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Information and communication technologies (ICT) in construction and development of logistics systems

Technologie informacyjno-komunikacyjne (ICT) w budowie i rozwoju systemów logistycznych

Abstract. The higher and higher level of competitiveness of enterprises, the increasing expectations of customers or internalization of business are just a few examples of challenges that most of companies must face nowadays. None of these challenges may be faced, however, if the companies do not cope with logistics problems. The increasing number of problems, among others related to the necessity of diversification of products, of provision of frequent, fast and small deliveries, of ensuring reliability and flexibility in operation, of transfer of goods almost all over the world, can no longer be solved with application of traditional methods. Condition of success in contemporary logistics is implementation of modern technology. Companies without IT systems, without automatic identification of goods or electronic exchange of data have not chances for strong presence in today's supply chains or other modern forms of business. In this paper characteristics of selected information and communication technologies (ICT) were presented with reference to the operation of contemporary logistics systems. The introduction presents the role and substance of the information resources in logistics. Technological solutions concerning transfer of information were grouped and characterized according to the following types: family of electronic connections, corporate networks and information highways. In each group of the solutions main faults and benefits were presented, from the perspective of possibilities of application in logistics.

Key words: logistics, information and communication systems, logistics systems, technological solutions

Synopsis. Coraz wyższy poziom konkurencyjności przedsiębiorstw, rosnące oczekiwania klientów czy internalizacja biznesu to tylko nieliczne przykłady wyzwań, przed którymi stoi dziś większość firm. Żadnemu z tych wyzwań nie da się jednak sprostać, jeśli firmy nie poradzą sobie z problemami logistycznymi. Coraz więcej problemów m.in. związanych z koniecznością dywersyfikacji produktów, zapewnienia częstych, szybkich i jednostkowych dostaw, zapewnienia niezawodności i elastyczności działania, przesyłu towarów niemal na całym świecie nie może być już rozwiązane przy zastosowaniu tradycyjnych metod. Warunkiem sukcesu we współczesnej logistyce jest wdrażanie nowoczesnych technologii. Firmy bez systemów informatycznych, automatycznej identyfikacji towarów czy elektronicznej wymiany danych nie mają szans na silne uczestnictwo w dzisiejszych łańcuchach dostaw, czy innych nowoczesnych formach biznesu. W artykule przedstawiono charakterystykę wybranych technologii informacyjno-komunikacyjnych (ICT) w odniesieniu do działania współczesnych systemów logistycznych. We wprowadzeniu przedstawiono rolę i istotę zasobów informacyjnych w logistyce. Rozwiązania technologiczne dotyczące przesyłu informacji pogrupowano i scharakteryzowano według następujących typów: rodzina połączeń elektronicznych, sieci korporacyjne i autostrady informacyjne. W każdej grupie rozwiązań przedstawiono główne wady i korzyści z punktu widzenia możliwości zastosowania w logistyce.

Słowa kluczowe: logistyka, systemy informacyjno-komunikacyjne, systemy logistyczne, rozwiązania technologiczne

Introduction

Information in logistics, understood as provision of suitable resources to all so-called basic processes [Chaberek 2002], constitutes the basis for all actions. According to this definition, information is also a subject of flow in time and space. Information is subject to purchase, processing, transfer, storage and sale. Information (information systems) is the basic element of logistics systems. Informatio transfer channels create channels of transfer of goods and services (logistics channels). They consolidate the modules of logistics system, such as: centers of supply, inventory, production and sale, creating specific organization structures (not always formalized, for instance virtual enterprises) [Boysen et al. 2015]. Flow and use of information must be monitored and controlled. The same is for lack or glut of materials, shortage or surplus of information – they may cause great problems in enterprise operation. Enterprises may measure value of their information resources by sharing information with recipients. Achieving competitive advantage depends on to what extent the enterprise is able to use the information, so that the information would not be used by the competition. So, on one hand a challenge for the enterprises is releasing the information, and maintaining strict control over how the information will be transferred and used. The aim of this paper is characteristics of selected information and communication technologies, and specification of their roles in operation of logistics systems, and also their systemization. Considering the fact that the subject of this paper remains within the field of economics and management science, so for methodology purposes herein attention was focused on humanistic methodological approach towards them. The humanistic methodological approach promotes application of hermeneutical methods of research[1], which means analysis, explanation and interpretation of any written sources related to the subject of research[2].

[1] The very term hermeneutical comes from Greek *hermeneutikos* – referring to explanation. In hermeneutics we observe theories of "operations of understanding with reference to text interpretation". See: [Wikipedia...].

[2] A characteristic feature of this model is emphasizing of a particular role attributed to the systems of values, source texts and their contexts, and also to the words through which qualitative research is conducted, being the core of this method of "doing" science. See: [Kuciński 2010].

Characteristics of selected technological solutions for information transfer

To particular groups of information sources various channels of information transfer are applied with various techniques and technologies. Logistics systems, forming various formal and organizational structures, require different channels of information flow, applying various technologies of data transfer. These differences consider, for instance, the cost of implementation of particular technology, various speeds and infallibility of transfer, different level of data security, etc. The level (generation) of these techniques and channels determine abilities of development of information tasks – one of the main objective of logistics. Technological solutions within transfer of information may be classified according to the following types [Kisielnicki and Sroka 1999]:

- family of electronic connections,
- corporate networks,
- information highways.

The family of electronic connections is the whole range of technological solutions, providing a computer mode of communication between market partners (legal entities, natural persons) on various economic topics and issues [Długosz 2017]. Contemporary generation of these devices, characteristic structure of software, hardware and communication are oriented toward the application of large and centralized computing powers, whilst data access for users is provided by communication and terminal drivers. The main advantage of electronic connections is complete time coordination of the logistics process (and the basic processes, such as production, distribution, dispatch, customs clearance, etc.) with the cycle of documentation and settlement service. Technical possibilities, such as the electronic exchange of trade data between contracting partners (transfer of documentation), or electronic settlement of payments, create a new quality in shaping trade relations. Thus, the electronic connections, as the systemic channels of information transfer reflecting the logistics processes within the material sphere, constitute a significant factor of integration of the logistics environment.

Internal networks, the synonyms of which are the corporate information systems or company internal networks, are the software-hardware solutions serving for communication and group/team work in the dispersed environment [Niedzielska 1997]. Among such information systems one may distinguish three various models of transfer and processing information, which may be regarded as the corporate information systems. They are as follows: host centric, PC centric and network centric systems. The basis for differentiation of the abovementioned models of information provision are the procedures of gathering and sharing data, methods of data management and proportions between information services provided globally or/and locally to the systems' users. The basis for host centric model of processing is concentration of data and of managing of access to the data. This enables centralized coordination of the system of permissions and responsibilities within preparation and processing of data and planning, implementation and maintaining IT resources.

The main value of the host centric model of information provision is its usefulness in operations that support centralized management of settlements. Unquestionable benefits of the use of this type of solutions are obviously the possibility of electronic exchange of data, electronic transfer of documents and payments, or electronic transmission of messages to and from interactive databases [Adamczewski 2001]. Apart from that, the centralized solutions are effective due to:

- high control of the system of data processing,
- possibility to gain the exact match of the information system services to the needs of users.

However, a disadvantage of centralized solution may be some lack of flexibility, following from:

- lack of openness of the centralized information system outside the sphere of one economic entity,
- stagnation of the centralized applications and processing resulting from supplementing the information system with target-oriented applications [Adamczewski 2001].

Information systems based on the PC centric model are most often applied in economic practice. Their development and universality of application are the result of commonness of PC use, access to proper software and also to supporting communication techniques. This model assumes spatial and functional distribution of information and existence of the system of connections (most often with the use of technologies of local computer networks), providing communication and sharing of the same resources. The objective of dispersion of data distribution is natural matching of the information system structure to the organization structure of a company, increase in productivity by acceleration of processing and its approximation to the place of data generation and application.

The network model is a sort of combination of the host centric and PC centric processing. It enables both preservation of the features of the host centric processing model, related to the supervision over data, and their effective use (in the PC centric model), at the same time allowing decrease the contributions on infrastructure and limitation of costs of administration and maintaining the IT system [Maffei and Meredith 1995].

Value of the network model follows from limitation of costs of the information system, with preservation of the ability to introduce changes fast, for instance in the response to the change of conditions of conducting activity supported by a particular system. Apart from that, the advantages of the network system of processing are:

- effectiveness of integrated, globally and locally dispersed computing services,
- openness to implementation of changes in applications and processes with a response to changes in the environment where the computer-aided activity is conducted.

The core of the network model of processing is a computer network, characterized by:

- an easy access for users to the data dispersed spatially and functionally,
- openness to effective and fast implementation of advanced applications and solutions,
- economic effectiveness related to both rational use of information resources and possibility of integration of various computer and communication platforms.

Corporate information systems as elements of logistics systems

A relatively new quality in corporate information systems used in the sphere of management of supply chains is the intranet – that is the internal company network using (in place of deliberately tuned standards) WWW technology [Handfield and Nichols 1999].

This is the active data (information) search conducted by the user, replacing a traditional, target-oriented distribution of data (information). In place of the system based on the data distribution to all or/and selected recipients, determined by a particular application, there is an access by the data user possible from particular places, and in a current defined time. Introduction of the intranet as a corporate information system solution signifies among others, an implementation of such principles of organization:

- central data sharing (which means their coherence and lack of redundancy),
- supplementing and changing of local contents of the preserved collections of data,
- access to all employees in the network.

In the intranet network it is possible to organize segments with specific authorization solutions for access permission. The intranet requires application of central administration of search mechanism, allowing supervision of places and types of the stored data. A practical value and usefulness of the search mechanisms depend on the quality and integrity of data.

Progressive cooperation and globalization of economic activity have created the latest type of connections referred to as extranet. This subsystem of information channel is a part of the intranet that goes beyond corporation. It may be assumed that extranet is a nucleus of the corporate network that is most often defined as the web of local computer networks [Alam et al. 2015].

Sometimes corporate networks are referred to as the web connecting dispersed environments and functional resources, including collecting, preserving, distributing and processing of data with the aim to share them with users, regardless of their position in the corporation. The network of such type contains both elements owned by a corporation and also IT solutions supplied from outside by private or public operators. If companies cooperating with an entity that provides international logistics services and this entity performed integration of their external connections and information channels, they would obtain an information network able to serve the whole international distribution/production process.

Development of information systems applied in logistics

Proper operation of logistics systems within regional operational systems depends on availability of the integrated information system [Kawa and Wieczerzycki 2006]. Both the integrated regional network and the operational one are usually characterized by cyclical cooperation of many small enterprises located within small distances. In such bodies, routine operations, sending company messages, guidelines, orders and technical or trade documentations often cause trouble. In a spatially dispersed environment, which at the same time is technologically integrated, the information of permanent nature (available all the time from any place, being "within sight") have the bigger and bigger share in total resources [Huemer 2002].

Databases of companies providing logistics services must contain, among others, information about spare capacity of cooperating companies or characteristics of services provided by them. The data should be available to all cooperating companies within the chain of supplies. Many techniques of categorization of data enable their application and full use. The following solutions may serve as examples: SWOT (IT Supported System of

Trade in Goods), SIT (System of Goods Information) or Hannibal – IT system that helps to collect economic information about enterprises, their products and services, as well as proposals of international cooperation.

The wide web of corporations, tasks of which are now fulfilled by the widely-available Internet, may be perceived as the foundation of global information infrastructure for international business relations [Atzori et al. 2012]. Undoubtedly, the use of any techniques of information provision, applied in all disaggregated processes reflected in a model of virtual company, gives a wide range of opportunities. The increasing reliability, popularity and availability of telecommunication technologies and of electronic media, such as the Internet, give many organizations a chance to access almost unlimited range of partners. Operation of a virtual company bases on contacts by electronic means with application of highly advanced information technologies.

Within cooperation of networks of companies jointly creating a virtual company, frequently including international cooperation located on various continents, the field of IT seems to be the smallest problem, compared to such issues as: physical flow of goods, legal and administration aspects, etc. Most of applications of IT now supporting the logistics in Polish enterprises correspond to solutions with respect to technological advancement. The above state is influenced mostly by financial conditions, but also by awareness of the owners and managing teams. A short characteristic of domestic applications of IT was presented in Table 1.

Table 1. Features of present and proposed IT applications in Poland
Tabela 1. Cechy obecnych i proponowanych aplikacji informatycznych w Polsce

Present state	Required state
– single domain-specific systems, most often: finance, HR, payroll, less often logistics, – partialness of solutions of many suppliers of system components, – functional inconsistency and lack of integrity, – dependence on one software platform, – weak support for management processes, – lack of management accounting and controlling of logistics processes high costs of acquisition and maintenance of system, limited possibilities.	– functional complexity, integration of data and procedures – one supplier – integration of solution – software-hardware independence – benefiting from EDI, intra and Internet and multimedia – full support for management processes within process orientation – lack of management accounting and controlling of logistics processes

Source: own study based on [Kale 2001, Długosz 2009].

The Integrated Management Information Systems are at present the most advanced form of support provided for management and logistics processes. Development of information systems applied in logistics is presented in Figure 1.

Main features of the Integrated Management Information Systems [Bond et al. 2000]:

– functional complexity – a system comprises all fields of technical/economic activity of an economic entity (reflected within the functional sphere);

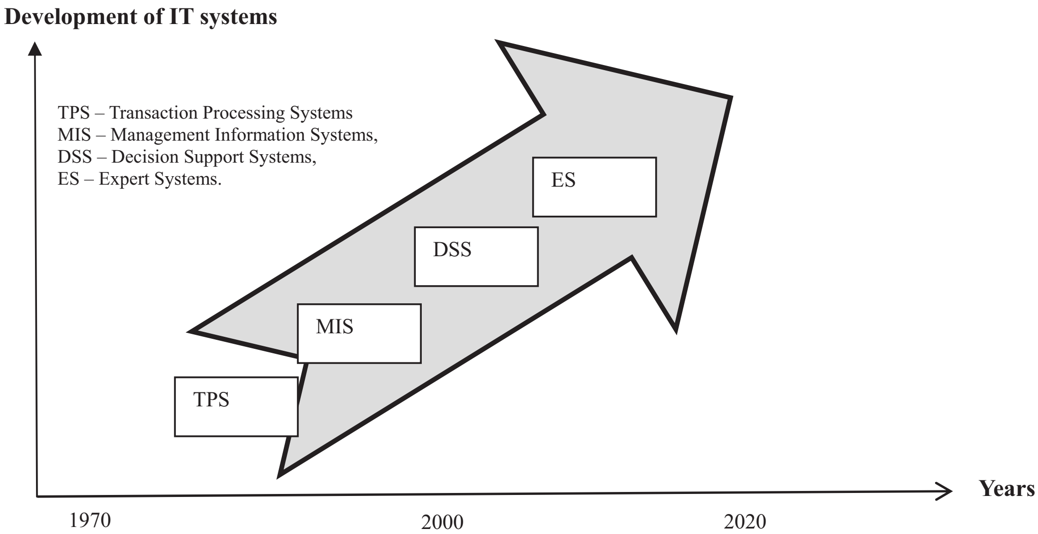

Figure 1. Development of information systems applied in logistics
Rysunek 1. Rozwój systemów informatycznych stosowanych w logistyce
Source: own study based on [Gamdzyk 1996].

– functional and structural flexibility – provides maximum adaptation of software and hardware solutions (within technical and functional structures) to the requirements of an object at the moment of installation and launching of the system, and also enables its dynamic adaptation when requirements and needs, generated by the environment, change;
– openness – guarantees ability to broaden the system by new modules, scalable architecture (usually: client-server) and creation of new connections with internal systems, such as systems of market partners;
– substantive advancement – provides full IT support for information and decision-making systems, with the use of mechanisms of free data aggregation, variance, optimization and forecasting, etc.,
– technological advancement – guarantees accordance with current standards for software and hardware, with a possibility of migration onto new platforms of hardware, operating systems, media and communication protocols;
– compliance with Polish regulations, for instance with the Accounting Act, with particular consideration for principles of bookkeeping with application of information technology, with principles of settlement and reporting financial results of economic entity, and principles of drawing up financial statements, etc.

Speaking of the roles of information and communication technologies in operation of the logistics systems we must still take into consideration the traditional techniques of communication, such as phone or facsimile machine, and we must not underestimate their importance. They are still bases of direct communication, especially in countries with low level of industrialization.

Summary

Development of logistics in Poland and globally was and has been a result of changes taking place in the system of information supply. Specific information and communication technologies have created special environment for logistics of information, and thus for logistics industry as a whole. Only the new possibilities within the sphere of logistics of information gave rise to the development of idea, of concept and application of logistics on an unprecedented scale-service of economic processes within provision of suitable resources in proper place, in proper amount and at suitable costs. That gave rise to new opportunities within the field of logistic services and created a new quality of operation of economic systems.

This paper distinguishes three basic types of technological solutions, concerning transfer of information:
– family of electronic connections,
– corporate networks,
– information highways.

The main advantage of the first type of solution is complete time coordination of the logistics process (and the basic processes, such as production, distribution, dispatch, customs clearance, etc.) with the cycle of documentation and settlement service. Among the second type of solutions we may point out various models of systems of information transfer and processing: the host centric, the PC centric and the network centric systems. Undoubtedly, a benefit of such solution is a possibility of communication and group/team work in the dispersed environment. The pillar of global information infrastructure of the contemporary international economic relations is obviously the Internet. The Integrated Management Information Systems are at present the most advanced form of support provided for management, including the management of logistics processes.

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A comparison of logistics infrastructure development level of European Union countries using TOPSIS and VIKOR methods

Porównanie poziomu rozwoju logistyki w krajach Unii Europejskiej z zastosowaniem metod TOPSIS i VIKOR

Abstract. The purpose of the research was to compare the logistics and logistic infrastructure development level in EU countries. To evaluate overall rank of each country in term of that traits, it was used eight variables which describes logistic characteristics. In this purpose, two of the multi-criteria models of decision making: a Multicriteria Optimization (VIKOR) and Compromise Solution and a Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) were applied and the results obtained by those two methods were compared. The results showed that VIKOR is more preferable method in comparison to TOPSIS methods and the countries where the logistic is developed the most according to the scores in created rankings are Germany, France and Poland.

Key words: logistics, UE countries, TOPSIS, VIKOR, rankings comparison, linear ordering

Synopsis. Celem badnia było porówanie poziomu logistyki oraz infrastruktury logistycznej w poszczególnych krajach Unii Europejskiej. Do zbudowania rankingu i określenia w nim pozycji poszczególnych państw pod względem cech logistycznych użyto ośmiu zmiennych opisujących obecny stan infrastruktury. Do obliczeń zastosowano dwa modele wielokryterialnego podejmowania decyzji, mianowicie Multicriteria Optimization (VIKOR) i Compromise Solution and a Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS), a wyniki uzyskane za pomocą obu metod zostały porównane. Z badań wynika, że w świetle zastosowanego zestawu danych metoda VIKOR jest bardziej skuteczna w podejmowaniu decyzji i wyboru najlepiej rozwiniętego logistycznie kraju, jednak obie metody jednakowo wysoko w rankingu wykazały Niemcy, Francję oraz Polskę.

Słowa kluczowe: logistyka, kraje Unii Europejskiej, TOPSIS, VIKOR, porównanie rankingów, porządkowanie liniowe

Introduction

The development of logistics services and communication technologies has revolutionised production and distribution processes and created a global market. Shippers require efficient logistics services that can move their goods to the right place, at the right time, in the right condition, and at the right price so can drive the rapid development of this field. From theoretical point of view it can be stated that growth in transport at infrastructure corresponds to growth in the economy. There is a number of publications proving that transportation and logistics has substantial direct and indirect effects on economic efficiency and economic growth [Vilko 2011, Sánchez 2017, Skorobogatova and Kuzmina-Merlino 2017, Vulevic 2018]. Therefore the logistics development is very important for the national economy of each country. Currently, at the regional markets, there is a disproportion between the growing demand for transportation and logistics services and the availability of facilities needed for their implementation. It is estimated that European freight transport will increase in 2050 by about 80% in compared to 2005, while passenger traffic will increase by 51% [Krysiuk and Zakrzewski 2013]. Transport infrastructure, due to constantly increasing price competition and the need to guarantee considerable flexibility of supplies, is the main criterion for location decisions of business entities [Kauf and Tłuczak 2017] which resulted in economic development of the region.

Components of the country's logistic potential include transport infrastructure, i.e. the length of the road and rail network and the density of transport points (e.g. airports, sea ports) and is influenced by the geographical location. On the other hand the diversity of transport intensity in European Union countries is also often associated with geographical location and other factors e.g. economic. To evaluate and compare countries in order to many different characteristics connected with logistics and transportation it is possible to use one of the MCDA methods.

Multiple-criteria decision analysis (MCDA) also known as Multiple-criteria decision making (MCDM) is a scientific area and matured branch of operations research that is concerned with designing mathematical and computational tools to support the subjective evaluation of a limited number of decision alternatives under a limited number of performance criteria by a single evaluator (or decision maker) or by group of evaluators [Opricovic and Tzeng 2004]. To support the subjective evaluation the MCDA incorporates knowledge from different fields, including behavioral science theory, mathematics, economics, computer technology and information systems. It can be stated that MCDA/MCDM is an active research area with many theoretical and practical papers and books. The main goal of MCDA/MCDM is to designate to select the most preferable alternative, classify them into small number of categories or rank considered alternative in a subjective preference order. The main steps in multi-criteria decision making are the following [Roszkowska 2011]:

- establish system evaluation criteria that relate system capabilities to goals,
- develop alternative systems for attaining the goals (generating alternatives),
- evaluate alternatives in terms of criteria,
- apply one of the normative multiple criteria analysis methods,
- accept one alternative as "optimal",
- if the final solution is not accepted, gather new information and go to the next iteration of multiple criteria optimization.

In general, the MCDM problems can be split into two distinctive types due to the different problems solving: the first type of problem considers a finite number of alternatives and the second type considers an infinite number of alternatives. Considering classical problem associated with selection of the best alternative, the number of potential alternatives is limited. On the other hand, considering problems related to design, selected variables may take any value in a range resulting in infinite number of potential alternatives. Results presented in this paper consider only the first type – with a finite number of alternatives.

Many authors have proposed several analytical models to support decision making process in conflict management situations. Nowadays, with the help of computer software, proposed methods have become more and more popular and easier to use by the end-users. Considering the most popular set of multi-criteria techniques like SAW, MAXMIN, MAXMAX, AHP, TOPSIS, VIKOR, SMART, ELECTRE and PROMETHEE seem to be the most frequently used methods [Roszkowska 2011], but in many statistical software package it is nowadays available some build in models and methods of MCDM calculation. In this paper were chosen two multi-criteria techniques: TOPSIS and VIKOR.

In the light of the aforementioned reasons, the main purpose of the research was to compare the logistics and logistic infrastructure development level in European Union countries. It is important goal which may give guidelines for governments supporting their decision which countries the special financial programs should be directed to in order to improve their logistic infrastructure development level.

The second purpose was to compare two multi-criteria techniques: TOPSIS and VIKOR. The goal was set based on the review of results presented by Opricovic and Tzeng in 2004 where theoretical aspects of the considered methods were presented. This research also tried to provide answer the advantage of one method over the other on the basis of that kind of empirical data collection.

Data source and methods

The analysis was conducted based on the data collected by European Commission and available in Eurostat database for 2016 [Eurostat database 2019] (it was the last year for which information for each selected country is available) and also obtained from Polish statitics [Statistics Poland 2019]. Diagnostic data collection were determined based on the article of Pinar Hayaloglu [2015] who was evaluating the impact of developments in logistic sector on economic growth for 32 OECD countries. He had analyzed panel data and the variables of inland transport infrastructure investments, railway transportation, road transportation, airline transport were used as proxy of development of logistics sector. In our study we also used diagnostic variables for three branches of transport: sea, land and air transport. All variables are strongly connected to the aim of the study. Some variables have been recalculated relative to the country's area for comparability. Countries differ in area size so for example length of roads or railways cannot be compared in absolute units, only in relative to the country land surface area.

The second important factor for the variable selection was data availability. Because of many cases of the missing values for some countries the variable could not be selected to the analysis. Diagnostic variables adopted for analysis are as follows (Table 1).

Table 1. Characteristics of variables
Tabela 1 Charakterystyka zmiennych

X_1	Index 2010 = 100	Volume of freight transport relative to GDP. Index of inland freight transport volume relative to GDP, 2010 = 100 updated annually. Indicator defined as the ratio between tons-kilometers (inland modes) and GDP (chain-linked volumes, at 2010 exchange rates) indexed on 2010. Inland freight transport includes rail and inland waterways transport based on movements on national territory, road transport based on all movements of vehicles registered in the reporting country.
X_2	km/100 km^2	Railway lines operated.
X_3	million t/km	Railway transport of goods. Data on transport of goods and passengers by railway transport include domestic and international transport on railway lines within the boundaries of individual countries.
X_4	km/100 km^2	Length of roads.
X_5	million t/km	Roads-goods transported. Data on transport of goods by road transport cover transport in domestic and international traffic. Data concern road transport for hire or reward, i.e. the execution of services for remuneration carried out both by entities for which road transport is the basic economic activity.
X_6	thousand t	Goods loaded in seaports. Data on transshipment at sea ports relate to the loading and unloading of goods in international trade on ships and ships of all flags at the ports of the country, including trans-shipment from customs warehouses.
X_7	thousand t	Goods unloaded in seaports. Data on transshipment at sea ports relate to the loading and unloading of goods in international trade on ships and ships of all flags at the ports of the country, including trans-shipment from customs warehouses. The figures do not include: luggage of passengers, mail, supply ships.
X_8	million t/km	Air transport of goods. Data on transport of goods and passengers in air transport relate to the scheduled transport carriers registered in the country.

Source: own calculation on the basis on Eurostat Data and Statistics Poland.

All variables were classified into the stimulant set. The numerical characteristics of diagnostic variables are presented in Table 1. In the analysis the following countries were selected all European Union countries (state for 2016). The special situation is on the Cyprus and Malta. Variables connected to the railway transport (X_2, X_3) in those countries are equal to 0 because railways were not operating since 1931 in Malta, and since 1951 in Cyprus. Also for these countries values of X_5 variable were lack of current data. In case of X_6 and X_7 minimum value equal to 0 concerns countries without access to the sea.

The compared methods were selected based on the following literature: [Hellwig 1968, Hwang and Yoon 1981, Kukuła and Luty 2015a]. In this research it is assumed that each diagnostic variable brings the same amount of information to final rankings [Kukuła and Luty 2015b]. The linear ordering is based on the creation of a ranking of compared objects, i.e. this is based on juxtaposition of the objects from the best one to the worst one in the analyzed research context [Kaczmarczyk 2018]. Variables to be ordered should be comparable. When they are measured on a range or quotient scale, they need to be normalized.

