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Digital e-CMR consignment note – added value for supply chain partners involved

Cyfrowy list przewozowy e-CMR – wartość dodana dla zaangażowanych partnerów w łańcuchu dostaw

Abstract. The introduction of innovative solutions and digitization in the supply chain are the key to the rapid development of enterprises. The constant development of technology is an important aspect of the supply chain readiness to support Industry 4.0 logistics. One of the breakthrough solutions for paper documentation in the transport process is the electronic e-CMR consignment note. The article reviews the literature in the field of digitization and digitization of documentation. A diagram is presented that explains the functioning of the e-CMR, taking into account the individual participants who use the document at a given time and place. A comparison of was made a traditional CMR letter with an electronic letter was made in terms of various criteria, and then the benefits of introducing e-CMR. Were indicated It has been shown that a digital consignment note can significantly add value to the supply chain partners involved. Based on the research carried out in a selected company providing transport services, the significant benefits of implementing the e-CMR system were also presented.

Key words: digitization, Industry 4.0, logistics, digital technologies in supply chain, electronic Waybill e-CMR, added value

Synopsis. Wprowadzenie innowacyjnych rozwiązań i cyfryzacja w łańcuchu dostaw są kluczem do szybkiego rozwoju przedsiębiorstw. Ciągły rozwój technologii jest ważnym aspektem gotowości łańcucha dostaw do wspierania logistyki Przemysłu 4.0. Jednym z przełomowych rozwiązań dokumentacji papierowej w procesie transportu jest elektroniczny list przewozowy e-CMR. W artykule dokonano przeglądu literatury z zakresu digitalizacji i digitalizacji dokumentacji. Przedstawiono schemat wyjaśniający funkcjonowanie e-CMR, z uwzględnieniem poszczególnych uczestników, którzy korzystają z dokumentu w danym czasie i miejscu. Dokonano porównania tradycyjnego listu CMR z listem elektronicznym pod kątem różnych kryteriów, a następnie korzyści z wprowadzenia e-CMR. Wykazano, że cyfrowy list przewozowy może znacznie zwiększyć wartość dodaną zaangażowanych partnerów w łańcuchu dostaw. Na podstawie badań przeprowadzonych w wybranej firmie świadczącej usługi transportowe przedstawiono również istotne korzyści płynące z wdrożenia systemu e-CMR.

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Słowa kluczowe: cyfryzacja, Przemysł 4.0, logistyka, technologie cyfrowe w łańcuchu dostaw, elektroniczny list przewozowy e-CMR, wartość dodana

JEL codes: L14, L90, L91, R40, Q55

Introduction

Logistics is becoming the foundation of many industries. Enterprises more and more often adapt their procedures in relation to current and upcoming logistics trends, using such solutions as: machine learning, automation and robotics, artificial intelligence [Wolak 2019]. Customers pay attention to the introduced changes and appreciate companies that ensure transparency and availability of activities such as: ongoing monitoring of the order status and the fastest execution of orders. Currently, basically every logistic process uses digital technologies of Industry 4.0 to improve organizational and manufacturing activities [Kubera 2019].

The explosive growth of technology of information technologies in the range of communication forces certain changes in people's behaviour and the adaptation of legal provisions to new techniques [Soomro et al. 2021].This situation also takes place in international road transport, in which a traditional, written form of communication between participants of transport processes has operated for several decades. This rule was changed by the Additional Protocol to the CMR Convention of 2008. It introduced the electronic consignment note into the legal order and the possibility of electronic communication between the parties to the contract. Thanks to this solution, the transport of goods becomes simpler and transparent. Security services also gain, which can more easily track trucks and transported loads [Groński 2020].

In the era of Industry 4.0, in order to meet market requirements, enterprises focus on more and more autonomous flow of resources, goods and information [Koliński and Stajniak 2019, Stanisławski and Szymonik 2021] They decide to implement modern systems, such as Supply Chain Management or Warehouse Management System, which enable, among other things, appropriate supply chain management. Taking into account the introduction of innovations, the area of administration cannot be ignored, which often contributes to delays and provide a bottleneck in the process of handling the delivery [Zaborowski and Stolarczyk 2019]. Therefore, the development of IT technologies has supported the work on the electronic consignment note e-CMR, which allows for real-time tracking of the shipment, ongoing access to transport data, as well as reducing costs related to traditional documentation [Dziechciarz 2018].

The digitization of logistics processes is progressing every year. The use of TMS, WMS or vehicle positioning software does not surprise anyone anymore, and despite the widespread need to improve the method of proving the performance of transport, Europe is still struggling with the implementation of solutions enabling the use of electronic (digital) waybills [Chwalczuk 2020].

In Europe, road freight transport prevails, in this connection the CMR is the most frequently used transport document [Koźlak 2019]. The application of the consignment note results from the Convention on the Contract for the International Carriage of Goods by Road CMR and serves as evidence of the contract of carriage between the sender and the recipient. The application of the International CMR Letter depends on the condition in which the place of sending and the place of delivery of the shipment must be in two different countries and at least one of them is a signatory to the CMR Convention. [Tomicova et al. 2021]. The consignment note is also an important source of information, inter alia, on the individual parameters of the transport operation, which are important for the proper conduct of customs formalities [Momchmil 2020]. In addition, according to the Polish Chamber of Forwarding and Logistics, from 2026 electronic waybills will be mandatory in the EU. Meanwhile, for this solution to be used, it has to be adopted all over the world. The only thing that is missing for the implementation of the electronic consignment note is the agreement by the United Nations of the digital signature authentication standard [Esoszynska 2021].

The aim of the study is to present the e-CMR digital consignment note as an added value for the involved partners in the supply chain on the example of a selected company dealing with the implementation of transport and warehouse services, to describe the use and operation of the electronic e-CMR consignment note, including the presentation from conduct of interview results and observation research, cost and time comparison analysis of tasks and presentation of significant benefits resulting from the implementation of e-CMR.

The literature review aims to show the significance of the impact of the digital Bill of Lading on the performance of transport services for the parties to the contract of carriage. In addition, showing entrepreneurs-users of the digital Letter what profitable values for the supply chain can bring the implementation of the digital Letter. In addition, to show that digitization is progressing, and as a consequence, an obligation will be imposed on the parties to the contract of carriage to use the digital letter. The research carried out on the basis of the real data provided from the surveyed company is to show future users of e-CMR what "values" they may have to deal with when implementing a digital List in their companies.

In the article necessary were, literature studies such as: Dziechciarz M., "The use of an electronic consignment note (E-CMR)", carrier's guide – [Groński 2020], to familiarize with the progressive digitization and the electronic e-CMR letter. On the other hand, the empirical background for the research was, inter alia, items such as: Ponzoa Casado J.M., Gómez Funes A., García-Doncel J. [2021] "Digital Transformation: Advantages and opportunities of E-CMR in international cargo logistic", Świeboda J., Seluianova O., Shubenko D. [2021] "Electronic Bill of Lading e- CMR – report" and Tomicova J., Poliak M., Aleksandrovna Zhuraleva N. [2021]"Impact of using e-CMR on neutralization of consignment note" and Momchil A. [2020] "Possibilities for Application of E-CMR from a customs point of view". These items primarily helped indicate the selection of criteria to test their relevance and the impact of the digital e-CMR on the transport service process in the supply chain. In addition, it could be proved that the process of implementing the e-CMR brings with it immeasurable benefits for the parties of contract of carriage – users of consignment note. The other sources included in the bibliography supplemented the theoretical and empirical content of the article.

Research methodology

Based on the analysis of literature in the field of digitization and digitization of documentation, a review was made and a preliminary cost and time analysis was carried out resulting from the possibility of implementing an electronic e-CMR letter on the example of a selected company. The analysis included the benefits for both the audited entity and the customers using their transport services. Cost and time savings calculations were carried out, for which the e.CMR.pl calculator was used. However, in order to verify the more precise results, calculations were made on the basis of data and documentation from the examined company.

Consignment note and CMR convention

The CMR Convention (fr. *convention relative au contrat de transport international de marchandises par route*) signed in Geneva in 1956 is the basis for the rules of international carriage of goods by road. Poland joined it in 1962. The Convention introduces and unifies [Madej et al. 2016]:

- Carrier's liability,
- mode of complaints
- shipping documentation,
- claims arising from carriage,
- contract conditions for the carriage of goods by road
- transport carried out successively by several carriers.

Additionally, it also regulates [Madej et al. 2016]:

- the ordering paymaster right to dispose of the goods,
- carrier's obligations for documentation or its misuse,
- obligations and liability of the ordering party (sender or recipient) towards the carrier,
- carrier's liability for cargo and exceptions exempting him from liability,
- complaints and claims arising from transport, the mode and their limitation
- conditions for accepting the goods from the sender and releasing the goods to the recipient,
- the possibility of the consignee refusing to accept the cargo,
- management carriers of unclaimed cargo.

CMR Convention does not apply [Foltyński 2015]:

- for the transport of dead bodies,
- for the transport of items of resettlement,
- for transport performed on the basis of international postal conventions.

The provisions of the Convention must be followed by carriers who perform the transport in question between two or more states, at least one of these states having ratified the convention.

The document confirming the conclusion of the contract on international transport of goods is the international consignment note (CMR), which contains, information such as [Rożej et al. 2019, Wysocka-Bar 2020]:

- name of the carrier,
- surname (name) and address of the sender,
- name and address of the recipient,
- place and date of issue,
- place and date of acceptance of the goods for transport and the intended place of their release,
- gross weight or other unit of goods,
- number of pieces, their features and numbers,

- the description in common use of the nature of the goods and the method of packing, and, for dangerous goods, their generally recognized description,
- costs related to transport,
- instructions necessary for completing customs and other formalities.

The CMR International Consignment Note is issued in three identical copies, and in accordance with the model developed by the International Road Transport Union – in four copies, each in a different colour [Stochaj et al. 2018]:

- original – blue – intended for the recipient
- quotation – red – intended for the carrier,
- spine – green – remaining at the sending station,
- black – duplicate – issued to the sender of the parcel.

Usually, the International consignment note is issued by the carrier at the place of loading, the shipper of the goods or the forwarder representing them. It is worth noting that the sender can be both the company that physically loads the means of transport, as well as an entity located elsewhere, but only ordering the loading. Under the CMR Convention, the bill of lading is a proof of the contract of carriage and the determination of the terms of such a contract. In its content, it contains not only a number of declarations of will, but also statements of knowledge placed both at the time of concluding the contract and during the transport. The basic functions of the Bill of Lading include [Wrzecionek 2017]:

- evidentiary function – confirms the conclusion of the contract of carriage, its conditions and acceptance of the cargo by the carrier.
- information function – it consists in informing about the transport in the letter, it gives the hint an indication of the content of the contract of carriage, thus allowing the carrier to control the correct performance of the contract.
- instructions function – is essential when something sudden occurs during the transport; it boils down to indicating the contact details of the person with whom to contact in the event of an obstacle.
- ID function – consists in the fact that the possession of the first copy of the letter entitles the sender or the recipient to pursue claims and direct the goods. If the first copy of the consignment note is in the possession of the consignor, the consignor is entitled to suspend shipment, change the place for delivery, or deliver it to an addressee other than that indicated on the consignment note. In the case of the sender, this right shall cease to apply when the second copy is delivered to the recipient.

The carrier is obliged to check the information contained in the bill of lading with the actual state, and in case of noticing any discrepancies, mark it in the bill of lading.

Summing up, the Bill of Lading is an important document of concluding the contract of carriage in international transport of goods, and also protects the interests of all parties involved in the transport. According to the literature, therefore, according to Neider and Marciniak-Neider, the CMR convention is a legal act that regulates the principles, rights and obligations of the parties to the contract of international road transport for profit [Neider and Marciniak-Neider 2011].

Based on information from the researched company, a diagram (Figure 1) of the circulation of a traditional CMR Letter has been shown.

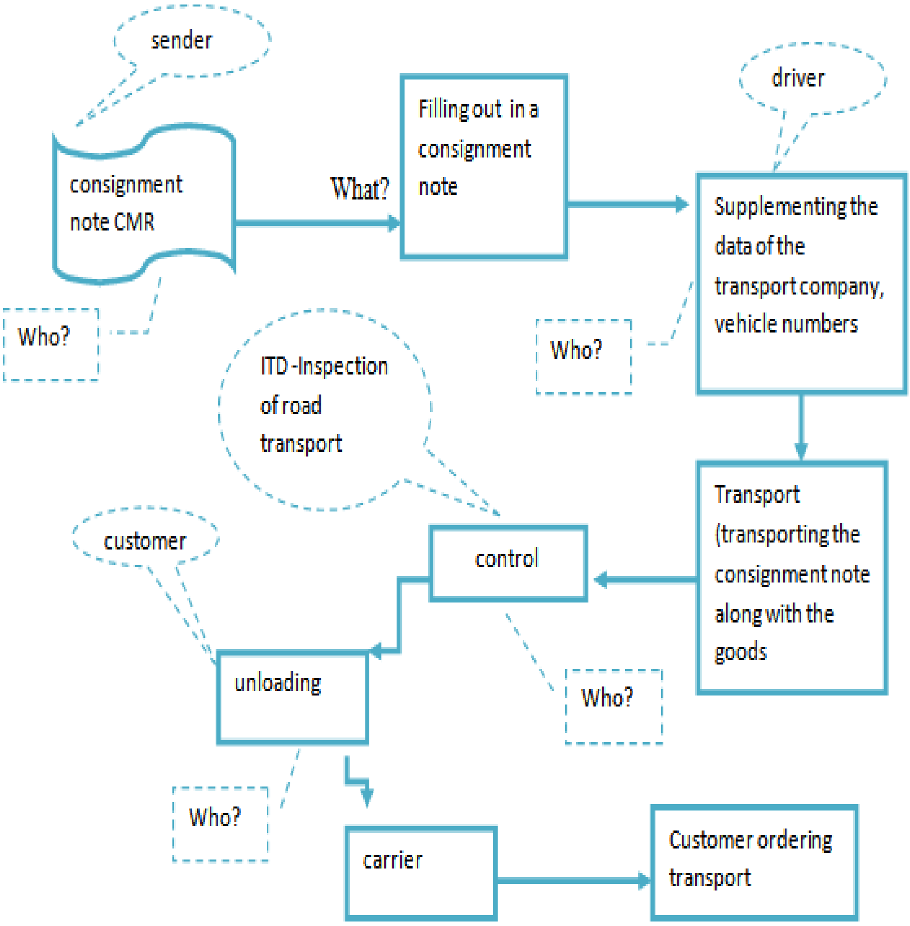

Figure 1. Diagram of the circulation of a traditional CMR Consignment Note on the example of a selected company
Rysunek 1. Schemat obiegu tradycyjnego listu przewozowego CMR na przykładzie wybranej firmy
Source: own study.

