

## Streszczenie

In the USA, logistics was transferred from the military sector to the commercial one in the 1960s. Nevertheless, recent years have resulted in a spontaneous development of its application in European countries, as well as in the creation of a logistic company and logistics-based management concepts. A properly organized, state-of-the-art supply chain is of key importance not only for a given industry or for trade in general. In the era of globalization, logistics is an important factor when it comes to ensuring a competitive advantage of the entire economy.

Logistics, the inherent feature of which is the integration of flows and processes, plays an important role when it comes to modern management. It is mainly visible in the increasingly more important impact of logistics on changes in enterprise management system and its individual subsystems<sup>352</sup>. The concept of logistics-oriented management in an enterprise covers all substantive issues related to setting the logistics goals of a given firm along with the methods of achieving such goals. It is a complex process that can be identified in many interrelated phases of the company's undertakings and that plays an increasingly important role in various enterprises. Logistics-related activities can be identified in all units of a given organization. It also has to be stated that logistics within a company is organized in the form of a system.

Processes occurring in every enterprise are closely interrelated with each other and influence the added value offered by a given firm. Their improper functioning interferes with the effective operation of the entire company, hence the importance of a proper process management, including regular monitoring and improvement. The fact that the method of managing logistics processes may not have a significant impact on costs does not necessarily mean that the management of logistics processes does not have a notable effect on the financial results of enterprises. The conducted pieces of research have proved that the impact of the efficiency of logistics processes in the form of, inter alia, good logistics-oriented servicing on customers, increasing their satisfaction and resulting in higher sales may be of a greater importance. It may happen assuming that customer service is a significant factor when it comes to a given company's competitiveness. What is more, the efficiency of logistics-related processes impacts the effectiveness of other processes, such as production.

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<sup>352</sup> R. Matwiejczuk, *Integracja jako kluczowy wyznacznik koncepcji logistyki*, Zeszyty Naukowe Politechniki Częstochowskiej Zarządzanie No. 26 (2017), pp. 83–90.

In practice, when it comes the management of enterprises in highly developed countries, the idea of logistics is implemented to a remarkable extent and with greater and greater outcomes. Recent years have shown the growing need to shape logistic functions and processes in terms of not only integration, but also strategy, which is reflected in the continuous evaluation of logistics processes. The necessary conditions for maintaining the market position and gaining a competitive advantage are predominantly economic operations, the reduction of logistic costs, the efficiency of logistics processes, as well as the use of modern instruments for managing said processes<sup>353</sup>.

The contemporary approach to business management requires a process-based scheme. As it is in the case of the very concept of logistics or processes connected with it, management is subject to constant changes due to a continuous technological development.

The nature and objectives of logistics-related management boil down to reducing costs wherever possible, as well as conducting effective logistics process being in line with the company's strategy. While taking into account the total costs incurred by a given enterprise, not only is the share of logistics costs important, but also - the possibility of reducing them. The logistics-oriented literature emphasizes the need for the so-called holistic approach – treating the issue as an integral whole. It consists, among other, of searching for optimal solutions from the point of view of the benefits to the entire system, rather than to its individual parts.

The pace of changes contemporary in the contemporary business environment forces enterprises to constantly adapt in order not to risk losing their share on an increasingly competitive market. Nevertheless, the increasingly volatile and dynamic market in which modern enterprises operate makes the prior successful methodology of verification, evolution and continuous adaptation becoming less and less effective. There is the need to implement innovative solutions, which are revolutionary rather than evolutionary in nature<sup>354</sup>. Many studies in this field have shown that innovations are closely related to the increasing efficiency and competitive position of a company on the market<sup>355</sup>. The efficient functioning of logistics is largely based on the technical and organizational structure of the company and on the openness to the implementation of innovative solutions. Due to the competition on the market, enterprises are forced to use modern IT systems that comprehensively support

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<sup>353</sup> A. Godzisz, A. Ścibisz, *Wpływ logistyki na konkurencyjność współczesnego przedsiębiorstwa*, Logistyka 5/2013, p. 62.

<sup>354</sup> A. Bujak, *Innowacyjność i innowacyjne rozwiązania w logistyce*, Logistyka 2/2011, p.85.