Table 2. Selected characteristics of adopted diagnostic variables
Tabela 2. Wybrane cechy przyjętych zmiennych diagnostycznych

Specification	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Mean	93.8	5.1	15532.3	156.5	66484.9	22.2	28.0	1355.8
Q25	85.2	2.7	2562.2	57.4	12665.7	0.0	0.0	2.4
Q75	105.3	6.8	16173.8	167.0	46881.3	30.8	28.6	1168.3
Median	98.2	4.6	9248.5	129.3	34145.8	5.2	7.8	176.6
Min	45.7	0.0	0.0	12.2	0.0	0.0	0.0	0.003
Max	122.1	11.9	129361.0	903.8	348559.0	115.7	207.6	7901.7
Std	16.0	3.2	24881.9	174.6	91117.6	32.1	50.3	2382.7
Skewness	–1.0	0.6	3.5	3.0	2.0	1.7	2.5	1.8

Source: own elaboration.

Two linear ordering procedures were selected to determine the synthetic variable. The first method is TOPSIS [Hwang and Yoon 1981]. The TOPSIS selects the alternative closest to the ideal solution and farthest from the negative ideal alternative [Roszkowska 2011]. The second method is Compromise Ranking Method, also known as the VIKOR method (VlseKriterijumska Optimizacija I Kompromisno Resenje in Serbian means Multicriteria Optimization and Compromise Solution). VIKOR is an effective methods and this method introduces the multi-criteria ranking index based on the particular measure of ‘closeness’ to the ‘ideal’ solution. An important advantage of the classic TOPSIS method is its computational simplicity, the ability to analyze quantitative and qualitative quantities but VIKOR method is also widely accepted among researchers studying and using MCDM tools [Bulgurcu 2016]. Other methods (for example Electre II) are much more algorithmically complex what hinders its implementation and makes the calculation time depend on the data characteristics and can be very long.

TOPSIS

Based on the literature review, TOPSIS is one of the most popular methods used in MCDM. The fundamental idea of TOPSIS is that the best solution is the one which has the shortest distance to the ideal solution and the furthest distance from the anti-ideal solution [Yoon 1980, Hwang and Yoon 1981, Lai et al. 1994). The TOPSIS algorithm is one of the more convenient and well-known methods for resolving multi-criteria problems. These types of issues can be found in many areas of life, in particular in the broadly understood financial and economic planning. In logistics it can be important to determine the best route for a truck or ship, in trade and production – choosing the best supplier of goods or raw materials – in both the TOPSIS method would be helpful. On the stock market it is necessary to build the most effective investment portfolio, in computer science – recognition of the best computer network model – again we can use TOPSIS for resolve those problems.

In the TOPSIS method, the only subjective parameter are the weights associated with the criteria. The procedure of TOPSIS is as follows:

1. Determine the decision matrix $X = [x_{ij}]$ where x_{ij} are the values for $i = 1, ..., n$ alternatives (in this paper: countries) and $j = 1, \ldots m$ criteria (in this paper: variables).
2. Calculate the normalized decision matrix $Z = [z_{ij}]$ where z_{ij} are the normalized values for $i = 1, ..., n$ alternatives (in this paper: countries) and $j = 1, \ldots m$ criteria (in this paper: variables). Various standardization methods are given in the literature [Chakraborty and Yeh 2009, Ishizaka and Nemery 2013). In this case, it was used Ideal Normalization:

   for stimulant: $z_{ij} = \frac{x_{ij}}{f_j^+}$, where: $f_j^+ = \max_j\left(x_{ij}\right)$

   for destimulant: $z_{ij} = \frac{x_{ij}}{f_j^-}$, where: $f_j^- = \min_j\left(x_{ij}\right)$

   In this study, the variables were only stimulants.

   $$w_{ij} = w_j \cdot z_{ij}, \quad \text{for: } \sum_{j=1}^{m} w_j = 1$$

3. Calculate normalized weighted decision matrix $W = [w_{ij}]$, the normalized decision matrix Z multiplied by determined weights $w_j \in [0,1]$, where:

   In this study there were adopted equal weights $w_j = 1/m$
4. Determine the positive ideal and anty-ideal solutions.

   $A_j^+ = [w_j^+, \ldots, w_m^+]$ for ideal solution

   $A_j^- = [w_j^-, \ldots, w_m^-]$ for anty-ideal solution

   The literature [Ishizaka and Nemery 2013] presents three ways to determine w_j^+ and w_j^-:

   a) Method I:

   for stimulant: $\begin{cases} w_j^+ = \max_j\left(w_{ij}\right) \\ w_j^- = \min_j\left(w_{ij}\right) \end{cases}$ for destimulant: $\begin{cases} w_j^+ = \min_j\left(w_{ij}\right) \\ w_j^- = \max_j\left(w_{ij}\right) \end{cases}$

   b) Method II:

   for stimulant: $\begin{cases} w_j^+ = 1 \\ w_j^- = 0 \end{cases}$ for destimulant: $\begin{cases} w_j^+ = 0 \\ w_j^- = 1 \end{cases}$

   This method for determining w_j^+ and w_j^- was used in this paper

   c) Method III: the ideal and anti-ideal point are defined subjectively
5. Calculate the distance measure of each alternative from positive ideal solution d_i^+ and negative ideal solution d_i^-.

   $$d_i^+ = \sqrt{\sum_{j=1}^{m}\left(w_{ij} - w_j^+\right)^2} \quad \text{and} \quad d_i^- = \sqrt{\sum_{j=1}^{m}\left(w_{ij} - w_j^-\right)^2}$$

6. Calculate the relative closeness to the positive ideal solution:

$$C_i = \frac{d_i^-}{d_i^- + d_i^+} \quad \text{where: } C_i \in [0,1]$$

The relative proximity ratio closer to 1 is the preferred solution. Since for a solution closer to an ideal C_i strives to 1, while for a solution closer to an anti-ideal, C_i approaches 0, the C_i indicator can be the basis for creating a ranking of decisions [Opricovic and Tzeng 2004].

VIKOR

In the last time it can be observed increasing number of studies have employed the VIKOR method to solve different multi-criteria decision problems. The VIKOR methods was created/invented to determine a compromise solution for a problem with conflicting criteria. In this methods, the solution combines a maximum group utility and a minimum individual regret of the opponent.

The procedure of VIKOR is as follows [Sayadi et al. 2009, Sanayei et al. 2010, Bazzazi et al. 2011, Crist´obal, 2011, Kim 2013]:

1. Determine the decision matrix $X = [x_{ij}]$ where x_{ij} are the values for $i = 1, ..., n$ alternatives (in this paper: countries) and $j = 1, \ldots m$ criteria (in this paper: variables).
2. Determine the positive ideal $f+$ and negative ideal $f-$ solutions for every criteria:

$$\text{for stimulant: } \begin{cases} f_j^+ = \max_j (x_{ij}) \\ f_j^- = \min_j (x_{ij}) \end{cases} \quad \text{for destimulant: } \begin{cases} f_j^+ = \min_j (x_{ij}) \\ f_j^- = \max_j (x_{ij}) \end{cases}$$

In this study, the variables were only stimulants.

3. Determine the weights $w_j \in [0,1]$ associated to the different criteria, where:

$$\sum_{j=1}^{m} w_j = 1$$

In this study, to ensure comparability of results were adopted equal weights $w_j = 1/m$

4. Compute the values S_i and R_i for each of the alternatives (in this paper – countries):

$$S_i = \sum_{j=1}^{m} w_j \frac{(f_j^+ - f_{ij})}{f_j^+ - f_{ij}} \qquad R_i = \max_j \left(w_j \frac{(f_j^+ - f_{ij})}{f_j^+ - f_{ij}} \right)$$

5. Compute the values Q_i for each of the alternatives (in this paper – countries):

$$Q_i = v \frac{(S^i - S^+)}{S^- - S^+} + (1 - v) \frac{(R_i - R^+)}{R^- - R^+}$$

where $S^+ = \min_i S_i$, $S^- = \max_i S_i$, $R^+ = \min_i R_i$, $R^- = \max_i R_i$..

$v \in [0,1]$ is a weight of strategy of 'the majority criteria' (or 'the maximum group utility'), in this study $v = 0.5$ (which means the preference of consensus). The coefficient v can also be determined differently – which will not be considered in this paper.

6. Rank the order of preference by the value Q. The alternative with the smallest Q value is determined to be the best value.

VIKOR is a useful tool in multi-criteria decision making. The VIKOR method provides compromise solution because it provides a maximum "group utility" (represented by min S_i) of the "majority", and a minimum of the individual regret (represented by min R_i) of the "opponent" [Opricovic and Tzeng 2004].

Research results

Variables were selected based on the available information from Eurostat and the final results are presented in Tables 3 and 4.

Table 3. Results for TOPSIS method
Tabela 3. Wyniki dla metody TOPSIS

Country	C_i	Rank	Country	C_i	Rank	Country	C_i	Rank	Country	C_i	Rank
DE	0.1054	1	GB	0.0566	8	AT	0.0448	15	GR	0.0384	22
FR	0.0789	2	SI	0.0494	9	DK	0.0441	16	PT	0.0378	23
PL	0.0672	3	MT	0.0492	10	FI	0.0426	17	RO	0.0367	24
LU	0.0663	4	HU	0.0492	11	HR	0.0414	18	LV	0.0364	25
BE	0.0625	5	ES	0.0482	12	IT	0.0404	19	CY	0.0274	26
CZ	0.0592	6	SE	0.0476	13	LT	0.0399	20	IE	0.0272	27
NL	0.0567	7	SK	0.0453	14	BG	0.0392	21	EE	0.0216	28

Source: own preparation.

Considering output from TOPSIS analysis, the best worst three countries were Estonia, Ireland and Cyprus (with C_i on the levels: 0.0216, 0.0272, 0.0274 respectively) while the best three countries are: Germany, France and Poland. The values of C_i for the most developed countries are as follows: 0.1054, 0.0789, 0.0672. It can be observed that value of C_i or the Germany is much higher in comparison to the second and third alternatives, but France and Poland alternatives had C_i values with slight difference.

Table 4. Results for VIKOR method
Tabela 4. Wyniki dla metody VIKOR

Country	Q_i	Rank	Country	Q_i	Rank	Country	Q_i	Rank	Country	Q_i	Rank
FR	0.1653	1	FI	0.8273	8	IT	0.9011	15	LV	0.9281	22
DE	0.3377	2	NL	0.8292	9	LT	0.9049	16	HR	0.9301	23
PL	0.6675	3	CZ	0.8514	10	GR	0.9091	17	BG	0.9301	24
SE	0.7520	4	HU	0.8839	11	SK	0.9111	18	MT	0.9384	25
LU	0.8147	5	ES	0.8850	12	DK	0.9161	19	IE	0.9893	26
BE	0.8160	6	SI	0.8864	13	PT	0.9198	20	EE	0.9980	27
GB	0.8171	7	AT	0.8999	14	RO	0.9201	21	CY	1.0000	28

Source: own preparation.

In contrast, the best three countries for VIKOR method are the same countries but in different order: France, Germany and Poland. The values of Q_i for these countries are as follows (the smallest value, the higher position in ranking): 0.1653, 0.3376, 0.6675. The differences between those values are significant for the first 4 countries in the ranking. The worst in order were again Cyprus, Estonia and Ireland (Q_i equal to 1.0000, 0.9980 and 0.9893 respectively). The low rank in case of Estonia is connected to its weak air and road transport of goods and small volume of freight transport relative to GDP. In Ireland case there it is mainly because of amount of goods loaded and unloaded in seaports.

It is quite interesting that all three best countries were selected as the best alternatives alike by VIKOR and TOPSIS method. Additionally, the set of top three and the last three countries selected by VIKOR and TOPSIS are very similar. The differences appears in the other ranks, where in TOPSIS the fourth and fifth country was Luxembourg and Belgium, but in VIKOR method the fourth country was Sweden and fifth Luxembourg, while Sweden in TOPSIS methods is on the 13th place. The high rank in Luxembourg case is quite surprising, because it is very small country without the sea access, but when we consider length of tracks and roads in relations to area and number of passengers, it turns out that Luxembourg is one of the best alternatives. The worst three alternatives – the last countries in the VIKOR ranking, which means the least developed in term of logistic (26, 27 and 28th position), were Ireland, Estonia and Cyprus (the last one is excused while the whole country lies on the island), and in TOPSIS method: Cyprus, Ireland and Estonia. So again the end of the final rankings both by TOPSIS and VIKOR are the same countries but in different order.

Visualization of final rankings resulted from TOPSIS and VIKOR can be found on Figure 1.

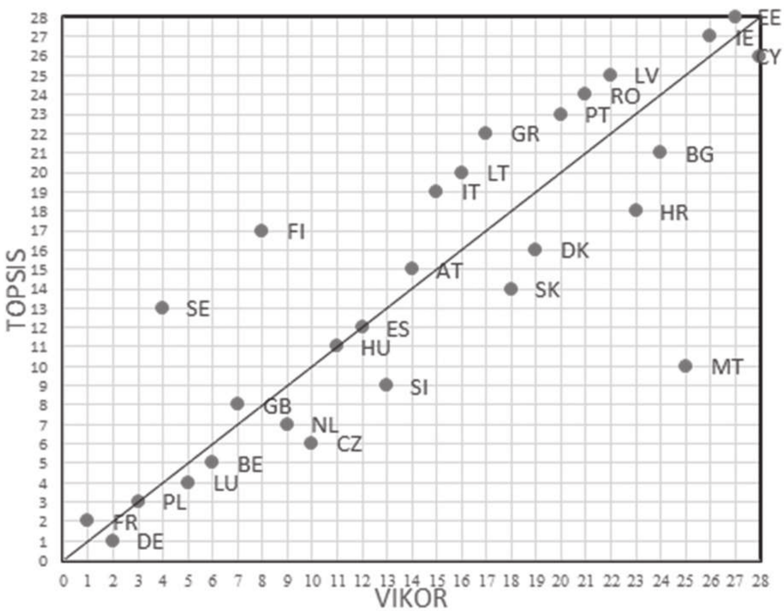

Figure 1. Positions of countries obtained by the TOPSIS and VIKOR method
Rysunek 1. Pozycje krajów uzyskane za pomocą metod TOPSIS i VIKOR

Source: own elaboration.

Correlation coefficient value between both rankings is p_s = 0.8418. Differences of countries ranks are subtle although in case of some countries quite visible. The biggest differences between rankings is shown for Malta (15 ranks of difference), Sweden and Finland (nine ranks of difference) or Greece and Croatia (five ranks of difference). For the rest of the countries difference did not exceed four ranks. In both rankings there were a lot similarities, some countries had exactly the same locations like Poland (third), Hungary (11th) and Spain (12th).

Summary

Based on the previous results it may be stated that VIKOR and TOPSIS are very similar methods constructed based on the "closeness to the ideal" solution. The hidden assumption of TOPSIS is that the selected alternative should have the "shortest distance" from the ideal alternative and at the same time the "farthest distance" from the "anti-ideal" alternative. It should be highlighted that TOPSIS considers two "reference" points without providing any weights for these points. In contrast, in VIKOR method is constructed based on the "shortest distance" from the ideal alternative and input of individual regret.

It should be stated that selected methods use different kinds of normalization methods. The TOPSIS method considers vector normalization, whereas the VIKOR method considers the linear normalization. The vector normalization may impact final normalized values depending on the evaluation units. Whereas, the linear normalization do not impact the final normalized values. To overcame the problem with vector normalization, in scientific literature it could be found the modified TOPSIS methods incorporating the linear normalization as interesting alternative to the previous one.

In the searched literature there is no such comparative studies of logistics development each countries report their own achievements or compare to the neighbor countries, however the most papers analyze the implication of transport infrastructure development of European countries on sustainable economic growth [Cigu et al. 2019] The aim of this paper was to order European Union countries in terms of logistic infrastructure characteristics and to indicate the countries with the lowest development requiring attention and possible funding. Results of the research on the basis of the available data proved high positions of Germany, France, Poland, Luxembourg and Belgium in rankings of best logistics infrastructure developed countries in European Union. They are all transit countries with high development of road and rail networks. Poland is on the third position in both rankings because of its fortunate location between large European countries, commercial ports and bordering Russia and other eastern countries as well. Luxembourg, which achieved high rank in both rankings, is a separate case. The good logistic development characteristics of this country is primarily determined by road density, good rail network and air transport of goods. In this study, all variables were treated equally, which also unfairly disadvantages countries without access to the sea, while two variables are based on the seaport loads.

Sweden or Finland have a low population density, are relatively large in area and therefore the values for some variables, especially those calculated per km^2 of land, may be lower in comparison to the rest European regions. Neither they are countries with the key location for transit in the European Union, in particular by road and rail, so despite good sea communication the final rank was not so high and there were big differences in ranks obtained by those two methods (outliers in correlation).

The least logistic developed countries in European Union were Ireland, Estonia and Cyprus. Non-continental countries like Cyprus and Malta (lying completely on islands), are a special case – both have not operating railways and the transport of goods is also not so large which is resulted by the area of the land and inhabiting population. But surprisingly Ireland and Estonia are on the end of the list and it can be concluded that those countries need to be focused on and some funds to ensure sustainable development in logistics.

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The role of IT systems in strategic management and building competitive advantage of companies in the logistics industry

Rola systemów informatycznych w zarządzaniu strategicznym i budowaniu przewagi konkurencyjnej przedsiębiorstw w branży logistycznej

Abstract. The rapid development of the IT industry is a fact. Digitalization covers practically all areas of enterprises and the full spectrum of their processes. IT systems are usually treated as a tool to achieve a specific goal, relatively rarely is there any talk of implementing IT systems as an element of strategic management. However, it should be borne in mind that, given the key impact on organisations, the implementation of an IT system should be treated as an important element of strategic planning. The literature on this subject is relatively modest, and the author target of this science work and publication has aimed to analyse to what extent the implementation of an IT system (and why) should be treated as part of strategic management. The research problem presented in the paper was solved, among others, by a critical analysis of the literature concerning the area in question, in selected elements supported by an analysis of available statistical data.

Key words: strategic management, information technologies, IT solutions

Synopsis. Gwałtowny rozwój branży informatycznej jest faktem. Digitalizacja obejmuje praktycznie wszystkie obszary działania przedsiębiorstw i pełne spektrum realizowanych przez nie procesów. Systemy informatyczne traktowane są zwykle jako narzędzie do realizacji konkretnego celu, relatywnie rzadko mówi się o wdrożeniu systemów informatycznych jako o elemencie zarządzania strategicznego. Należy jednak mieć na uwadze, że z uwagi na kluczowy wpływ na organizacje wdrożenie systemu informatycznego potraktować należy jako ważny element planowania strategicznego. Literatura na ten temat jest stosunkowo skromna, a celem pracy badawczej autora w niniejszej publikacji było przeanalizowanie, w jakim stopniu wdrożenie systemu IT (i dlaczego) powinno być traktowane właśnie jako element zarządzania strategicznego. Problem badawczy przedstawiony w pracy rozwiązywany był m.in. krytyczną analizę piśmiennictwa dotyczącego omawianego obszaru, w wybranych elementach wspartą analizą dostępnych danych statystycznych.

Słowa kluczowe: zarządzanie strategiczne, technologie informacyjne, systemy informatyczne

Introduction

Among the many definitions of strategic management, one can indicate, among others that it is "a set of management decisions and actions that determine the long-term results and fate of the organization" (Wheelen and Hunger) or that it is "a process of defining and redefining objectives and strategies in the context of changes in the environment in a reactive and anticipating or triggering manner" (Urbanowska-Sojkin) [Lozano Platonoff and Gadomska-Lila 2018].

Regardless of the definition adopted, it should be considered that elements of strategic management are those elements of an organization's operations which influence its basic shape or way of functioning, in terms of its long-term market presence. Therefore, there is a space for key decisions concerning the way the company is organized (e.g. organizational structure), the way its presence on the market is shaped (therefore, key decisions concerning activity on selected markets, price and product strategy, the way sales activities are implemented, etc.). One of the elements of building a competitive advantage has also become the appropriate management of logistics activities – hence the shape of logistics processes is increasingly taken into account also in the area of strategic activities. In recent years, more and more attention has been paid to build the right shape of IT infrastructure by company. Should infrastructure therefore be considered as part of strategic activities? Is the creation of a certain organizational culture in the area of IT and a certain vision of development and shape of these systems also a strategic activity? The purpose of this article is to try to answer the question: whether and to what extent the implementation of IT systems can (and should) be part of strategic management.

IT systems in strategic management

"The main goal of the organization is to produce products and services that meet customer requirements" [Waters 2001]. Following this path, areas that directly or indirectly influence the shape of these goods and services should be considered as strategic elements of the organization's activities. Is this also the IT infrastructure? The role and task of IT systems is, among others optimizing processes and improving quality in the field of information management. To this extent, appropriate IT tools definitely influence the shape and quality of products or services offered. They also directly affect the ability to provide information on these products and services and are therefore an important element in determining an undertaking's proper communication with the market. As Griffin explains, a well-thought-out organizational strategy is one that focuses on three basic areas: outstanding skills, but also the reach and distribution of the organization's resources [Griffin 2017].

Logistics is nowadays put forward as one of the areas in which companies can seek a competitive advantage. "Getting a competitive advantage nowadays is not an easy matter. Good organization of business processes in a company is no longer enough. It is necessary not only to analyze and search for trends in the possessed data sets, but also in various sources that are often located outside the company (social networking sites, external, publicly accessible databases). The amount of information that arises every day inside and around the company is enormous" [Gontar 2019]. IT systems, as they have a key impact on the efficiency of information management, have a critical impact on the conduct of an appropriate information policy by the company. Increasingly, their task is to filter information properly in order to extract the most important ones for the company.

The multitude of decisions made within the framework of the broadly understood management of an organization makes it necessary to ask the question: which of these decisions are important for the development of an enterprise and building its competitive advantage? "Some decisions are very important for the organization and have several years of consequences. Others are less important, their consequences are limited to a few days or several hours. We can divide decisions according to their importance into strategic, tactical and operational. Strategic decisions are taken by the board of directors, have long-term effects, involve many resources and are associated with high risk. Tactical decisions are taken by mid-level staff, their time span is medium, they involve fewer resources and are associated with less risk. Operational decisions are taken by bottom-up management; they are short-term, involve fewer resources and are low risk" [Waters 2001].

In this case, the question can be asked: which decisions concerning IT systems have a long-term impact in the organization? The fact of choosing a particular type of IT system (e.g. WMS – Warehouse Management System) is therefore seen here as a strategic decision – it has a long-term impact on the company and its processes. Selecting a specific supplier – may be a strategic or tactical activity. The selection of the appropriate technology or functional scope should also be considered as such.

About the role that data management plays in the organization it was already written many years ago, even when globally operating IT systems were still in their infancy. We are talking about ERP (Enterprise Resource Planning) systems, commonly used today by medium and large enterprises. By covering them with one coherent IT system, they become an excellent example of the global impact of IT infrastructure on a broad spectrum of international and global companies.

An important element of strategic management is to define the vision of the company's development and its place on the market. Therefore, if building an IT infrastructure is to be an element of strategic management, then also shaping IT infrastructure development becomes an element of strategic management. As early as 2003, Galliers and Newell were already discussing the concept and foundations of IT systems development in the new millennium, wondering what the "fashion" will be and which way IT systems development will go. Is this still supposed to be information management? Or rather they will become tools of knowledge management in the organization (they even pointed out the term "wisdom management" for this purpose). Credibility and the truth of information becomes the source of the company's strength, which brought some small disagreement, but was not objectively discussed. And the new context of information management directly related to decision-making has become a reality [Galliers and Newell 2003]. Later in the article, the author's aim was to find links between the IT system and knowledge management.

IT system as an element of knowledge management in an organization

In a knowledge-based economy, an information is the basic capital accumulated by a company and which determines its effectiveness. “The acquisition, creation, distribution (transfer, transfer), storage, monitoring and evaluation of knowledge can be considered as basic tasks in the field of knowledge management” [Perechuda 2005]. All these elements are inseparable from the processing of information. Processing, for which it is definitely best to use IT tools.

The process of knowledge and information management itself should be treated as a continuous process, constantly influencing the way a company operates and develops. Thus, the company’s IT facilities also become a resource participating in its development on a continuous basis. “Knowledge management in the process sense is a normative and disposable procedure, aimed at creating an appropriate environment that enables the efficient performance of operational functions, i.e. the implementation of organizational systems with the right structure, optimizing the main processes related to knowledge, the client and the organizational culture, which will direct people to develop knowledge, use it properly, etc.” [Perechuda 2005].

Issues related to IT infrastructure planning at the strategic level are relatively new and relatively rarely discussed in the literature. For many years, IT systems were usually treated as a tool and not an element of strategic management. Therefore, the number of publications concerning the analyzed issues is relatively small. The problem of strategic planning of IT tools was raised by Harris [1991]. It draw attention to the fact that such an approach is not only possible, but above all crucial for IT analysis. It mentions, for example, the role that strategic planning tools (including IT) play in achieving the organization’s goals.

IT systems have also become now an important element in the creation and development of Logistics 4.0 – often referred to as the direction of changes in logistics management, supply chains and networks. Winkelhaus and Grosse [2019] point out that among the key six aspects that make up the multidimensional understanding of the concept of Logistics 4.0, there are, among others information, and its role cannot be overestimated – which is indicated, among others, by the test results. “Information is at the center of all technologies examined in this study. The technologies can thus be grouped into three subcategories [Winkelhaus and Grosse 2019]:

– technologies to generate information,
– technologies to handle information,
– technologies to use information.

Authors point out that Logistics 4.0 as a new concept is not intended to replace other concepts in the area of management (such as for example lean logistics), but it supports and complements them, also in terms of information management and management in general.

This approach allows to combine requirements related to the implementation of IT systems with the challenges of management science. It emphasizes the role of information in the implementation of logistics processes, also in line with the latest trends. It is impossible to talk about IT systems without the context of the information they manage.

Modern technical solutions for logistics usually mean the management of large data sets, which in turn would not be possible without adequate IT support. And the role and goals of Logistics 4.0 fits perfectly with the requirements of modern logistics and the needs of modern business.

Modern organizations are based on modern technologies. Intelligent production and logistics management are based on concepts such as cloud computing, big data analytics, Industry 4.0, Internet of Things or artificial intelligence. And all this combined with Web 2.0 technologies [Liu et al. 2019].

It is worth to mention here the Web 2.0 idea. The concept of Web 2.0 has been present on the Internet for several years and basically refers to all services, in the creation (and management of content) of which the users themselves participate. Linking the Web 2.0 concept with the planning of IT infrastructure development at the strategic level allows to put forward the thesis that the future of IT is also those tools that allow to interact with the environment. An interaction, which of course can take various forms, is always based on direct contact with the outside world. Such an approach is most consistent with the trends in modern logistics, where it is increasingly assumed to build partnership relationships in supply chains, interactions in many dimensions or tightening of these relationships.

Criteria for selecting IT systems

Having already known the element determining the strategic management and knowledge management in an organization, it is necessary to consider the benefits of implementing IT systems and, more often than not, the criteria determining the choice of IT system. As a strategic decision with a long-term impact on the company, the choice of the IT system should be made at the highest decision-making level of the organization. In practice, this is not always the case, and the choice of the right tool for logistics is primarily determined by the logistics manager and IT manager.