In Figure 1 you can see that the traditional CMR letter is in circulation and is successively supplemented by participants who have concluded a contract of carriage. The Bill of Lading is issued by the sender or carrier. The diagram shows the document flow sequence (4 copies), which in the case of the traditional Letter "circulates" successively between the users of the transport service who concluded the contract of carriage. Figure 1 shows which user of the stage of the transport process has successively a given copy of a traditional CMR Letter and is responsible for its filling. It can be noticed that this process works in the form of a chain, which can often affect the reaction or the mode of certain actions related to the transport service, e.g. verification of a mistake, correction of errors, filing a complaint and others. In addition, this circulation may include other participants, not necessarily concluding a contract of carriage, such as the Road Transport Inspection, Police, Customs and Tax Office or the Border Guard. In addition, inspection services, to check what a given vehicle is transporting, must stop it and inspect it directly.

The use of the e-CMR electronic consignment note in the era of digitization

The E-CMR is a document issued using electronic communication by the carrier, sender or other party interested in the performance of the contract of carriage. It is authenticated by the parties to the contract of carriage using a reliable electronic signature ensuring its linkage with the electronic consignment note [transport-manager 2019]. The Digital Bill of Lading is primarily a convenience for all sides of the supply chain. As shown by the research conducted by the Polish Road Transport Institute, in which enterprises from a diverse sector of the TSL sector participated, showed that the respondents (logistics, forwarders, drivers) would like to work with the electronic consignment note e-CMR by vast majority of votes. The logisticians showed the greatest willingness among the respondents, because almost 80% of the respondents indicated that they support the digitization of the Bill of Lading. Both drivers and shippers, more than half the votes, are also in favour of implementing the e-CMR. In addition, the respondents answering the question: Do you think that when using e-CMR there will be fewer errors and shortening the time of filling in and handling the consignment note? Over 80% of them answered yes. Summarizing the above, all respondents agree that the introduction of the e-CMR will shorten its service time and also reduce the number of errors [Świeboda et al. 2021]. Considering this fact, it can be admitted that going digitization is a source of solutions to some problems, and also significantly improves processes.

According to the procedures, the e-CMR consignment note will be acknowledge when get reliable electronic signature. In addition, the electronic consignment note is to contain the same information as in the traditional CMR. The e-CMR procedure is to ensure the integrity and invariability of the data contained therein, except for the data that occurs during the data transfer between the parties to the contract.

The use of a digital e-CMR consignment note brings many benefits for the carrier, sender, recipient and other participants in the supply chain. The most obvious are, [Dziechciarz 2018, Blog transportowy 2020, Chwalczuk 2020, Lysionok 2021, Tomicova et al. 2021]:

- easy archiving of logistics documentation,
- saving paper and ink,
- saving space for storing documentation,
- improvement of invoicing – no need to wait for the originals to issue an invoice,
- time saving:
    - in finding specific details of documentation,
    - in sending documentation,
- constant control over the load,

- faster initiation of complaint procedures,
- elimination of errors when filling in the consignment note,
- convenience during a pandemic (no possibility of infection),
- maximum shortening of the waiting time for payment.

Summing up, it can be stated that the implementation of the e-CMR electronic consignment note may contribute to the improvement of many aspects of enterprises' operations, as well as raise enterprises to a higher level of functioning quality [Rut and Miłaszewicz 2013]. What's more, a number of presented benefits may also affect the company's development in the future and broaden the horizon for cooperation with other logistics partners. According to the authors: Kulikowska-Wielgus A., Wawryszczyk B., Ziemkowska D., Hennig K., Wolak M., Jakubowska N.,: "Digitization and technologies create a more effective value chain in all sectors of the economy. The transition from paper documents to electronic documents will enable cheaper, faster and more transparent processes in domestic and international transport" [Kulikowska-Woielgus et al. 2019].

Functioning of the e-CMR

The purpose of the Electronic Bill of Lading is to define the terms of a single transport contract. It is drawn up by the sender or carrier, it is a proof of receipt of the goods with all the details of the service provided. It contains, just like in a traditional CMR, information about the place and time of loading and unloading, as well as vehicle data. The e-CMR consignment note is issued via electronic communication, and the parties approve it using an electronic signature [Blog transportowy 2020]. Figure 2 presents a diagram showing the functioning of the e-CMR.

Figure 2 shows, similarly to Figure. 1, the circulation of the e-CMR document, but the main difference is that in the traditional consignment note, each stage is performed in the order in which the transport process takes place and which participants are present at a given stage. In the electronic List, however, this order may change, because digitization means that several participants can have the List simultaneously in real time. To show the advantage of the electronic e-CMR consignment note over the traditional CMR, Table 1 has been prepared in which the criteria that have been compared are listed.

It should be noted that already at the time of issuing the e-CMR consignment note by the sender, the parties interested in the transport service have access to the digital Letter immediately in real time, which allows them to react directly to various situations and events, including for the introduction of corrections, monitoring the status of the shipment. In addition, inspection services do not have to stop the vehicle for inspection to find out what it is carrying. Just enter the registration number of the vehicle into the system and you immediately know what it is carrying.

From the compiled content in Table 1, it can be clearly stated that the implementation of e-CMR in enterprises brings immeasurable benefits. By analysing the above, it can be concluded that the Electronic consignment note in terms of each of the criteria given in Table 1 is better than the traditional.

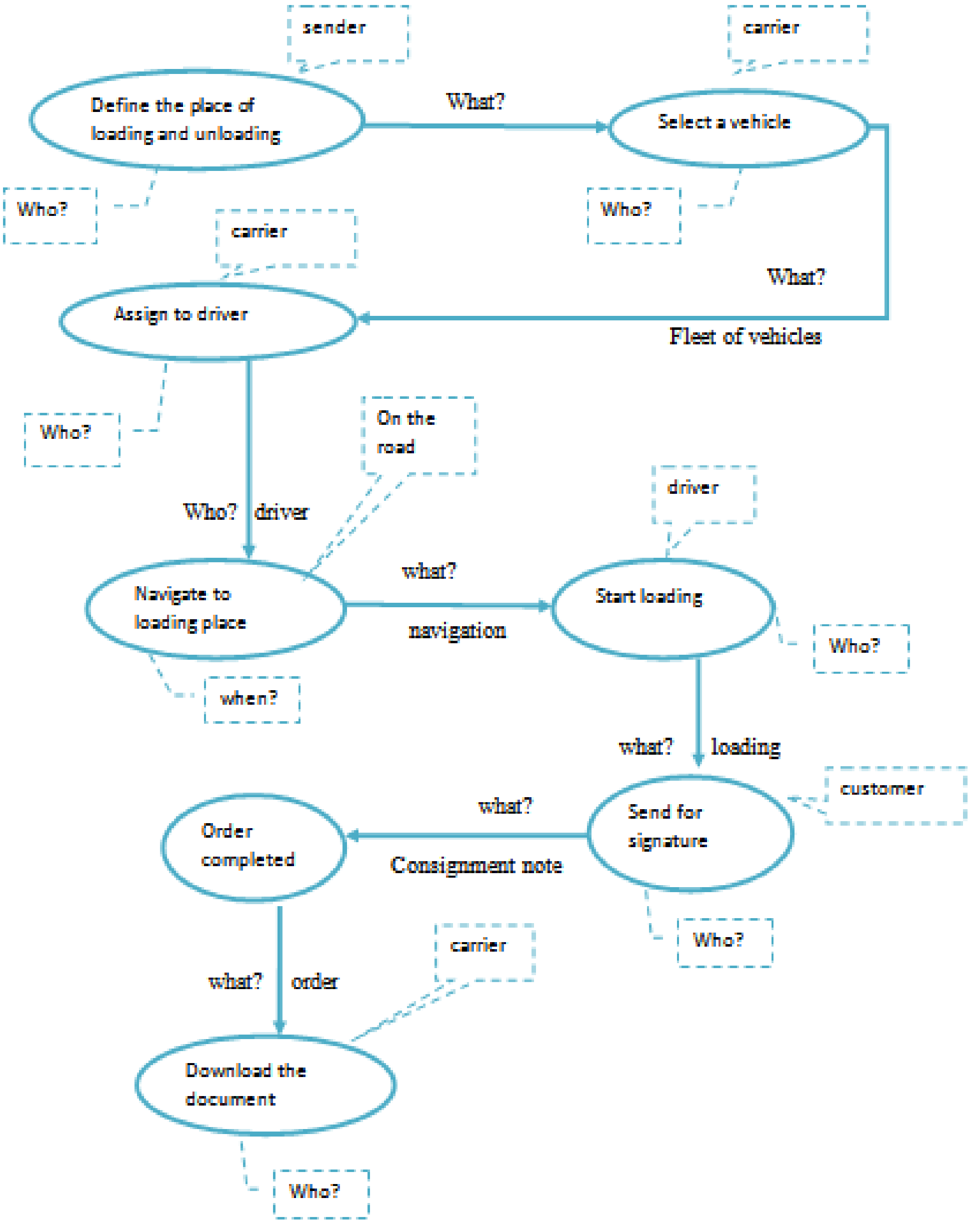

Figure 2. Diagram of the functioning of the e-CMR
Rysunek 2. Schemat funkcjonowania e-CMR
Source: own study.

Table 1. Comparison of the Traditional CMR with the electronic e-CMR
Tabela 1. Porównanie tradycyjnego CMR z elektronicznym e-CMR

Criterion	CMR	e-CMR
Availability of information	The data available to each interested party is that on their copy of the paper consignment note and is therefore only available to the person who owns the paper.	The data are stored on a digital medium, thanks to which it can be made available to all interested persons on various types of devices with Internet access. It also allows simultaneous access for several devices.
Legal certainty	It is recognized by several countries and is widely used across the EU, providing legal certainty to the parties.	It is recognized in some European countries, but there are still countries such as Germany and Italy that do not recognize it. However, the EU regulation of July 15, 2020 sets August 2021 as the deadline for its acceptance in all Member States.
Information consistency	Several copies of the information are made up, one for each stakeholder. Since carbon paper is used, the information on all copies is the same. Even if there are several copies, additional information can be added to some of them.	There is one data repository, which ensures information consistency.
Protection against errors	The recorded information is handwritten by the carrier at the beginning of the transport phase. Some of this information may be obtained by various means, e.g. by telephone, while receiving the load. There are several possibilities for errors to occur.	Information entered by the data controller is not passed on to others. It does not eliminate the possibility of error, but it reduces the risk; the data handler is the one who records it, thus avoiding communication errors.
Squander reduction	Some copies of the paper bill of lading must physically travel between the different actors in the process. Issuing CMR documents at the end of the transport stage to administrative staff in order to issue an invoice causes an ineffective delay. Administrative staff will also need to enter all information into their corporate billing systems.	The information is available in digital format from any terminal with internet access, with the existence of one master copy. In this way, all 'physical travel' is eliminated, and the concept is time-saving. By using the e-CMR platform API, data can be automatically sent to companies' billing systems, reducing time wasted on manual data entry and avoiding human error.
Data integrity	Several copies are generated for each interested party so that if any modification were to take place on one of them, it would be detectable in comparison with the other copies. However, this situation requires different copies to be made available again because there is no reliable trust pattern for all parties. Printed copies may be damaged or lost.	The data are stored and guarded by a third party outside the operational process, which is responsible for its consistency. Data storage on a digital medium allows the use of other technologies, such as blockchain, which fully guarantee the immutability of data. Digital storage also helps to avoid physical deterioration.

Source: own elaboration based on: [Ponzoa Casado et al. 2021].

Electronic consignment note e-CMR in the researched company

The company was founded 30 years ago and operates in the transport and broadly understood logistics industry. The 30 years of experience, customer requirements, and constantly increasing costs begotten resulted in the development and implementation of the latest IT solutions available on the market.

Digitization in the audited entity includes modern TMS systems, cost management and monitoring systems, systems enabling connection with potential and existing customers, dedicated customer portals enabling real-time transport monitoring.

The company's fleet consists of over 100 modern trucks and nearly 200 trailers. The trucks, in addition to the basic telematics system, are equipped with on-board computers for ongoing communication between drivers, planners and customers.

The vehicle that carries out the current customer order can be sent back to another destination in real time, without being contacted by the standard communication path, such as mobile phones.

If the customer changes the status of the order or the order during its implementation, he can report this fact to a special e-mail address of the company. The e-mail is verified in terms of reliability and the ability of the fleet, then goes to the TMS system, and then is sent to the vehicle's on-board computer.

Modern systems and technological solutions are still not able to eliminate the trivial problem of the circulation of CMR transport documents, on the basis of which the company is settled by the customer. That is why the widely progressive digitization gives the possibility of introducing, among others, in the near future the electronic e-CMR consignment note.

Analysis of the comparison of costs and time related to the use of a traditional CMR consignment note in the researched company

In order to verify the benefits of having the e-CMR electronic consignment note, a calculation was carried out (Table 2) based on data from the surveyed company.

Table 2 Comparison of e-CMR with traditional CMR according to the e-CMR.pl calculator
Tabela 2 Porównanie e-CMR z tradycyjnym CMR według kalkulatora e-CMR.pl

Criterion	**Traditional CMR**	**Digital e-CMR**
Printing	4 000 × 1 PLN = 4 000 PLN	4 000 × 0PLN = 0 PLN
Shipment	4 000 × 8.70 = 34 800 PLN	0 PLN
Shipping time	4 000 × 7 day = 28000 days	4 000 × 1 seconds = 4 000 seconds
Total	38 800 PLN 28 000 days	0 PLN

Source: own study.

According to the e-cmr.pl calculator, the surveyed company that carries out an average of 200 transport orders a day can save PLN 38,800 per month and 28,000 days of additional time.

However, in order to show the real benefits for both the carrier and the potential customer using transport services that may result from having an e-CMR, the results are presented in Table 3.

Table 3 Comparison according to the criteria of the examined entity CMR with e-CMR
Tabela 3 Porównanie według kryteriów badanego podmiotu CMR z e-CMR

Criterion	**Traditional CMR**	**Digital e-CMR**
Number of orders	200/1day 4 000 orders/month 48 000/year	
Costs 1 piece	0,60 PLN	0 PLN
Time needed to fill 1 piece	2 minutes	1 seconds
Shipping time1piece	4 working days	0 working days
Filing time per year	48 000 × 2 minutes = 96 000 minutes = 1 600hours	48 000 × 1 seconds = 48 000 seconds = 800 minutes = 13,3hours
Cost of purchasing documents per year	48 000 × 0,60PLN= 28 800PLN	________________________
Document workflow until the transaction is finalized	around 20 days	currently
Complaint procedure	even to 20 days	currently
Sheets of paper in [kg]	1 page = 4g 1 order = 4page 4 page × 4g = 16g 48 000 × 16g =76,8kg	0 kg of paper
Receipt of payment for the service	from the moment of receiving CMR + the payment deadline, the document circulation time is extended, i.e. a maximum of 20 days + 30 days = 50 days	from the moment of receiving the e-CMR – only the payment term is taken into account (maximum 30 days)

Source: own study based on data from the enterprise.