<sup>355</sup> B. Ślusarczyk, *Wspieranie konkurencyjności polskiego przemysłu w świetle założeń nowej polityki przemysłowej*, Zeszyty Naukowe Politechniki Częstochowskiej Zarządzanie No. 22 (2016), pp. 7-16.

logistics-related management processes, as well as to opt for the supervision over the entire enterprise.

In the case of logistics, there are numerous technologies that can effectively increase the efficiency of companies and help them create a competitive advantage. The most innovative ones are called virtual and augmented reality. They can be widely utilized in logistics-oriented companies. Gartner predicts that VR will become popular as early as in 2020, whereas AR-based solutions will be widely used within the next 5-10 years. It does not mean, however that there are currently no implementations that are worth looking closer at. Said technologies are already used, for example, in repair and maintenance companies, in product storage, and in logistics. Virtual and augmented reality technologies are slowly beginning to enter the business sphere as well. Over time, they will become indispensable in widely understood logistics-oriented sector. Even currently, millions of goods stored in warehouses, monitored, and shipped to customers on daily basis require the involvement of many people and the use of appropriate tools, machines, vehicles, as well as IT systems. Virtual reality (VR) and augmented reality (AR) technologies turn out to be extremely useful when it comes to improving the overall workflow.

The „Augmented Reality” term pertains to a process of extending the perception of a human being by means of utilizing computer generated information. Even though the notion in question has been typically seen through the prism of action films from the 80s, it is now predicted that it may have an important impact when it comes to the development of technological and intra-logistics solutions. Warehouse managers and forklift operators may – by opting for modern devices – analyze information shown to them on special displays oriented towards presenting computer generated data.

As a result of the evolutionary perspective, after the emergence of 4.0 industry, the interest in AR technologies is expected to grow exponentially in the upcoming years. The industrial applications for augmented reality are wide. Some developed countries have already started exploring the potential of AR with regard to the future of smart factories. The usefulness of AR has been shown to significantly improve the planning of intra-logistics processes. It gives a greater flexibility while planning logistics systems and allows designers to respond more efficiently to market dynamics. For example, product designers would no longer be constrained by physical boundaries, as they would have the ability to better visualize and flexibly manipulate the three-dimensional parameters of product design in real time. In the case order realization, warehouse operators equipped with AR devices such as head-mounted displays (HMD) and smart glasses could benefit from AR visualization and

improved content delivery to reduce the blind spot caused by, *inter alia*, searching for information in a mobile data terminal (MDT) or in a paper list used conventionally. In addition, augmented reality is a quantum leap when it comes manufacturing activities, as well as key factor with regard to the intelligent use of the industrial environment and next generation of advanced manufacturing solutions. Various benefits of the aforementioned approach cannot be questioned, as they include: the support for specific production tasks by ensuring proper assembly time for components and moving materials, visual advising and guidance pertaining to maintenance procedures, as well as the creation of an efficient, intuitive management and control system together with an optimal workplace for training and learning. Furthermore, AR applications include transport activities optimization and allow for engaging customers in enjoyable marketing experiences.

Even though AR offers many opportunities in the field of logistics, the incorporation of this technology into organizational processes poses many problems that undermine its widespread use and make the suitability of AR for business applications questionable. There have been only few examinations highlighting the limitations of AR technology in logistics. Pieces of research pointing to the limitations of augmented reality in logistics are therefore rather scarce. The majority of scholars who have studied AR in the context of logistics have focused on the capabilities of this technology and its impact on business processes, while at the same time neglecting the discussion on either obstacles or complexities connected with the incorporation of AR technology into the organizational structure. In order to fill said research gap and broaden the general knowledge in the field of widely understood AR, the author of this dissertation has characterized the conditions for the implementation of augmented reality in a manufacturing company.

The paper incorporates an introduction, five chapters being both theoretical and empirical in nature, as well as a summary including final remarks.

**Chapter one** provides the overview of the literature of the subject on the nature of both logistics and logistics-related management. It deals with the explanation of basic notions connected directly with logistics and management, specification of their importance, and discussion on the most basic elements of logistics-related management specified by scholars in the literature of the subject.

**Chapter two** incorporates the overview of the literature on the subject on both virtual and augmented reality. It deals with notions being closely connected to the aforementioned technologies and provides the scope of their usage.