The research conducted within the Panel of Polish Logistics Managers shows that in 35% of cases the choice of product and IT supplier is the responsibility of the manager of logistics (assuming that he is not a member of the board). In 34% of cases – the company's Management Board is responsible. In 17% of cases, the owner of the company or the Supervisory Board is responsible for the decision, in 7% – the head of IT [Logisys 2014]. The results confirm that in more than half of the cases (51%), it is not managers specializing in logistics who are responsible for the decision concerning the choice of product and IT supplier. It should be noted that regardless of their managerial competence, they usually do not have specialist knowledge of logistics. Choosing an IT solution provider for specific business processes requires such knowledge. In such a situation, there is therefore a risk that it is not merotic arguments that are critical in making these decisions, but others (financial, management, etc.). It should be noted that other actors – heads of IT departments, external advisors and consultants and others – play a relatively minor role in decision making.

The authors of the survey also indicate both in the case of persons responsible for IT and logistics in the company, these persons evaluate their influence on the decision to choose the system in most cases positively. Almost 1/3 of IT bosses (29%) think it has an entirely sufficient influence on the decision to choose the system, 52% think it is sufficient, only 20% of IT bosses think it has an insufficient influence on the choice of the system. Similarly, in the case of heads of logistics – 76% believe that it has a sufficient (or entirely sufficient) impact on the choice of the system, 24% indicate one of the three answers (slightly less than sufficient, insufficient, definitely insufficient) [Logisys 2014].

These results can be analyzed from several perspectives. It should be noted that there is a situation where the decision-maker manager is able to make a decision: logistics is an important position in the organizational structure of the company and he is a member of the management board. Then the situation is as close to perfect as possible – such a person can make a decision taking into account both the business needs of the logistics department and the global conditions of the entire company. In many cases the decision to choose an IT solution is a joint decision – the department responsible for the implementation of logistics processes and the company's management board (when the company's management board treats the opinion of the logistics department as crucial for making a decision). This allows for a smooth decision-making process and the right decision for the organization.

An interesting alternative in the decision-making process is to make decisions in conditions of non-compliance, with a positive decision of the management board and a negative decision of the logistics and/or IT department or vice versa. The choice of an IT system is, after all, a multi-faced decision, which includes, among others selection of technology, scope of functionality, evaluation of the selected solution in terms of compatibility with other elements of the company's IT infrastructure. It is also a cost analysis, concerning the costs of implementation and maintenance of the system, and the choice of the appropriate technology also translates into these costs. It should therefore be borne in mind that since decisions of a strategic nature are usually the responsibility of the company's board of directors, the choice of IT tools should also be decided by the top management as a key element in the development of the company.

Szymonik [2011] points out that computerization of an enterprise is an extremely difficult investment – both due to the complexity of the process itself and the amount of expenditure. In order to ensure proper efficiency here, it is necessary for the management to overcome difficulties in four areas: financial, technological and hardware, organizational and psychological. "Logistics can properly function and participate in the achievement of company objectives if the following systems are properly defined, designed, organized and operated: information, IT, IT management, logistic information system and logistic information system" [Szymonik 2011]. Treating the IT system as one of the key elements of the area of activity is a clear sign that without sustainable development of the IT infrastructure there is no long-term development of the company today and building a competitive advantage on the market. And taking into account the dynamics of changes in the modern economy – the lack of development in the area of information systems not only does not allow the company to build an advantage on the market, but even makes it lose distance to market leaders. The development of the IT infrastructure is therefore becoming necessary in order to maintain an appropriate position in the market, and not only to strengthen it.

Functions and strategic role of IT systems

Depending on the specifics of the implemented logistic processes, the company's logistic infrastructure may consist of various groups of IT tools. It can basically be divided into two basic groups – tools supporting the entire process management in the company, as well as tools dedicated primarily to the implementation of logistics processes.

An important area affecting the strategic role of IT system decisions is both financial value. The labor market lacks IT specialists. This is one of the reasons why services in the IT industry are relatively expensive today, and therefore the value of all investments in IT systems is increasing. Given the constant increase in demand for this type of services, this trend is not expected to reverse in the coming years.

According to Allied Market Research, companies employing approx. 100 employees have a budget of more than USD 300,000 [Mejssner 2018]. On the other hand, Software Connect data show that in the case of companies with more than 500 employees, the average budget for WMS implementation is over USD 372,000, and over 1000 employees – over USD 401,000 [Mejssner 2018]. The budgets for implementation of IT systems in combination with accompanying technologies (automatic identification systems, picking systems, warehouse automation equipment) may of course be many times higher than this average.

The strategic role of IT infrastructure is an effect of, among others the effect of computerization processes covering all areas of the organization's operations. "In recent decades, software has transformed the way in which organizations and businesses coordinate and work, even going so far as to transform people's everyday lives. Software is used in notebooks and mobile devices; it is embedded actively and passively to steer cars, organize households, and label and control groceries. Enterprises rely on software systems to organize their workforce, bill their customers, and manage innovations. Software is ever-present and has become an important part of our society" [Bertram 2016]. Strategic management covers key areas from the point of view of the company's financial economy. And the functions and budgets of IT systems are an area of strategic decisions.

IT systems are a strategic tool for the development of large enterprises and are increasingly becoming a strategic development tool for small and medium enterprises (SMEs). Drechsler and Weißschädel [2018] point out that the literature on this subject is very incomplete and needs to be sorted out: „The majority of papers with an immediate relevance to IT strategy in SMEs take a conceptual or explanatory stance, providing voluntary or involuntary IT managers in SMEs with comparably little actionable advice. Many papers on IT strategy in SMEs limit their analyses to specific industry sectors or countries. In addition, many frequently cited papers are between 10 and 15 years old, sometimes even older, and do not necessarily reflect current IT management practices in SMEs, or the current state of IT management and IT strategy research" [Drechsler and Weißschädel 2018]. In Drechsler and Weißschädel`s opinion [2018], it is now becoming clear that a lack of involvement in the development of IT strategies and the related strategic process planning can cause clear losses in terms of attractiveness and competitiveness.

The strategic role of IT systems is also demonstrated by the examples mentioned in the literature. Although more and more is being written about the strategic role of IT systems, there is still a certain lack of satisfaction in the literature. The number of publications relating to practical considerations (concerning the impact of IT on the strategic area of the organization) is still not large. In publications on IT system implementations, the authors usually refer to the benefits resulting from system implementation or technical aspects. It is important to treat IT systems as tools for solving operational or tactical problems, less frequently treated as an element of building the entire organization and its strategy.

Rusu and El Mekawy [2009] point to the strategic role of IT on the basis of two retail companies from the Swedish market described by them. They point to a certain strategic triangle in the area of IT, which combines the three vertices "organizational strategy", "business strategy" and "information strategy". They thus indicate that these are the three critical elements necessary to build a company in a coherent way at the strategic level. In their research, the Swedish researchers focused on trying to answer the questions: How does IT support the business and organizational strategies? And how IT and business strategies are aligned? [Rusu and El Mekawy 2009]. The conclusions they have reached are interesting: to achieve success within the three elements mentioned above, it is necessary to integrate IT with business in order to achieve full management of information. The IT infrastructure (department) cannot exist "next to" business departments, and IT managers should be strongly committed to business [Rusu and El Mekawy 2009].

Studies conducted in the conditions of a developed Western European economy confirm that although an IT system is often treated only as a tool for achieving business objectives, it is only the full cooperation of both areas that leads to synergies and long-term benefits in both areas. However, in order for this full cooperation to be implemented, it is necessary to treat these two areas together already at the level of setting long-term goals of the organization, i.e. strategic management. The presented fragment of the article describes the criteria determining the role of IT in building and developing the organization, what are summarized in Figure 1.

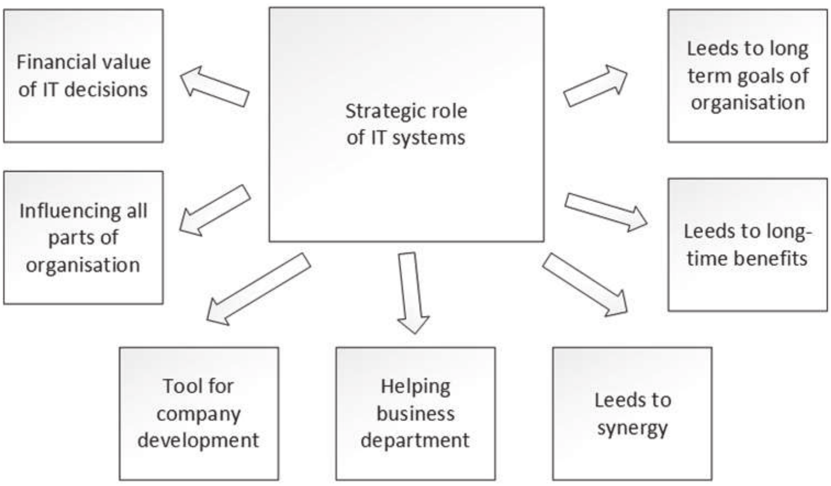

Figure 1. Strategic role of IT systems
Rysunek 1. Strategiczna rola systemów IT
Source: based at own work.

IT systems as a basis for technology development in logistics

An important, but often missed area of IT systems implementation remains role if IT in building the whole company information's culture. In today's highly technological world, the implementation of an IT system remains one of the key elements of implementing modern technologies in a company. Thus, the implementation of IT systems should be analyzed in a wider context – not only the individual implementation of an IT tool, but the construction of the entire IT and technological infrastructure of the enterprise. This can be seen, for example, in the logistics industry, where an IT system is very often a tool that links various other tools and technologies, such as warehouse automation, picking support systems, automatic identification systems, fleet management and process monitoring tools.

Thus, the IT system becomes a universal platform for technology management in an organization. All other contemporary concepts of management and technology implementation should be looked at in a similar way. Therefore, the IT system performs three basic functions in the organization, becoming: a technology base, a base combining all management concepts, and also a base for process management and development. And the IT base is increasingly being put up as part of future management.

Naturally, strong importance is attributed to IT infrastructure wherever management itself is by definition highly computerized, e.g. in the area of e-business. "Information technology (IT) plays an important role in e-business management. It enables the development of e-business IT systems and affects the way of how the e-business is conducted. To support e-business based organizations in achieving excellence and the competitive edge, IT for future e-business management must rise to new challenges by providing tools to analyze large volumes of data from various sources and support decision making, generating models for investigating factors in fast growing e-commerce sectors, and developing mechanisms for improving the efficiency of processes, etc." [Fei and Chung 2015]. As Fei and Chung explain, the horizon for the implementation of information technology for e-business companies is clearly marked here, especially in the area of data analysis and information management. The authors point out, among others for contemporary challenges in the field of modern process management models, increasing process efficiency, flexible service delivery or challenges related to the digitalization of customer relationship process management.

Statistics on the impact of digitization on the economy can provide evidence of the importance of computerization. The indicator of the level of digitization may be one of the indicators for the evaluation of the issue under examination. McKinsey's experts in the report "Digital Poland" indicate that in terms of demand for digital resources Poland is only strangely away from Western Europe – the Digitalization Index for Western European countries is 13, and for Poland 11 – the difference is therefore 16%. However, the comparison of digital content supply is much worse – for Western Europe this indicator is 12, for Poland – 7, so the difference is as much as 44%. The average size of the gap in the Digitalisation Index is –34% for Poland, the highest level of this gap is recorded in the simple industrial production (–78%) and transport (–63%) sectors [McKinsey&Company and Forbes Polska 2016].

Computerization is also clearly visible in the public sector. From the data of the report on the value of IT projects implemented by the public sector in the years 2004–2015 amounted to PLN 8069.22 million, of which PLN 5972.83 million was financed by EU funds [Institute of Communications 2016]. It should be noted that the money invested in digitization pays off. According to the Keralla Research Institute (based on the calculations of the Civic Development Forum analysts), the funds of PLN 180 billion invested in digitization in the national economy in the years 1993–2016 translated into 10–15% economic growth. IT companies produce approx. 4% of GDP, and more than 70% of this development is provided by those companies for which IT is not their core business but invests in innovative IT solutions [Keralla Research 2018]. Polish IT market increased its value from USD 1.2 billion in 1995 to USD 15.7 billion in 2015 – so about thirteen times [Rokicki 2017].

Modern technologies have a strong impact on companies. An example of such an impact is the impact of the Garner Hype Cycle methodology on the organisation. According to the Garner Hype Cycle methodology, expectations of modern technologies change with time. The first element, in the innovation phase, is the peak of expectations, followed by a clear drop in expectations. And only in the next stage, the "slope of enlightenment" leads to a phase of stabilization and "plateau of productivity" [Gartner n.d.]. This methodology is reflected, among others, in in the logistics industry. The implementation of an IT system is often accompanied by "euphoria" and a violent discussion about functional possibilities, the potential resulting from the implementation or numerous business benefits. This is the case, for example, with the implementation of WMS class systems, where stabilization in terms of productivity only appears after a certain time. The concept presented by Garner assumes, among others a certain life cycle of technology. The afore-

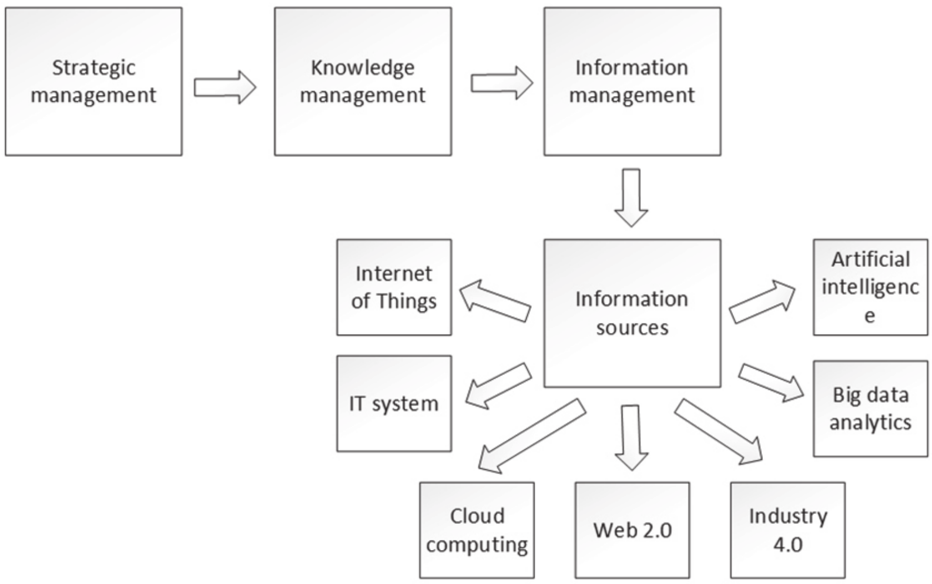

Figure 2. From strategic management to IT system – way of delivering information

Rysunek 2. Od zarządzania strategicznego do systemu informatycznego – sposób dostarczania informacji

Source: based at own work.

mentioned phases of the technology life cycle are directly related to its commercialization. And the awareness of these cycles allows, among others for reducing the risks of investing in technology [Gartner n.d.].

Conclusions

Based on the analysis presented, the following conclusions can be reached. Information management is seen as one of the basic elements of building an enterprise in a knowledge-based economy and, more broadly, modern and tailored to the market requirements of strategic management. The element that manages information is its sources, and among them – IT systems other modern technologies used in the logistics industry (as can be seen at Figure 2). The advantage of organizations implementing IT systems results from skillful information management and building competitive advantage on its basis. The indicator of the level of digitization may be one of the indicators for the evaluation of the studied issue – and attempts to determine this indicator may determine the directions of further research in this area. In addition, an interesting area of research is being developed in connection with the coronavirus epidemic – as a result of remote work, access to modern IT tools has become even more important.

The author's aim was to indicate the key areas of the company's activity in the area of strategic management and their reference to the role that IT systems play in modern organizations. The role of modern IT systems today is not only to manage information, but to create a stable basis for managing the entire organization processes. The aim of the work has been achieved, which is confirmed by the graphics in Figure 2 and the presented conclusions. Today, an IT system is not only an operational tool, but it is becoming an element of building an organization's competitive advantage, an element of strategic management in the organization and a strategic area from the point of view of decisions made.

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Advancement level of logistic information management systems in Polish food industry

Poziom zaawansowania systemów zarządzania informacją logistyczną w polskim przemyśle spożywczym

Abstract. The paper presents the results of research on differentiation of the advancement level of solutions and logistics management systems based on ICT (Information and Communication Technologies) used in the Polish food industry. The research was conducted in terms of industry, employment size and three market characteristics of the surveyed enterprises: investment level, financial situation and market position. The study used the IAI (Information Advancement Index) synthetic indicator and two methods for categorizing its values: uniform across the range of values and based on mean values and standard deviation. The paper also presents the reference of the obtained research results to the productivity paradox of Solow and the results of similar research previously carried out on the level of advancement of logistics solutions and systems in the Polish food industry.

Key words: food industry, information management systems, logistic information, advancement level, synthetic index

Synopsis. W pracy przedstawiono wyniki badań nad zróżnicowaniem poziomu zaawansowania rozwiązań i systemów zarządzania informacją logistyczną opartych na technologiach ICT (Information and Communication Technologies) wykorzystywanych w polskim przemyśle spożywczym. Badania przeprowadzono w ujęciu branżowym, wielkości zatrudnienia oraz trzech charakterystyk rynkowych badanych przedsiębiorstw: poziomu inwestycji, sytuacji finansowej i pozycji rynkowej. W badaniach wykorzystano wskaźnik syntetyczny IAI (Information Advancement Index) oraz dwie metody kategoryzacji jego wartości – równomierną w całym zakresie wartości oraz opartą na wartościach średniej i odchylenia standardowego. W pracy zaprezentowano również odniesienie uzyskanych wyników badań do paradoksu produktywności Solowa oraz wyników analogicznych badań przeprowadzonych wcześniej nad poziomem zaawansowania rozwiązań i systemów logistycznych w polskim przemyśle spożywczym.

Słowa kluczowe: przemysł spożywczy, systemy zarządzania informacja, informacja logistyczna, poziom zaawansowania, wskaźnik syntetyczny

Introduction

In modern society, information plays a key role. It is treated as a good, ware and one of economic resources equivalent or more often more important than other traditional goods such as land, real estate, capital or labor. In such a society, the economy is based on knowledge, which is treated as a strategic, albeit intangible resource of economic entities. That is why the possibilities of access, processing for own needs and using information determine the possibilities of effective conducting business activity and gaining competitive advantage. At the same time, the readiness, preparation and skills of using various ICT information and communication technologies enable full participation in social life, and their lack most often determines partial or total exclusion from it. Such society was initially referred to as the Postindustrial Society. This term was popularized in the early 1960's by the American economist Bell [1962, 1973]. Currently, the term Information Society by Japanese anthropologist Umesao [1963], which appeared in literature almost simultaneously, is used much more often.

Also in the modern economy, the ability to obtain information, their effective processing into usable information, as well as manage it are one of the most important factors determining the possibility of achieving market success by enterprises. The authorship of the concept of the knowledge-based economy, its use as a key factor in economic development and the condition for achieving commercial successes, as well as the concept of the information sector consisting of entities managing knowledge and providing information services is attributed to the American economist Machlup [1962]. Closely linking economic activity with the effective use of information resources is not possible today without extensive use of ICT. That is why the modern economy is often referred to as Electronic or Digital Economy. This term was popularized by the well-known Canadian economist Tapscott, although his authorship is often attributed to the American architect Negroponte [Negroponte 1996, Tapscott 1997, Tapscott et al. 1999]. One of the characteristics of such an economy is the rapidly growing number and increasing availability of transactions concluded exclusively via digital technologies. Economic activity based on ICT, primarily the Internet, is referred to as e-business or, more often, e-business.

The digital economy is embedded in the information society, and the most important binder and foundation without which it would not be possible for them to be created are ICT technologies and systems commonly used for storing, processing and transmitting information. Rational information management both within business entities and as part of cooperative cooperation is not only a factor contributing to better business efficiency, but above all a necessity in the modern global market with a high level of competitiveness. Digital information management concerns many areas of activity of individual enterprises, as well as various areas of the economy as a whole. In the modern digital economy, ICT technologies are widely used in virtually all sectors of the economy, including those that are not traditionally associated with them, e.g. in agriculture or the food industry.

Information solutions and systems based on modern ICT technologies are implemented primarily to improve the productivity of enterprises understood as both profitability, efficiency, as well as better financial liquidity and lower debt levels. However, in the 70s and 80s of the last century, the results of empirical research on the state of the economy in the US showed a decrease in productivity despite very significant and increasing investments in modern technologies of information processing and transmission. The results obtained have not confirmed in any way the existence of a positive relationship between the implementation of modern information and communication technologies and the increase in productivity. In addition, it turned out that the largest decrease in productivity occurred in sectors of the economy in which investments in ICT technologies were the largest and the share in employment of people serving them was the highest [Brynjolfsson 1993]. Therefore, as early as 1987, Solow formulated his famous productivity paradox, noting that investments in increasingly modern ICT solutions that are catalysts of change in almost all areas of life, do not translate into increased productivity both on a micro- and macroeconomic scale [Solow 1987].

The purpose of the work is to present the diversity of the level of advancement of solutions in the field of logistics information management using ICT exactly in the Polish food industry. It constitutes one of the most important sectors of the Polish economy, generating almost 17.5% of the value of sold production of Polish industry and 12.6% of Polish exports. In addition, it is a sector of industry characterized by a large diversity both in industry and in terms of employment. The selection as a food sector research area was dictated by two main premises. The first was the fact that the food sector is one of the most important branches of the Polish economy. The second is the fact that it is very diverse both in terms of industry and employment in enterprises. This premise led to the conclusion that also the occurrence of the Solow productivity paradox will be characterized by a large diversity both in individual industries and in employment size groups.

Characteristics of Polish food industry

Agriculture and food production have always played a significant role in the Polish economy. As a consequence, Poland has been and still is perceived as a large agricultural country as well as an important food producer [Borkowski et al. 2003]. Therefore, the agri-food processing sector plays a very important role in the Polish economy. Over the past 25 years, he has undergone significant changes that have completely changed his face. First, in the 90s of the last century they were associated with the social and political transformation, as a result of which the Polish economy transformed from centrally managed to free market. At that time, changes in the agri-food processing sector concerned mainly the ownership and organizational structure of enterprises as a result of privatization processes and foreign investments. Then, as a consequence of Poland's efforts to join the EU, both before and after accession, changes in the agri-food processing sector covered the organization and technology of food production. They were, in turn, a consequence of the need to adapt Polish food producers to EU legal regulations and quality standards [Krajewski and Borkowski 2002].

Despite significant transformations, the Polish food industry not only brilliantly coped with the problems resulting from the political transformation, but also quickly became a source of significant revenues for the state budget, as well as one of the sectors that strongly stimulated the development of the Polish economy. The most important factor driving the development of the agri-food processing sector was the opening of the Polish market to foreign entities. It resulted in almost a sudden increase in the level of competition on the market as a result of the emergence of foreign food concerns, characterized by a high organizational and technological level and large investment opportunities. Another negative stimulus for the development of the Polish food sector was undoubtedly the need to adapt enterprises to legal regulations and quality procedures in force in the EU, which was most often associated with the need for significant investments and implementation of modern technologies. Among the most important positive stimulators for the development of the food sector should be mentioned subsidies and subsidies, both before and after accession, which made it possible to carry out many modernization investments in Polish enterprises. In turn, integration with the EU market also enabled significant foreign investment in the processing industry. They not only ensured the inflow of funds, but also became a source of a number of important organizational and technological innovations [Jałowiecki 2018].

The Polish food industry generates 17.5% of total industrial production sold and 20.4% of the manufacturing industry. Exports of food products account for 12.6% of total Polish industry exports. The average employment in the food industry is 15.3% of employment in total industry and 18.0% of employment in the processing industry. Investment outlays in the food industry account for 11.3% of investment outlays in total industry and 21.4% of investment outlays in the processing industry.

In addition, the food sector is one of the most diverse in terms of industry (Figure 1) and in terms of employment (Figure 2). Bakeries constitute a very large overrepresentation in the Polish food sector (43.88% in 2015). In turn, enterprises producing tobacco products constitute only 0.22% of all entities operating within the sector. In addition, real and market-leading volume production (over 99% of cigarettes) is produced by four companies, which are currently owned by the largest international tobacco concerns: Philip

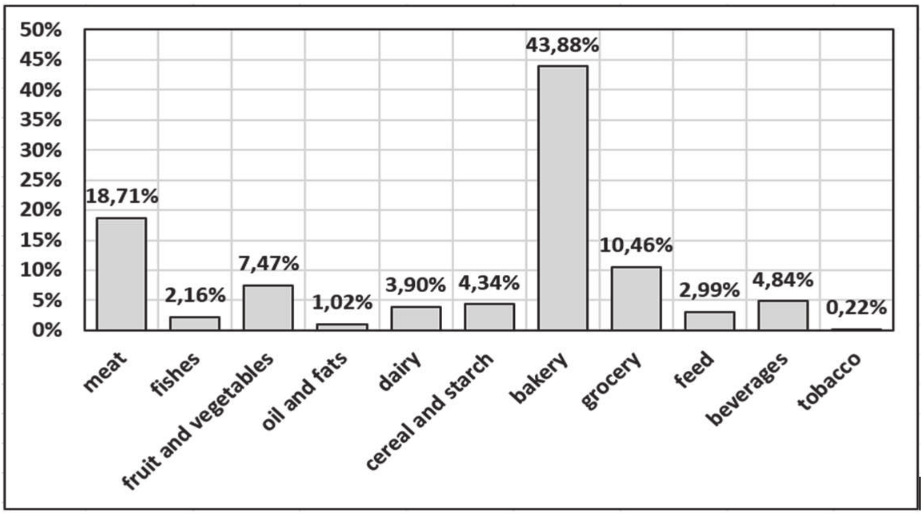

Figure 1. Sectorial diversity of the Polish food industry in 2015 (on the axis y number of studied enterprises)

Rysunek 1. Zróżnicowanie branżowe polskiego przemysłu spożywczego w 2015 roku (na osi y liczba badanych przedsiębiorstw)

Source: own study.

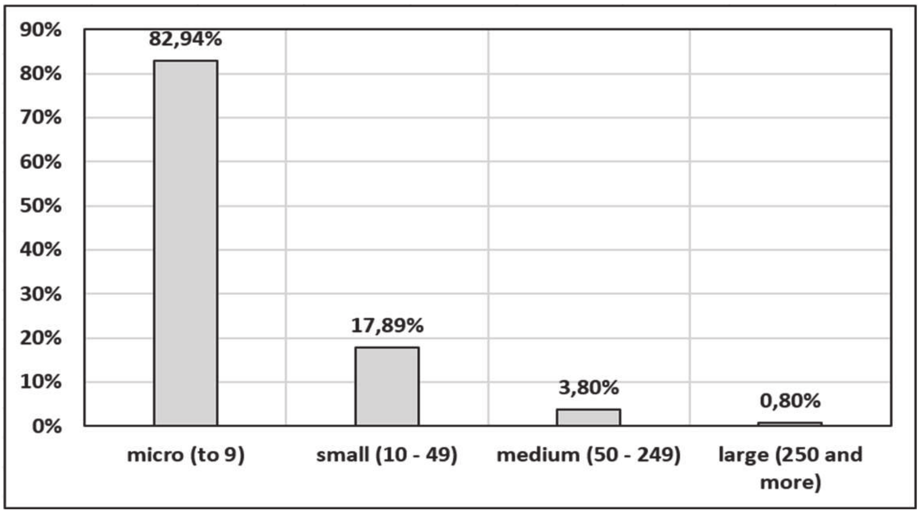

Figure 2. Diversification of food enterprises in terms of employment in 2015
Rysunek 2. Zróżnicowanie przedsiębiorstw spożywczych pod względem wielkości zatrudnienia w 2015 roku

Source: own study.