Table 3 shows the costs and time of using a traditional CMR, as well as the possible benefits that may be the result of implementing e-CMR. Analysing the above, it can be concluded that the mere filling in of documents, which takes 1600 hours per year, or 200 full-time working days of an employee, shows that one employee can only be hired to fill out the Bill of Lading. Another very important aspect is financial liquidity, which can be made possible by the electronic Waybill by issuing an invoice immediately after completing the transport, and this allows you to save time up to 20 working days on one invoice. It is very important, taking into account the current costs related to the daily operation of vehicles, which must be borne by the carrier, including fuel costs, etc. Considering the circumstances in which the current community functions – where we live in the time of the Sars-Cov-2 pandemic, it is worth emphasizing that the elimination of direct contact with a paper document protects the parties to the contract of carriage against infection. An additional improvement is the complaint procedure, which in the case of a traditional CMR consignment note often lasts 20 days. It is also worth noting the ecological aspect, where by implementing e-CMR we do not generate about 77 kg of paper per year with such a number of orders. The implementation of the e-CMR system will be reflected in real time when the complaint is initiated. It should also be noted that this comparison did not take into account qualitative benefits that cannot be quantified, such as: comfort and convenience of people using e-CMR, access to current information, or elimination of the risk of infection during a pandemic.

Summary and conclusions

The aim of the study is to present the e-CMR digital consignment note as an added value for the improvement in the supply chain on the example of a selected company dealing with the implementation of transport and warehouse services, to describe the use and operation of the electronic e-CMR consignment note, including the presentation from conduct of interview results and observation research, cost and time comparison analysis of tasks and presentation of significant benefits resulting from the implementation of e-CMR.

The CMR consignment note is an indispensable element of the transport service. Its functions complete the service and make the individual stages of the transport process performed according to the recipient's and sender's criteria. Due to technological and IT progress, the documentation, including the CMR consignment note, has been digitized. The consequence of this will be the complete elimination of the CMR consignment note, turning it into e-CMR. The only thing that is missing for the implementation of the electronic consignment note is the agreement by the United Nations of the digital signature authentication standard.

The e-CMR Electronic consignment note is one of the effects of the current document digitization. The main goal of introducing the e-CMR is primarily to reduce costs. Potential users of the electronic Bill of Lading can also count on other benefits of using this solution, including: efficient exchange of documentation or real-time exchange of notification. As it results from the calculations carried out on the basis of the examined entity, it can be clearly indicated that the everyday implementation of the "tool", which is e-CMR, will bring immeasurable benefits. Elaborated calculation of costs and time is showing, how the convenience of an electronic consignment note.

The research assumed the average number of orders related to the implementation of transport services by the audited entity. The costs associated with the use of the traditional Letter and other determinants were also estimated by the audited entity. It is not possible to provide an exact cost calculation and determinants related to the use of traditional CMR, because these aspects are influenced by the number of orders, seasonality of services, employee leaves, holiday periods, number of working days per month, volatility of printing prices, postage stamps, discounts taken into account, or the supplier of consignment note CMR sheets. The research results are intended to present a visual overview on the basis of the tested entity, what benefits can they affect the use of a digital consignment note, realizing that the traditional letter works according to a specific pattern, and additional the letter receive successively one of the parties to the contract of carriage as the transport process takes place, furthermore, it was presented what the company can expect after the implementation of the e-CMR. The direction of further research may be an in-depth analysis of monthly costs and a review of the documentation of the audited entity in order to provide accurate data related to the use of traditional CMR. In undertaking further research, it should also be checked whether there is any risk resulting from the implementation of the e-CMR, e.g. related to a long-term suspension of the system, or another failure or a possible "intrusion" of a hacker.

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Tools used in intelligent transport systems of city logistics

Narzędzia wykorzystywane w inteligentnych systemach transportowych w logistyce miejskiej

Abstract. Cities are large areas with numerous buildings between which there is an extensive road infrastructure. A society lives in them, which in order to be able to function must move. The need to move, combined with a high population density in the city, causes a lot of traffic – especially road traffic. Improving road traffic flow and reducing road congestion enables the use of intelligent transport systems in city logistics. The aim of the article is to present the tools used in intelligent transport systems of urban logistics. The research methodology used is the development of a diagram in which individual ITS tools were assigned to the appropriate link of the transport environment. Due to the growing requirements of people traveling by public transport, telematics is an important element. The article presents the tools that the passengers of the research facility can use, and thus traveling becomes more effective and comfortable. The use of appropriate tools of intelligent transport systems means not only following the principles of proper and effective functioning of urban logistics areas, but also increased comfort of travelers and improvement of road traffic safety. Research on increasing capacity in cities is an important topic in urban logistics. The need to conduct research on urban agglomerations results from the systematic increase in the demand for effective movement of people in urban agglomerations. The scope of entities is a narrow research group, however, the indicated elements belonging to intelligent transport systems translate into the possibility of using them in most urban agglomerations.

Key words: intelligent systems, transport, smart cities

Synopsis: Miasta są wielkimi obszarami z licznymi zabudowaniami, pomiędzy którymi przebiega rozbudowana infrastruktura drogowa. Żyje w nich społeczeństwo, które by móc funkcjonować, musi się przemieszczać. Potrzeba przemieszczania się połączona z dużym zagęszczeniem ludności w mieście powoduje duże natężenie ruchu – zwłaszcza ruchu drogowego. Poprawa płynności ruchu drogowego oraz zmniejszenie kongestii drogowej umożliwia zastosowanie inteligentnych systemów transportowych w logistyce miejskiej. Celem artykułu jest przedstawienie narzędzi stosowanych w inteligentnych systemach transportowych logistyki miejskiej. Zastosowana metodologia badawcza to opracowanie schematu, w którym przypisano poszczególne narzędzia ITS dla odpowiedniego ogniwa otoczenia transportowego. W związku z rosnącymi wymaganiami osób podróżujących przy pomocy komunikacji miejskiej, ważnym elementem jest telematyka. W artykule przedstawiono narzędzia, jakie pasażerowie obiektu badawczego mogą użytkować i tym samym podróżowanie staje się efektywniejsze i wygodniejsze. Zastosowanie odpowiednich narzędzi inteligentnych systemów transportowych to nie tylko postępowanie zgodnie z zasadami prawidłowego i efektywnego funkcjonowania obszarów logistyki miejskiej, ale również zwiększony komfort podróżujących oraz poprawa bezpieczeństwa w ruchu drogowym. Badania nad zwiększeniem przepustowości w miastach to istotny temat w logistyce miejskiej.

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Potrzeba prowadzenia badań nad aglomeracjami miejskimi wynika z systematycznego zwiększania się zapotrzebowania do efektywnego przemieszczania się osób w aglomeracjach miejskich. Zakres podmiotów to wąską grupa badawcza, jednakże wskazane elementy należące do inteligentnych systemów transportowych przekładają się na możliwość wykorzystania w większości aglomeracji miejskich.

Słowa kluczowe: inteligentne systemy transportowe, transport, *smart cities*

JEL codes: L90, L92, O18

Introduction

The systematic increase in the movement of people in urban agglomerations, using various means of transport, forces the authorities of urban agglomerations to improve the city's capacity. The necessity to move is related to the high population density in the city, which causes a lot of traffic – especially road traffic. The subject of Intelligent Transport Systems (ITS) is directly related to urban logistics. ITS is a broad collection of various tools based on information or telematics technology.

The aim of the article is to present the tools used in intelligent transport systems of urban logistics. The research methodology used is the development of a diagram in which individual ITS tools were assigned to the appropriate link in the transport environment. Every day, tens or even hundreds of thousands of passenger cars travel along city roads. As a result of the high volume of road traffic in relation to the low capacity of city roads, we are dealing with congestion – usually cyclically, in the morning and afternoon rush hours. Currently, the main goal of urban agglomerations is to reduce or even exclude the phenomenon of congestion, which will contribute to a better quality of life. There are many tools of intelligent urban logistics transport systems that help to smooth the road traffic.

Materials and methods

The research is based on scientific literature, own observation and data from research objects. Research entities are the urban agglomerations of Opole and Gdynia. The period of analysis of research objects is the second and fourth quarter of 2021. The applied research method is a case study of selected urban agglomerations. The aim of the case study is to show the concept of intelligent transport systems that are applicable in most urban agglomerations. In the chapters, the characteristics of intelligent transport systems and tools used in intelligent transport systems, materials are presented based on a wide review of domestic and foreign scientific literature on the intelligent transport systems tools available on the market that can be used in urban logistics. Individual tools are presented along with an indication of the form of use of a given device or system. The chapter on telematics solutions supporting public transport in city logistics presents the possibilities of using the tools of intelligent transport systems. Data on the urban agglomeration come from the official application and website of the cities.

Characteristics of intelligent transport systems

The concept of transport is defined many times in the literature. According Tarski I., it is a technological system for the distance transport of people, energy or goods [Tarski 1993, Gentile and Noekel 2016]. This concept is related to the use of specific infrastructure and means of transport [Madeyski et al. 1971, Koźlak 2008, Neider 2008]. The concept of transport is formulated by activities such as transporting goods, operating technical devices, delivering goods to the destination, as well as additional services [Neider 2008]. Transport is an essential part of our lives, the needs of which grow together with systematic economic and social development. Transport is a concept that defines the movement in a given time and space of our needs by means of appropriately selected means of transport. The subject of ITS is one of the most analyzed areas related to the functioning and impact of transport on other logistics processes. Intelligent transport systems are built from a variety of tools based on information technology, mobile telecommunications and vehicle electronics. They enable effective management of transport infrastructure [Koźlak 2008, Marczak and Kozłowski 2014]. Facilities using ITS can use a wide range of tools. The use of intelligent transport systems gives benefits ranging from economic, through an increase in the level of safety in transport, and ending with ecological ones [Nikitas et al. 2020]. The genesis of intelligent transport systems from the evolution of telecommunications and information technology, through transport telematics to intelligent transport systems is presented below transport systems (Figure 1).

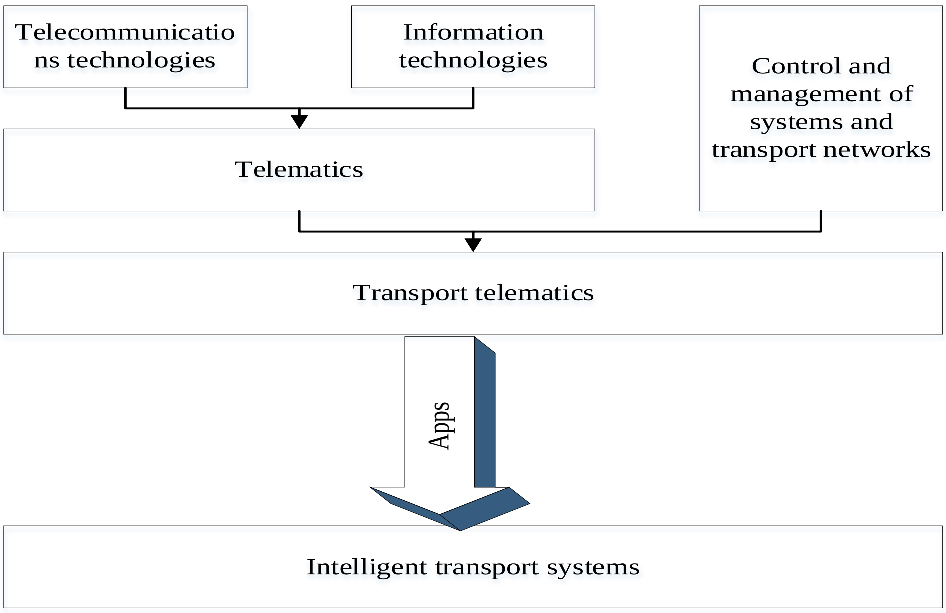

Figure 1. The genesis of intelligent transport systems
Rysunek 1. Geneza inteligentnych systemów transportowych
Source: own study based on: [Koźlak 2008].

ITS are a wide collection of various tools based on information technology, wireless communication and vehicle electronics. Due to the complexity of the above elements, they enable efficient and effective management of transport infrastructure, including city logistics. In such systems, the functioning of transport is largely supported by integrated measuring solutions (sensors, sensors), telecommunications, IT and information solutions, as well as automatic control [Koźlak 2008].

The scope of application of intelligent transport systems tools [Koźlak 2008, Maruszczak 2016]:

- road traffic management systems,
- public transport management systems,
- cargo transport and vehicle fleet management systems,
- road incident management systems and emergency services,
- traffic safety management systems and monitoring of violations of regulations,
- information services for travelers,
- electronic payment services and electronic toll collection systems for road use,
- advanced technologies in vehicles.

The implementation of transport policy is one of the priorities in the application of Intelligent Transport Systems (ITS) in individual areas of urban logistics. The most important effects of using ITS are [Koźlak 2008, Kamiński 2020]:

- general improvement in the efficiency of the transport system (in particular, shortening the travel time, reducing the number of stops and road incidents),
- increasing the level of road safety,
- reduction of harmful exhaust components, dust and noise emissions.

The field of application of intelligent transport systems that is important for improving the functioning of transport is freight and rolling stock management. Dissemination of ITS in this area helps to increase the efficiency of transport, but also contributes to the improvement of road safety.

Tools used in intelligent transport systems

The city as a living organism is a constantly changing structure, therefore it requires the use of already existing management concepts or the creation of new concepts in order to meet today's challenges. Various concepts that fall under the main element, i.e. city logistics, are also used to manage an urban agglomeration. All concepts belonging to urban logistics, to a different extent, have the potential to influence the development of an urban area [Festag 2014].

The purpose of using intelligent tools for urban logistics is to minimize or eliminate certain undesirable phenomena and to improve broadly understood flows in urban agglomerations. The table 1 identifies intelligent tools in city logistics.