**Chapter three** characterizes chosen areas of logistics in the case of which the augmented reality-based technology can be implemented. It also deals with the market of augmented reality-oriented solutions both in Poland and around the world. It also offers a comprehensive analysis of own research outcomes pertaining to the maturity of augmented reality technology in Poland and in Europe.

**Chapter four** discusses the concept of managing logistics-related processes by opting for augmented reality solutions. It focuses on determinants shaping the logistics-based added value chain, as well as the impact of logistics-related costs on the final cost of goods produced by a given company. The chapter also characterizes the realization of strategic logistics goals through the prism of utilization of augmented reality.

**Chapter five** deals with the assumptions of the model of logistics process management oriented towards the use of augmented reality. It characterizes the conditions for implementation of the aforementioned technology. The final element of the chapter in question is the proposal of a model of production line supply process based on augmented reality.

The dissertation analyzes data obtained from 375 surveyed enterprises, including preliminary information on the basic parameters of such enterprises, as well as data contained in the surveys, which have been the basis for the verification of the main hypothesis. The knowledge of augmented reality technology and openness to its application have been analyzed. The influence of technology on work efficiency, as well as the knowledge of costs and determinants of said solution implementation in the enterprise have also been checked. The last stage of the research has been the creation of the proposed model of logistic process management in a production company, taking into account the increase in productivity as a result of the adoption of augmented reality.

The study covered small, medium, and large enterprises. The respondents were managers of enterprises, logistics managers, managers of *Lean management* departments, as well as employees of said production companies. The subject of the research were production companies located in Europe. The research was carried out between 2019 and 2020.

The utilized questionnaires included questions allowing the author to gather information on:

- age, size, and the scope of the company's activity,
- knowledge on augmented reality technology, its use, and costs,
- approach to using AR technology from the point of view of technical, management and social aspects,

- openness to the process of implementing augmented reality technology,
- knowledge of augmented reality technology by future generations of logistics,
- trends affecting the use of augmented reality in logistics,

The paper incorporates a single main hypothesis: *Augmented reality influences the effectiveness of logistics processes, while at the same time creating new elements of competitiveness of a production company.*

In order to verify the main hypothesis, the following auxiliary hypotheses have been formulated:

- HS1 Implementation of augmented reality depended on the size of the company, the scope of its operation, and its age.
- HS2 Number of employed individuals is a determinant of the implementation of augmented reality.
- HS3 Scope of the company's operation is the determinant of AR implementation.
- HS4 There is a correlation between the use of augmented reality and the level of knowledge pertaining to its specificity.
- HS5 Implementation of augmented reality depended on the willingness to improve logistics-related processes.
- HS6 Implementation of augmented reality depended on the type of enterprise.
- HS7 Fact that an enterprise implemented augmented reality might have had the effect on recognizing the increased effectiveness of training as a benefit of the adoption of augmented reality during training sessions.
- HS8 Increasing complexity of logistics-related processes will accelerate the use of augmented reality.
- HS9 AR implementers knew the difference between augmented reality and mixed reality.
- HS10 Fact that an enterprise implemented augmented reality might have an impact on the perception of increasing employee safety as the most appropriate logistical challenge to solve by means of augmented reality application.
- HS11 Determinant of the implementation of augmented reality is the desire to improve the processes of procurement, storage, and order completion.
- HS12 Implementation of the augmented reality technology was caused by the desire to improve the efficiency of employees.

- HS13 Fact that an enterprise implemented augmented reality might have an impact on the perception of increasing complexity of logistics-based processes as a trend that would accelerate the scope of utilization of AR solutions.
- HS14 The fact that an augmented reality has been implemented in a given company has an impact on the perception of the problem of employment reduction in connection with the implementation of AR.
- HS15 Use of AR was connected with the use of younger workforce.
- HS16 Process of implementing augmented reality technology was dependent on the employee's gender.

Percentage distributions have been utilized to showcase the characteristics of the respondents and their answers to specific questions. The statistical significance of differences in responses provided by the two analyzed groups has been checked by using the Chi-square test or the Fisher test. Correlations between the studied variables have been specified by using regression models. Due to the fact that in all the examined cases variable have been dichotomous, logistic regression has been used. Result tables made for the models have provided the author with information on the ratio of chance for an affirmative answer for a question with which the explained variable has been connected for the reference category of the explanatory variable and the tested category. They have also provided information on whether differences in probabilities have been statistically significant.

Examination outcomes have been presented in both graphical and table-based form.