Morris, British-American Tobacco, Japan Tobacco International and Imperial Tobacco. Also, companies producing oil and fat products are very few. They constitute only 1.02% of entities belonging to the food sector.

Also in terms of the size of employment between individual groups of enterprises there are quite large differences in the number of entities. The vast majority are micro enterprises employing up to and including nine employees. The number of entities is steadily decreasing with the increase in the employment size group (Figure 2). As a consequence of The SME sector (small and medium-sized enterprises) comprises 99.2% of business entities operating on the food market.

The choice of the food sector as a research area, in addition to the interesting diversity of enterprises belonging to it, both industry and in terms of employment, was also dictated by the lack of research results in this area. Considering the results of research conducted earlier, the large diversification of the food industry and the industry in terms of size promised a good chance of checking the heterogeneity of the occurrence of the Solow productivity paradox.

Data source and methods

Source data used in the study came from a survey of 512 companies in the Polish food sector. The survey contained 56 questions that could be classified into three groups: general questions, solutions used in the field of resource management logistics, and solutions in the field of logistics information management together with ICT supporting them. Out of 11 food industries, the research did not cover two: fish and tobacco. The reason was the small number of enterprises belonging to these industries that responded to the survey. However, all four groups of employment sizes in line with the classification used by the Central Statistical Office (GUS) were included. Consequently, the surveyed enterprises were divided into nine industries: meat, fruit and vegetable, oil and fat, dairy, cereal and starchy, bakery, food, feed and beverage production, and into four employment size groups: micro enterprises (up to nine employees), small enterprises (from 10 to 49 employees), medium (from 50 to 249 employees) and large (250 and more employees).

To assess the level of advancement of solutions in the field of logistics information management based on ICT technologies used in the surveyed enterprises, a dedicated IAI (ICT Advancement Index) was used, which was created as a result of aggregation of six characteristics of the surveyed enterprises (Table 1).

Index IAI values have been determined for individual enterprises as well as for all surveyed industries and employment size groups as the arithmetic mean value belonging to a given subgroup of entities.

The study used the value of the IAI indicator and selected characteristics of the surveyed enterprises (employment size, investments scale, financial situation, position on market) in a categorized form. Two methods of categorizing the values of examined variables were used and compared. The first method A consisted in evenly dividing the range of the value of the examined variable into a fixed number of intervals of the same width in

Table 1. Components of the synthetic indicator of the level of sophistication of information management solutions (IAI)

Tabela 1. Składniki wskaźnika syntetycznego poziomu zaawansowania rozwiązań w zakresie zarządzania informacją (WZI)

Components of the IAI index	Values
The fact of having one comprehensive information system.	1 for positive answer, 0 for negative response
IT support for five areas of logistics activities: transport, inventory management, packaging and returnable logistics, warehouse management, order management	1/5 for each affirmative answer
The way of providing information in the internal circulation (inside the organizational structure of the enterprise)	0 for failure to provide information, 1/6 for the declaration of oral communication in internal circulation, 2/6 for transmission on paper, 3/6 by telephone, 4/6 by fax, 5/6 by e-mail (e-mail) or instant messengers, 1 via computer programs
The method of transferring information in the external circulation (between the enterprise and market partners)	above
The level of comprehensiveness and technological advancement of your information system	0 for the lack of any information system, 1/5 for having an FA (Financial and Accounting) system, 2/5 for EDI (Electronic Data Interchange) system, 3/5 for MRP (Materiel Resources Planning) system, 4/5 for ERP (Enterprise Resources Planning), 1 for BI (Business Intelligence)
Method of preparing and using forecasts	0 for no formal forecasts prepared, 1/5 for production depending on the supply of raw material, 2/5 for production based on orders received, 3/5 for using only archival data from the enterprise for forecasts, 4/5 for using only market data, 1 for using both categories of data

Source: [Jałowiecki and Jałowiecka 2013].

accordance with formulas (1). The second method B, in order to determine the ranges of values of the studied variables, uses the division by mean value and fold standard deviation according to formulas (2). Both classification methods have been previously used in researching the differentiation of the level of sophistication of logistics solutions and systems in food enterprises [Jałowiecki 2019].

$$\begin{aligned}
&\text{very low} = 1 \quad \text{for } \min(x) \le x \le \overline{x} - s_x \\
&\text{low} = 2 \quad \text{for } \overline{x} - s_x < x \le \overline{x} - \frac{1}{2} \cdot s_x \\
&\text{middle} = 3 \quad \text{for } \overline{x} - \frac{1}{2} \cdot s_x < x \le \overline{x} + \frac{1}{2} \cdot s_x \\
&\text{high} = 4 \quad \text{for } \overline{x} - \frac{1}{2} \cdot s_x < x \le \overline{x} + s_x \\
&\text{very high} = 5 \quad \text{for } \overline{x} + s_x < x \le \max(x)
\end{aligned} \tag{1}$$

Where: $\overline{x}$ – average value of IAI index;
s_x – standard deviation of IAI index.

$$\begin{aligned}
&\text{very low} = 1 \quad \text{for } \min(x) \le x \le \min(x) + \frac{1}{5} \cdot \left(\max(x) - \min(x)\right) \\
&\text{low} = 2 \quad \text{for } \frac{1}{5} \cdot \left(\max(x) - \min(x)\right) < x \le \frac{2}{5} \cdot \left(\max(x) - \min(x)\right) \\
&\text{middle} = 3 \quad \text{for } \frac{2}{5} \cdot \left(\max(x) - \min(x)\right) < x \le \frac{3}{5} \cdot \left(\max(x) - \min(x)\right) \\
&\text{high} = 4 \quad \text{for } \frac{3}{5} \cdot \left(\max(x) - \min(x)\right) < x \le \frac{4}{5} \cdot \left(\max(x) - \min(x)\right) \\
&\text{very high} = 5 \quad \text{for } \frac{4}{5} \cdot \left(\max(x) - \min(x)\right) < x \le \max(x)
\end{aligned} \tag{2}$$

In examining the relationship between IAI values and selected characteristics of the surveyed enterprises, a linear regression model was used. The coefficient of determination R^2 was used to assess the fit of the estimated linear regression models. His definition is so common and known that it was decided to omit it at work.

For comparative purposes and due to the use of data in categorized form to assess the strength of the relationship between the level of sophistication of ICT solutions used and selected characteristics of the surveyed enterprises, the χ^2 independence test was also used according to the formula (3).

$$\chi^2 = \sum_{i=1}^{k} \sum_{j=1}^{l} \frac{\left(n_{ij} - \hat{n}_{ij}\right)^2}{\hat{n}_{ij}} \tag{3}$$

Where: i – number of categories of the first characteristic examined, e.g. employment size;
j – number of categories of the second characteristic examined, e.g. employment size;

n_{ij} – subgroup size in the multi-division table for row i and column j;
$\hat{n}_{ij}$ – theoretical size of the subgroup in the multi-division table in row i and column j.

Because the χ^2 test of independence used only identifies a significant or not statistical relationship, the following factors were used to assess its strength: T-Czuprow indicator according to formula (4) and V-Cramer indicator according to formula (5).

$$T_{xy} = \sqrt[2]{\frac{\chi^2}{n \cdot \sqrt[2]{(k-1)\cdot(l-1)}}} \tag{4}$$

$$V_{xy} = \sqrt[2]{\frac{\chi^2}{n \cdot min\,(k-1, l-1)}} \tag{5}$$

Where: n – sample size,
k – number of categories of x variable;
l – number of categories of y variable;
χ^2 – value of empirical test statistics.

The only major limitation of the above coefficients used to assess the strength of the relationship between the studied variables is the inability to indicate the direction of this relationship as is the case with correlation coefficients.

Obtained results

The average IAI value for all surveyed enterprises was $\overline{x} = 2.03$, and the standard deviation was $s = 0.99$. Consequently, the coefficient of variation was $w = 49.1\%$. Therefore, the differences in the absolute value of the IAI should be assessed as not very high. A typical range of variation for the IAI value was from $x = 1.03$ to $x = 3.02$, which meant that 352, or 68.9% of surveyed enterprises, belonged to the range of variation.

Considering the researched food industries, definitely the highest level of advancement of ICT solutions used was found in dairy enterprises, while definitely the lowest in bakeries, cereal and starch enterprises and producing feed. Such results were obtained using both methods of categorization A and B (Figure 3). The obtained results confirm the fact that the most advanced information management solutions are used in industries with the most complex technological processes, while the least advanced in industries characterized by not very complex technologies in the production of food products [Jałowiecki 2018].

By examining the level of advancement of ICT solutions and systems in individual employment size groups, a very strong relationship was found between the increase in employment volume and the higher value of the IAI index. This situation took place both using the categorization method of the surveyed enterprises A and B (Figure 4).

The study of the relationship between the level of advancement of solutions in the field of logistics information management based on ICT and the scale of investments made by food enterprises has clearly demonstrated a strong relationship between both characteristics. The higher the investment level, the higher the level of ICT solutions and

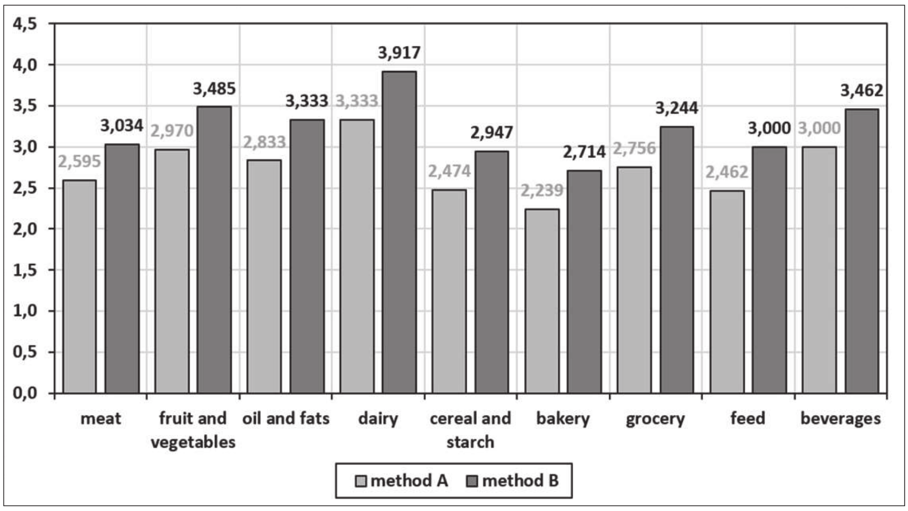

Figure 3. Average IAI index values in the analyzed food industry sectors in Poland
Rysunek 3. Średnie wartości wskaźnika WZI w badanych branżach przemysłu spożywczego w Polsce

Source: own study.

Figure 4. Average IAI index values in the analyzed food industry sectors in Poland
Rysunek 4. Średnie wartości wskaźnika WZI w badanych branżach przemysłu spożywczego w Polsce

Source: own study.

systems. At the same time, this relationship was somewhat stronger when the B categorization method was used (Figure 5).

The analysis of the relationship between the level of advancement of ICT technologies used to manage logistics information and the financial situation of Polish food enterprises regardless of the categorization method used (A or B) showed a very strong relationship

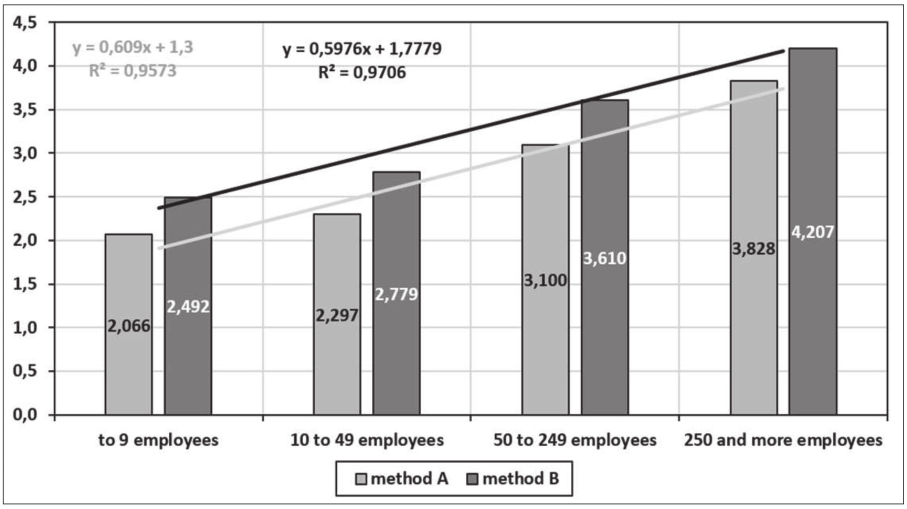

Figure 5. Average IAI values in groups of investment level in polish agri-food companies.
Rysunek 5. Średnie wartości WZI w grupach poziomu inwestycji w polskich przedsiębiorstwach rolno-spożywczych.

Source: own study.

between a higher IAI value and a lower ocean of financial situation (Figure 6). This situation confirms the existence in the Polish food sector of the Solow productivity paradox in its traditional form, i.e. that investments in modern ICT technologies do not translate directly into the financial result of economic entities making them.

In turn, the analysis of the relationship between the level of advancement of ICT solutions used primarily for logistics information management and the market position of the

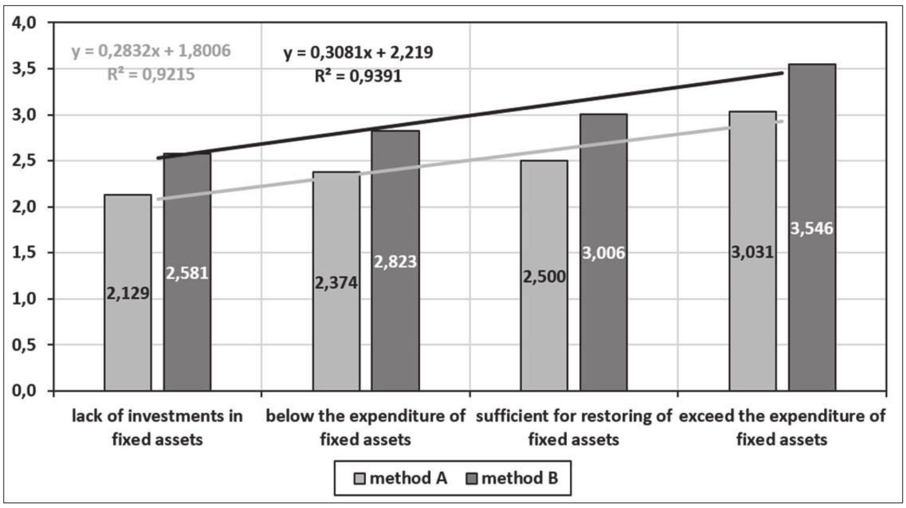

Figure 6. Average IAI values in groups of financial situation level in polish agri-food companies
Rysunek 6. Średnie wartości WZI w grupach poziomu sytuacji finansowej w polskich przedsiębiorstwach rolno-spożywczych

Source: own study.

company indicates a very strong positive relationship, i.e. the higher the level of advancement of ICT solutions and systems used, the better ocean market position of enterprises (Figure 7). In turn, such results seem to contradict the Solow productivity paradox in the Polish sector. It is also worth adding that they are very similar to each other using both methods A and B when categorizing the surveyed business entities.

The results obtained with regard to the occurrence of the Solow productivity paradox seem to be somewhat contradictory. This is confirmed by the results of previous studies. However, the explanation of this contradiction should be sought in the selective occurrence of the aforementioned paradox in various aspects of productivity, such as operational efficiency, profitability, financial liquidity or level of debt, as well as in the diversity of its occurrence in various industries and employment size groups [Jałowiecki 2018].

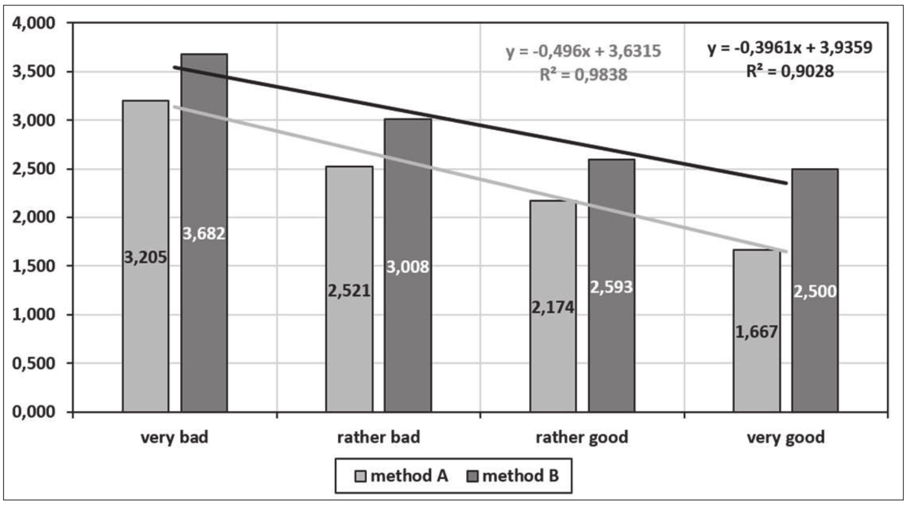

Figure 7. Average LAI values in groups of market position level in polish agri-food companies
Rysunek 7. Średnie wartości LAI w grupach poziomu pozycji rynkowej w polskich przedsiębiorstwach rolno-spożywczych

Source: own study.

As already mentioned, for the purposes of comparison, an χ^2 independence test was carried out to assess the statistical significance of the relationship between the level of advancement of logistics information management solutions based on ICT technologies and systems on the one hand, and employment, investment level, financial situation and market position on the other hand (Tables 2 and 3).

Table 2. Independence χ^2 test results for method A
Tabela 2. Wyniki testu niezależności χ^2dla metody A

Characteristics of enterprises	χ^2	$\chi^2_{\alpha,df}$	p-value	T_{xy}	V_{xy}
Employment size	144.847	21.026	< 0.001	0.287	0.309
Investments scale	434.357	21.026	< 0.001	0,521	0,560
Financial situation	65.637	21.026	< 0.001	0.194	0.209
Position on market	556.284	21.026	< 0.001	0.570	0.613

Source: own study.

In order to assess the strength identified as statistically significant relationships, the values of T-Czuprow and V-Cramer coefficients were determined, using the A and B methods of categorization of IAI index values (Tables 2 and 3).

Table 3. Independence χ^2 test results for method B
Tabela 3. Wyniki testu niezależności χ^2 dla metody B

Characteristics of enterprises	χ^2	$\chi^2_{\alpha,df}$	*p*-value	T_{xy}	V_{xy}
Employment size	132.776	21.026	< 0.001	0.275	0.295
Investments scale	457.925	21.026	< 0.001	0.535	0.575
Financial situation	68.016	21.026	< 0.001	0.198	0.213
Position on market	578.667	21.026	< 0.001	0.582	0.625

Source: own study.

The results obtained using the A and B categorization methods of the IAI index were very similar. Definitely the strongest were the relationships between the level of advancement of IAI solutions and systems, and market position and the scale of investment. Both dependencies were positive (the increase of one variable was accompanied by the increase of the other). The relationship between IAI and employment was also significantly weaker, but also positive and statistically significant. However, the weakest relationship was definitely the weakest (the increase in one variable was accompanied by a decrease in the other) between the level of advancement of ICT technologies used and the financial situation of the surveyed enterprises.

Conclusions

Comparing the obtained research results on the differentiation of the level of advancement of logistics information solutions and systems based on ICT technologies with the same differentiation of the level of advancement of logistics systems, it should be stated that they are shaped in a similar way [Jałowiecki 2019]. This confirms the results of previous studies, according to which the traditional understanding of the Solow productivity paradox regarding ICT should be extended to include logistic solutions and systems operating in close convergence with the former.

On the other hand, comparing the results of analyzes of the relationship between the level of advancement of ICT solutions and systems with selected characteristics of the surveyed food enterprises obtained using methods A and B categorization of IAI index values, very similar results were obtained. A completely different situation took place during similar studies previously carried out for the level of advancement of solutions and systems in the field of logistics [Jałowiecki 2019]. In these studies, the methods used to categorize the LAI (Logistic Advancement Index) identical to those described in the paper, describe the level of advancement of logistic solutions and systems in Polish food enterprises. On the basis of the results of both studies, of course, one cannot prejudge the smaller or greater effectiveness of the methods of categorizing the values of synthetic indicators IAI and LAI, but one should be aware that despite very many convergences in terms of differentiation of the level of ICT and logistics solutions, there are also significant differences.

This indicates significant differences between the differences in the occurrence of the Solow productivity paradox in the Polish food industry, which indicate the need for further in-depth research in this thematic area. Such studies should undoubtedly take into account more characteristics of IT solutions used in the surveyed enterprises.

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Integrated IT systems in logistics company management

Zintegrowane systemy informatyczne w zarządzaniu przedsiębiorstwem logistycznym

Abstract. The paper presents issues related to integrated IT systems, which are used in the management of many enterprises, including those dealing with logistics. The source of materials was a literature review. The study is a review. The evolution of the approach from MRP systems to integrated MRP II and from ERP to ERP II respectively is shown. The systems cooperating with ERP, such as CRM, SCM and WMS are also presented. Finally, important aspects related to the implementation of integrated ERP class IT systems are presented.

Key words: IT solutions, logistics, MRP, ERP

Synopsis. W artykule przedstawiono zagadnienia związane ze zintegrowanymi systemami informatycznymi, które są wykorzystywane w zarządzaniu różnymi rodzajami przedsiębiorstw, w tym logistycznymi. Źródłem materiałów był przegląd literatury. Badanie ma charakter przeglądowy. Pokazano ewolucję podejścia od systemów MRP do zintegrowanego MRP II i odpowiednio od ERP do ERP II. Przedstawiono również systemy współpracujące z ERP, takie jak CRM, SCM i WMS. Na koniec przedstawiono istotne aspekty związane ze wdrażaniem zintegrowanych systemów informatycznych klasy ERP.

Słowa kluczowe: rozwiązania IT, logistyka, MRP, ERP

Introduction

Today, one of the determinants of competitiveness is the ability to use information and effectiveness in managing the decision-making process. The information era has begun, in which communication by means of information technologies is becoming common [Kisielecki and Sroka 2005]. To use information resources effectively, a company needs an appropriate information system, which integrated with the management system will ensure control and development of all processes in the company. The functionality of such a system should be of great importance. Reliability is required in the transfer of current, comprehensive information to all levels of the organization. Only such an approach affects the appropriate economic efficiency of operations. It allows for accurate and quick decision making by the authorities responsible for it and eliminates the possibility of creating an information gap. The information management system, supported by computer technology, is applicable to all operations carried out on information [Flakiewicz 2002].

Of course, the quality of the information used in the management process must always be kept in mind. Precision, reliability, completeness, timeliness and compatibility of information is important [Kiełtyka 2002]. The information should also be useful in a given situation, concise and immediately usable [Długosz 2009].

Integrated IT system of an enterprise means a modularly organized IT system, serving all levels of its activity, starting from marketing and planning and supply, through technical preparation of production and its control, distribution, sales, repair management to financial and accounting works and human resources management. The functional scope will be different in a production company and different in trade or services [Adamczewski 2001]. The components of an information system are usually human resources, information resources (databases, method bases, model bases, knowledge bases), procedural resources (algorithms, procedures, software), technical resources (hardware, telecommunications infrastructure, data carriers) [Dudka 2011]. The process of integration of the company's information systems used for logistics purposes is considered in the following dimensions: organizational and management, technical and technological and social. The organizational dimension is particularly important. It refers to the structure of the company management system, production processes and administrative works, behaviors of human teams and adaptation processes, information resources, material production factors [Nowicki 2006].

The emergence and growing popularity of integrated systems supporting business management is the result of the mutual complementarity of logistics, trade and computerization, which supports the sale of products and services. An extremely important reason for the development of integrated IT systems is the fact that most of the leading manufacturers of these systems offer the possibility of working with web browsers. The user then has access to the system's individual functions anywhere, even outside the company [Lech 2003, Zutshi and Sohal 2005].

Aim and methodology of the tests

The main aim of the study is to present the most important integrated IT systems used to support the logistics activities of the company. The specific objectives were: to show the functionality of the most important IT systems, to determine the conditions for implementing these solutions. The study is a review. The source of materials was a literature review.

Evolution of IT systems from MRP to MRP II

An important group of systems are MRP/MRP II (Material Requirements Planning). Their introduction to use took place in the 1970s. The system's operation consisted in combining the demand for individual products with the demand for materials in their production and the use of a computer to make the necessary calculations. This made it possible to purchase the necessary materials at the earliest possible date, which significantly reduced the costs, while at the same time maintaining all the deadlines resulting from arrangements with the customer [Roberts and Barrar 1992].

The main objectives and functions of MRP systems include: determining the amount of production costs, precise determination of the time of delivery of raw materials and semi-finished products, reduction of stocks, optimization of the use of infrastructure resources (e.g. warehouses, production capacity), dynamic response to changes in the environment, control of production stages [D'Avino et al. 2014].

MRP systems have been very successful in business management. They covered more and more business areas. Therefore, companies decided to extend the use of computer techniques. The result of these activities was the creation of the MRP II (Manufacturing Resource Planning) system, i.e. the planning of production resources, in which all activities of a manufacturing company, including sales, purchases, maintenance, engineering, personnel, etc., were integrated with the MRP system. MRP II systems give the possibility to receive answers to the following questions, i.e. [Olszak and Sroki 2001]:

- can we deliver the products expected by our customers within a specified time and at the lowest cost?
- what and in time should be produced to meet current demand? what range?
- what and how long does it take to complete production?
- what resources does the company have at its disposal at any given time?
- what should be taken into account in planned purchases in order to carry out production?

The MRP II system covers the whole company and coordinates manufacturing, sales and financial activities. The system processes the demand for production resources into financial requirements. It shows the results of production activities in financial terms. The processing of production resources helps to calculate the company's capital capacity to implement the plan. The task of this function is to present the financial aspects of the production plan in the form of appropriate indicators [Turgay et al. 2007].

The "MRP II Standard System", the official description of MRP II, presents 16 groups of functions to be fulfilled [Majewski 2002]. The use of MRP II class systems has resulted in an increase in the overall dynamics of the business environment. The principles of their operation have also changed, including the economic efficiency of economic processes [Miclo et al. 2019].

It can be stated that MRP II applied the methodology of the so-called "rolling planning", which is based on the analysis of internal and external demand while maintaining model stock levels, minimizing costs while using the available machinery [Jakimowicz et al. 2015].