Tabele 1. Tools used in intelligent transport systems of city logistics
Tabela 1. Narzędzia wykorzystywane w inteligentnych systemach transportowych logistyki miejskiej

Tools used in intelligent transport systems of city logistics	
Equipment	**Application form**
City logistic terminals (city-terminals)	One way to reduce the number of commercial vehicle trips around the city is to create city terminals. The location for this type of facility should be close to interchange junctions. The possibilities that arise from the introduction of this type of terminals are: – consolidation of shipments, – working out optimal delivery routes to avoid empty runs. Reloading of cargo incoming to the city to low-emission means of transport, which then deliver the goods directly to the addressees in the city.
City Card	It is an IT system that enables more convenient use of city services. The data carrier in this IT system is the City Card with a unique identification number assigned to each card. Thanks to the introduction of the City Card and its integration with many services, residents of the urban agglomeration can: pay for journeys by public transport, renting city bikes, parking, cinema, theater, museum, swimming pool. Money for payments with the city card is deducted from the personal account assigned to this card or from the funds to which the card is topped up.
System	**Application form**
Smart city	It is a concept of creating a smart city, which was established in 2007 as a result of the European Union's activities aimed at managing the energy sector and reducing greenhouse gas emissions. According to the definition, a Smart city is: an urban agglomeration that freely uses all technological and communication solutions. In order to improve the efficiency of city infrastructure, its interactivity and stimulating the increase of awareness of city dwellers. It can be considered that a smart city is a method of managing an urban agglomeration aimed at improving the quality of life of city residents. The concept of a smart city consists of several different elements, such as: creating long-term city management plans, using technological facilities, focusing on environmental protection, creative people, the possibility of implementing innovation and eliminating problems.
Expansion of the city's transport infrastructure	The transport infrastructure in the city consists of many elements that every inhabitant of the urban agglomeration encounters on a daily basis, such as: roads and traffic lights, pedestrian communication routes, bridges, viaducts, signs, tracks for various types of vehicles railways, energy networks, bus stops, bays, depots, transfer junctions, stations, parking lots, garages, reloading locations. As you can see, the whole urban infrastructure consists of many different elements, which, however, make up one functional whole. Due to changes in road traffic, transport habits and preferences of the population, the city's transport infrastructure must also be constantly developed and adapted to the modern expectations of urban infrastructure users. This task is not easy due to the relatively small space in the cities. Therefore, any reconstruction or transformation of the road infrastructure must be thought out and planned in detail with a view to the future. The current problem of cities is road congestion, therefore the road infrastructure is expanded with new roads (access roads to new housing estates and ring roads in order to relieve the city center from as many vehicles as possible) along with modern infrastructure in the field of road telematics.

cont. Table 1

Transport telematics	It is a combination of modern information technologies with communication technologies and control methods. Transport telematics can support various types of areas, such as: road infrastructure, vehicles, organization of road and pedestrian flows, and all indirect activities related to the above-mentioned areas. Telematics systems are characterized by: – immediate readiness to change actions, – collecting a lot of data, – the option of linking various devices and their functionalities, – continuous operation, – an option to expand the system's capabilities. The road telematics systems include all: sensors, detectors, cameras, various types of electronic or telecommunications communication systems, traffic lights, variable message boards, websites, mobile applications, data transmission means. Thanks to all these components, working on the proper functioning of road telematics systems, we can distinguish such telematics solutions as: variable message signs, weather stations, intelligent light signals, traffic control systems, video sensors, warning system against road works and accidents, detection of too high vehicles, a traffic volume survey system, passenger flow counting systems, information systems for free parking spaces and many others. The use of telematics in cities results, above all, in smoothening vehicle traffic, making public transport more attractive, reducing environmental pollution resulting from the large amount of exhaust fumes in cities, and reducing passenger car mileage.

Source: own study based on: [Saniuk and Witkowski 2011, Kądziela et al. 2012, Neumann 2017, Rześny-Cieplińska and Wach-Kloskowska 2017, Zawieska and Pieriegud 2018, Ostaszewski and Białek 2020].

Today's concepts must be innovative and modern, and most often relate to the city's infrastructure, logistics, ecological and economic infrastructure. The main goal of developing various logistics concepts regarding the city area is to minimize the occurrence of the phenomenon of congestion, improve the smoothness of driving in the city, improve accessibility to the city, and if possible, remove delivery vehicles or trucks from city centers [Tundys 2012]. Thanks to continuous analyzes of all flows in the city, all negative phenomena are monitored on an ongoing basis. As a result, you can work on the methods of solving the most difficult points in everyday life. Creating solutions to problems and then introducing them is often a long process, with a long period of preparation and implementation.

Telematics solutions supporting public transport in city logistics

The issue of urban public transport in urban agglomerations is an extremely important issue for the inhabitants and for the very functioning of the city. The functioning of the city's communication network improves the mobility of residents, especially those who do not have their own means of road transport. In addition, buses running on urban roads have the potential to relieve urban roads of passenger cars, which at the same time reduces the negative impact on the natural environment (reducing passenger vehicles, i.e. reducing noise and the amount of exhaust gases). In order to meet modern needs and requirements, city logistics must use more and more modern solutions that will ensure the achievement of goals. In the case of public transport in the city, which is operated by buses, it is important to make the most recent and up-to-date information available to travelers. The most useful information for travelers is, of course, arrival/departure time, travel time, and up-to-date information on delays. Additionally, the payment options for city tickets are important, so that the payment method and the availability of tickets do not cause any problems for travelers [Barceló et al. 2005].

Due to the growing requirements of people traveling by public transport, telematics has proved to be helpful. It allowed for visible development in the area of public transport infrastructure, making traveling more pleasant and comfortable. In addition, telematics increases the competitiveness of public transport in relation to individual modes of transport by providing passengers with the latest information and modern payment methods.

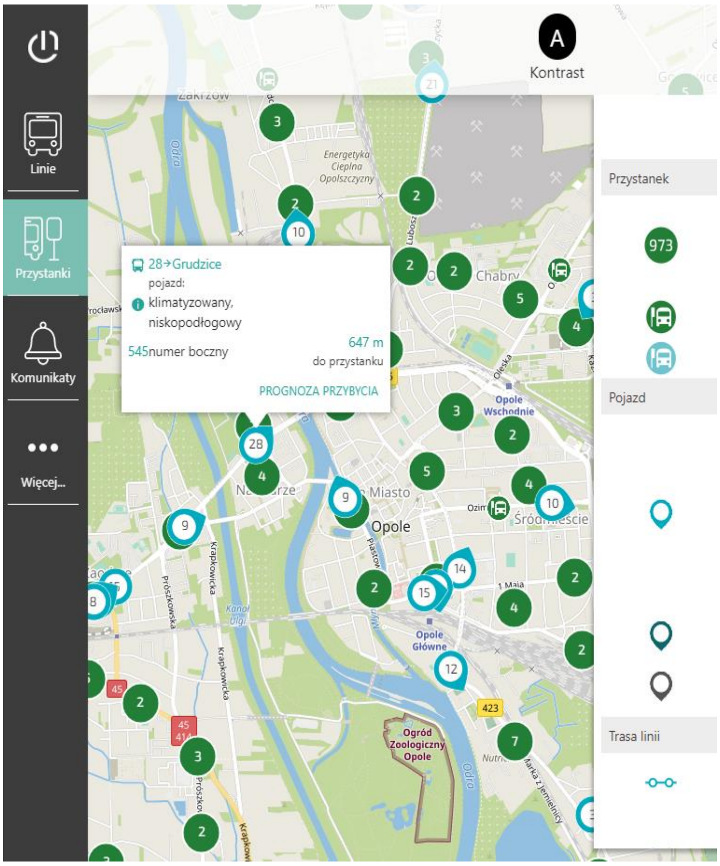

Figure 2. Passenger portal – dynamic passenger information MZK Opole

Rysunek 2. Portal pasażerski – dynamiczna informacja pasażerska MZK Opole

Source: [Dynamiczna informacja…].

As telematics solutions supporting public transport in cities, the following can be distinguished:

1. Dynamic passenger information system – it is a system whose task is the ongoing management of information flow and making it available. Thanks to this, people using the transport offered by the organizer of the public transport network have constant and free

access to up-to-date data on: commuting, bus position. Due to the wide use of GPS transmitters in public transport vehicles, it is possible to read the current position of the vehicles, which are then transferred to the management center. The management center is then able to process the information received and provide passengers with the actual arrival time of the buses and any delays caused by traffic congestion [Brożyna 2017]. All information regarding the time of departures, arrivals, delays and bus features (such as: low floor, air conditioning) is transferred to passenger portals (Figure 2), mobile applications and electronic variable message boards (Figure 3).

Figure 3. A variable message board at the bus stop in Opole
Rysunek. 3. Zmienna tablica ogłoszeń na przystanku autobusowym w Opolu
Source: [maj and usz 2020].

The passenger portal is able to provide the passenger with all the relevant information about the time and position of the bus, and even the remaining distance to the nearest stop. In addition, the designers of the portal took care of the clear and legible appearance of the website so that everyone could read the necessary information without any problems.

Locating variable message boards at bus stops in the realities of the frequent road congestion in cities, which causes delays in the arrival of city buses, has a huge impact on: reducing the uncertainty of travelers as to the arrival of the bus, improving the comfort of waiting for the bus due to the possibility of making sure that the bus did not depart anymore [Kaszubowski and Oskarbski 2011].

2. Priority system for public transport vehicles – the growing number of passenger cars and other private means of transport has resulted in the phenomenon of congestion, which has extended the travel time through the city streets. For this reason, more and more

extensive implementation of the priority system at intersections for public transport vehicles has started. In order to obtain the greatest possible continuity of city bus traffic, modern telematics elements are used, which can identify public transport vehicles even several meters before the intersection – in order to adjust traffic lights in time for all road users, taking into account the priority for the oncoming bus, of course. Identification of public transport vehicles can be performed using: induction loops and video detection. For the priority system to function properly, special signals for buses are used at intersections, and the whole is managed by a controller usually located in the vicinity of the intersection [Perzński and Lewiński 2016].

3. Electronic toll collection system – toll collection systems for journeys by means of public transport may also be modern. In order to facilitate the purchase of tickets for individual city zones or the number of journeys, automatic toll collection systems have been implemented. They record the time a passenger gets on and off, so that fares can be charged in direct proportion to the number of stops traveled - instead of a predetermined ticket price, regardless of the number of stops traveled.
4. In addition to the fair distribution of costs for bus journeys, the carrier obtains data, inter alia, on the number of passengers and stops used by the most people. On the basis of what you can decide about a greater number of stops on the so-called task [Biniasz 2016].
5. Dynamic bus lanes – most often in Polish cities you can meet fixed bus lanes by placing appropriate road signs and painting horizontal signs. However, access to telematics solutions allows the introduction of flexible bus lanes, which are introduced only when they are needed. This is an interesting idea, because in some places bus lanes cannot be marked constantly in both directions of travel. Therefore, we can distinguish dynamic bus lanes located on the outer lanes of the road and dynamic variable-direction bus lanes, which are marked at the axis of the road. The variable-direction bus lane will find its application especially on three-lane roads, which are characterized by heavy traffic and the occurrence of congestion during rush hours. Therefore, the middle lane designated as a floating lane in the morning rush hours may function as a bus lane towards the center, while in the afternoon rush hours the bus lane would function in the opposite direction. According to the current regulations, there are no regulations that would determine the specific marking of dynamic bus lanes. Certainly, in terms of organization, changing a given lane in a bus lane must be preceded by displaying the new traffic organization in advance. This is due to the fact that all vehicles driving in a dynamically changing lane have time to leave it freely. On the other hand, drivers of vehicles who see the new marking must comply with it and not enter the dynamic lane. In this way, after some time, the dynamic bus lane will be free from means of individual transport, and buses will be able to use it, reducing travel time as a result of, for example, a missed traffic jam [Molecki 2016]. It should be taken into account that the main condition for creating dynamic bus lanes is a road consisting of at least three lanes (Figure 4).

Figure 4. Markings for a dynamic bus lane
Ryc. 4. Oznaczenia dynamicznego pasa dla autobusów
Source: [Ruciński n.d.].

All the above-mentioned telematic systems for payments, organization, traffic management and information flow are designed to support the currently functioning public transport networks. The solutions presented in this chapter were created mainly for passengers, their comfort and convenience, as well as improving the bus travel time during rush hours. However, these activities do not only affect the benefit of people using public transport, but also create a competitive advantage of public transport companies over individual transport – thus they can reduce road traffic, reduce the incidence of road congestion and help to reduce the amount of exhaust fumes in cities.

System environment diagram for Intelligent Transport Systems

Intelligent transport systems have numerous tools that can be used in city logistics. The ITS architecture is the basis for planning, defining, connecting and coordinating individual transport subsystems in the areas of city logistics. It was defined on the basis of the transport system, the main link of which is the system environment, i.e. city logistics. On Figure 5 is a diagram of the elements of intelligent transport systems in city logistics.

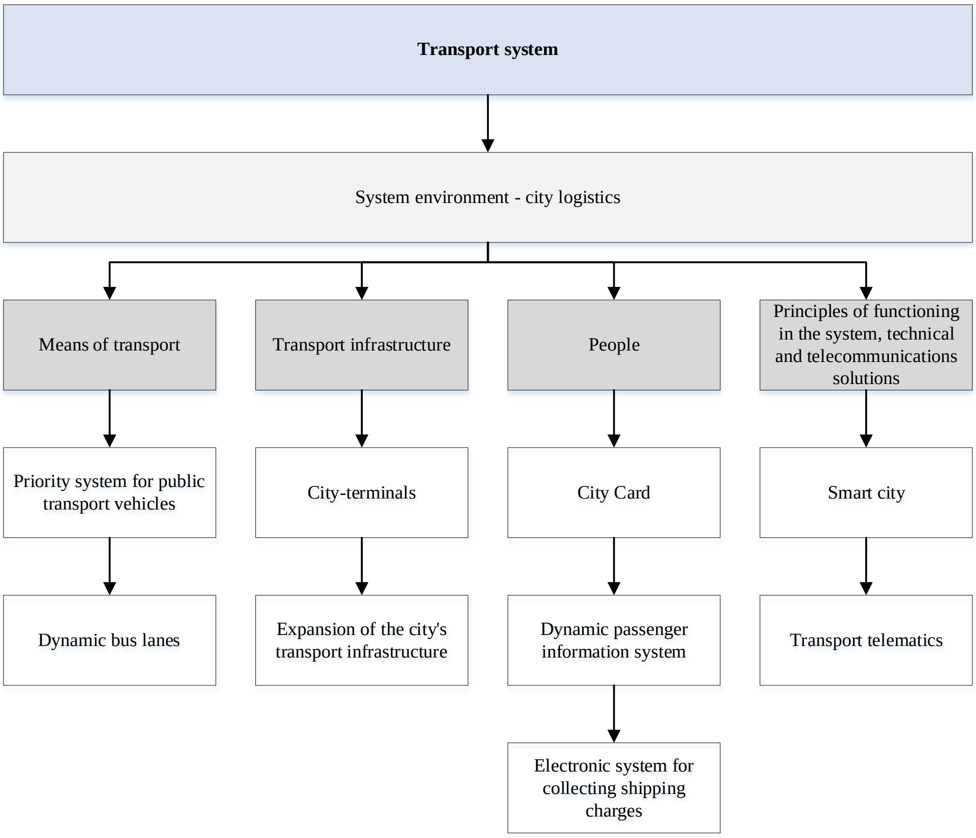

Figure 5. System environment diagram for Intelligent Transport Systems
Rysunek 5. Diagram środowiska systemowego dla inteligentnych systemów transportowych
Source: own study.

The functioning and development of a transport company and urban logistics areas should rely on the ability to adapt the transport system to the environment. Therefore, the four main links in the system environment have been characterized:

- means of transport,
- transport infrastructure,
- people,
- principles of functioning in the system, technical and telecommunications solutions.

Appropriate tools belonging to the group of intelligent transport systems in city logistics have been assigned to a particular group of the environment. By presenting the tools in a pictorial way, it was possible to adjust the appropriate element to the needs of a given area of city logistics. The ITS is the basis for the effective development of city logistics. Indication of elements where appropriate tools can be introduced makes it easier for individual units that will want to implement appropriate ITS tools to familiarize themselves with the elements.

Cities are large areas with numerous buildings between which there is an extensive road infrastructure. The need to move is connected with a high population density in the city, which causes a large volume of traffic – especially road traffic. Improving road traffic flow and reducing road congestion is possible thanks to the use of intelligent transport systems tools.