The structure of the paper and its content are results of complex theoretical and research goals that have been achieved. The theoretical part of the work has been developed on the basis of a literature review. Theoretical chapters present topics related to the concept of logistics and management systems, describe the history of virtual and augmented reality technologies, as well as familiarize the reader with their areas of application. The conditions and benefits of implementation of augmented reality have also been provided. Empirical chapters contain analyses and summaries of examinations carried out. The content of individual chapters focuses on factors and conditions aimed at the verification of hypotheses formulated.

In the case of the theoretical part, the basic method utilized has been the study of the literature of the subject with the focus being put on both primary and secondary sources. The primary sources have been survey questionnaires, whereas the secondary ones have included pieces of information taken from scientific publications. The theoretical part deals with issues

related to the logistic management process ensuring a competitive position of a production company on the market by opting for an innovative solution being the augmented reality technology. Information pertaining to said field have been systematized. Basing on theoretical considerations, the increasing role of innovative solutions in the area of logistics to reduce logistics costs and thus improve the condition of the entire production company, as well as the overall quality of a product made has been indicated. Said observation has been the subject of this dissertation.

While justifying the decision to start researching the use of augmented reality in manufacturing companies in order to improve the efficiency of logistics processes and creating new elements of competitiveness on the basis of the collected questionnaire results, it is possible to clearly indicate the need for enterprises to increase their overall competitiveness. It is obvious, as proved by the examinations carried out that workplaces perceive the growing complexity of logistics processes and the procedure of increasing workforce efficiency as determinants of the implementation of augmented reality. It is worth noting that entrepreneurs perceive augmented reality as a tool to improve employee safety, thus confirming the theoretical assumptions of human resource management that people are the most important element of every workplace.

By critically analyzing the available literature, it has been found that the approach to management changes just like it is in the case of the constantly changing market conditions. Enterprises implementing numerous innovative solutions not only have to develop work culture, but also adopt an approach towards integrated process management. The lack of integration may lead to an increase in operating costs, greater involvement of human resources, as well as competence and organization-related chaos, which - in the era of globalization and growing competition – simply cannot be afforded.

It has been noted that even though AR offers many opportunities in the field of logistics, the incorporation of this technology into organizational processes poses many problems that undermine its widespread use and make the suitability of AR for business applications questionable. Focusing on determining the right application for specific scenario may provide a satisfactory value and employee support. The main factor behind the use of augmented reality in many manufacturing companies is the curiosity and willingness to use it before the key pieces of information on the technology are obtained. Quite a common challenge for enterprises wishing to implement AR is the inability to correctly identify the area where said technology can yield greatest benefits. Identifying the appropriate case for



AR implementation and testing its capabilities are included in three most important priorities for enterprises planning to implement said solution.

The evidence of the existence of enterprises using augmented reality in Poland and Europe has been the conducted survey, which has been used to determine the maturity of augmented reality technology in said areas. Among 375 respondents, 129 have confirmed the regular utilization of AR, being 34.4% of all surveyed individuals. It has been noted that the most positive responses have been received from the following countries: Germany - 40; United Kingdom - 21; France - 19; Spain - 12; Czech Republic and Sweden, 7 each; Poland, Italy, the Netherlands, Slovenia, 4 each; Norway and Portugal 3 each; Switzerland - 1. The distribution of enterprises using augmented reality depends on research centers and companies implementing AR. In terms of European VR and AR companies, France, Germany, Great Britain and the Netherlands are clear leaders. The increasing VR and AR-related activity in the Nordic countries (Sweden and Finland), Switzerland, Spain, Italy and - to a more limited extent - Eastern Europe (Poland and the Czech Republic) are also worth noting. Specific "hot spots" when it comes to VR and AR-related undertakings can be found in Paris, Laval, London, Amsterdam, Berlin, Munich, Stockholm, Zurich, and Madrid. London and Amsterdam have been creating favorable conditions for new VR and AR startups, predominantly thanks to a vibrant business environment and innovative culture.

Within the framework of the executed examinations, both the main hypothesis and the auxiliary ones have been verified.

The result of the carried out questionnaire-based examination is a proprietary descriptive model pertaining to the implementation of augmented reality in the process of supplying production lines that is proposed in chapter five of this dissertation - *Smart Extended Management Vision*.

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15/09/2020