Transition from ERP to ERP II

The development of ERP systems results from changes in management logistics. At an early stage, the systems only supported management within the company. With the development of technology, and the consequent spread of computer systems, the need arose to connect business entities in the entire logistics chain. This resulted in the development of

ERP systems. The system was extended with additional functions that are applicable in the supply chain. They enabled companies to integrate and optimize logistics processes. The basic property of ERP systems is the optimization and arrangement of the whole range of processes occurring within a business entity, i.e. logistics, production, sales and financial management [Długosz 2009].

The scope of basic functions of integrated ERP systems includes: distribution, sales and marketing (customer relationship management – CRM subsystems), reports, service, personnel administration, finance (fixed assets and controlling subsystem), manufacturing, accounting and procurement (supply chain management systems – SCM and warehouse process management systems – WMS), electronic data transmission (EDI) subsystem, business intelligence (multidimensional data analysis processes – OLAP and data warehouses). From the above mentioned functions it can be concluded that ERP systems are able to function thanks to their detailed structure, which consists of many modules and covers individual departments of the company. The elements of the system may interact with other modules after appropriate integration, or operate separately. An indispensable condition for staying on the market is effective management of relations between the company and its business partners, i.e. external company processes. Specialists in innovative IT systems from Gartner Group were the first to create a definition of this transformation called ERP II (Enterprise Resource and Relationship Processing). ERP II is a set of industry-specific applications that generate value for customers and shareholders by making available and optimizing operational and financial processes, both within the company and between companies – partners [Stancu and Drăguţ 2018].

Among the main processes that support the ERP II system, the following are distinguished: accounting, purchasing, order registration, sales, cost estimation. Among the operational processes there should be those that give the possibility of cooperation with business partners. From the technical point of view, the construction of ERP II is based on a network and consists of components, while the ERP system consists of modules, thanks to its architecture ERP II integrates more easily with other systems and has an active and immediate participation in the chain of information exchange between business partners. ERP II systems operating in typical manufacturing companies connect with the systems of suppliers and sellers, with the systems of financial branches, and through network distribution channels, also directly with consumers. In the future, logistic concerns will compete for who will catch the demand, the demand for a good or a service to be delivered faster [Kanicki 2001].

Solutions that work with integrated systems

In a time of constant competition and struggle for the customer, companies must watch every step of the customer before, during and after the use of services or purchase. This is exactly what CRM (Customer Relationship Management) does. This approach has been used since the mid-1990s. Customer Relationship Management is a business strategy consisting of building relationships and managing customers to optimize long-term benefits. CRM requires the introduction of a customer-focused business philosophy and culture that ensures effective marketing, sales and service processes. CRM applications should give the possibility of effective Customer Relationship Management leading to the primacy of this approach over the overall strategy and culture in the company [Zając 2007]. CRM systems allow to create a classification of customers with a division into key customers (generating a substantial profit) and less profitable and sometimes even unprofitable customers (generating too little profit or even losses) [Laskowska-Rutkowska 2006].

Another integrated IT system that needs to be characterized is SCM (Supply Chain Management), which is a supply chain management system. The dynamically changing concept of supply chain management among enterprises has led to a situation where the functionality of ERP-class integrated systems no longer fulfills its purpose. ERP is a proven and effective system that improves business processes, but it is designed for individual companies and does not provide the ability to manage information within the supply chain building network. Therefore, organizations started to look for systems that would provide appropriate processes going beyond the boundaries of the enterprise with the concept of comprehensive supply chain management. SCM enables the management of the entire logistics chain from the point of design and establishing the source of supply of appropriate materials, through demand planning and distribution of goods to the delivery of the finished product to the consumer [Ciesielski 2006]. Integrated SCM IT systems optimize internal and external logistics processes, both sourcing and as a starting point for optimizing own customer relations. Users of SCM systems are more efficient on the market because they flexibly influence customers and suppliers and include them in the supply chain at the very beginning of the planning process [Majczak 2007].

The last integrated IT system discussed is the WMS (Warehouse Management System), which is a warehouse management system. The diversity of the software used and its functionality must always result from the function and nature of a particular warehouse [Niemczyk 2008]. The WMS is an effective and functional tool supporting the management of operations carried out in the warehouse and all processes related to the distribution of goods in the warehouse. It also gives the possibility to manage any number of warehouses, divided into areas, classes and places. The most important functions of the WMS include management of the article database, management of packaging structures, defining the division of the warehouse (warehouse locations), handling of hazardous materials, receipt and storage of goods, management of the order list, order picking, goods storage, packing, co-packing (repacking) and preparation of sets, management of goods in the warehouse, inventory, dispatch of goods (release from the warehouse). WMS solutions are of great importance primarily for logistics operators (service providers), handling in their warehouses and terminals a large number of diverse shipments every day, coming from many senders and directed to more recipients. There should be an integrated structure of information transfer between the ERP and WMS systems, which allows for complete automation of product movement in warehouses [Kotowicz 2008].

Implementation of ERP class integrated systems

An optimally selected system and meticulously executed implementation of an integrated ERP system provides the company with many benefits, the ability to apply all functional capabilities of the system. If we want to get acquainted with the general benefits resulting from the implementation of an ERP system in logistics companies, we may come across numerous encouraging benefits guaranteed by suppliers, such as [Dudka 2011]:

– compromise response to immediate customer needs, changes in the business plan and production risks,
– minimizing work in progress by about 30%,
– increase, even up to 50%, the adherence to deadlines,
– reduction of the average time of delivery (order execution),
– minimizing the shortage of parts for assembly from 75 to 90%,
– an increase in labor productivity of 10 to 20%,
– reducing stockpiles from 10 to 50%,
– improving the average stock turnover rate,
– sales increase from 15 to 25%,
– reducing the average number of employees in material supply services,
– reduction of purchase costs from 7 to 15%;
– increase the profit from the company's operations.

An important part of the corporate IT system is the integrated ERP system. Its proper implementation is very important. However, it should be remembered that ERP class systems are subject to constant changes in terms of technology used and functionality offered. The directions of development and improvement of ERP systems include [Soja 2001]:

– integration of new business planes by adding new modules (applications) to the system, or by developing newer versions of existing modules;
– taking into account industry-specific solutions so far supported only by specialized software (e.g. insurance, banks, financial services, construction);
– providing mechanisms to optimize production within the logistics chain and adapting the logistics chain to the needs of the individual company;
– change of package architecture to systems consisting of a core offering basic minimum functionality and sets of components that can be independently created or purchased from external manufacturers;
– outsourcing of ERP systems by offering the client only access to the system (via a web browser), while the database system and computers are located in a remote data center managed by the provider;
– the use of platforms and technologies enabling the realization of e-commerce using Internet access.

It should be noted that there are no rigid standards for this system as with MRP II, which clearly defines the functions available in the program. When ordering an ERP system, the manufacturer may modify the program according to the customer's needs [Jakimowicz et al. 2015].

After the implementation of the ERP system, the company acquires the ability to quickly circulate and assimilate information and control the directions of economic processes in both external relations, e.g. contractors' customers and internal, i.e. employees. When making a decision to purchase and implement an ERP management system, companies must make a thoughtful and reasonable choice from among the many software offered on the market. Attention should be paid to adapting selected ERP packages to the planned type of business activity and to the easy operation and reliability of the system.

From the very beginning, one has to reckon with the possibility of negative consequences of improper adjustment of the system, which may significantly worsen the process of implementation of ERP systems, as well as the current functionality of the company. The most common implementation problems of ERP class systems are [Kanicki 2011]:
- insufficient and unsystematic knowledge of the management about processes functioning in the organization;
- an incorrectly selected supplier with no relevant industry experience or an incorrectly selected system that does not meet the requirements of the economic sector concerned;
- imprecise or wrongly defined objectives and expectations for implementation;
- lack of sense of importance of the company and support at the highest management levels;
- system tests performed in an inaccurate and incomplete manner, resulting in undetected errors;
- failure to meet safety requirements and formal and legal regulations system;
- difficulties in identifying the person responsible for the project, resulting in incorrect management of changes, risks and project scope;
- the lack of responsibility and the lack of an implementation team on the part of the company in which the system is implemented;
- too many reported system modifications affecting the planned schedule and budget of the project;
- undefined business processes in the initial phase of implementation;
- incorrect calculation of implementation costs as a result of incorrectly agreed scope of implementation with the supplier.

Implementation is the most frequently described issue concerning integrated management information systems. In the case of implementation, the main focus was on the issue of preparing for implementation (e.g. ERP system) from the technical and organizational point of view and proceeding during the implementation project [Fogli and Provenza 2010, Yuesheng 2011, Salmeron and Lopez 2012]. However, apart from the implementa-

Table. Evaluation of ERP class solutions in the opinion of its users
Tabela. Ocena rozwiązań klasy ERP w opinii ich użytkowników

Kind of cloud ERP solutions	Number of ratings	General rating	Evaluation & Contracting	Integration & Deployment	Service & Support	Product Capabilities
CloudSuite	10	4.5	4.5	4.6	4.5	4.5
Workday	104	4.4	4.3	4.1	4.3	4.4
Intacct	52	4.4	4.3	4.2	4.4	4.5
Oracle ERP Cloud	51	4.4	4.3	4.4	4.3	4.4
Microsoft Dynamics 365	49	4.4	4.2	4.3	4.1	4.4
Oracle NetSuite ERP	12	4.3	4.2	4.2	4.5	4.6
Deltek Vision	40	4.2	4.3	4.3	4.4	4.2
ePROMIS ERP	18	4.2	4.4	4.3	4.5	4.3
SAP Business ByDesign	13	4.2	4.3	4.0	4.2	4.5

Source: [Gartner n.d.].

tion, it is also worthwhile to take an interest in the decision making, acquisition, use, maintenance and development phases, up to the final stage [Bernat and Cieśliński 2016].

Reviews for Service-Centric Cloud ERP Solutions Market were presented. Maximum given solution could receive five points. Table lists the available ERP class systems, the number of assessments made, the average of ratings received for the last 12 months (from July 2019 to June 2020) and average ratings in specific areas. The review was performed by representatives of large companies from around the world that used thises solutions. The differences between the solutions were not big. However, there were differences in the assessment of individual areas. Each enterprise can choose the solution best suited to the company's needs. There are many solutions on the market.

Summary and conclusions

1. The activity of logistics companies is determined by the ever-growing need to obtain up-to-date information, both from external and internal sources of the business environment. The development of integrated IT systems presented in the study allows us to state that at the beginning the basic integrated systems, e.g. MRP, served individual processes of the company's activity, such as production or warehousing. The evolution has transformed them into complex integrated systems covering all internal and external organization processes concerning relations with business partners.
2. The study collected and systematized basic knowledge about the most popular integrated MRP, ERP systems and their complementary packages, such as CRM, SCM and WMS. Overarching functions and benefits resulting from their application were presented. The aim of using the above mentioned IT systems is to gain a competitive advantage, which is created by precise control of business processes, improvement of the way the organization operates and better quality of information. On the basis of the literature review, it was concluded that the use of even the simplest IT systems significantly entitles enterprises to work. Depending on the needs, an MRP system or more extensive MRP II or ERP can be used.
3. The ERP system covers all the key areas of business operations. Additionally, it is possible to include additional areas. The system can be individually adapted to the customer's needs. Supporting the management process in an enterprise with integrated IT systems has become a standard and practice that determines competitiveness in a company.
4. The selection of methods and tools used to improve a particular organization must be adapted to the characteristics of the enterprise concerned, the problems it is facing. Each individual case, as well as the entire organization, should be considered on an individual basis, as there are no two identical companies. Implementation of system solutions based on information technologies always generates significant expenditures. Therefore, appropriate actions at the stage of system implementation are important. Only the application of an appropriate implementation of an IT system may result in an increase in productivity.

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Interoperability and data flow between JTLS-GO simulation system and LOGFAS logistic system during CAX (Computer Assisted Exercise) exercises

Współpraca i przepływ danych pomiędzy systemem symulacyjnym JTLS-GO i systemem logistycznym LOGFAS w ćwiczeniach dowódczo-sztabowych wspomaganych komputerowo

Abstract: The purpose of this article is to present the results of the research concerning the possibility of interoperability between the JTLS-GO military simulation system and the LOGFAS military logistic system during Computer Assisted Exercises. The JTLS-GO system is the primary simulation system used in the Polish Armed Forced (PAF) while LOGFAS is the main logistics tool within NATO. Preparing CAXs requires extensive work in terms of building a database of military units, command and logistic structure, combat systems and supply categories. The main goal is to prepare as realistic an environment as possible enabling commanders and staff to use real IT command support systems (C4I) along with real procedures to produce orders for virtual sub-units according to the principle: "train as you plan to fight". The main benefit of CAXs is minimal cost – a real training audience uses virtual troops in a virtual world using real procedures and decision-making processes. Logistic support is one of the most important areas implemented during such exercises, and the LOGFAS system is the main tool supporting the planning and implementation of logistical support during operations.

Key words: JTLS-GO system, LOGFAS system, CAX exercise, combat system, supply category, RIC, NIC

Synopsis: Celem tego artykułu jest zaprezentowanie wyników badań dotyczących możliwości połączenia pomiędzy systemem symulacyjnym JTLS-GO a wojskowym systemem logistycznym LOGFAS, podczas prowadzenia ćwiczeń dowódczo-sztabowych wspomaganych komputerowo. Głównym systemem symulacyjnym używanym w Siłach Zbrojnych RP jest JTLS-GO, podczas gdy LOGFAS jest głównym narzędziem dla logistyków w ramach NATO. Przygotowanie ćwiczeń dowódczo-sztabowych wspomaganych komputerowo wymaga włożenia znacznego wysiłku w zakresie budowania bazy danych zawierającej: jednostki, strukturę dowodzenia, systemy walki i środki (klasy) zaopatrzenia. Głównym celem jest

przygotowanie środowiska zbliżonego do realnego, aby umożliwić dowódcom i sztabowi użycie wdrożonych systemów informatycznych wsparcia dowodzenia, i rzeczywistych procedur do wytworzenia dokumentów rozkazodawczych dla wirtualnych pododdziałów zgodnie z zasadą: trenuj tak, jak będziesz walczył. Główną zaletą takich ćwiczeń jest minimalizacja kosztów – prawdziwe ćwiczące organy dowodzenia używają jednostek wirtualnych podwładnych w wirtualnym świecie przy zastosowaniu jednakowoż faktycznie funkcjonujących procedur i obowiązującego procesu podejmowania decyzji. Wsparcie logistyczne jest z jednym z istotniejszych obszarów realizowanych podczas takich ćwiczeń, a system LOGFAS – głównym narzędziem wspierającym planowanie i realizację wsparcia logistycznego podczas prowadzenia operacji.
Słowa kluczowe: system JTLS-GO, system LOGFAS, ćwiczenia dowódczo-sztabowe wspomagane komputerowo, system walki, kategoria zaopatrywania, RIC, NIC

Introduction

In the modern world our lives are supported by IT technologies and accordingly developers support the needs of individual users with a wide range of specialised IT systems which facilitate and speed up planning process and resource management. Using specialised IT systems such as Enterprise Resource Planning (ERP) can increase enterprise profitability. Document handling systems improve the flow of documents, bills, and receipts within an organization facilitating the organisation of work, support of customers and working together with partners.

An army is an organisation the main goal of which is to defend its country's borders and its nation against potential opponents during conflict or war. To achieve this task an army needs to be trained in as realistic as possible conditions. Map Exercises (MAPEX), Command Post Exercises (CPX), Live Exercises (LIVEX) and Computer Assisted Exercises (CAX) with virtual troops, combat systems and supplies within a virtual world can provide this realism to train a Training Audience (TA) in real decision-making processes and the production of operation orders [Çayirci and Marinčič 2009].

One of the best simulation systems at the operational-strategic level Joint Theater Level Simulation – Global Operations (JTLS-GO), is used in CAXs by the Polish Armed Forces. However, at the tactical level the preferred choice is the Joint Conflict and Tactical Simulation (JCATS) simulation system. Finally, at the tactical level, Czech Bohemia Interactive Simulations Virtual Battlespace 3 (VBS3) virtual training environment based on commercial gaming technologies is used.

These three systems enable a TA to train in a virtual environment which provides virtual troops and resources (constructive simulation concept). It is also possible to deploy real troops with real equipment, weapons and ammunition against a fictional enemy (live simulation concept) or train tanks, Armoured Personnel Carriers (APCs), aircrafts squads using virtual simulation provided by any kind of link trainers [Çayirci and Marinčič 2009].

Commanders and staffs play as the training audience preparing different courses of action (COA), plans (Operation Plan – OPLAN), orders (Fragmentary Order – FRAGO, Operational Order – OPORD) with appendixes designed for each type of force (e.g. Command, artillery, engineers, logistics), Concept of Operation (CONOPS) and so on, using their operational knowledge, own experience, and skills and interacting at iterative staff meetings as well as using real Command Control Communication Computers and Intelligence (C4I) systems. For logistics LOGFAS is NATOs standard tool for the exchange of information. An overview of both JTLS-GO and LOGFAS is provided in the next two chapters as a necessary background to the main theme of this article.

The general goal of this article is to present the possibility of interconnection between the JTLS-GO military simulation system and LOGFAS the military logistic system during Computer Assisted Exercises. This connection is required and necessary to increase overall operational logistic awareness by delivering the right data and placing it into the proper logistic tools to enable logistic planning and ensure the best support for fighting troops when considering different COA's (courses of action) in the Commander's decision making process. And finally, after the Commander has chosen his best course of action from those put forward by his staff the final order can be fully supported by the virtual logistic troops to the full advantage of the operational troops. All cells in the command post must use the mandatory decision-making process in their activities including phases, stages, steps, and the preparation of documents in accordance with their real SOP's (Standard Operating Procedures).

Overview of JTLS-GO system

The Joint Theatre Level Simulation – Global Operations [Rolands & Associates Corporation n.d.] is an interactive, Internet-enabled simulation that models multi-sided air, ground, and naval civil-military operations with logistical, Special Operation Force (SOF), and intelligence support. System JTLS-GO has been primarily used as a training support model that is theatre-independent and more importantly does not require a knowledge of programming to operate effectively.

The primary focus of the JTLS-GO system is conventional joint and combined operations at the Operational Level of War. The Simulation supports low-intensity conflict and pre-conflict operations at the level below war, as well as support of Humanitarian Assistance and Disaster Relief (HA/DR) scenarios. It has also limited nuclear and chemical effects representation.

JTLS servers run on the RedHat Enterprise Linux (RHEL) operating system, while a Java-based Web Hosted Interface Program (WHIP) client runs both the Linux and Windows operating systems. System JTLS-GO has a client–server architecture and practically the number of clients is not limited. Large scale exercises with over 100 client workstations can be run. The main WHIP window is presented in Figure 1. By default it contains on the left of the Command Hierarchy window units organized as they were set up in the Order of Battle (ORBAT), in the middle Map window the same units are placed in their positions (depending on actual map scale) and with the drawing tool and settings pane on the right, and on the left below the SitRep window (Situation Report). In the settings there is a search field and 13 icons: filters with rich and precise possibilities for filtering units, symbol size, terrain, areas, networks (road, rail, river, pipeline), range rings for different kind of weapons, routes for moving units, country boundaries, different kinds of map layers, alert messages about different warnings about fighting units, emitters, Direct Search Areas (DSAs), and chemical and nuclear contamination. The SitRep window is designed to show detailed information about one object selected from the Command Hierarchy or a Map unit. Additionally, each operator can run in his WHIP Message Browser window (a list of messages about the actual state of units and the game), the Information Management Tool (IMT) window with combat systems or supply categories in table format, above 200 orders formats to enter specific orders for specific units. There are specialized windows for Airspace Control Order (ACO)/Air Tasking Order (ATO) Viewer, Logistic Hierarchy, link to Online Player Manual (OPM) webpage and other.

System JTLS-GO version 5.1 has a complicated structure deep inside, with many modules and uses complicated Lanchester differential equations to compute combat effects. However, it is reasonable easy to learn only requiring a two-week intensive course which looks deep inside to master the use all of the features. The software is used widely throughout NATO.

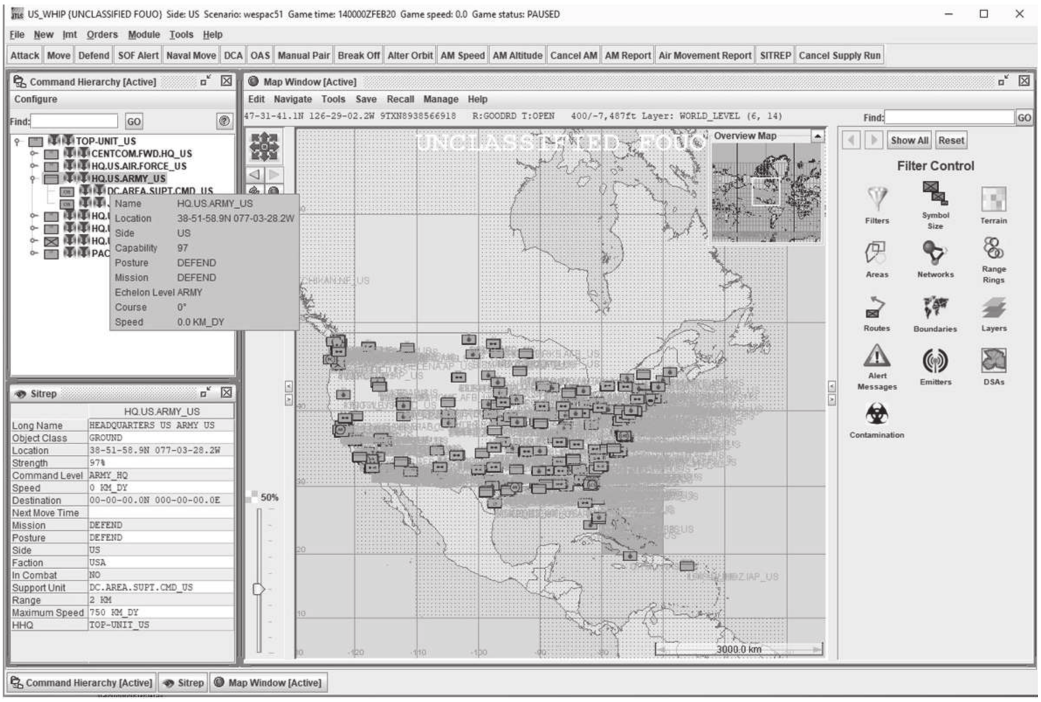


Figure 1. Java-based WHIP client for players

Rysunek 1. Oparty na Javie klient WHIP dla operatorów systemu symulacyjnego

Source: own study based on WHIP client.

Apart from operational simulation JTLS-GO also provides logistic players significant and vital capabilities to augment the automatic requisitioning and delivery processes [Byłeń and Sołoducha 2016]. Logistic players must interact with the Simulation by monitoring the IMT, requesting reports, interpreting advisory messages, scheduling resupply airlifts, sending supplies to units in trouble or lacking supporting units, changing stockage objectives and reorder levels, assigning new support units, or directing mandatory transfers of supplies. The following logistics functions are available in JTLS-GO [Rolands & Associates Corporation 2019b]:

– intra-theatre movement of supplies between units by air, truck, barge, or rail;

- mandatory transfer of supplies from one unit to another;
- creation of logistics loads for use in future orders;
- operation of pipelines, including drawing supplies from pipelines and replenishing supplies;
- modification of stockage objectives and/or reorder thresholds of one or more supply categories for either a single unit, a group of units, or all units;
- airlift operations (through the air module). An aircraft squadron or helicopter company is capable of lifting either a unit or supply load from a loading location to an offloading location;
- sealift operations (through the naval module). A naval unit or formation is capable of sealifting either units (amphibious operations) or a supply load from a loading location to an offloading location;
- evacuation of remains (Killed in Action – KIA). A fraction of killed personnel are recovered by their unit. These KIA are retained by the unit until they can be evacuated;
- use of trucks from one unit to pick up supplies from one or more other units, and deliver them to other units or locations;
- automatic or Player-directed resupply of units;
- creation of supply caches for future use;
- capture of enemy supplies and recovery of own supplies;
- change of the depot from which a unit orders its supplies or from which a pipeline is replenished;
- airdrop operations (through the air module). An aircraft squadron or helicopter company is capable of airdropping a unit or supply load at a specified primary location or alternate location;
- evacuation of casualties whose expected recovery time is longer than a Faction specific maximum time. A faction is a part or side e.g. land forces are part of Polish Armed Forces. Casualties are evacuated by convoys that deliver supplies to the unit and are evacuated to the unit's support unit.

Those activities can be done by completing logistic orders and sending them to the engine of the JTLS-GO system. The engine of JTLS-GO is called the Combat Event Program (CEP) and collects all prepared orders and executes them one by one computing the effect of each specific order changes the state of the game. The menu for some logistic orders is shown in Figure 2.