Conclusion

The public transport network in each city plays a very important role, as it allows residents to maintain a high level of mobility throughout the entire urban agglomeration. Along with the increasing popularity of a passenger car, the scale of congestion in cities is increasing, which has a negative impact primarily on the natural environment and the quality of life of city residents. City authorities are taking various measures to reduce vehicle traffic and make driving smoother. One of the elements of increasing the capacity of urban agglomerations is the implementation of intelligent transport systems tools. The functioning and development of a transport company and urban logistics areas should rely on the ability to adapt the transport system to the environment. Therefore, the four main links in the transport system environment have been characterized, namely: means of transport, transport infrastructure, people, principles of functioning in the system, as well as technical and telecommunications solutions. Improving road traffic flow and reducing road congestion is possible thanks to the use of various tools of intelligent transport systems of urban logistics. Research facilities are two urban agglomerations. Despite the fact that the scope of entities is a narrow research group, they translate into most urban agglomerations.

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Parking space occupancy as an example of a shared resource modelling problem

Zajmowanie miejsc parkingowych jako przykład problemu modelowania zasobów współdzielonych

Abstract. City logistics is at the forefront of mainstream logistics. In the literature, definitions of this logistics include, among others, the issues of traffic flow and parking space availability in cities. There is a steady increase in the number of wheeled vehicles in cities of all sizes. This generates the problem of parking space availability. The limited amount of available parking resources, which will always be insufficient, especially with increasing vehicular traffic, causes the need for their rational use. In this paper, we analyse the problem of occupancy and demand for free parking spaces. A discrete simulation method was used. A stochastic model was developed in a computer environment, taking into account such parameters as: (a) density of traffic streams; (b) demand of vehicles for free space; (c) vehicle parking times; (d) actual parking space utilisation in examples. Simulations using the developed model were carried out for three car parks. These showed that only car park B maintained traffic flow, as it had enough spaces to handle the traffic flow. Car parks A, and B are inefficient and allow for a smooth parking period of 2 to 3 hours from a neutral state. However, this is impossible in practice as these car parks are never empty as there are always vehicles parked there. The simulation gives reliable results within a 90% confidence interval.

Key words: logistics, parking spaces, modelling, parking utilisation analysis

Synopsis. Logistyka miejska znajduje się w czołówce logistyki głównego nurtu. W literaturze definicje tej logistyki obejmują m.in. kwestie płynności ruchu i dostępności miejsc parkingowych w miastach. Obserwuje się stały wzrost liczby pojazdów kołowych w miastach każdej wielkości. Powoduje to problem dostępności miejsc parkingowych. Ograniczona ilość dostępnych zasobów parkingowych, która zawsze będzie niewystarczająca, zwłaszcza przy rosnącym ruchu kołowym, powoduje potrzebę ich racjonalnego wykorzystania. W artykule analizujemy problem obłożenia i zapotrzebowania na wolne miejsca parkingowe. Zastosowano dyskretną metodę symulacji. Model stochastyczny został opraco-

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wany w środowisku komputerowym, biorąc pod uwagę takie parametry, jak: (a) gęstość strumieni ruchu; (b) zapotrzebowanie pojazdów na wolną przestrzeń; (c) czas parkowania pojazdów; (d) rzeczywiste wykorzystanie miejsca parkingowego w przykładach. Symulacje z wykorzystaniem opracowanego modelu przeprowadzono dla trzech parkingów. Wykazały one, że tylko parking B utrzymywał płynność ruchu, ponieważ miał wystarczająco dużo miejsc do obsługi przepływu ruchu. Parkingi A i B są nieefektywne i pozwalają na płynny okres parkowania od 2 do 3 godzin od stanu neutralnego. Jest to jednak niemożliwe w praktyce, ponieważ parkingi te nigdy nie są puste, ponieważ zawsze są tam zaparkowane pojazdy. Symulacja daje wiarygodne wyniki w 90-procentowym przedziale ufności.

Słowa kluczowe: logistyka, miejsca parkingowe, modelowanie, analiza wykorzystania parkingów

JEL codes: L91, R40, R41, M20

Introduction

Logistics is a relatively young and quite capacious field of knowledge, and its importance in the economy and business is growing in parallel with the increase in com-petition on the market. It affects not only large concerns but also a medium, small, and micro-enterprises. The tasks posed to logistics in enterprises vary depending on the organisation of the company, its size, and structure, as well as the multiplicity and range of tasks that it can cover [Brzeziński 2006].

A completely different category of problems is tackled by city logistics, which has a prominent place in mainstream logistics. In the literature there are many definitions of city logistics [Würdemann 1992, Stabenau 1993, Sołtysik 2001, Taniguchi et. al 2001, Krawczyk 2004, Crainic 2009] in which one of the most important priorities to improve is the fluidity of communication and availability of parking spaces in cities. Hence the idea for the topic in this paper. As the number of wheeled vehicles is con-stantly increasing in cities of all sizes, the same problem occurs – the limited amount of available parking resources, which will always be insufficient, especially with in-creasing vehicular traffic.

This study aims to show a new method and possibilities of computer modelling of resource occupancy, using the example of the use of parking spaces – as a resource shared with other road users. As a consequence of simulations, it will be possible to estimate the demand for parking spaces, taking into account local conditions such as traffic flow density and average packing times in a given area. In a broader context, the presented solution may find application in many fields, among others:

- investigation of the occupancy of car parks, post boxes, parcel machines, etc;
- survey on the occupancy of borrowed resources, library, bicycle rental, etc;
- testing the occupancy of toilets, vending machines, or other public facilities;
- testing the occupancy of any buffer zones in urban traffic or industry.

State of the art review

For a better understanding of the problem, previously applicable approaches for the analysis of the use of already existing car parks will be shown, as well as methods for estimating the required number of parking spaces for new developments. In construction projects, it is assumed that the number of parking spaces is determined by accepted standards. Using these global benchmarks ignores the existing variation in local traffic behaviour. This paper [Stienstra 2014] describes a calculation method that takes into account local conditions. The essential elements in the calculation are:

- the number of arrivals,
- parking period,
- the permissible level of car park occupancy.

In the proposed approach, the number of parking spaces needed for the development can be calculated using equation (1).

$$P = \frac{A*D}{B*T} \tag{1}$$

where:

P – number of parking spaces required,
A – number of vehicle arrivals during the survey period (e.g. working day or Saturday),
D – average dwell time,
B – average permissible occupancy level,
T – test period, number of hours (minutes) for the test period.

The variables *D* (mean parking time) and *T* (test period) shall be expressed in the same units (e.g. hours or minutes). The average idle time (*D*) of the cars is calculated using formula (2).

$$D = \frac{\sum d_i}{A} \tag{2}$$

To calculate the value of (*D*), an additional variable d_i is introduced in formula (2), which denotes the parking time of a single car in the car park. However, if the adopted unit of time measurement is the minute, then the total number of parking minutes used will be expressed by formula (3).

$$\mathrm{A} \cdot \frac{\sum d_i}{A} = A \cdot D \tag{3}$$

An incremental method for determining the demand for free parking spaces at MOPs along motorways and expressways is presented in the paper (Stawowy et al. 2017). The use of video monitoring for computer counting of vehicles entering and leaving the service area was used. Based on the computer processing of discrete data, the demand for parking spaces in a given period is calculated. Aggregation of events to designated periods will enable the presentation of the number of vehicles as a function of time. The number of cars entering the MOP in the period from $t_1$to t_2 is determined using formula (4). The number of cars leaving the MOP in the period from $t_1$to t_2, formula (5).

$$n_{1(t_1;\, t_2)} = \sum_{t_2}^{t_1} e_{1\,(t_1;t_2)} \tag{4}$$

$$n_{2(t_1;\, t_2)} = \sum_{t_1}^{t_2} e_{2\,(t_1;t_2)} \tag{5}$$

$$n_z = \sum_{t_3}^{t_4} \left(\sum_{t_1}^{t_2} e_{1(t_1;t_2)} - \sum_{t_1}^{t_2} e_{2(t_1;t_2)} \right)_{(t_3;t_4)} \tag{6}$$

where:

- e_1 and e_2 are vehicle registration events at the entrance and exit of the MOP respectively,
- t_1 and t_2 are the initial and final times (moments), respectively, for determining the value of n.

The authors calculate the parking demand in a given period using formula (6), where the period from t_3 to t_4 is the time for determining the parking demand of the car park n_z.

Slightly different but important indicators were considered when analyzing the use of parking spaces in the Krakow Paid Parking Zone [Pietruch 2017]. In addition to the typical counting of vehicles and occupancy, parking turnover was measured, the basic measure of which was the parking turnover ratio W_r according to formula (7), as well as the parking space utilization ratio W_p according to formula (8).

$$W_r = \frac{P_{pn}}{M_p} [P/\text{stanowisko}] \tag{7}$$

$$W_p = \frac{P_p}{M_p} \cdot 100[\%] \tag{8}$$

where:

- P_{pn} is the total number of vehicles using the parking spaces during the study period,
- M_p is the total supply of parking spaces,
- P_p is the number of parked vehicles in a given period (defined as the percentage of parking spaces occupied by parked vehicles in a given period).

A very interesting, but different approach to estimating the need for parking spaces is presented in another paper [Hampshire 2018]. In this case, the authors focused on studying the traffic stream in order to estimate the number of parking spaces needed based on its intensity. An observation was made of an empty parking space in the vicinity of the traffic stream. They then counted how many vehicles are willing to occupy this empty space. On this basis, formula (9) was developed to calculate the parking demand.

$$\hat{p} = \frac{n}{\sum_{i=1}^{n} x_i} \tag{9}$$

The method is very easy and practical to apply because it answers the question of what part of the traffic stream wants to park. Each car in motion creates a traffic stream. In order to use this method in practice, it is necessary to make *(n)* observations, to check how many cars drive past a free parking space and how many want to park there. One vehicle trip is one observation, i.e. an attempt to park in the free space. Each attempt can end in two ways:

- success – the car is parked,
- failure – the car passes a vacant parking space and drives on.

The estimation is performed based on a geometric probability distribution. For each observation, we count the number of attempts needed to achieve success, i.e. to park the vehicle. The probability of observing success (p), forms the share of drivers in the traffic looking for free parking. We assume that $X_1, X_2, \ldots, X_n$ corresponds to a sequence of n-independent observations at a newly vacated parking space, where X_i is the number of passing cars before the first success. Based on equation (9), it is possible to estimate the probability of the share of cars in traffic. And the estimated share of cars in traffic is the inverse of the average number of cars that want to park. Of course, such an estimation is always subject to statistical error and should be expressed in terms of a confidence interval, giving the standard deviation or variance.

The computational example given by the authors is as follows. Suppose that 20 observations have been made of how many cars pass a vacant parking space before occupying it. Consider the following distribution of the distribution:

- in 10 attempts, parks the first oncoming car that sees a clear space.
- in 5 attempts, parks the second passing car that sees a clear space.
- in the remaining 5 five trials, park the third car that sees the open space.

The calculation for all trials for success is as follows:

$$\sum_{i=1}^{20} X_i = 10 \cdot 1 + 5 \cdot 2 + 5 \cdot 3 = 35$$

The estimated amount of parking space required will be according to formula (9):

$$\hat{p} = \frac{20}{35} = 0{,}57.$$

The reported result of 0.57 falls within the standard 95% confidence interval of *0.41* $\leq p\hat{} \leq$ *0.73*, according to the authors' assumptions the number of observations above 300 already gives very precise estimates suitable for practical applications.

In the following paper [Spławińska and Solecka 2017], a review of existing methodologies for estimating parking spaces at MOP facilities in various countries, including Poland, the United Kingdom, the USA, and Germany, is presented. As a result of comparing the existing methodologies used in these countries, the characteristics on which the number of needed places at MOPs may depend were singled out and taken into account in the proposal of a new national methodology formula (10).

$$P_T = N_T \cdot SDR_T \cdot WS_T [\text{liczba miejsc/15km}] \tag{10}$$

where:

T – type of vehicle (light, heavy),

P_T – number of parking spaces required,

N_T – conversion ratio (taking into account peak parking demand, average parking time, percentage of vehicles stopping at the ILO, ILO facilities, spatial linkage),

SDR_T – average daily traffic per year in the analysed traffic direction,

WS_T – index of seasonal variation (taking into account the peak month and day of the week of the year).

The most important change in the proposed solution is the consideration of the seasonal variability of traffic (the highest average traffic volume per year instead of the average daily traffic per year) and the directions of traffic. Furthermore, it is possible to clearly define the length of the road section for which the number of parking spaces will be determined (for example the minimum required for motorways i.e. 15 km) as well as the attractiveness of the MOP. On the other hand, the methodology is universal (it allows determining the number of spaces needed for light and heavy vehicles) and simple (tabulated volumes).

In addition to demand planning and parking space location, an important new class of problems arises with parking management systems. Today, city logistics and so-called *smart city* solutions use intelligent systems to manage parking vacancies, space reservations and driver guidance. Smart parking systems receive parking requests one by one, which have to be processed in real-time and operate online. Examples of such solutions can be found in the extensive literature on the subject, including works [Zhao et al. 2014, Amato et al. 2016, Litman 2016] and others.

Materials and methods

A discrete simulation method will be used to analyse the occupancy and demand for available parking spaces. A stochastic model will be developed in the computer environment to take into account parameters such as:

- the density of traffic flows;
- vehicle requests for space;
- vehicle parking times,
- the actual development of parking spaces in examples.

Based on the input variables, statistical distributions will be developed for the generation of events in the simulation model. A well estimated statistical distribution is able to accurately represent the real events using a random number generator. The input events, i.e. parking requests, will be described by an exponential distribution, widely described in the literature [Matuszak 2011, Grishkevich 2015][1]. This distribution is widely used in many fields, such as traffic modelling, customer service, handling incoming requests, etc. It is the so-called "memoryless" distribution, the best for generating randomness, described by the function $f{:}R \rightarrow R$, formula (11), where $\lambda > 0$ is the probability density of the event. On the other hand, the expected value of the arrival of an event (in the literature can be found under the name of the scale parameter), is described by formula (12).

$$f(x) = \begin{cases} 0 & dla\ x<0 \\ \lambda e^{-\lambda x} & dla\ x\geq 0, \end{cases} \tag{11}$$

$$E(X) = \frac{1}{\lambda}, D^2(X) = \frac{1}{\lambda^2} \tag{12}$$

Vehicle traffic and driver behaviour observations will be carried out at three randomly selected car parks in Przemyśl (Figures 1, 2, 3):
Specification of individual car parks:

- **A** city-center car park on the surface, payable, 89 parking spaces + 5 disabled parking spaces (Figure 1) – mainly tourist services, shopping, offices, offices;
- **B** parking at the shopping centre, underground, free of charge, 800 parking spaces including handicap spaces (Figure 2) – shopping, entertainment;
- **C** parking at the municipal office, parking along a one-way road, 20 spaces + space for a disabled person (Figure 3) – administrative matters.

