardoso, 2018; Uhl & Gollenia, 2016) who argued that, from a business perspective, such digital transformation is perceived as a profound and precise process with regard to business processes, activities, competencies, and business and commercial models. In doing so, companies should take advantage of the opportunities and benefits offered by the integration of innovative pervasive technologies into business processes and the opportunities and challenges of the European Union, which is trying to help them build ambient intelligence with its tools and measures.

5.4 Limits of Research

The research carried out has certain limitations and constraints. We conducted the questionnaire survey by randomly selecting companies in the Slovak Republic. The research sample is limited by its regional scope. Another limitation of the research is the measuring instrument used. Respondents an-

swered individual questions by self-assessment, and their answers could have been influenced by various factors (lack of time, mood, immediate events while filling out the questionnaire). These limitations restrict the degree to which we can generalize the findings and conclusions of the research.

5.5 Benefits and Recommendations for Scientific Research, Business Practice, and Education

The following section presents, in a generalized form, the benefits of ambient intelligence for scientific research, business practice, and education. The fulfillment of the main objective and individual partial objectives of the research led us to identify the individual points of benefit.

Benefits for the field of scientific research

Currently, there is no comprehensive, holistic view of the issue of ambient intelligence in the domestic environment. Previous research has focused only on individual platforms and elements of ambient intelligence. This scientific monograph thus expands the current state of knowledge in the field of scientific research ( ). Specific benefits in this area can be considered to be:

- Enumeration of fundamental differences between individual concepts that are often associated with or confused with the concept of ambient intelligence.
- Identification of areas of interest in ambient intelligence.
- A proposed definition of the concept of ambient intelligence in relation to the integration of innovative pervasive technologies in enterprises, which emerged from the conceptual framework of theoretical principles and the taxonomy of ambient intelligence.
- A set of characteristics of ambient intelligence that we have identified from chronological, developmental definitions of the concept of ambient intelligence.
- Knowledge about current scenarios for the integration of information and communication technologies and ambient intelligence.
- A complex set of factors that support ambient intelligence in social acceptance and integration.
- A defined set of technologies that build ambient intelligence within individual areas of integration.
- Proposal for phases of business transformation leading to the creation of an ambient ecosystem.

Benefits for business practice

The scientific monograph addresses individual topics and, through its conclusions, expands knowledge about innovative pervasive technologies and ambient intelligence, thus providing new comprehensive information for business practice and increasing the availability of information about ambient intelligence. The scientific monograph contains:

- An assessment of the current state of integration of innovative pervasive technologies in companies in the Slovak Republic.
- Definition and quantification of predictors influencing the level of ambient intelligence.
- Identification of the effects achieved by building ambient intelligence.
- A set of significant barriers that hinder the building of ambient intelligence in a company.
- Definition of areas for building ambient intelligence in a company.
- Proposal for phases of enterprise transformation leading to the creation of an ambient ecosystem.

CONCLUSION

The main objective of the scientific monograph was to examine the current state of integration of innovative pervasive technologies in business practice in Slovakia and to identify predictors influencing the level of ambient intelligence of a company.

Ambient intelligence changes business processes, creating an entire ecosystem of employees, suppliers, customers, business partners, and distributors fully connected to an integrated digital, virtualized network linked to other networks around the world. Building ambient intelligence enables the redesign and creation of new business models within Industry 4.0 that leverage the economics of mass customization, where a product is created as a set of a single complex process (Geissbauer, Vedsø & Scharauf, 2016).

The functioning of ambient intelligence and the development of the industrial revolution require fundamental changes in organisational procedures and corporate structures. The changes also affect the modification and creation of new information system architectures and data management. The integration and use of innovative pervasive technologies will require adjustments to legal regulations and tax systems. The new digitally oriented culture is creating ever-increasing pressure on employees' knowledge and skills in information literacy, where data analysis will have to be one of the basic skills.

In the first chapter of the scientific monograph, we compare the definitions of domestic and foreign authors, which we have defined from a technological, multi-faceted, and visionary perspective. There is no clear specification of the term ambient intelligence in the currently available literature. We have identified areas of interest in ambient intelligence and defined the characteristics and elements of ambient intelligence. Based on an analysis of theoretical foundations, systematization, and generalization, we have proposed a definition of ambient intelligence. We define ambient intelligence as a multidisciplinary approach that integrates innovative pervasive technologies and systems forming an ecosystem that intelligently responds to user requests based on collected, transformed, analysed, and evaluated data.