Database developers and exercise planners have total control over how a force side support hierarchy is designed, and over units' initial quantities, usage rates, and other supply status data. On the one hand, units may be given unlimited supplies. This permits assessment of operations in an environment that is totally unconstrained by availability of supplies. At the other extreme, high-resolution micro-management of the logistics situation is permitted by the very specific Directed Resupply, Airlift, Airdrop, Sealift, Reorder Level, and Stockage Objective directives. Between these two extreme conditions, simulating normal constrained availability, automatic requisitioning, and automatic (player-initiated) Push shipments provides a medium-level management-by-exception capability. An unlimited number of different supply categories can be represented. Categories of supply need not correspond to the standard military classes of supply. For example, a very small unclassified JTLS-GO database included these categories: Personnel,

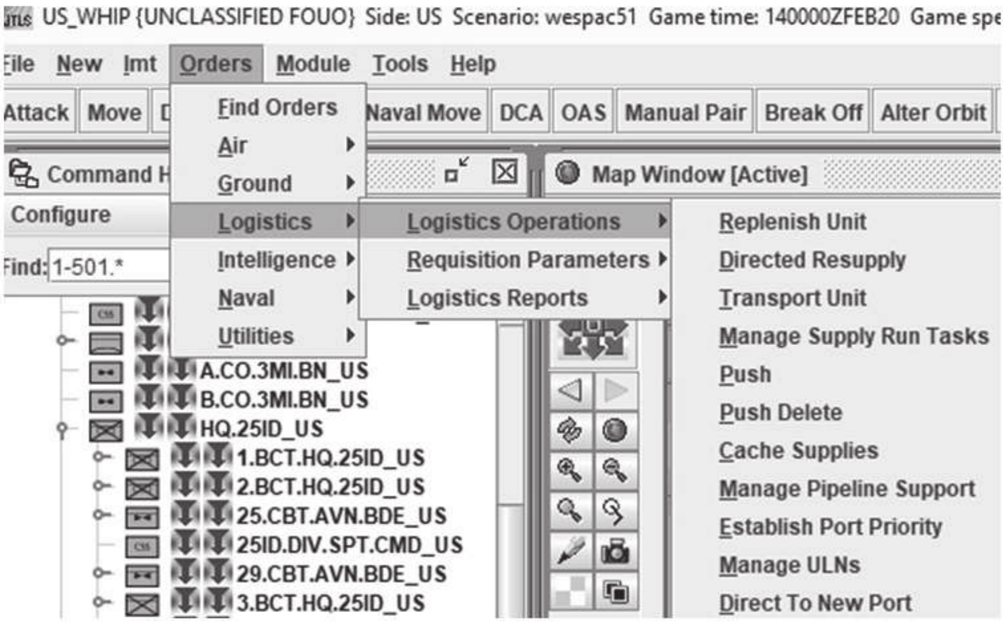
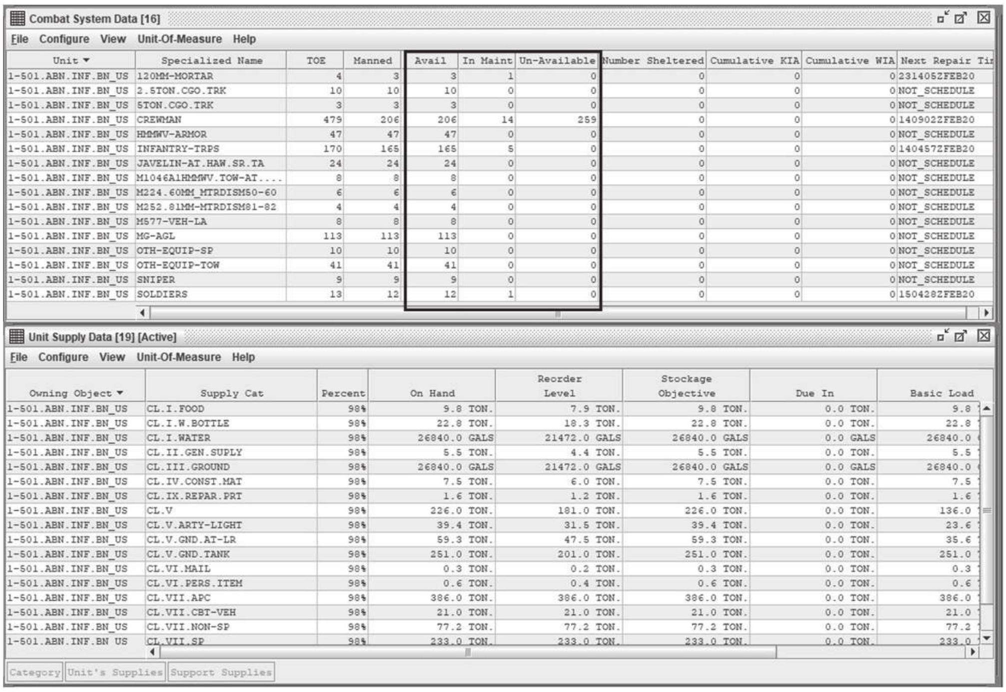


Figure 2. WHIP menu for logistic orders

Rysunek 2. Menu WHIP dla rozkazów logistycznych

Source: own study based on WHIP client.



Combat System Data [16]

Unit	Specialized Name	TOE	Manned	Avail	In Maint	Un-Available	Number Sheltered	Cumulative KIA	Cumulative WIA	Next Repair Ti
1-501.ABN.INF.BN_US	120MM-MORTAR	4	3	3	1	0	0	0	0	231405ZFEB20
1-501.ABN.INF.BN_US	2.5TON.CGO.TRK	10	10	10	0	0	0	0	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	5TON.CGO.TRK	3	3	3	0	0	0	0	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	CREWMAN	479	206	206	14	259	0	0	0	140902ZFEB20
1-501.ABN.INF.BN_US	HMMWV-ARMOR	47	47	47	0	0	0	0	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	INFANTRY-TRPS	170	165	165	5	0	0	0	0	140457ZFEB20
1-501.ABN.INF.BN_US	JAVELIN-AT.HAW.SR.TA	24	24	24	0	0	0	0	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	M1046A1HMMWV.TOW-AT....	8	8	8	0	0	0	0	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	M224.60MM_MTRDISM50-60	6	6	6	0	0	0	0	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	M252.81MM-MTRDISM81-82	4	4	4	0	0	0	0	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	M577-VEH-LA	8	8	8	0	0	0	0	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	MG-AGL	113	113	113	0	0	0	0	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	OTH-EQUIP-SP	10	10	10	0	0	0	0	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	OTH-EQUIP-TOW	41	41	41	0	0	0	0	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	SNIPER	9	9	9	0	0	0	0	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	SOLDIERS	13	12	12	1	0	0	0	0	150428ZFEB20

Unit Supply Data [19] [Active]

Owning Object	Supply Cat	Percent	On Hand	Reorder Level	Stockage Objective	Due In	Basic Load
1-501.ABN.INF.BN_US	CL.I.FOOD	98%	9.8 TON.	7.9 TON.	9.8 TON.	0.0 TON.	9.8
1-501.ABN.INF.BN_US	CL.I.W.BOTTLE	98%	22.8 TON.	18.3 TON.	22.8 TON.	0.0 TON.	22.8
1-501.ABN.INF.BN_US	CL.I.WATER	98%	26840.0 GALS	21472.0 GALS	26840.0 GALS	0.0 GALS	26840.0
1-501.ABN.INF.BN_US	CL.II.GEN.SUPLY	98%	5.5 TON.	4.4 TON.	5.5 TON.	0.0 TON.	5.5
1-501.ABN.INF.BN_US	CL.III.GROUND	98%	26840.0 GALS	21472.0 GALS	26840.0 GALS	0.0 GALS	26840.0
1-501.ABN.INF.BN_US	CL.IV.CONST.MAT	98%	7.5 TON.	6.0 TON.	7.5 TON.	0.0 TON.	7.5
1-501.ABN.INF.BN_US	CL.IX.REPAR.PRT	98%	1.6 TON.	1.2 TON.	1.6 TON.	0.0 TON.	1.6
1-501.ABN.INF.BN_US	CL.V	98%	226.0 TON.	181.0 TON.	226.0 TON.	0.0 TON.	136.0
1-501.ABN.INF.BN_US	CL.V.ARTY-LIGHT	98%	39.4 TON.	31.5 TON.	39.4 TON.	0.0 TON.	23.6
1-501.ABN.INF.BN_US	CL.V.GND.AT-LR	98%	59.3 TON.	47.5 TON.	59.3 TON.	0.0 TON.	35.6
1-501.ABN.INF.BN_US	CL.V.GND.TANK	98%	251.0 TON.	201.0 TON.	251.0 TON.	0.0 TON.	251.0
1-501.ABN.INF.BN_US	CL.VI.MAIL	98%	0.3 TON.	0.2 TON.	0.3 TON.	0.0 TON.	0.3
1-501.ABN.INF.BN_US	CL.VI.PERS.ITEM	98%	0.6 TON.	0.4 TON.	0.6 TON.	0.0 TON.	0.6
1-501.ABN.INF.BN_US	CL.VII.APC	98%	386.0 TON.	386.0 TON.	386.0 TON.	0.0 TON.	386.0
1-501.ABN.INF.BN_US	CL.VII.CBT-VEH	98%	21.0 TON.	21.0 TON.	21.0 TON.	0.0 TON.	21.0
1-501.ABN.INF.BN_US	CL.VII.NON-SP	98%	77.2 TON.	77.2 TON.	77.2 TON.	0.0 TON.	77.2
1-501.ABN.INF.BN_US	CL.VII.SP	98%	233.0 TON.	233.0 TON.	233.0 TON.	0.0 TON.	233.0

Category | Unit's Supplies | Support Supplies

Figure 3. IMT tables with combat systems and supply categories for specific unit

Rysunek 3. Tabele IMT z systemami walki i kategoriami zaopatrzenia dla wybranej jednostki

Source: own study based on WHIP client.

Aviation Fuel, Ground Fuel, Major End Items, General Ammunition, Artillery Ammunition, Mines, Engineer Supplies. Units combat systems (Table of Equipment – TOE, manned, available, in maintenance, cumulative KIA and Wounded in Action – WIA, etc.) and supply categories with quantities (on hand, reorder level, stockage objective, due in etc.) can be accessible anytime in the game via IMT window (Figure 3).

Overview of LOGFAS system

The Logistics Functional Area Application Service (LOGFAS) [North Atlantic Treaty Organization] delivers applications which enable the users to collect, store, manage, analyse, present, and distribute information in support of logistics operations. The main processes supported are: Stockpile planning, Deployment and sustainment planning, Movement and transport of personnel and equipment, Reception, staging, onward movement and integration and Logistics reporting. The NATO LOGFAS system consists of several components: Allied Deployment and Movement System (ADAMS), Effective Visibility Execution (EVE), Logistics Reporting (LOGREP), Allied Commands Resource Optimization Software System (ACROSS), Coalition Reception, Staging and Onward Movement (CORSOM). LOGFAS servers run on Windows Servers and use open source Apache server for webhosting and open source PostgreSQL databases for data storing. Additional LOGFAS modules are: LOGFAS Connection Manager – LCM, LOGFAS Data Management Module – LDM, Supply Distribution Model – SDM, Sustainment Planning Module – SPM, User Management Module – UMM, GeoManager Module – GeoMan and PostgreSQL Admin Tool console. Actual used version of LOGFAS has number 6.4, the newest one 6.5.

ACROSS supports the stockpile planning efforts of the SCs and nations across all component operations. ACROSS consists of several sub-software modules. All sub-systems follow target orientated methodology and are used to calculate requirements on battle decisive munitions to defeat targets by conventional means.

ADAMS supports strategic deployment planning and facilitates multinational deployment planning and information transfer. ADAMS assists movement and transportation planners in developing deployment plans and testing their feasibility by enabling the rapid preparation, de-confliction and dissemination of plans between nations and NATO commands.

CORSOM enables the performance of detailed planning for reception, staging and onward movement (RSOM) and provides visualization and oversight of theatre movements during both deployment execution and sustainment operations.

EVE Websupports the prioritization, de-confliction and coordination of actual movement flow execution plans and provides visibility of movement. During execution, planners are able to monitor, with the support of EVE the progress of planned activities and adjust plans to meet operational objectives.

The Sustainment Planning Module (SPM) enables NATO and national planners to calculate sustainment requirements for operations, to check the sustainability of a given set of units in a given time interval, to calculate the packaging requirements for the sustainment of a set of forces assigned to an operational plan and to support the calculation of strategic stockpile planning for supplies other than battle decisive munitions.

As mentioned above, LOGFAS has wide-ranging possibilities for use within NATO during national as well as allied operations. Figure 4 shows the LDM Module screen filled with forces and equipment (which is equal to combat systems in JTLS-GO system) and supplies (which is equal to supply categories in JTLS-GO system). On the right the command hierarchy is organized as a Force Profiles and Holdings. First pane on the top presents equipment and supplies of the one unit chosen from the tree on the left. In the middle, choosing country from the list, cause displaying all units belonging to this specific country. Below this table, choosing country from the list, presents list of all equipment and supplies belonging to this specific country with assigned RIC and NIC codes.

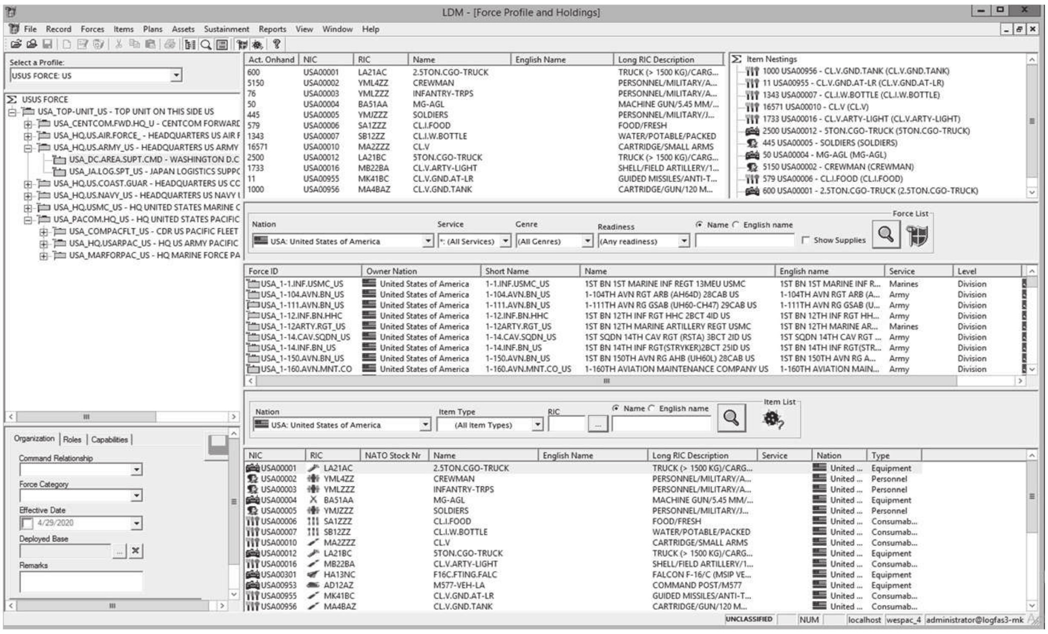


Figure 4. LOGFAS LDM module
Rysunek 4. Moduł LDM systemu LOGFAS
Source: own study based on LDM module.

The RIC, NIC concepts are essential to manage resources and for planning process. RIC – Reportable Item Code and NIC – National Item Code are categorized and coded list of combat systems (weapons, vehicles, APC's, tanks, aircrafts, ships) and supplies (food, water, munition, fuel, etc.) using six letter-number code which precisely assign specific combat system or supply to specific code. RIC codes are organized in hierarchical tree which means that mowing down this tree, like from branch to leaves, drive database users from general category to more detailed categories of combat systems or supply categories. Those codes are organized as the hierarchical tree shown on Figure 5. Each branch far from the tree root add new letter or number for specific resource. E.g. Vehicle (RIC: LA), has Truck category (RIC: LA2), Cargo subcategory (RIC: LA21), Up to 2 1/2 tonne sub-subcategory (RIC: LA21A) and finally High Mobility Sub-Sub-Subcategory (RIC: LA21AC). This same happened to resources: while the Subsistence has RIC code S, looking down leads to Canned Goods which have RIC code SA5. NIC are used and prepared by specific country according their national needs.

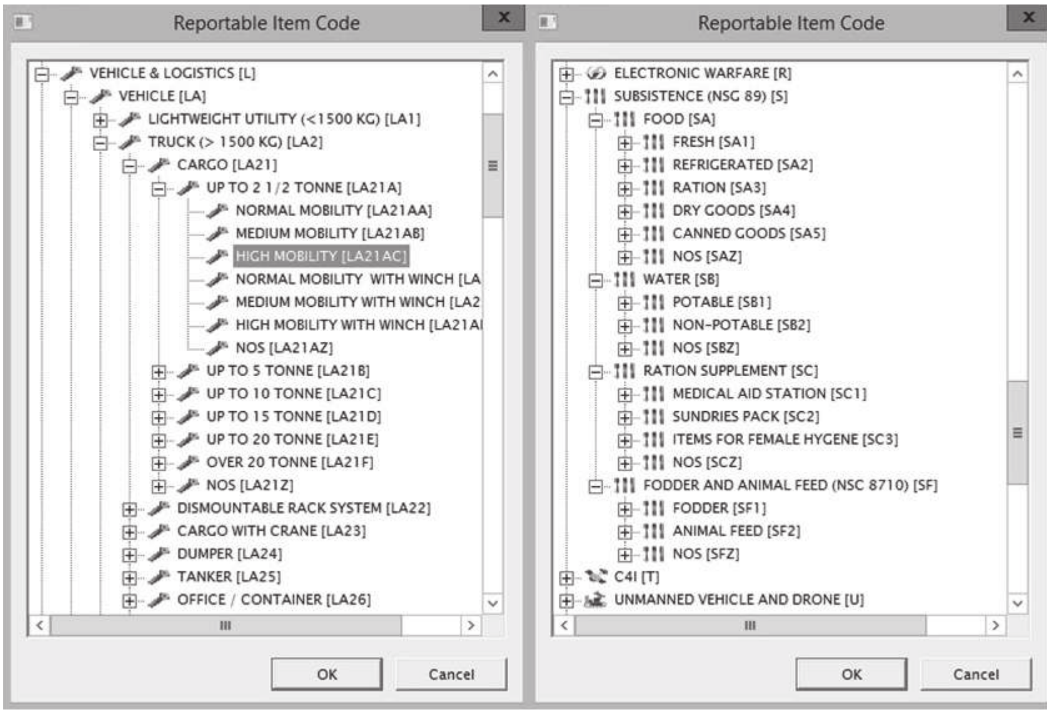


Figure 5. RIC hierarchical tree
Rysunek 5. Hierarchiczne drzewo kodów RIC
Source: own study based on LDM module.

Detailed description of LOGFAS system goes beyond of capacity of this article. Readers who need more information are pleased to read Polish article concerning different aspects of LOGFAS system use [Kupiec 2012, Sieczka 2012, Kupiec 2013a, b, c, Kupiec and Sieczka 2015, Sieczka and Kupiec 2015] or as well as logistics doctrine [NATO Standarization Office 2018] or LOGFAS User Documentation [LOGREP 2009, SPM 2009, SDM 2010].

Research goal and methodology

Due to COVID-19 restrictions the trials were carried out as a remote experiment. Two servers: JTLS-GO and LOGFAS were located in the War Games & Simulation Centre (WG&SC) server room and were accessible via Virtual Private Network (VPN) to all participants of the experiment. Technical administrators prepared a configured environment for tests for both systems. JTLS-GO Database Development System (DDS) database users prepared right data in proper tables using logical, but not tested settings, especially in terms of RIC and NIC codes. Some other analysts used their knowledge and experience about how data should be prepared and how to set up two different systems to make a one-way connection possible. It is important to stress that no member of this team was experienced in this type of connection. On the one hand, JTLS-GO has prepared internal services which can generate export files for both a STARTEX state and states during the running game. On the other hand, LOGFAS has an ensured option and wizard for importing data from external sources in xml format with an established file structure. There is therefore the technical possibility of transferring data from JTLS-GO to LOGFAS. However, this possibility has never been fully tested.

The primary hypothesis concentrated on how to continuously transfer data from the JTLS-GO database to the LOGFAS database during a few days of CAX exercise.

Questions/Problems to resolve were:

1. How to fill the DDS database tables with real RIC and NIC codes to achieve a one to one relationship between a specific combat system in JTLS-GO and the RIC, NIC hierarchical codes tree in the LOGFAS system? This is an important issue in order that units in JTLS-GO and subsequently data processing in LOGFAS have the same equipment and supplies with the correct quantities in both systems.
2. Which NIC code formats (in terms of naming convention and length of the NIC codes) should be used to make it possible for JTLS-GO to produce correctly formatted export data for LOGFAS to import without any issues and overwriting of data? The assumption was that no even a single record should be lost.
3. How does changing combat system and supply category data in the JTLS-GO system as a result of enemy/opponent activities influence changing data in the LOGFAS system?

To sum up, the research concentrated on the idea of how to connect two quite different systems which are designed to work in different areas and achieve unidirectional data flow from the JTLS-GO simulation system into the LOGFAS logistic system. The next step in the development of the CAX exercises conducted with the Armed Forces Support Inspectorate (AFSI) every two years in WG&SC at the War Studies University in Warsaw is to connect these two systems on the next exercises. No one tried connecting these two systems before. AFSI is responsible for the national database of NICs and RICs and keeping it updated in coordination with other users (divisions, brigade etc). This is the national RIC and NIC master database.

The process of populating ORder of BATtle (ORBAT), forces, combat systems, supply categories data into internal DDS database in the JTLS-GO system and putting them without any errors into the LOGFAS database must be done in the following steps:

1. Firstly, the JTLS-GO and LOGFAS servers should be installed, configured, running and available for the users. This is the responsibility of technical administrators for both systems;
2. Secondly, an established force structure using their own combat systems and supply categories should be written and stored in the internal JTLS-GO database. The DDS database is accessible via a webpage which runs as a client similarly to WHIP for Players in JTLS-GO. Those clients are managed by WG&SC Operational Branch specialists who input all this data into DDS tables. In order to do that the DDS base needs to be filled with right data for units, combat systems, supply categories, targets and so on. Each combat system and supply category need to have their own RIC and NIC code which is recognized and used in LOGFAS. This data is confirmed during conferences which take place in the CAX development process in exercise control (EXCON) before an exercise runs for a training audience (TA). These are: Initial Planning Conference (IPC), Main Planning Conference (MPC) and Final Coordination Conference (FCC) [Çayirci and Marinčič 2009, North Atlantic Treaty

Organization 2013]. Between some of these conferences database workshops occur to develop the concept of the exercise to prepare the right environment for the TA. This virtual environment is necessary to develop the intended key processes and training objectives in order to achieve the desired planning outcomes. The final step is “frozen” in the DDS database, which cannot be changed after this time. This base is called the STARTEX database which is the database for the start of the exercise.

3. Thirdly, after preparation of the DDS base in JTLS-GO, the initial transfer of this data should be done. In this step it is mandatory to prepare right internal JTLS service setup. This service is called the LOGFASTS – LOGFAS Transaction Service [Rolands & Associates Corporation 2019a]. After running this service files should be created to enable export of the DDS data from the JTLS-GO simulation system. This data needs to be in a file and structure format which is recognizable by the LOGFAS system.
4. Fourthly, the technical administrator needs to prepare the LOGFAS server and configure an empty database ready to import data from the JTLS-GO system. The difference between LOGFAS and JTLS-GO is that LOGFAS can work with many databases simultaneously but that JTLS-GO only works with one in the same time. After creating the base, STARTEX data from the JTLS-GO DDS database need to be imported into the empty LOGFAS database enabling the creation of the Force Holding and Profile in the LOGFAS Database Management (LDM) module.
5. Fifthly, the JTLS-GO LOGFASTS service needs to be running during the whole game without any interruption to create update files at every set up period e.g. two hours.
6. Sixthly, during the execution phase of CAX exercise updates JTLS needs to sequentially update the state of all required objects in the LOGFAS system. Only then will the data in the LOGFAS guarantee proper logistic planning and command over logistics troops based on true quantities of equipment and supplies in all units.

Research results

Steps one to four were completed without any issues. All efforts were focused on sending the one to one ORBAT structure with command and logistics hierarchy as well as units with their own combat systems and supply categories. Some problems occurred when combat systems and supply categories needed to be relabelled with the right NIC and RIC codes. It turned out that during the STARTEX data preparation phase some of the NIC codes were too long and, in some cases, the imported data was overwritten causing errors.

Drilling down into the export files was needed to find the reason for the bugs in the LOGFAS database and comparison with the JTLS-GO database. After several trials operational branch specialists prepared the right methodology for inputting NIC codes.

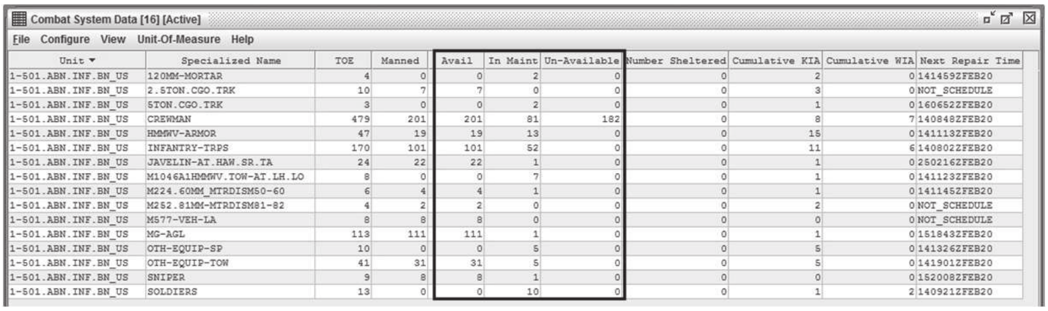
During testing a few questions arose and needed explanation:

1. JTLS-GO generates information about Combat Systems, Aircraft, and Supplies, which is then sent to the LOGFAS LDM, but the simulation system does not generate this kind of information about Targets, which are very important for the players – the participants of the exercise. The question is: how is it possible to send information about

Targets (Air Defense Class, Bridge Class, SSM (Surface-Surface Missile) Class, Jammer Type, Sensor Type) to the LOGFAS LDM?

2. During the game, JTLS-GO periodically generates files for the LOGFAS LDM. What should these files contain and how do they need to update data in the LOGFAS LDM?

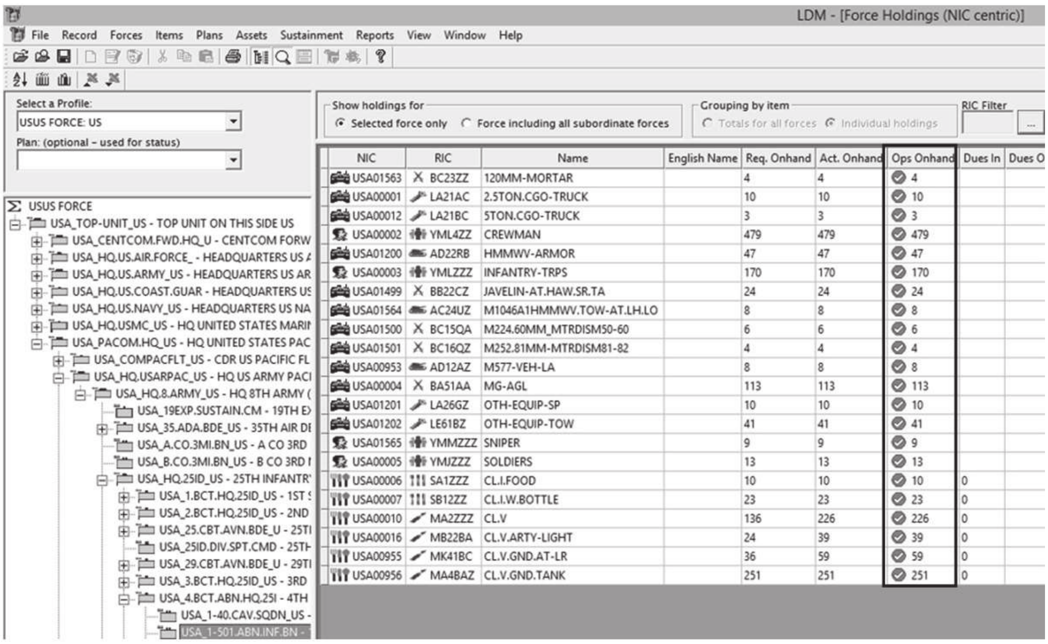
Figures 3 and 6 show JTLS-GO IMT tables containing 1-501.ABN.INF.BN_US unit combat systems. Upper table in Figure 3 shows combat systems before the pre-strike of opposing force whereas Figure 6 shows those combat systems after the post-strike. It is noticeable that most changes happened in HMMWV-Armor vehicles (15 destroyed in Cumulative KIA column), Infantry-Trps – infantry troops (11 killed in action in Cumulative KIA column), Crewmen (eight killed in action in Cumulative KIA column, seven wounded in action in Cumulative WIA column).