[1] https://wazniak.mimuw.edu.pl/index.php?title=Rachunek_prawdopodobienstwa_i_statystyka [accessed: 14.12. 2021]

Disabled parking spaces will not be included in the simulation model as their existence is regulated by separate legislation.

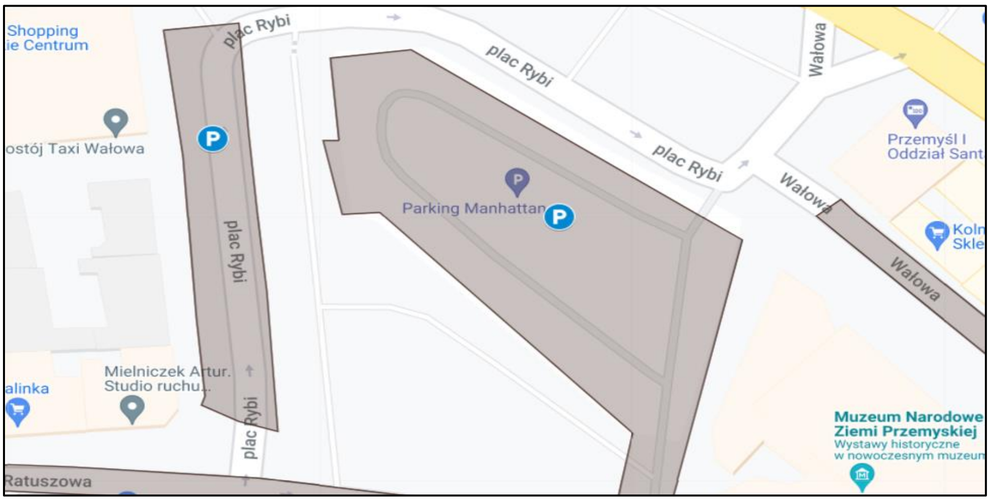

Figure 2. Car park A – Manhattan

Rysunek 1. Parking A – Manhattan

Source: Google Maps.

Figure 2. Car park B – shopping centre

Rysunek 2. Parking B – centrum handlowe

Source: authors' photo.

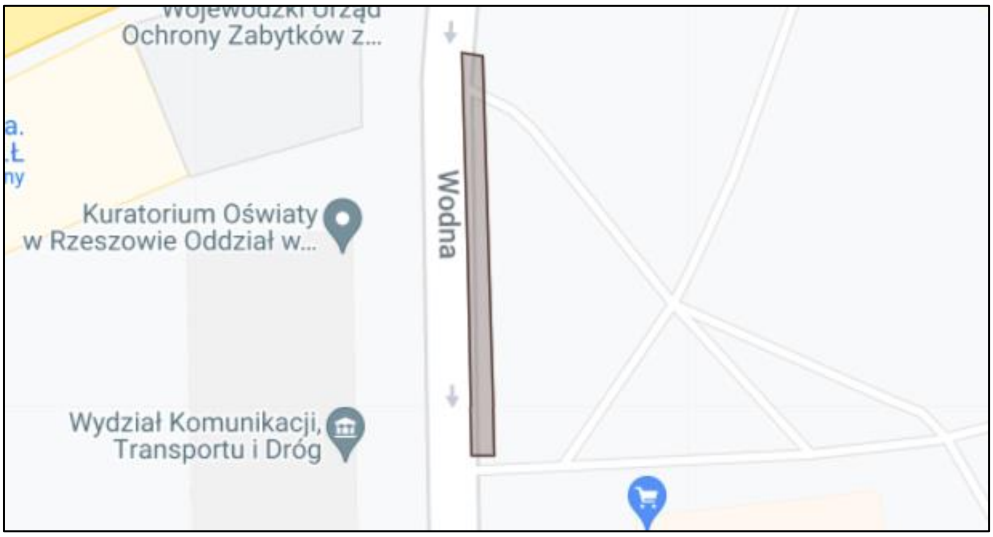

Figure 3. Parking area C – parking spaces along Water street in Przemyśl
Rysunek 3. Parking C – miejsca parkingowe wzdłuż ulicy Wodnej w Przemyślu
Source: Google Maps.

Quantitative measurements in traffic conditions were carried out at car parks A, B, C, the visualisations of which are presented in Figurs 1, 2, 3. Input data for the model were estimated based on empirical observations during the daily traffic rush hours between 3 p.m. and 5 p.m. on working days. The following parameters were assumed for the statistical distribution:

- the frequency of accesses to car park A averages 1 vehicle per minute;
- parking time at car park A is 90 minutes on average;
- frequency of accesses to parking area B average of 1 vehicle every 20 seconds;
- parking time at car park B on average 120 minutes;
- frequency of accesses to car park C average of 1 vehicle every 125 seconds;
- Parking time at car park C is 60 minutes on average;

It is worth reminding that these are not values for simple arithmetic mean, but estimated intervals of events in the Poisson process, which in a short period of time are very random, only in a long period of observation they tend to the mean values recorded in the model. This way of an event description is the best for modelling randomness in traffic. The second advantage of such a description of data is the possibility to realise many scenarios for conducting a series of simulation experiments with variable input parameters.

Figure 4 shows a block diagram of the computer model for investigating parking space occupancy. The necessary computational algorithms have been developed and the input parameters have been entered, i.e. entry frequencies, parking times, and available parking space resources. In the following section, the results obtained from the simulations carried out will be discussed.

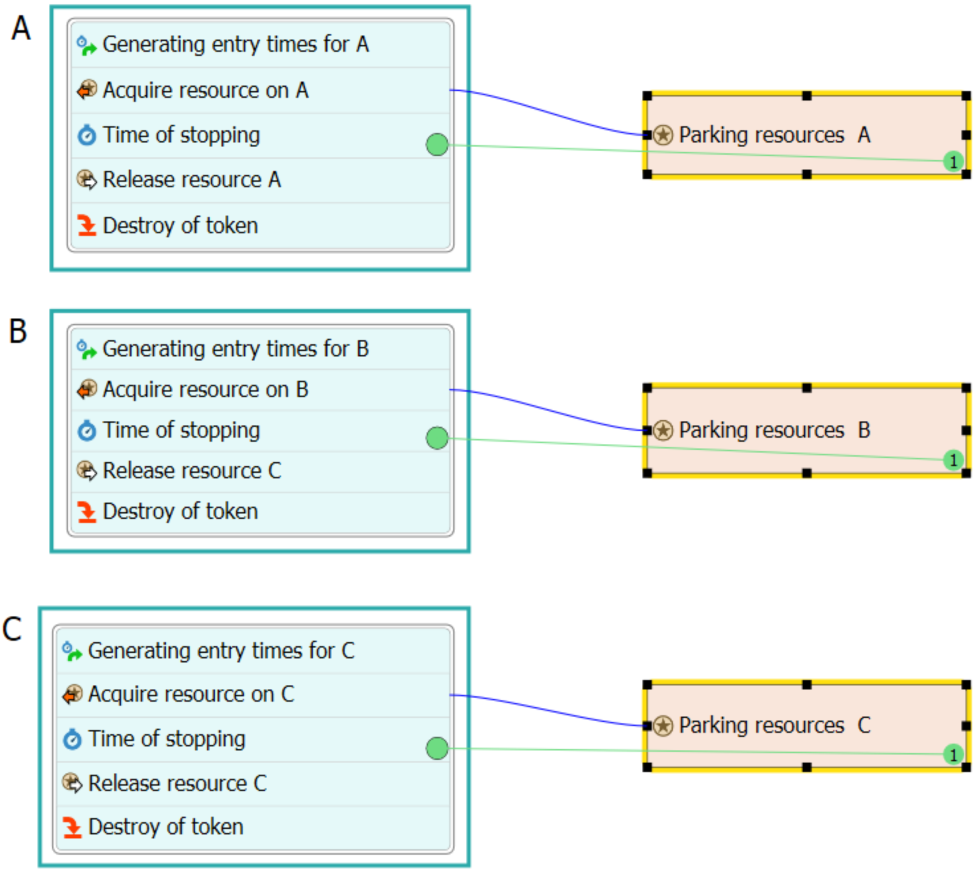

Figure 4. Block diagram of the computer model for the implementation of events in car parks A, B, C
Rysunek 4. Schemat blokowy modelu komputerowego do realizacji zdarzeń na parkingach A, B, C
Source: own studies.

Results and Discussion

The results of the analysis for car park A are presented graphically in Figure 5, which consists of three diagrams. Assumed time unit 1 second, simulation period 8-hour shift from 8.00 a.m. to 4.00 p.m..

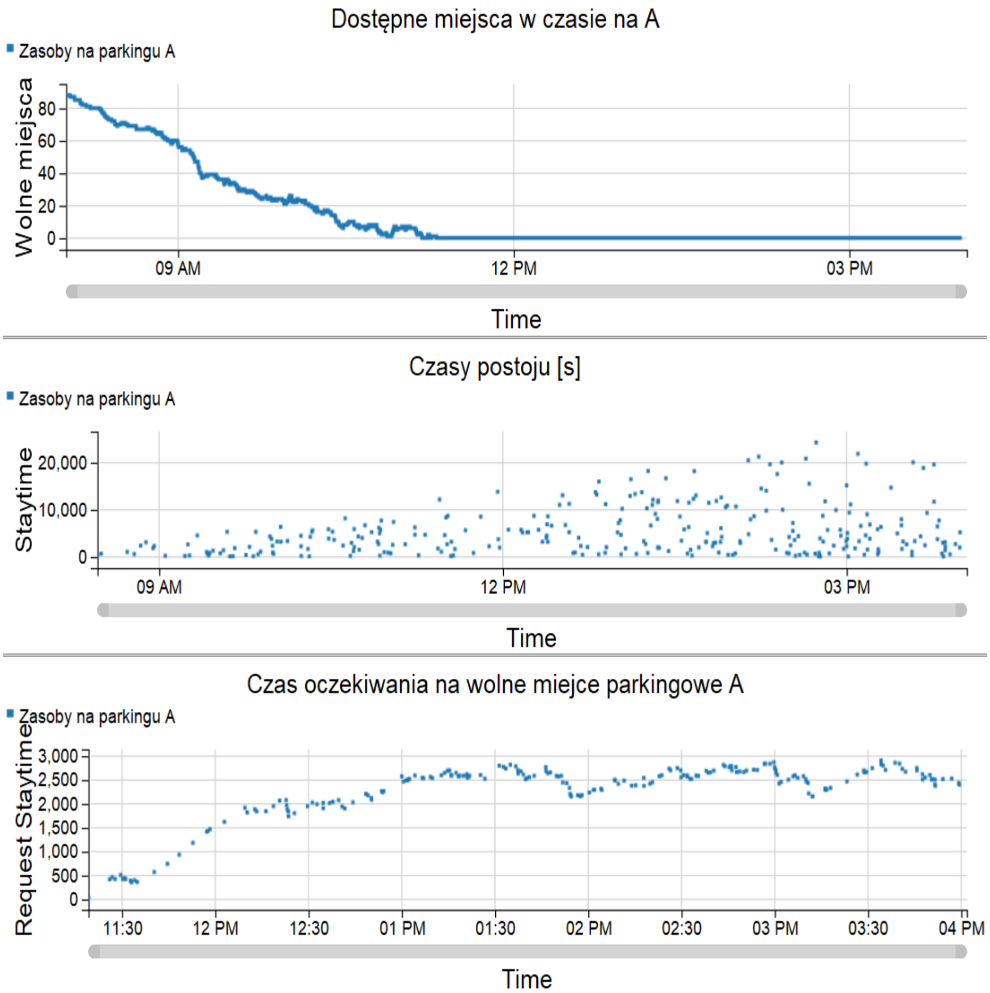

Figure 5. Test results for car park A
Rysunek 5. Wyniki badań dla parkingu A
Source: own studies

Figure 5 is in three parts, going from the top it can be seen that free parking spaces are exhausted already around 11.15 a.m., the size of the stock from this point on is zero. After this hour, the next arriving cars have to wait for free space or they give up parking. Then going down the figure one can read the next operational parameters:

- dwell time: min.: 10.71, max: 23327.71, mean: 5027.48;
- parking requests: 487
- vehicles serviced: 372
- unserviced vehicles: 115
- theoretical average waiting time for free space when the entire car park is full: 1844.89 seconds.

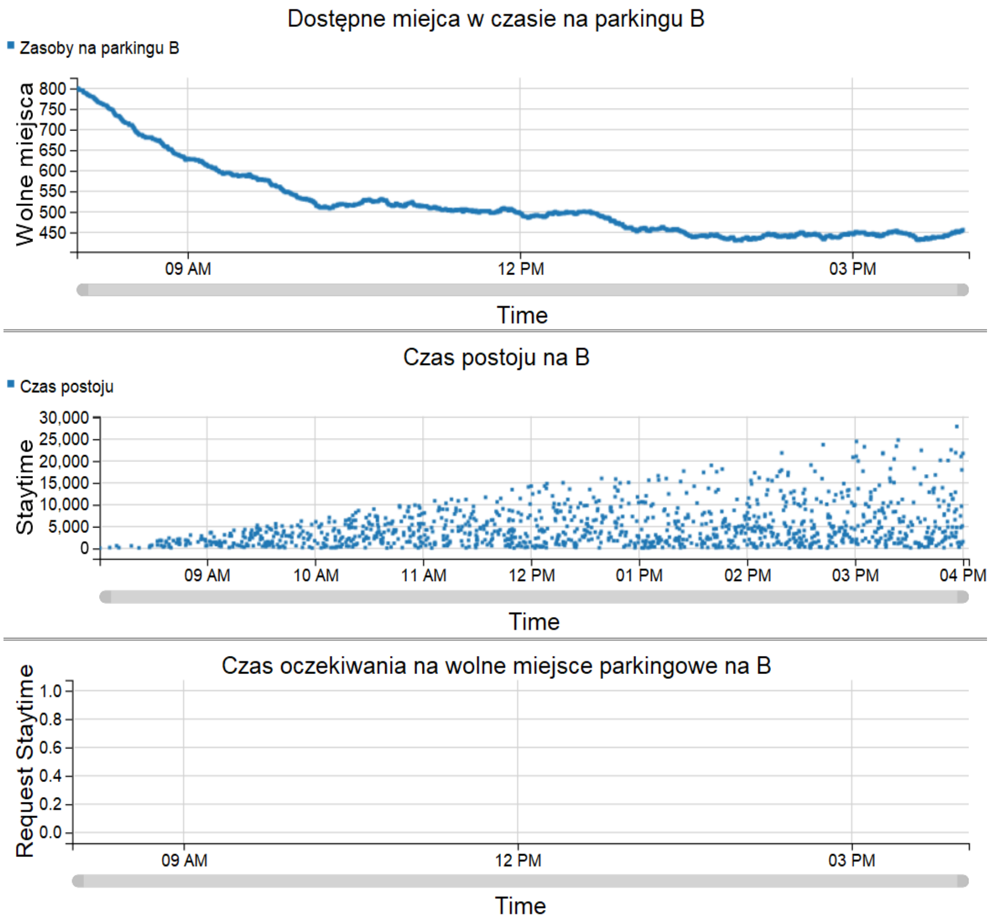

Figure 6. Test results for car park B
Rysunek 6. Wyniki badań dla parkingu B
Source: own studies

Simulation results for car park B are shown in Figure 6, which also consists of three diagrams. Assumed time unit 1 second, simulation period 8-hour shift from 8.00 a.m. to 4.00 p.m. In this case, the free parking spaces are not exhausted, the average number of free resources is maintained at about 517 spaces. As there are no problems in this car park and free spaces are available the waiting time is zero, the bottom diagram in Figure 6 is empty. Key performance parameters estimated by the model:

- dwell time: min: 22.20, max: 27821.87, mean: 4892.49;
- parking requests: 1534;
- vehicles serviced: 1534;
- vehicles not serviced: 0;

- theoretical average waiting time for free space when the entire car park is full: 0 seconds.