Ambient intelligence consists of several platforms that can be categorized based on two aspects, namely technological and integration aspects. In the case of technological platforms of ambient intelligence, significant scientific and technical progress can be observed in the field of information and com-

munication technologies. Developments in this area are very difficult to predict; we can only indicate areas for further development. It is very important that these technologies be implemented into business processes within the framework of vertical and horizontal integration.

The theoretical foundations formed the basis for the formulation of the research problem and correspond to the partial outputs in the results of the work. The findings from this part of the scientific monograph were confronted with the results of the work in the Discussion section.

The second chapter contains the main objective and partial objectives of the research. The chapter also includes research assumptions, questions, and hypotheses with their justifications.

The third chapter contains the research model that was applied to solve the research problem. The measuring instrument was a questionnaire survey in companies in the Slovak Republic. The chapter presents work procedures, methods of data collection, and data sources. We provide detailed information on the use of individual scientific methods in the evaluation and interpretation of partial results of the work.

The extensive chapter Results of the research contains analyses and interpretations of the conclusions from the evaluation of the survey conducted among companies in the Slovak Republic. We focus on the current state of integration of innovative pervasive technologies, predictors influencing the development of ambient intelligence, the effects achieved from the integration of innovative pervasive technologies, barriers to the development of ambient intelligence, and areas of its development.

The essence of ambient intelligence consists of innovative pervasive technologies characterised by their ubiquity (pervasiveness) and ability to collect, evaluate, and analyse data. These technologies communicate with each other, respond unobtrusively to user requests, and are capable of learning. In order to build ambient intelligence, companies perform activities such as data analysis, digitisation, virtualisation of business processes, and implement augmented reality into business processes. In the results of our work, we examined the dependence between individual predictors influencing the level of ambient intelligence in a company, thereby indicating a certain possibility of prediction on a general level. For the purpose of deeper scientific research, we examined the functional and predictive relationship between individual variables and quantified it precisely using linear regression analysis. By quantifying the predictors influencing the level of ambient intelligence, we found that the achieved level of ambient intelligence of a company

is predicted by the extent to which the company analyses data, the attitude of company management towards the integration of innovative pervasive technologies into business processes, and the level of virtualisation of business processes. We found that these activities build ambient intelligence independently, but when they interact, their effect on the level of ambient intelligence begins to diminish. Therefore, it is necessary to choose their combination appropriately.

Companies achieve the highest level of ambient intelligence through a high degree of data analysis, virtualisation of business processes, and a positive attitude of company management towards innovative pervasive technologies. When virtualising business processes, companies must have digitized individual processes in which innovative pervasive technologies communicate with each other. Data analytics plays an important role in providing relevant data for the response of individual technologies. Without a positive attitude of company management towards innovative pervasive technologies and alignment with the company's strategy, the significance of these activities would be lost and the development of ambient intelligence in the company could lag behind.

Companies that are becoming active in the field of ambient intelligence and Industry 4.0 are finding that the benefits of implementing and integrating innovative pervasive technologies extend beyond the expansion of their digital content or the sale of new types of products and services. Schwab (2017) argues in his book Shaping the Fourth Industrial Revolution that "unlike previous industrial revolutions, the spread of digital content of new technologies is developing at an exponential rather than linear pace..." Innovative pervasive technologies can shorten delivery times, increase resource utilization, and maximize the quality of products and services. Their application and use is wide-ranging, regardless of the industry or activity of the company.

The last part of the scientific monograph is the Discussion chapter, where we compare the results of our work with the theoretical foundations of domestic and foreign authors. We point out the significant parts of the results of our work in comparison with the results of other studies focused on innovative pervasive technologies and ambient intelligence. In this section, we pay particular attention to the proposed phases of business transformation leading to the creation of an ambient ecosystem. The limitations of the research that we have identified also predict the future direction of research, which is the subject of the fifth chapter. The conclusion of the chapter contains contri-

butions and recommendations for the scientific research field, business practice, the educational field, and ideas for the future direction of research.

We would like to express our conviction that this scientific monograph addresses the issue of ambient intelligence, which represents a new approach and concept in the field of information and communication technologies. We believe that this scientific monograph will contribute to the expansion of current knowledge in the field of ambient intelligence and innovative pervasive technologies, as well as to gaining insight into the current state of this field in companies in the Slovak Republic.

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