Unit	Specialized Name	TOE	Manned	Avail	In Maint	Un-Available	Number Sheltered	Cumulative KIA	Cumulative WIA	Next Repair Time
1-501.ABN.INF.BN_US	120MM-MORTAR	4	0	0	2	0	0	2	0	141459ZFEB20
1-501.ABN.INF.BN_US	2.5TON.CGO.TRK	10	7	7	0	0	0	3	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	5TON.CGO.TRK	3	0	0	2	0	0	1	0	160652ZFEB20
1-501.ABN.INF.BN_US	CREWMAN	479	201	201	81	182	0	8	7	140848ZFEB20
1-501.ABN.INF.BN_US	HMMWV-ARMOR	47	19	19	13	0	0	15	0	141113ZFEB20
1-501.ABN.INF.BN_US	INFANTRY-TRPS	170	101	101	52	0	0	11	6	140802ZFEB20
1-501.ABN.INF.BN_US	JAVELIN-AT.HAW.SR.TA	24	22	22	1	0	0	1	0	250216ZFEB20
1-501.ABN.INF.BN_US	M1046A1HMMWV.TOW-AT.LH.LO	8	0	0	7	0	0	1	0	141123ZFEB20
1-501.ABN.INF.BN_US	M224.60MM_MTRDISM50-60	6	4	4	1	0	0	1	0	141145ZFEB20
1-501.ABN.INF.BN_US	M252.81MM-MTRDISM81-82	4	2	2	0	0	0	2	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	M577-VEH-LA	8	8	8	0	0	0	0	0	NOT_SCHEDULE
1-501.ABN.INF.BN_US	MG-AGL	113	111	111	1	0	0	1	0	151843ZFEB20
1-501.ABN.INF.BN_US	OTH-EQUIP-SP	10	0	0	5	0	0	5	0	141326ZFEB20
1-501.ABN.INF.BN_US	OTH-EQUIP-TOW	41	31	31	5	0	0	5	0	141901ZFEB20
1-501.ABN.INF.BN_US	SNIPER	9	8	8	1	0	0	0	0	152008ZFEB20
1-501.ABN.INF.BN_US	SOLDIERS	13	0	0	10	0	0	1	2	140921ZFEB20

Figure 6. IMT Table showing Combat Systems of 1-501.ABN.INF.BN_US after strike of opposing force

Rysunek 6. Tabela IMT ze środkami walki batalionu 1-501.ABN.INF.BN_US po uderzeniu przeciwnika



NIC	RIC	Name	English Name	Req. Onhand	Act. Onhand	Ops Onhand	Dues In	Dues O
USA01563	BC23ZZ	120MM-MORTAR		4	4	4		
USA00001	LA21AC	2.5TON.CGO-TRUCK		10	10	10		
USA00012	LA21BC	5TON.CGO-TRUCK		3	3	3		
USA00002	YML4ZZ	CREWMAN		479	479	479		
USA01200	AD22RB	HMMWV-ARMOR		47	47	47		
USA00003	YMLZZZ	INFANTRY-TRPS		170	170	170		
USA01499	BB22CZ	JAVELIN-AT.HAW.SR.TA		24	24	24		
USA01564	AC24UZ	M1046A1HMMWV.TOW-AT.LH.LO		8	8	8		
USA01500	BC15QA	M224.60MM_MTRDISM50-60		6	6	6		
USA01501	BC16QZ	M252.81MM-MTRDISM81-82		4	4	4		
USA00953	AD12AZ	M577-VEH-LA		8	8	8		
USA00004	BA51AA	MG-AGL		113	113	113		
USA01201	LA26GZ	OTH-EQUIP-SP		10	10	10		
USA01202	LE61BZ	OTH-EQUIP-TOW		41	41	41		
USA01565	YMMZZZ	SNIPER		9	9	9		
USA00005	YMJZZZ	SOLDIERS		13	13	13		
USA00006	SA1ZZZ	CL.I.FOOD		10	10	10	0	
USA00007	SB12ZZ	CL.I.W.BOTTLE		23	23	23	0	
USA00010	MA2ZZZ	CL.V		136	226	226	0	
USA00016	MB22BA	CL.V.ARTY-LIGHT		24	39	39	0	
USA00955	MK41BC	CL.V.GND.AT-LR		36	59	59	0	
USA00956	MA4BAZ	CL.V.GND.TANK		251	251	251	0	

Figure 7. LOGFAS LDM module showing 1-501.ABN.INF.BN_US after strike of opposing force – no changes in Combat Systems

Rysunek 7. Moduł LOGFAS LDM ze środkami walki batalionu 1-501.ABN.INF.BN_US po uderzeniu przeciwnika – brak zmian w środkach walki

Source: own study based on LDM module.

Source: own study based on WHIP client.

Meanwhile, in Figure 7 showing the screen from LDM LOGFAS after updating data, there are no changes in active combat systems, which is obvious incorrect. These questions are still open and need to be resolved.

Unfortunately, these iterative tries provided proof that the update files from JTLS-GO were unexpectedly generated in a random time period and contained small items of wrong data. As one of many international users of the JTLS-GO system, the WG&SC, which is also the owner of contracted support rights according to a signing agreement, sent these conclusions to the JTLS-GO producer in order to initiate the process of fixing the bugs in the simulation system code and improve service work.

Summary and conclusions

As mentioned above six basic steps are needed to achieve full success. Unfortunately, the trials showed that only the first four steps could be completely successfully. The internal update service in the JTLS-GO system which is used to fill and update data in the LOGFAS system definitely was the interoperability issue. It was the first time, that this connection was made by the PAF (Polish Armed Forces), and it is quite probable that it was also the first time within NATO. The trial suggests that there is an issue with the data update process after each game turn. We believe that this issue has not been raised before with Roland's & Associates Corporation and hope that this problem can be resolved promptly by the issue of a patch or in the next version. This will enable input to prepare a much more precise and realistic environment for training audiences during CAX exercises.

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Electromobility in public transport – good practices and experiences of cities in Poland

Elektromobilność w publicznym transporcie zbiorowym – dobre praktyki i doświadczenia miast w Polsce

Abstract. Social and economic transformations in the 21st century brought many new changes in the lifestyle of the inhabitants, in the system of social values and urban mobility. In recent years, the desire to improve the quality of life of the inhabitants of urban areas was recognised by an increasing emphasis on environmental issues. For this reason, both national and European strategic documents indicating the direction of the development of public transport impose a number of restrictions on the negative impact of transport on the environment. One way of achieving ambitious targets in this area is to develop and popularize electromobility in cities. The article presents technical, economic, social and legal conditions of electromobility in Poland. Moreover, a review of good electromobility practices in public public transport was made and perspectives of further development of Polish cities in the aspect of electromobility were described and a SWOT analysis was made. The aim of the article is to identify factors, potential and limitations resulting from the implementation of electromobility in public public transport in Poland.

Key words: electromobility, electric buses, collective public transport

Synopsis. Przemiany społeczno-gospodarcze w XXI wieku przyniosły ze sobą wiele nowych zmian w stylu życia mieszkańców, systemie wartości społecznych i mobilności miejskiej. W związku z chęcią poprawy jakości życia mieszkańców aglomeracji miejskich, w ciągu ostatnich lat coraz większy nacisk kładziony jest na zagadnienia związane z ekologią. Z tego względu zarówno krajowe, jak i europejskie dokumenty strategiczne wskazujące kierunek rozwoju publicznego transportu zbiorowego narzucają wiele ograniczeń dotyczących negatywnego oddziaływania transportu na środowisko naturalne. Jednym ze sposobów osiągnięcia ambitnych celów w tym zakresie jest rozwój oraz rozpowszechnienie elektromobilności w miastach. W artykule przedstawiono techniczne, ekonomiczno-społeczne i prawne uwarunkowania elektromobilności w Polsce. Ponadto dokonano przeglądu dobrych praktyk elektromobilności w publicznym transporcie zbiorowym oraz opisano perspektywy dalszego rozwoju polskich miast w aspekcie elektromobilności, oraz dokonano analizy SWOT. Celem artykułu jest identyfikacja czynników, potencjału i ograniczeń wynikających ze wdrożenia elektromobilności w publicznym transporcie zbiorowym w Polsce.

Słowa kluczowe: elektromobilność, autobusy elektryczne, publiczny transport zbiorowy

Introduction

The electrification of road vehicles in collective public transport has now become a global megatrend. The key to understanding it lies in urban mobility. In European capitals, the share of public collective transport is often above 30%. In Helsinki and Lisbon, the share of collective public transport in the city is 34%, in London and Paris 36% and in Vienna, which is known for its high quality of these services, as much as 39%. In Madrid this percentage is 42%, in Prague 43%. Warsaw is even higher in this ranking. In the Polish capital as much as 47% of all urban traffic is served by subway and buses [Czernicki et al. 2019].

Public transport is the core of electromobility in Poland. Investing in new electric buses is a global trend. The main stimulus for its development is the desire to become independent of oil-derivative fuels and to reduce direct emissions from vehicles, which may contribute to the improvement of air quality in a given area. One of the pillars of the European Union's socio-economic policy is sustainable development aimed at a low-carbon economy, and electromobility is a part of this approach. For Poland, this is important for both environmental and energy security reasons. Poland belongs to the countries at the forefront of collective electro-mobility. Electrification of road vehicles in public collective transport provides certain environmental and operational benefits, improving the quality of life in cities. These include, among others, the lack of pollutant emissions at the place where electric buses are used, and the possibility of creating Clean Transport Zones, improving travel comfort and reducing noise emissions. This means that electric buses are becoming more and more popular and their supply is steadily growing.

Legal aspects of electromobility in Poland

In Poland, electromobility began in 2017, when the government adopted the Electromobility Development Plan on 17 March [Olkuski and Grudziński 2019]. The Electromobility Development Plan is one of the flagship projects of the Strategy for Sustainable Development (in Polish: SOR). This strategy assumes the production of electric vehicles and the construction of the necessary infrastructure, which will allow, among other things, for the creation of ecological public transport in Polish cities. The multidimensional objectives and activities to be brought about by the development of electromobility in Poland are based on a number of strategic documents, which form the formal basis for any actions to be taken by private bodies or entities. The implementation of the SOR objectives and the Electromobility Development Plan became the basis for the creation of a regulatory package consisting of the following strategic documents:

- the Electromobility Development Plan "Energy to the Future", adopted by the Council of Ministers on 16 March 2017,
- National Policy Framework for Development of Alternative Fuels Infrastructure, adopted by the Council of Ministers on 29 March 2017,
- Electromobility and Alternative Fuels Act of 11 January 2018,
- the Act establishing the Low-Emission Transport Fund, i.e. the Act of 6 June 2018 amending the Act on Biocomponents and Liquid Biofuels and other acts, signed on 10 July 2018.

The first package of regulations is the Electromobility Development Plan in Poland, which defines the benefits associated with the popularization of electric vehicles in our country and identifies the economic and industrial potential of this area. It includes detailed objectives of the electromobility plan, e.g.:

- to create conditions for the development of electromobility in Poland through the popularization of charging infrastructure and incentives to purchase electric vehicles,
- industrial development in the field of electromobility,
- the stabilization of the electricity grid through the integration of vehicles into the grid.

The foundations of the electromobility ecosystem along with the coordination of the development of the electromobility industry and the stimulation of the demand for electric vehicles will be provided for the successful development of electromobility [Ministerstwo Energii 2017]. In addition, the role of the administration plays a key role in the implementation of this process. In order to implement the assumptions of the Electromobility Development Plan in Poland, actions should be taken in the area of social, technological and legal conditions, as shown in Figure 1.

The Electromobility Development Plan in Poland provides for the use of appropriate tools that will create an algorithm optimizing and limiting the deployment of infrastructure to the so-called critical locations, i.e. where the lack of charging points will reduce the functionality of an electric vehicle. It is important that the algorithm should seek synergy between the development of passenger car charging infrastructure and the development of public transport infrastructure. At the same time, the Plan proposes tools for the development of the electric vehicle market, which will lead to an increase in the number of electric vehicles when a significant part of the infrastructure is ready. An additional factor that has been taken into account when proposing a sequence of actions consists in the need to link the development of the electromobility industry and the vehicle market with the development of the electricity grid. Incentives to purchase vehicles will be stepped up as soon as the industry is able to respond to the demand generated by the support instruments and the network is able to meet the growing demand for vehicle charging capacity and energy. The social aspect is also a tool for the development of electromobility in Poland. Increased awareness of city dwellers and the resulting change in the choice of means of transport from individual to public transport will positively affect the state of the natural environment and reduce the chronic phenomenon of congestion.

The second package of legal regulations is contained in the National Policy Framework for the Development of Alternative Fuels Infrastructure, adopted by the Council of Ministers on 29 March 2017. Alternative fuels within the meaning of the Directive are fuels or energy sources which serve, at least partially, as a substitute for crude oil

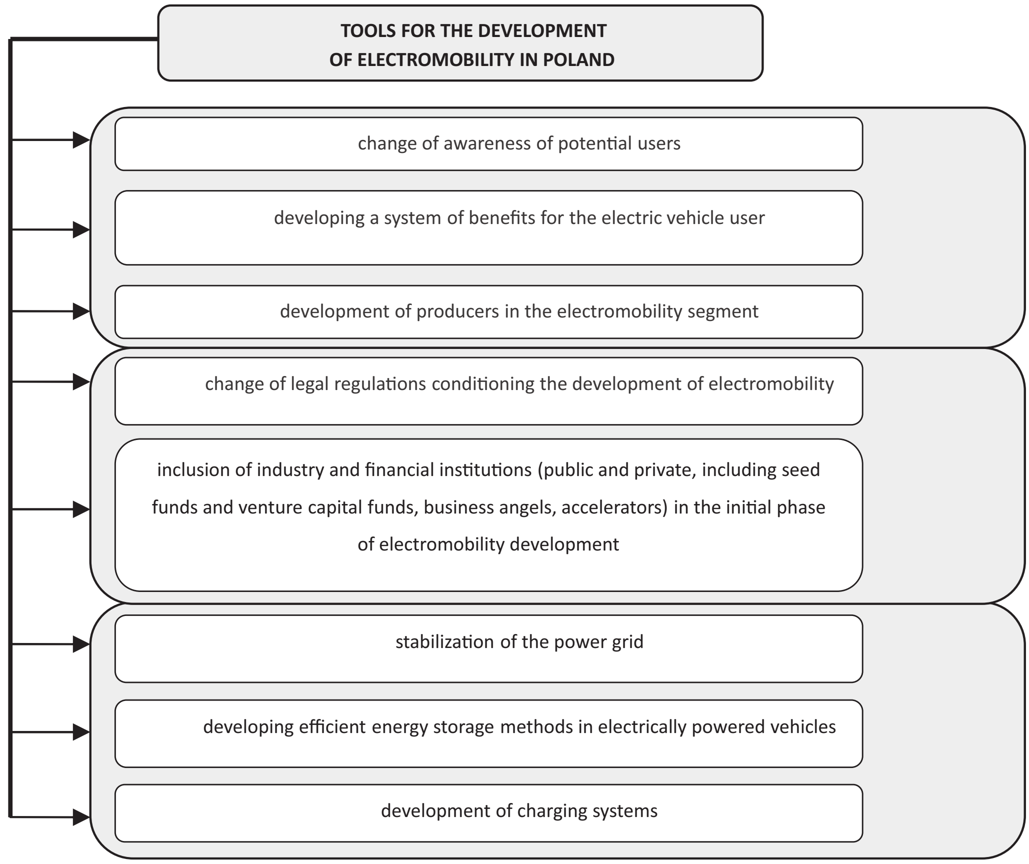

Figure 1. Tools for the development of electromobility in Poland
Rysunek 1. Narzędzia rozwoju elektromobilności w Polsce
Source: own elaboration based on [Ministerstwo Aktywów Państwowych 2019].

sources of energy in transport and which may potentially contribute to reducing the dependence of EU Member States on oil imports and to increasing the climate neutrality of transport and improving the environmental performance of this sector. These include, inter alia, electricity, hydrogen, biofuels, synthetic and paraffin fuels, natural gas (including biomethane) in the form of compressed natural gas (CNG) and liquefied natural gas (LNG) and LPG.

According to the report presented by the Ministry of Energy at the end of July 2019, 971 normal capacity charging points, 486 high capacity charging points and 28 CNG filling stations were available in Poland [Centrum Informacji o rynku Energii]. The national policy framework for the development of alternative fuel infrastructure sets out objectives, according to which, by the end of 2020, 32 selected agglomerations in Poland should offer six thousand charging points of normal power, 400 charging points of high power and 70 refueling points of compressed natural gas (CNG) [Ministerstwo Energii 2017]. At the same time, the report shows that 4,009 electric vehicles, 2,321 plug-in hybrid vehicles and 4,900 CNG vehicles were in use in Poland at the end of July [Ministerstwo Energii 2017].

The National Policy Framework for the Development of Alternative Fuel Infrastructure predicted that in 2020 and 2025, approximately 70,000 and 1 million electric cars would be registered in Poland, respectively. The draft of National Energy and Climate Plan assumes that there will be 50,000 electric cars in 2020 and about one million electric cars in 2025. Similar values are also provided for in the draft of Energy Policy of Poland until 2040. According to the data presented in the National Policy Framework, in the years 2020 and 2025, in Poland, almost 9.6 thousand and 54.2 thousand vehicles powered by natural gas CNG and about 0.5 thousand and over 2.7 thousand vehicles powered by natural gas LNG are to be registered respectively.

The monitoring of the level of achievement of the objectives set out in the National Policy Framework for the Development of Alternative Fuels, as well as the assessment of the level of achievement of these objectives by the Minister of Energy results from the provisions of the Directive of the European Parliament and of the Council on the development of alternative fuel infrastructure and the Act of 11 January 2018 on Electromobility and Alternative Fuels, which is the third package of electromobility regulation in Poland.

The Act on Electromobility and Alternative Fuels sets out the conditions for the development of and rules on the deployment of alternative fuel infrastructure for transport, on the provision of charging services for electric vehicles and on the refueling of natural gas vehicles. It also sets out information obligations on alternative fuels and the establishment of clean transport zones. The infrastructure for alternative fuels is to be developed in urban agglomerations, in densely populated areas and along major roads at an early stage. In this context, the Act focuses on charging stations for electric vehicles and natural gas stations. It defines the rules concerning the way of informing consumers about alternative fuels, the way of marking distributors and vehicles and the rules of creating and functioning of the Alternative Fuel Infrastructure Register. The Act provides a number of benefits for electric vehicle drivers, including an exemption from excise duty on the purchase of electric vehicles and hydrogen-powered vehicles, the possibility to drive electric vehicles on bus lanes, additional parking spaces and exemption from certain fees. The Act provides a legal framework for testing autonomous vehicles on public roads. In addition, it provides a legal basis for municipalities to introduce clean transport zones for environmentally friendly vehicles. The first clean transport zone in Poland was established in Kraków. It limits the movement of cars with combustion engines, thus promoting the so-called ecological transport, i.e. electric cars. The Act on Electromobility and Alternative Fuels is to stimulate the development of electromobility and promote the use of other alternative fuels in the transport sector in Poland.

The fourth package of electromobility regulation in Poland takes the form of the Low-Emission Transport Fund, which is administered by the Minister of Energy. The task of the Fund is to finance projects related to the development of electromobility and transport based on alternative fuels. Thanks to the funds from the Fund, the activities listed, among others, in the National Policy Framework for Alternative Fuel Infrastructure Development, the Electromobility Development Plan in Poland and the act of 11 January 2018 on electromobility and alternative fuels, i.e. documents implementing into Polish law the assumptions of EU regulations on the development of alternative fuel infrastructure will be carried out. The Low Emissions Transport Fund supports the development of alternative fuel infrastructure and the creation of a market for vehicles using these fuels.

The main benefits of launching financing from the Low Emissions Transport Fund include:

- the development of infrastructure for refueling natural gas, liquid biofuels and other alternative fuels and for charging electric vehicles,
- the possibility of introducing new business models based on alternative fuels and their infrastructure,
- the development of low-carbon vehicle fleets and low-carbon public transport,
- possible reduction in the costs of using alternative fuel vehicles for citizens,
- improvement of air quality resulting from the reduction of harmful emissions from road vehicles, particularly in large agglomerations.

According to the forecasts of the Ministry of Energy, the implementation of four regulatory packages dedicated to the development of electromobility in Poland is expected to result in the achievement of the following objectives for 2020 and 2025 [Ministerstwo Aktywów Państwowych 2019].

In 2020, in 32 selected agglomerations:

- in the electric vehicle segment: 50,000 vehicles will be moving on the roads, 6,000 points of normal charging power (the so-called slow charging points with a power not exceeding 3.68 kW) and 400 points of high charging power will be constructed,
- in the segment of cars powered by natural gas in the form of CNG (compressed natural gas), 3,000 vehicles will be moving on the roads and 70 refueling points will be constructed.

On the national level, the following indicators concerning electromobility are forecast for 2025:

- 1 million electric vehicles on the road,
- in the CNG segment of natural gas vehicles: 54,000 vehicles will be on the roads and 32 charging points will be available along the TEN-T core network.

Apart from the indicated documents, the political and legal grounds for the development of electromobility in Poland are based on the resolutions of the municipal councils in the form of Sustainable Development Plans for Public Transport and Sustainable Urban Mobility Plans.

Electromobility and sustainable development of public transport in the cities

At present, there is no turning back from urban transport development based on low-emission vehicles. Implementation of innovative solutions in the aspect of urban rolling stock electrification is aimed at improving the quality of life of the inhabitants by reducing the external costs of transport, i.e. noise or environmental pollution. Pro-ecological actions taken by city authorities are based on the principles of sustainable development. Before presenting the concept of sustainable development, one should look at the definitions of sustainability and development itself. The fundamental human desire to protect and improve the quality of life can be called sustainability. The concept of sustainability includes integrated human activities (the need for coordinated decisions between different interest groups, sectors and legislative systems) [Fajczak-Kowalska and Kowalska 2017]. On the other hand, development is inseparably connected with the continuity of the process of transformation (constant movement and related mutual influence of phenomena taking place in the surrounding reality). This process cannot exist without stable institutional, ethical, social, legal, technological and organisational foundations, which set directions and shape the behaviour of development entities.

Sustainable development of transport is a concept based to a large extent on creating an opportunity to seek a compromise between three components: economic, social and ecological reasons [Rokicka and Woźniak 2016]. A sustainable urban public transport system is a transport system that meets the communication needs of city dwellers [Chamier-Gliszczyński 2011]:
- in a safe manner that does not endanger human health or the environment,
- using renewable energy sources,
- economically accessible for the city residents,
- aiming at reducing harmful gas emissions,
- capable of functioning effectively, sustaining the economy and regional development,
- not causing congestion.

Public transport has important social, economic, spatial and environmental impacts and therefore it is an essential factor in relation to the sustainability of society and the economy. This is due not only to the implementation of legislation, both at European and national level, but also to the increasingly widespread greening of urban agglomerations and city authorities encouraging the use of electrified forms of transport.

From the passenger's point of view, the fact that an electric or diesel bus will drive to a bus stop does not determine the passenger's transport decisions. Only a holistic approach to urban transport services can determine its choices. Skillful application of road traffic incentives and privileges for public transport is currently a priority action, carried out within the framework of the implementation of sustainable mobility and development policies in order to increase the use of environmentally friendly forms of urban transport over individual transport.

Regardless of the rolling stock used, privileged treatment makes it possible to improve travel conditions for public transport passengers and improves the modal split between individual and public transport towards greater use of public transport [Motowidlak et al. 2019]. This in turn translates into a reduction in the number of individual means of transport in daily urban traffic, which is reflected, inter alia, in a lower need for space for car infrastructure (roads, parking lots) and a reduction in the chronic phenomenon of congestion on city roads.

Traffic is one of the factors that influences the poor air quality in cities. Although it is not the main cause of smog, but it significantly raises its level. It is also a substantial source of other pollutants. Road transport vehicles are also the main cause of noise in the vicinity of roads. The use of traffic priorities for public transport is an adequate means of action in the framework of urban transport policies. The most common solutions encouraging residents of urbanized areas to use low-emission public transport implemented in cities include the bus lanes. These are dedicated lanes where only bus traffic (or of other selected vehicles, e.g. taxis or special vehicles) is allowed. They are particularly effective on road sections with traffic jams [Szada-Borzyszkowski and Szada-Borzyszkowska 2017]. It is also possible to separate a part of the roadway for buses within the tram track. A special case of priority for bus transport is the bus lock, which consists in giving a signal to the bus allowing it to occupy any lane at the entry to the crossing before it is filled up with other vehicles.

Each of these measures is designed to reduce public transport travel times, which is an incentive for city dwellers. Thanks to the independence of bus transport from road traffic, the reliability of this means of transport is also increased and the randomness of its travel times is reduced.

City dwellers expect a high quality of life, which is considered to be the most important factor influencing the development of electromobility. Striving to improve the quality of life should be considered the overriding premise for the development of electromobility in urban public transport. It has mainly a social dimension.

Additional important drivers for the development of electrification of public transport in cities include the following aspects [Szumska and Witkowski 2018]:

- business – related to supporting the national capacity to build strong operators at all stages of the electromobility value chain,
- economic – resulting from the pursuit of rationalization of urban transport costs,
- transport – subordinated to the need to improve road traffic conditions,
- technical-technological – resulting from the possibility of powering vehicles with electric energy,
- operational – related to the susceptibility of public transport to implementation of electromobility,
- ecological – the expression of the aspiration to protect the natural environment.

Public collective transport is more susceptible to electrification than individual transport. This is due in particular to the fact that public transport has a regular character and is based on a timetable which determines the route, stops and departure times. Therefore, this specificity makes it easier to adapt the location of charging points due to the limited range of electric buses. In the case of a bus, there is no urgent need for a change of route or additional transport, which is acceptable in the case of cars used by private individuals or companies in the TSL sector.

This is why city buses have the greatest chance to become the first fully electrified group of means of transport in Poland.

Good practices of electromobility in public transport on the example of Polish cities

Solaris Urbino 12 electric is the most popular example of electric bus in Poland. It is a low-floor bus designed for passenger transport in cities. The energy of the vehicle is stored in two lithium-ion batteries with a capacity of 240 kW, which are located in the roof superstructure of the bus. The vehicle can be loaded in two ways. Either by means of a pantograph (Figure 2), which enables charging at bus stops or a plug-in connector (Figure 3), enabling charging by means of a charger located in the bus depot.

The bus is 12 meters long and has 30 seats. Buses of this brand have been manufactured in electric version by the manufacturer Solaris since 2011. In September 2017 Solaris Urbino 12 electric (new generation) was awarded at the prestigious fair in Hannover with the statuette “Bus of the Year”, winning in its category city buses with manufacturers such as: Irizar, Mercedes, Ebusco, Van Hool [Wierzbowski 2019]. Until 2015, these

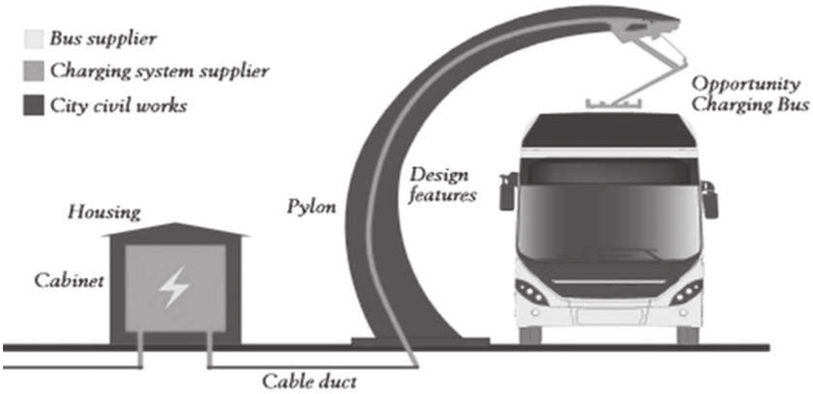

Figure 2. Electric bus charging scheme based on pantographs
Rysunek 2. Schemat ładowania autobusów elektrycznych oparty na pantografach
Source: [MM Magazyn Przemysłowy 2015].