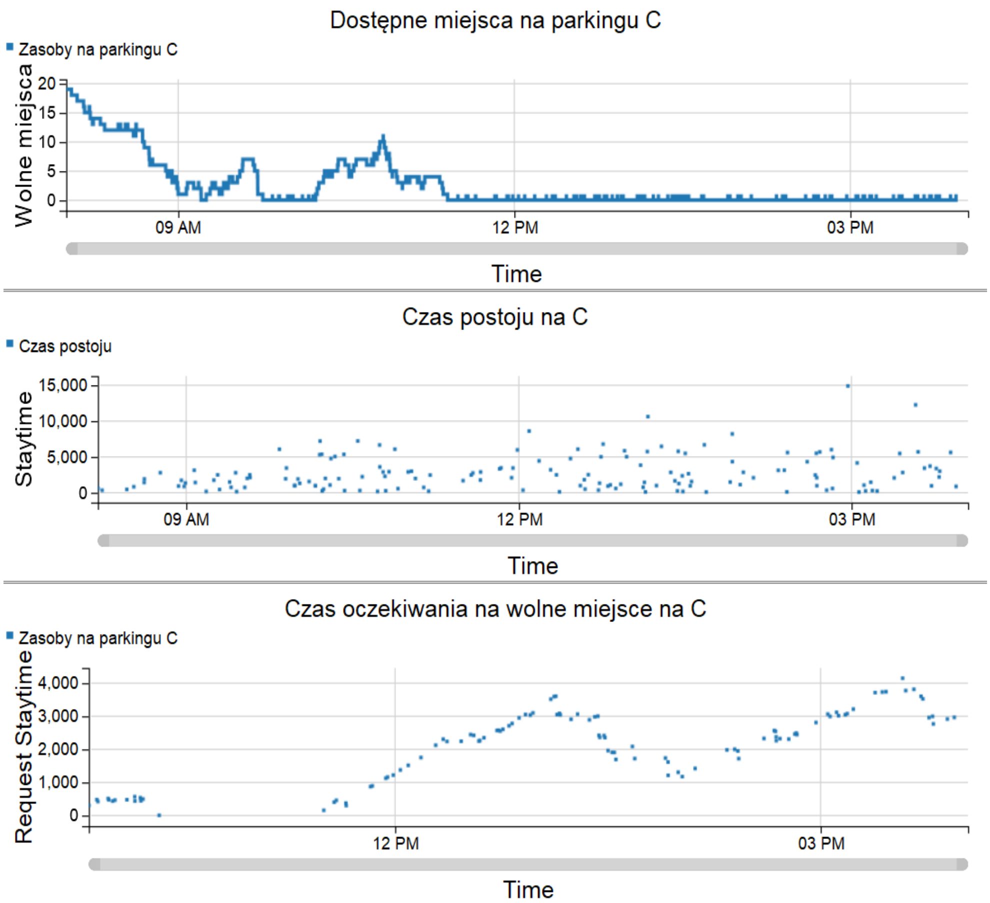

Figure 7. Test results for car park C

Rysunek 6. Wyniki badań dla parkingu C

Source: own studies

The simulation results for car park C are shown in Figures 7, which also consists of three diagrams. The time unit used is 1 second, the simulation period is an 8-hour shift from 8.00 a.m. to 4.00 p.m. In the first diagram (Figure 7), it can be seen that free parking spaces are exhausted already around 11 a.m., the volume of resources from then on is zero until the parking space previously occupied is released. After this hour, theoretically, the next arriving cars can wait for a free space, but practically they give up parking and drive on because of the obstruction of traffic. Other operating parameters can then be read out:

- Estimated stopping time: min.: 58.04, max: 14856.06, mean: 2710.78;
- parking requests: 204;
- vehicles served: 179;

- unserviced vehicles: 25;

theoretical average waiting time for free space when the entire car park is full: 1286.74 seconds.

Conclusion

As the simulations showed, only car park B kept traffic flowing as it had enough spaces to handle the traffic flow. Car parks A and B are inefficient and allow smooth parking from zero, i.e. from full capacity, within 2 to 3 hours. However, this is impos-sible in practice as these car parks are never empty because there are always vehicles parked there. The simulation carried out gave reliable results within a 90% con-fidence interval. In order to obtain more precise results, it would be necessary to make longer empirical observations (and not only during peak hours), as traffic volume changes quite dynamically during the day. In the simulations carried out for A and C, the maximum intensities were assumed. However, for car park B (shopping centre) the empirical studies based on which the model parameters were estimated concerned the average working day. Exceptional situations can be pre-holidays or special events, which can lead to all spaces being occupied.

Management in the area of city logistics is a multifaceted issue and modern simula-tion methods work well in this field. Often in city centres it is not possible to expand parking spaces due to various restrictions and lack of space. The only way to keep traffic flowing is through integrated management of available resources.

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Telematics in car fleet management

Telematyka w zarządzaniu flotą samochodową

Abstract. This work describes the characteristic of telematics used in car fleet management. The main aim of the work was to show the functioning of telematics systems in car fleet management. The genesis and history of telematics were presented. Issues related to the types and functionalities of telematics systems were addressed. The benefits and risks of using the telematics system in fleet management are listed. The benefits are lower fuel costs, lower operating costs, faster delivery. Threats include concerns about employee privacy, costly system implementation, and difficulties in familiarizing employees with the new system. The above-mentioned benefits and threats show whether it is worth introducing telematics solutions in a given enterprise and what to pay attention to when choosing a telematics system. The difference in the use of telematics in the world as a result of uneven economic development of selected countries was shown. The value of the telematics market in car fleet management, which is growing every year, is presented. The study of the global vehicle telematics market penetration rate and GDP per capita showed differences in the development of the telematics market in selected countries due to uneven economic development. Most countries with higher GDP *per capita* had higher automotive telematics market penetration.

Key words: telematics, fleet management, transport

Synopsis. W artykule przedstawiono charakterystykę telematyki wykorzystywanej w zarządzaniu flotą samochodową. Głównym celem pracy było rozpoznanie funkcjonowania systemów telematycznych w zarządzaniu flotą samochodową. Przedstawiono genezę oraz historię telematyki oraz zagadnienia związane z rodzajami i funkcjonalnościami systemów telematycznych. Wymieniono korzyści i zagrożenia wynikające z korzystania z systemów telematycznych w zarządzaniu flotą samochodową, do których należą: mniejsze koszty paliwa, mniejsze koszty eksploatacji, szybsza dostawa. Zagrożenia obejmują obawy o prywatność pracowników, kosztowne wdrożenie systemu, trudności w zapoznaniu pracowników z nowym systemem. Wymienione korzyści i zagrożenia pokazują, czy warto wprowadzać rozwiązania telematyczne w danym przedsiębiorstwie i na co zwracać uwagę przy wyborze systemu telematycznego. Wskazano różnicę w zastosowaniu telematyki na świecie w wyniku nierównomiernego rozwoju gospodarczego wybranych państw. Przedstawiono wartość rynku telematyki w zarządzaniu flotą samochodową, która z roku na rok się zwiększa. Badanie wskaźnika penetracji globalnego rynku telematyki pojazdów oraz PKB *per capita* wykazało różnice w rozwoju rynku telematyki w wybranych krajach spowodowane nierównomiernym rozwojem gospodarczym. W większości kraje o wyższej wartości PKB na mieszkańca miały wyższy wskaźnik penetracji rynku telematyki samochodowej.

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Słowa kluczowe: telematyka, zarządzanie flotą, transport

JEL codes: R40, R42

Introduction

The term "telematics" is a translation of the French word *télématique*. The term began to appear in the literature in the early 1970s. Telematics is a combination of two French words: telecommunications (fr. *télécommunications*) and informatics (fr. *informatique*). In Europe, the widespread use of the term telematics began only after the start of EU programs for the development of telematics in various fields [Rosiński 2014].

Telematics is usually defined as IT, telecommunication, information, and automatic control solutions. This term is mainly applied to electronic communication and electronic information acquisition and processing. Often the term is applied to technical solutions that use information and telecommunication systems in an integrated way [Wydro 2008].

The term telematics is usually used together with adjectives that define the field of application. Thus, we can distinguish certain areas such as urban, financial, operational, library, home, postal, medical telematics [Wydro 2008]. Telematics has developed at a very fast pace. Its origins date back to 1960. During the Cold War, the US Navy, using six satellites, managed to develop the Global Positioning System (GPS). The system was created to track submarines containing nuclear weapons. With the development of telematics, the world's first GPS satellite was launched into orbit in 1978. In the following ten years, a large number of such satellites were created and activated. In 1978, the term 'telematics' also appeared for the first time in a report created for the French government [The History…]. The year 1984 was a landmark in the early history of telematics. At that time, the European Parliament adopted a resolution to promote road safety. It was very important because it launched a large number of scientific studies relating to telematics [The History…]. In 1985, the world's first car navigation program was introduced to customers in the United States of America. The idea for this system came from Stanley Honey, CEO of Etak. It was a landmark achievement and marked the beginning of the large-scale use of GPS. In the 1990s, two significant trends emerged in the field of telematics. The first concerned the drive to improve the pieces of equipment that were responsible for securing vehicles. The second trend concerned the growing interest in developments in communications, electronics, mobile technology, and GPS. At the beginning of the decade, in 1990, Pioneer Electronics released the first navigation car system for consumer use. These systems used GPS satellites and CD-ROM maps to determine location [Palenchar 2014].

After some time, a directive was signed by President Clinton in 1996, which dealt with GPS and its international significance. The detente included information that citizens and companies would be able to use GPS free of charge [Antich 2017]. At the end of the 1990s, the first systems for vehicle location began to be developed. At the end of the decade, the company Data factory initiated in-vehicle, leading-edge web-based telematics interfaces. The development of telematics accelerated in the first decade of the 21st century. At that time, web-based fleet management systems were hosted on the web, and data could be seen in real-time. However, there was the disadvantage of map updates, which without broadband took half a day, while pages loaded very slowly [Antich 2013].

In 2004, TomTom introduced the world's first GPS receiver for satellite navigation. It changed the way people moved around the world. A year later, the innovative satellite began transmitting another signal to civilians. Towards the end of the decade, as a result of the global recession and subsequent financial crisis, there was an highted focus on increasing driver safety and reducing fuel consumption. In addition, a large number of different tools were developed and marketed, leading to increased efficiency and capability of fleet management systems, as well as increased driver safety. These tools included unified navigation linked to the vehicle's electronic systems, enhanced GPS navigations incorporating voice recognition, and GPS phones with Bluetooth headsets [The History…].

In 2010, smartphone applications linked to telematics were launched on the market. With these applications, fleet managers can remotely monitor vehicles and support drivers in daily administrative tasks. After 2010, telematics platforms started to offer cloud-based services with high-speed access to information. With the help of cooperation between different systems and API protocols, further opportunities were created in the telematics sector in 2014. These included, among others, the proliferation of systems connecting different devices, increasing companies' productivity, and connecting offices with the driver and the vehicle. Since 2015, companies have increasingly opted to use telematics. As a result, the telematics market value is growing at a rate of around 20–25% per year [Kilcarr 2015]. As of 2017, a large number of cars leaving factories are equipped with more than 100 sensors creating a regular stream of data [Richter 2017].

Telematics in transport offers the ability to analyze and monitor every detail of the logistics process. It helps to make proactive decisions that reduce operational costs, increase service levels, and maximize cargo and driver safety [Sharpe 2019]. The extent of the use and application of ICT (Information and Communication Technologies) in the management of transport systems applies equally to all modes of transport. Telematics solutions enable easier integration of these transport branches, influencing the creation of intermodal structures [Mikulski 2007]. Customer requirements are increasing as a result of continuous access to data via devices. More and more dynamic details are monitored, which concern every load in the truck fleet. In telematics, digitization is being pursued to make efficient use of the telematics data collected [Sharpe 2019].

The main aim of this paper was to show the functioning of telematics systems in car fleet management. The paper has the following specific objectives: to present the origins and history of telematics, to describe the types and services of telematics, to identify the benefits and risks of using telematics, to show the relationship between the degree of telematics development and the economic development of the country.

The paper sets out the following research hypothesis, according to which the use of telematics in the states studied depended on the country's level of economic development.

Materials and Methods

The area related to the use of telematics for car fleet management was selected for the study using of the purposive selection method. Sources of materials include domestic and foreign literature, articles, reports, specialist blogs, and websites. Descriptive and graphical methods were used to analyze and present the materials.

Results and discussion

Telematics functions in vehicle fleet management

An essential element of a telematics system is the placement of a monitoring device in the vehicle. The device allows, receiving, storing, and sending telematic data. When using a GPS receiver, important data is collected about the status of the vehicle and the current location of the vehicle in real-time. In-vehicle telematics also includes a trailer and asset monitoring, which is used to protect cargo under conditions of transit, condition, and location or storage. Drivers can to tag the GPS location when unhitching a trailer. The coordinates are then passed on allowing this direct navigation of the selected trailer [Bazylak 2020].

The optimization of routes and tasks also helps with telematics systems. As a result of combining the experience of logistics specialists in a transport company and telematics systems, drivers can drive the fastest routes, avoiding traffic jams and obstructions. Control and efficient transport management do not require sitting in an office. The entire command center can be located on a company laptop or smartphone [Optymalizacja procesów…].

Another functionality of telematics is to ensure the safety of traffic and the car. One example is checking the driving time of a vehicle so that, based on the GPS reading, it is possible to react immediately if the driver exceeds the maximum limit of hours on the road. As a result, regulations are complied with, and the risk of overtired drivers and subsequent accidents is reduced. With the help of cooperating control devices, we can obtain such data as driving with flat tires, approaching other cars, reaching the upper limits of engine speed, sudden slowing down and acceleration, dangerous cornering, etc. As a result of cooperation with speed cameras or traffic cameras, it is possible to detect offences such as failing to stop before a “stop” sign or driving through a red light. Telematics is also helpful in checking the technical condition of the vehicle. The assessment of the technical condition of the vehicle is influenced by the analyzed data on failures and defects. An increase in the frequency of faults and breakdowns is a message to replace the parts concerned or carry out a comprehensive inspection. One of the factors indicating irregular operation of a vehicle is an irrational increase in fuel consumption. Telematics systems provide information about the operational parameters of the vehicle and remind and register mandatory periodic inspections [W jaki sposób…].