Figure 3. Electric bus charging scheme based on the plug-in connector
Rysunek 3. Schemat ładowania szyny elektrycznej oparty na złączu wtykowym
Source: [TrackFocus 2011].

buses were mainly delivered to foreign customers, among which we can mention: Czech Republic, Spain or Germany.

The buses of this brand were also delivered to cities in Poland, serving urban passenger transport in cities such as Warsaw, Cracow, Jaworzno and Inowrocław.

Warsaw (Warszawa)

In June 2019, the fleet of electric buses operated by Miejskie Zakłady Autobusowe Sp. z o.o. in Warsaw (MZA Warszawa) consisted of 31 vehicles, which constituted 2% of the city bus fleet [Dybalski 2019]. 20 Solaris Urbino 12 electric buses and 10 Ursus City Smile 12 LFE buses operated in the city. When operating low-emission buses, Warsaw is guided primarily by social expectations regarding the quality of life in the city and the need to meet the requirements of the Act on Electromobility and Alternative Fuels. These expectations can be met by through total elimination of conventional fuels from city bus supply systems in the perspective of several dozen years to come [Urbanowicz 2018].

Warsaw MZA is one of the largest communication companies in Europe [Motowidlak et al. 2019]. Every day, it sends over 1.2 thousand buses to the streets of Warsaw. MZA Warsaw is also one of the European pioneers in the introduction of electricity and a low--carbon fleet to operate public transport. The development of electromobility is financed by MZA Warsaw with own funds, EU funds and loans. The limited availability of financial resources and the lack of bus charging points in the city are perceived by MZA Warsaw as the main barriers to the development.

Cracow (Kraków)

Cracow was the first of the big Polish cities to start testing electric buses. It is the first city in Poland to have a regular line operated by electric buses and a station for charging buses by a pantograph [Dybalski 2018]. It was also the residents of the capital of Małopolska Region who, as the first in Poland, had the opportunity to travel by the articulated electric bus. Deciding to operate electric buses, the city of Cracow is looking for solutions that will allow on the one hand to develop public transport, and on the other hand, to meet increasingly stringent environmental standards.

The use of electric buses to provide urban transport services is part of Cracow's strategic, low-carbon policy and reducing air pollution from urban transport [Motowidlak et al. 2019]. As early as in 2014, Miejskie Przedsiębiorstwo Komunikacyjne Sp. z o.o. in Cracow (MPK Kraków) tested electric buses in urban traffic.

Many months of testing confirmed, among other things, large savings for the carrier. It turned out that electricity costs for electric buses account for about a quarter of diesel costs. On average, MPK Kraków spent PLN 1327.21 thousand on driving a diesel bus for a million kilometers, while PLN 335.2 thousand for electricity is needed to cover this distance by the electric bus [Motowidlak et al. 2019].

With the objective of meeting the requirements of the Act on Electromobility and Alternative Fuels, the Cracow authorities have adopted general assumptions regarding the increase in the number of city bus fleets. These assumptions imply that at least 153 such buses must be purchased in the coming years, with the purchase to be carried out in the following manner: 3 electric buses until 2021.

The Cracow authorities plan that in 2025 one third of the city buses will be electrically powered and the others will meet the combustion standard of at least Euro 6 or use hybrid drive. The implementation of this plan may ensure the position of the city as one of the leaders in the development of electromobility in Poland.

Jaworzno

Jaworzno was the first city in Poland which in 2015 introduced an electric bus to permanent operation. In 2019, as of July 31, from about 60 buses used in the city, 23 were the electric vehicles [pap/mg 2019]. All electric buses have been equipped with a pantograph charging system, thanks to which the batteries can be recharged both on the route and in the depot. As a standard, the vehicles have a Plug-In connector for night topping up the battery from a stationary charger located in the depot. Thanks to the use of both depot chargers and pantograph chargers installed in the city, the operation of electric buses in Jaworzno is practically unlimited. Buses, thanks to wheelchair ramps and special bays, are adapted for the transport of disabled people. In addition to the extensive passenger information system, the manufacturer has installed an intelligent fleet management system in vehicles consisting of a location device and a GPS antenna, enabling real-time display of arrival and departure times from individual stops.

By 2020, the city intends to buy another 20 electric buses, and will also participate in the tests of prototypes of autonomous public transport vehicles. Thanks to the purchase of 20 new electric buses, as much as 80% of the PKM Jaworzno fleet will be electric vehicles, which will mean that in 2020 Jaworzno may become the first Polish city with completely zero-emission public transport.

Inowrocław

Inowrocław in 2020 enrolled on the map of Poland as the leader of electromobility. This is the first city in Poland with completely ecological rolling stock. Inowrocław is a spa town. 85 hectares of brine park are areas under special supervision. Therefore, the idea of introducing zero-emission vehicles was a priority for the city’s authorities. It was one way to improve air quality in the city. The first activities towards the implementation of electromobility were carried out in 2015, when classic hybrids (eight buses) were purchased. The effects were visible after a year from the implementation of the newly purchased rolling stock. In 2015, according to the World Health Organization, Inowrocław was the only Polish city that met stringent requirements for air purity [Motowidlak et al. 2019]. WHO examined around 150 cities in Poland in terms of air quality. Inowrocław took first place in 2016. All types of buses for Inowrocław were entirely manufactured in Poland, at the Volvo factory in Wroclaw. The city successively implements its activities in modern transport trends and already today meets the legal requirements for zero-emission public transport, which will be in force in Poland only from 2025. However, the city does not stop there and strives for further development. To this end, it is necessary, however, to plan and set directions for action, what the current Strategy for the development of electromobility for the City of Inowrocław is to help. A modern charging infrastructure has also been created – four pantographs are used for quick charging of electric buses during the implementation of courses in various parts of Inowrocław. Volvo 7,900 electric hybrid buses differ from classic hybrids in that they are mostly powered by electricity on most routes. The small internal combustion engine has only an auxiliary function. They can travel in electric mode about 70% of the route (depending on the conditions in which it moves), and the battery is topped up at the end stops and lasts only three to six minutes [Motowidlak et al. 2019]. Electric hybrids can also be charged in the depot using a plug-in connector, with a full charge of their battery requiring about two hours. Both charging methods are used in Inowrocław.

Prospects for further development of electromobility in Poland – SWOT analysis

The process of transformation in public transport from a fleet of conventional buses to a fleet of 100% electric buses requires a scientific approach, but and rational planning of all processes. This requires an analysis of the political, economic and business environment in Poland. Such an analysis must include planning future activities in order to create conditions for the realization of these intentions, depending on the importance (attractiveness). For this purpose, a SWOT analysis was carried out to determine the current state of electromobility in Poland and the prospects for its further development. The results of the analysis are presented in Figure 4.

STRENGTHS	WEAKNESSES
– energy efficiency – environmental benefits – promoting modal shift – enrichment of opportunities for travel for sers	– cost of living – limited travel range – demand for dedicated spaces – initial investment in rolling stock and charging stations – long charging time for buses using low-budget chargers – local shortages of power reserves and capacity of the power grid
OPPORTUNITIES	THREATS
– possible synergies in combination with low emission zones and parking activities – possible renewal of the public transport fleet – possibility to optimise electricity consumption by adjusting the charging time to the minimum load of the energy systems or building an infrastructure for replacing vehicle batteries	– underdeveloped network of voltage lines, necessary for power output in case of building significant electricity sources – uncertainty in the market (such as plugs and charging standards) – difficulties in obtaining land for network investment

Figure 4. SWOT analysis of electromobility in Poland
Rysunek 4. Analiza SWOT elektromobilności w Polsce
Source: own elaboration.

The basic problems in the implementation of the plan for the development of electromobility in Poland are the functionality of low-emission rolling stock in public transport. There is no doubt that low fuel and operating costs (e.g. no need to change oil or some filters) are a very attractive asset for the electric rolling stock, and financial incentives can offset the high acquisition cost, which is a significant barrier to access.

Batteries are a key element of electric rolling stock in public transport, but for the whole electromobility ecosystem, charging stations are also important. Lack or inadequacy of these stations is currently the main barrier to be overcome on the road to the spread of electromobility in Polish cities.

The issue of ensuring sustainable urban mobility will be one with the most important tasks that will be faced by metropolitan self-governments in the future. Already today, many of them are facing increasing vehicle traffic, an overloaded and inefficient public transport system and at the same time want to combat air pollution. Settlement factors In the city, access to work, infrastructure, including low-carbon public transport, is now a major challenge in terms of planning and urban transport efficiency.

Conclusions

Transport is currently responsible for a significant proportion of CO_2 emissions. Forecasts assume that by 2050 carbon dioxide emissions from this sector will increase from 6–7 gigatons to 16–18 gigatons [Leonardo ENERGY.pl 2018].

In addition, around 30% of Europeans live in cities where air pollution levels exceed EU air quality standards. Conventional fuels consumed by buses are one of the largest sources of emissions of: CO_2, nitrogen oxides and particulates. In order to improve the quality of life and protect the natural environment, a law on electromobility and alternative fuels has been adopted in Poland, and the Electromobility Development Plan and the National Policy Framework for the Development of Alternative Fuel Infrastructure have been introduced. Electrification of transport has become a common trend leading to the achievement of sustainable development. Electric buses in Polish cities improve the quality of life of city dwellers by reducing air pollution and noise. Environmental protection and constant technological progress make electric buses the future of public transport, along with trams, subways, fast urban railways and other electric vehicles.

The number of electric buses in Polish cities is growing at a record pace, bringing benefits to residents, transport operators and vehicle manufacturers. Electromobility is able to significantly reduce air pollution and noise in cities, and electrification of public transport can be the first important step in the transition to "clean" individual transport for citizens.

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The impact of Intelligent Transportation Systems on road safety in Poland

Wpływ ITS na bezpieczeństwo ruchu drogowego w Polsce

Abstract. An Intelligent Transportation System is a modern solution which aims to improve the functioning of transport by, among other things: reducing congestion, shortening travel time, or improving road safety. This solution is used in many cities around the world, bringing economic effects and improving the comfort of life of the inhabitants. In Poland, as a result of the European Union's promotion of the development of intelligent transport systems through their co-financing, many cities have introduced such solutions. In the article, against the background of theoretical considerations, the impact of intelligent transport systems on road safety in the years 2014–2018 was analysed on the example of selected cities.

Key words: Intelligent Transportation System, cities, road safety

Synopsis: Inteligentny System Transportowy to nowoczesne rozwiązanie, którego celem jest poprawa funkcjonowania transportu poprzez między innymi: zmniejszenie kongestii, skrócenie czasu podróży czy poprawę bezpieczeństwa ruchu drogowego. Rozwiązanie to jest stosowane w wielu miastach na świecie, przynosząc efekty ekonomiczne, oraz poprawiając komfort życia mieszkańców. W Polsce w wyniku promowania przez Unię Europejską rozwoju inteligentnych systemów transportowych, poprzez ich dofinansowywanie, wiele miast wprowadziło tego typu rozwiązania. W artykule na tle rozważań teoretycznych przeanalizowany został wpływ inteligentnych systemów transportowych na bezpieczeństwo ruchu drogowego w latach 2014–2018 na przykładzie wybranych miast.

Słowa kluczowe: Inteligentny System Transportowy, miasta, bezpieczeństwo ruchu drogowego

Introduction

According to studies presenting world population forecasts, by 2030 almost 5 billion (61%) of the 8.1 billion people in the world will live in cities [Smart City... 2016, Eurostat 2019, Sumara 2019, Worldsensing]. This means that there will be more and more older people in cities, more cars, and more demand for transport services. This, in turn, will increase congestion, the demand for parking spaces, the number of road accidents and the deterioration of the environment. To address these risks, many cities around the world are introducing Intelligent Transportation Systems (ITS) to address urban transport problems and to pursue the Vision Zero concept [ISSA n.d.]. The implementation of Intelligent Transportation Systems solutions is having positive effects. In 1999 the Helsinki Public Transport Signal Priority and Passenger Information (HeLMi) system was launched. Six European cities participated in this programme. The energy savings achieved for all seven cities are equivalent to 57,000 tonnes of petrol [Szczukiewicz 2004]. In contrast, the application of the congestion charge introduced in London in 2003 reduced the size of the congestion in the toll zone by over 20% in 2006 already [Transport for London 2007, Ciepaj 2012]. In turn, in Kraków, after the implementation of the traffic management system, the driving time will be reduced. On the Kurdwanów–Krowodrza Górka route, where before the ITS implementation the scheduled driving time was 42 minutes, it has decreased to 36 minutes [Selwon 2017]. Also, more and more cities in Poland have this type of solutions, which improves the functioning of transport.

The aim of the article is to present ITS solutions introduced in selected voivodeship cities and an attempt to assess their impact on the number of road accidents in the years 2014–2018. The research methods adopted for the implementation of the problem are a diagnosis of the subject literature and documents and an analysis of quantitative data showing the discussed problem.

The Intelligent Transportation Systems concept and its benefits

The concept of Intelligent Transportation Systems was introduced at the first World Congress on Intelligent Transport Systems in Paris in 1994. It denotes systems that represent a wide range of different technologies (telecommunications, IT, automation and measuring) as well as management techniques used in transport in order to increase the safety of traffic participants, increase the efficiency of the transport system and protect environmental resource [European Communities 2004, Koźlak 2008, B.W. n.d.]. Since then, a variety of studies on ITS implementation and the desired and obtained benefits have been developed [Grant-Muller 2014, Kolosz 2015, Mitsakis 2015, Alrovi 2017]. These studies indicate specific groups of services (Table 1) resulting in specific changes (Table 2) [Oskarbski 2006, Koźlak 2008].

Among the presented effects of the implementation of intelligent transportation systems, the benefits related to the improvement of road safety are clearly visible, reaching up to 80%. The area of road safety is one of the most important from the European Union's point of view [Directive 2010/40/EU…]. Intelligent Transportation Systems should include systems that promise the greatest potential for improving road safety, such as automatic speed supervision, intelligent speed adjustment, collision avoidance systems, and lane and track keeping assistance systems. Infomobility [Drive Safely…] is an important solution in this area [Smirnov et al. 2014]. In a study conducted in the UK it was discovered that reducing the average speed by 3 kph every year in Europe would save the lives of 5,000 to 6,000 people and allow for avoiding 120,000 to 140,000 accidents,

Table 1. Division of Intelligent Transport Systems according to ISO TC 204
Tabela 1. Dział inteligentnych systemów transportowych zgodnych z ISO TC 204

Category of services	Service number	Service name
Traveller information	1	pre-trip information
	2	on-trip driver information
	3	on-trip public trasport information
	4	personal information services
	5	route guidance and navigation
Traffic management	6	transportation planning support
	7	traffic control
	8	incicdent management
	9	demand management
	10	policing/enforcing traffic regulations
Vehicle	12	vision enhancement
	13	automated vehicle operation
	14	longitudinal collision avoidance
	15	lateral collision avoidance
	16	safety readiness
	17	pre-crash restrain deployment
Commercial Vehicle	18	commercial vehicle pre-clearance
	19	commercial vehicle administrative process
	20	automated roadside safety inspection
	21	commercial vehicle on-board safety monitoring
	22	commercial vehicle fleet management
Public transport	23	public transportation management
	24	demand responsive transport management
	25	shared transport management
Need for assistance (Emergency)	26	emergency notification and personal security
	27	emergency vehicle management
	28	hazardous materials and incident notification
Electronic Payment	29	electronic financial transaction
Safety	30	public travel safety
	31	safety enhacement for vulnerable road users
	32	intelligent junctions

Source: own work based on: [McQueen 1999, Bartczak 2004].

Table 2. Effects of Intelligent Transportation Systems
Tabela 2. Efekty inteligentnych systemów transportowych

Effect of application	Type of ITS application	The scale of the effect
Increase in the capacity of the street network	Highway Traffic Management System	up to 25%
	alternative route guidance system via variable message signs	up to 22%
	use of electronic toll collection (compared to traditional methods)	200–300%
Reduction of time loss in the street network	use of traffic lights	up to 48%
	control systems at highway entrances	up to 48%
	traffic incident management systems	up to 45%
	use of electronic toll collection systems (compared to traditional methods)	up to 71%
	priority of traffic lights for public transport vehicles (in addition to the reduction of time loss, it allows to increase punctuality up to 59%)	up to 54%
Improvement in road safety (reduction of accidents)	speed surveillance cameras	up to 80%
	traffic control at highway entrances	up to 50%
	advanced traffic control systems	up to 80%
	traffic incident management systems	up to 50%
Improvement of the effectiveness of rescue services	application of incident management systems and rescue services to reduce time of: − vehicle detection − the emergency services' travel arrangements	 up to 66% up to 43%
	application of automatic vehicle location systems for rescue services and vehicle navigation to the accident site – reduction of travel time	up to 40%
Environmental impact	demand management systems – reduction of exhaust emissions	up to 50%
	highway traffic management – reduction of fuel consumption	up to 42%
	urban traffic management systems – reduction of exhaust emissions	up to 30%

Source: own work based on: [Koźlak 2008].

which would generate savings of EUR 20 billion [Jamrozik 2008]. The effects of actions concerning ITS and improvement of road safety were presented in the report on Support study for the ex-post evaluation of the ITS Directive 2010/40/EU [Tsamis et al. 2018]. According to the annex to the aforementioned document, the pace of changes in Poland in 2017 in this area was slower as compared to 2004. Sweden, in particular, is very active in this area and achieves high road safety rates [Komenda Główna… 2019].

ITS in selected voivodship cities in Poland

Intelligent Transportation Systems are being implemented in many Polish cities. These were introduced particularly intensively in the years 2007–2015, among other operational programmes co-financed from European funds allocated for the period of financial perspective 2007–2013 [Centrum Unijnych Projektów Transportowych]. The EU's support resulted in the implementation of many ITS subsystems in almost all voivodeship cities. The scope of these implementations is presented in Table 3.

Table 3. Selected ITS subsystems implemented in voivodship cities in Poland
Tabela 3. Wybrane podsystemy ITS wdrożone w miastach wojewódzkich w Polsce

City	Signalling control sub-system	Induction loops	Subsystem for driver information using variable message signs	Video surveillance subsystem	Subsystem for vehicle registration at red light	Sectional speed measurement subsystem	Temporary speed measurement subsystem	Recognition of registration plates	Vehicle dynamic weighing subsystem	Parking information subsystem	Meteorological information subsystem	Early detection of traffic events subsystem
Białystok	×	×	×	×	×	×	*	×	*			×
Bydgoszcz	×	×	×	×		×		×		×	×	×
Gdansk	×	×	×	×	×	×	×	×	*	×	×	×
Gorzów Wielkopolski	*	×										
Katowice	×	×	*	×				×	*			
Kielce	×	×										
Kraków	×	×	×	×			×	×		×	×	*
Lublin	×	×	×	×		×		×				×
Łódź	×	×	×	×		×	×	×	×	×		×
Olsztyn	×	×	×	×	×		×	×		×	×	×
Opole	×	×	×	×				×	×	×	×	×
Poznań	×	×	×	×	×	×	×	×	×	×		×
Rzeszów	×	×	×	×	×			×	×	×	×	×
Szczecin	*	×	×	×					*		×	×
Toruń	×	×		×								
Warsaw	×	×	×	×			×	×	×	×	×	×
Wrocław	×	×	×	×	×	×	×	×	×	×	×	×
Zielona Góra*												

*cities currently designing intelligent transportation systems.

Source: own wok based on [Tomaszewska 2016, Motofakty.pl 2017].

The scope of the works introduced varies greatly from city to city. In Warsaw, the Integrated Traffic Management System has been operating since 2008. Szczecin has had the system since the end of 2012. At the end of 2015, the cities of Gdynia, Gdańsk and Sopot launched their own ITS (Tristar), and so did the city of Białystok [Fabisiak 2016] in June of the same year. In Gdańsk, Sopot and Gdynia at the end of 2015, shortly after the launch of the Tristar system, the time of travel by public transport has decreased by 6.5%, and by car – by 5.5%. The system was designed to give priority to public transport vehicles [Fabisiak 2016]. In Białystok, as the only city in Poland, the system covered the entire city area. Such solution allowed for comprehensive control and better timing of traffic signalling. In the Tom Traffic Index report for 2016, Białystok turned out to be the least congested city among those that implemented ITS systems in Poland [Krawczyk 2017], and in the 2019 report it was one of the few cities in which the congestion increased by only 1% [Tomtom 2019]. Positive effects of ITS implementation were also confirmed in Bydgoszcz. The basic objective of the project was to shorten the time of travel by tramway transport by 8.3% and motor vehicles by 6.0%. As a result of the introduction of the system, the time of travel by tram was shortened by about 13% and by about 31% for motor vehicles [Oficjalny Serwis Bydgoszczy 2019]. In Rzeszów, in turn, the implementation of ITS contributed to the increase in punctuality of public transport vehicles from 50 to 80% [Madej 2018]. In each of the cities where an ITS system has been implemented, positive changes in various areas of transport functioning were observed.

Impact assessment of intelligent transport systems for road safety

The theoretical considerations and the presented implementations in voivodship cities show that many of them have systems affecting road traffic safety. Table 4 presents the number of passenger cars in selected cities in Poland in the years 2014–2018.

As can be seen from the table, the number of cars in all listed cities has increased. The cities with the highest number of vehicles are Warsaw, Kraków, Wrocław, Łódź and Poznań. The increase in the number of passenger cars and transformations in the road infrastructure affect the number of road accidents. Data concerning the number of road accidents show that the number of road accidents did not decrease in every city where an ITS was implemented (Table 5).

The data presented in the table show that the highest number of accidents per 100 thousand inhabitants takes place in Łódź, Rzeszów and Poznań. In some voivodeship cities in 2018, as compared to 2014, the number of road accidents has increased. These are such cities as: Białystok, Gdańsk and Poznań. The biggest increase in the number of accidents can be observed in Poznań. The causes of road accidents in this city are: failure to give the right of way, failure to adjust the driving speed to road conditions, incorrect lane change, incorrect reversing, and failure to maintain an appropriate distance between vehicles [KaT 2020]. Despite the fact that Poznań has an ITS system, the number of road accidents increased significantly. The reason for this situation may be the fact that the system covers only a part of the city as well as the increase in the number of passenger cars. Out of the 18 examined cities, only three observed an increase in the number of accidents, while in the remaining ones there is a decrease in the number of accidents, which despite the increase in the number of cars and road renovations carried out in many cities may indicate that an ITS system improves road traffic safety.

Table 4. Number of passenger cars in selected cities in Poland in the years 2014–2018 [pcs.]
Tabela 4. Liczba samochodów osobowych w wybranych miastach w Polsce w latach 2014–2018 [szt.]

City	Year				
	2014	2015	2016	2017	2018
Białystok	111 480	116 510	122 421	127 969	134 603
Bydgoszcz	182 640	188 143	194 402	200 554	208 691
Gdańsk	250 545	255 176	265 308	275 418	288 384
Gorzów Wlk.	62 188	63 792	66 878	69 369	72 963
Katowice	180 879	189 419	199 139	208 617	216 348
Kielce	89 085	92 658	97 343	102 079	107 211
Kraków	406 925	424 026	448 004	468 657	494 021
Lublin	158 361	164 618	172 128	180 399	189 281
Łódź	341 170	351 870	365 931	380 267	396 349
Olsztyn	78 621	81 335	84 701	87 598	91 604
Opole	71 894	74 322	77 610	83 381	88 156
Poznań	327 748	338 984	356 788	371 610	388 958
Rzeszów	86 437	90 973	96 672	103 057	108 750
Szczecin	189 720	197 426	205 779	214 074	223 160
Toruń	91 973	95 247	99 307	103 487	108 108
Warsaw	1 075 500	1 131 120	1 194 068	1 261 803	1 332 923
Wrocław	365 058	381 831	403 063	420 935	442 005
Zielona Góra	60 251	65 194	70 298	75 175	80 335

Source: [GUS, Bank Danych Lokalnych].

Table 5. Number of road accidents in voivodship cities in Poland in the years 2014–2018 per 100 thousand inhabitants
Tabela 5. Liczba wypadków drogowych w miastach wojewódzkich w Polsce w latach 2014–2018 na 100 tys. mieszkańców

City	Year				
	2014	2015	2016	2017	2018
Białystok	46.7	51.8	53.0	54.9	53.1
Bydgoszcz	58.3	55.7	50.4	37.9	48.7
Gdańsk	115.2	109.4	108.6	112.2	118.8
Gorzów Wielkopolski	53.1	41.1	50.8	45.2	37.8
Katowice	91.7	93.4	102.7	85.5	85.3
Kielce	142.9	148.6	142.6	129.7	130.4
Kraków	151.0	151.7	154.6	135.0	125.9
Lublin	65.3	58.3	64.9	62.3	62.1
Łódź	252.8	243.9	245.3	232.5	228.3
Olsztyn	152.8	140.7	169.9	148.6	147.9
Opole	148.3	125.6	132.0	113.9	130.2
Poznań	54.5	56.2	79.2	166.1	161.1
Rzeszów	221.6	207.3	218.2	224.7	164.5
Szczecin	151.9	136.6	112.2	127.1	108.6
Toruń	32.0	21.2	32.6	26.2	26.2
Warsaw	64.3	55.3	52.4	61.0	62.3
Wrocław	102.0	87.3	90.9	88.5	93.5
Zielona Góra	60.7	67.7	59.0	67.4	38.5

Source: [GUS, Bank Danych Lokalnych].

Summary

The considerations carried out in the paper allowed to indicate a few conclusions and generalisations below.

– Intelligent Transportation Systems have been deployed worldwide for many years and the reasons for this are the growing urban population and the desire to improve communication, travel, and life.
– In Poland, the implementation of intelligent transport systems related to obtaining funds for this purpose under the EU programme. Many cities have used the funds for this purpose, including almost all voivodeship cities, introducing solutions to a varying extent in order to reduce congestion, the number road accidents, and travel time.
– The implemented solutions have improved the functioning of the city transport in various areas. The main benefits relate primarily to the reduction of travel time by public transport.
– The analysis of quantitative data concerning the number of accidents per 100,000 inhabitants in the surveyed cities indicates that out of 18 cities under consideration, only in three of them was there an increase in the number of accidents per 100,000 inhabitants, a statistic which should be considered a positive factor in ITS implementation.
– In order to clearly indicate the impact of ITS on the number of road accidents, especially in Poznań, it seems reasonable to carry out detailed research, as to indicate the main causes of the increase in the number of road accidents.
– It should be noted that the deployment of ITS is virtually an ongoing process resulting from the social needs on the one hand, and the growing capabilities of the system on the other hand, and these factors may influence the development of subsystems that will have a significant impact on improving road safety in cities.

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