Telematics makes it possible to create a fair, legal, and motivating driver accounting system. Telematics data, combined with the experience of company logisticians, makes it possible to determine the average efficiency of the fleet. By setting a certain range of kilometers and freight, it is possible to establish a base salary for the driver. There is also the option of adding bonuses for meeting selected criteria or achieving high results in comparison with other drivers [Telematyka jako narzędzie].

The control of refueling is also one of the telematics solutions. Telematics makes it possible to indicate the specific place of refueling and automatically integrates it with the invoice. The refuelings can be verified together with the value of the respective invoice. In addition, effective fuel measurement from a fuel probe, an algorithm, and also analytics are also used. This is a guarantee of no refueling discrepancies and a small fuel discount during refueling. A fuel filler safety device is also used to protect against driver abuse [Gospodarka paliwowa].

Benefits and risks of telematics systems in fleet management

One of the benefits of telematics is the reduction in fuel costs. Fuel consumption for a selected route depends on several factors. The most important parameters influencing fuel consumption are mainly the length and number of stops, consumption while driving, and route choice. The driver's driving style also affects fuel consumption. Telematics systems can detect wasteful driving and effectively eliminate it.

Telematics solutions make it possible to effectively reduce the overuse of vehicles by continuously monitoring all parameters that are important to the fleet manager. With the implementation of telematics, maintenance and repair costs can be reduced as the driver is aware that his behavior is being recorded and therefore drives more carefully. As a result, the risk of a collision or accident and the wear and tear on the car is reduced. In addition, telematics systems send diagnostic information to the selected vehicle and signal, for example, the approaching inspection time. As a result, the fleet manager can plan the shutdown of the vehicle.

Telematics enables effective management of drivers' working time. This is crucial when it comes to scheduling the delivery of loads to their destination. The arrival time of a vehicle can be predicted concretely and irrefutably. This results in a significant reduction in delivery delays.

The use of telematics makes it possible to speed up deliveries. Very often, information about existing traffic obstructions reaches the driver too late to change the route. The data provided by telematics systems enables both the planning of optimal routes and the adaptation of the current route to the situation.

The implementation of telematics reduces administrative costs. It is possible to reduce the amount of work connected, for example, with tachographs or driver's working time accounting. Automation of such processes using telematics systems not only shortens the time in which they are performed but also affects their flawless and timely execution. Monitoring the exact time of the start and end of a journey enables better payroll management. This helps in verifying proper remuneration for hours worked and eliminates time spent on calculations and manual sheet checking.

Another advantage of implementing telematics is the improvement in driver safety. When driving, all mileage and vehicle use is recorded, resulting in drivers driving less aggressively and more carefully.

Telematics makes it possible to check driver abuse. Fuel theft and the use of company cars for private purposes are fairly common problems. Such incidents can be prevented with well-thought-out telematics solutions. Telematics systems monitor the level of fuel in the tank, the place of refueling, the frequency, and situations when the tank has been opened beyond refueling. In more advanced systems it is possible to introduce two driving modes: private driving and business driving. As a result, the fleet manager obtains information on how often the car assigned to a given employee is used for business purposes and how much time is used exclusively for private purposes.

The above-mentioned benefits will be achieved only if a telematics system is implemented that is equipped with all the necessary functions. Such a system should be comfortable and intuitive to use [Telematyka w transporcie…]. Telematics devices raise concerns about employee privacy. Constant monitoring raises concerns. Some employees may feel that their privacy is being invaded. The company should address any privacy concerns by explaining for what purpose the tracking device is being installed and how the information captured will be used [Saribardak 2019].

It can be difficult for employees to familiarise themselves with new software. Familiarisation with an unknow system can be complicated. If an employee has not used a telematics system before, it can take a long time to get used to it. A significant problem is also the implementation of the systems, which is costly. The initial cost of setting up telematics equipment can consume a significant amount of cash. Buying and installing telematics systems is an expensive undertaking. The total investment cost depends on the type of telematics system purchased [Insurancehotline.com 2013].

Telematics devices record what the vehicle does and what the driver does. There are times when drivers are forced to make decisions to avoid accidents. In these situations, there may be a need to act less safely. The device registers these actions against the driver as unsafe behavior. Telematics has many advantages, but also some disadvantages. Overall, the advantages of telematics devices outweigh the disadvantages [Insure TAXI 2016].

Automotive telematics market

The global automotive telematics market is driven by increasing demand for transportation and logistics. Figure 1 shows the global automotive telematics market penetration rate and GDP per capita in 2016.

In the United States, the penetration rate of automotive telematics in 2016 was 20%, in Italy 17%, and in Singapore 9%. In Poland, the ratio was 1% in a slow-growing market. The market in the countries with the highest penetration rate was mature. Analyzing the data presented in Figure 1, we see differences in the use of telematics in selected countries in 2016. Typically, countries with a higher per capita GDP had a higher penetration rate of automotive telematics. The exceptions to the norm were China, which had a low value of GDP per capita, and Switzerland, which had a high value of GDP *per capita*.

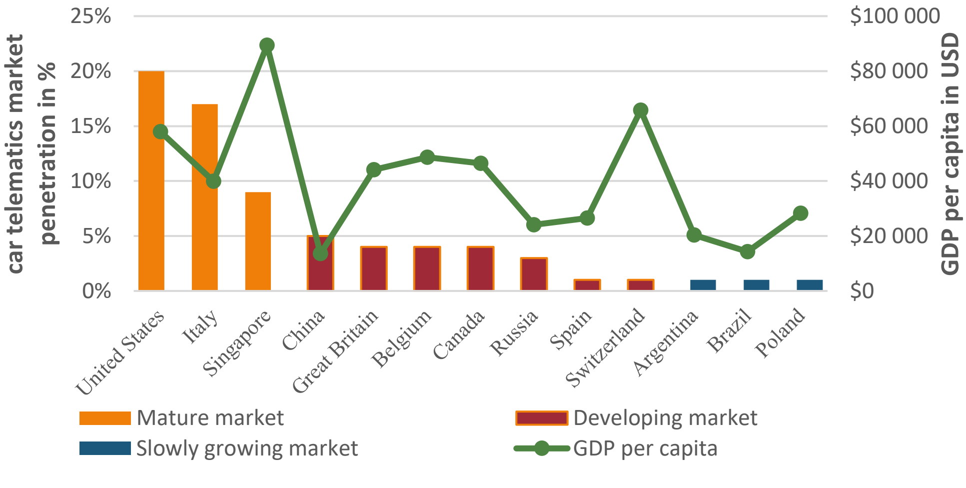

Figure 1. Global car telematics market penetration and GDP *per capita*

Rysunek 1. Współczynnik penetracji rynku telematyki samochodowej na świecie oraz PKB *per capita* na jednego mieszkańca

Source: [Dharani et al. 2018].

The global vehicle telematics market was valued at USD 115.49 billion in 2019, according to a report by Fortune Business Insights. The fleet management segment accounted for the largest share in this market [Vehicle telematics…]. North America accounted for the largest share of the global fleet management industry in 2019. This was mainly attributed to the large-scale implementation of supportive government regulations. The Asia Pacific also occupied a significant share of the market [Business Wire 2020]. In 2018, the Indian government made it mandatory for all commercial vehicles to be equipped with tracking devices. Europe also witnessed growth in the fleet management telematics market. This was attributed to the mandatory equipping of commercial vehicles with eCall telematics systems imposed by the European Commission at the beginning of 2018 [Vehicle telematics…]. In the UK, one in three fleets used telematics in 2018, which was a good result [UK is the number…].

Increasing sales of networked vehicles, implementation of supportive government measures and regulations, and the growing popularity of telematics solutions were the major reasons behind the growth of the automotive telematics market. Difficult economic conditions, poor technological infrastructure, and low internet availability in certain regions play a key role in limiting the adoption of telematics. Most African countries have faced various economic and infrastructural challenges, which makes the use of telematics less prevalent [Telematic market…].

One trend evident in the automotive telematics market is the increasing number of collaborations and partnerships between various telematics solution providers. The global automotive telematics market is projected to be worth USD 144.47 billion by 2027 [Vehicle Telematic…]. The Asia-Pacific region is expected to account for the largest market share. The major countries expected to witness the highest growth in the market were China, Japan, and South Korea [Telematics Solutions…].

Conclusions

The aim of the study was to present the possibilities offered by the use of telematics in car fleet management. The paper presents the history of car telematics. It also defines the importance of telematics in transport. Areas of application, user needs, and possibilities of telematic transport systems are presented. Individual functions of telematics in car fleet management are covered. The functions of telematics have been discussed in detail. The benefits and risks of using telematics in car fleet management have been shown. The benefits include lower fuel costs, reduced operating costs, faster delivery. Threats include fears for employee privacy, costly system implementation, difficulties in familiarising employees with the new system. The benefits and threats listed above show whether it is worth introducing telematics solutions in a given enterprise and what to pay attention to when choosing a telematics system. However, the decision requires detailed analysis in each enterprise.

The value of the telematics market in car fleet management, which has been growing year on year, is presented. The study of the global vehicle telematics market penetration rate and GDP *per capita* has shown differences in the development of the telematics market in selected countries due to uneven economic development. For the most part, countries with a higher value of GDP per capita had a higher car telematics market penetration rate. The research hypothesis set out in the study was confirmed.

Further research may concern the application of telematics in specific enterprises. Then you can get to know the specific advantages and disadvantages of these solutions. Companies themselves see the need for telematics, so no additional incentives are needed in this regard. Competition and the market force the use of this type of solutions.

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Deployment of solutions in smart city on the example of Opole

Wdrażanie rozwiązań w *smart city* na przykładzie Opola

Abstract. Smart cities are becoming an increasingly common concept. Metropolises are striving to be called Smart. In pursuit of certain goals, city authorities implement a number of improvements that enhance the condition of the city and make their solutions visible. From the resident's perspective, such measures are sometimes awaited due to certain expectations. The actions currently undertaken in the city pave a certain path towards achieving this, although according to the inhabitants there is still a lack of solutions for the times of the 21st century. The solutions proposed in the article can be used to pave a path on which managers should strive to achieve their goals. From the research carried out, it can be concluded that the inhabitants of Opole look forward to improving the existing solutions, wanting to be on a par with other highly developed cities. The aim of this paper is to analyze the existing telematics solutions used in the city and to propose smart solutions in order to qualify the city as a smart city.

Key words: smart cities, telematics systems, intelligent transport systems (ITS), congestion

Synopsis. Inteligentne miasta stają się coraz powszechniejszą koncepcją. Metropolie starają się być nazywane inteligentnymi. W dążeniu do określonych celów władze miasta wdrażają wiele usprawnień, które poprawiają kondycję miasta i uwidaczniają ich rozwiązania. Z perspektywy rezydenta takie środki są czasami oczekiwane ze względu na pewne oczekiwania. Działania podejmowane obecnie w mieście torują pewną drogę do osiągnięcia tego celu, choć zdaniem mieszkańców wciąż brakuje rozwiązań na czasy XXI wieku. Rozwiązania zaproponowane w artykule można wykorzystać do utorowania ścieżki, na której menedżerowie powinni dążyć do osiągnięcia swoich celów. Z przeprowadzonych badań można wywnioskować, że mieszkańcy Opola z niecierpliwością oczekują na doskonalenie istniejących rozwiązań, chcąc być na równi z innymi wysoko rozwiniętymi miastami. Celem artykułu jest analiza istniejących rozwiązań telematycznych stosowanych w mieście oraz zaproponowanie inteligentnych rozwiązań w celu zakwalifikowania miasta jako *smart city*.

Słowa kluczowe: inteligentne miasta, systemy telematyczne, inteligentne systemy transportowe (ITS), zatory komunikacyjne

JEL codes: J62, J88, L30, L96, M15

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Introduction

Many cities are currently struggling with the problem of congestion, meaning in the context of work more traffic than the capacity of the transport infrastructure [Ministerstwo Transportu…, Lai et al. 2020]. This is due to the constant increase in the number of vehicles travelling on them. The development of road infrastructure is very costly, time-consuming and not always possible [Singh 2021]. These are based on telematics. Solutions directly related to traffic control are called Intelligent Transport Systems or ITS systems for short. Intelligence in this context is understood as the ability of a system to make decisions in changing circumstances [Roth 2003, Iwan et al. 2013].

The performance of an ITS system can be geared towards aspects such as safety, transport system efficiency, environment, comfort and recreation. These can be improved by technologies such as [Hasegava 2015, Mjenjou et al. 2018, Dahri et al. 2019, He et al. 2019]: information and communication technology; positioning technology; sensory technology; control technology; human-machine communication technology; map technology; other fundamental technologies.

Examples of systems for improving the previously mentioned parameters related to the above technologies [Santosh et al. 2019, Husain et al. 2020, Hoi et al. 2020]:

- accident management system,
- a traffic control system,
- transport planning and road management system,
- a pedestrian-oriented system,
- environmental and energy management system,
- logistics system,
- telematics, others.

In practice, the use of IT solutions is an indispensable part of the functioning of almost any system. Therefore, Table 1 presents a list of the more important ITS solutions and their example applications in physical units.

Table 1. Examples of telematics solutions used in physical units
Tabela 1. Przykłady rozwiązań telematycznych stosowanych w jednostkach fizycznych

Main ITS applications	Application functions	Examples of solutions
Traffic ans network management	traffic incident management,	– Traffic Incident Management (TIM) – responding to traffic accidents, incidents and other unplanned events.
	information services for travelers,	– travel information – traffic information, – assistance for travelers.

cont. Table 1

traffic lights and urban artery management (including adaptive signal control)	– urban traffic control, – traffic control strategies, – traffic signal optimization, public transport priority, – tidal flow.
bus and transit priority systems	– prioritizing the passage of traffic lights
means of transport used on a part-time basis, e.g., 'Park & Ride'	– construction of parking areas on the outskirts of towns near tram terminals or bus stops
Route guidance (services before and during the journey)	– navigation – charging/fueling information, driver feedback, – eco–driving, – driver health.
speed control and management	– roadside graphics and variable message signs – informing drivers of real–time conditions, – dynamic speed limits, – camera-based speed monitoring.
flow control, directional lane control	– Urban Traffic Control (UTC) – traffic control strategies, – Traffic signal optimization, – adaptive traffic signal control, – public transport priority, – tidal flow.
traffic management on motorways	– Variable Message Signs (VMS), – ramp metering, – lane control, – dynamic lane management, – "hard shoulder running", – speed control, variable speed limits, – active traffic management.
parking management	– Parking information
fleet and passenger transport management	– planning and scheduling – vehicle management, driver management, – public transport priority, – passenger management, – depot management
information on road weather conditions	– winter service, – collecting data on weather conditions, – information on weather conditions.
minimizing pollution	– other functionalities contribute to it by, for example, reducing the number of vehicles in city centers.

cont. Table 1

	management of infrastructure rehabilitation	– minimizing the exposure of repair and construction workers to motorized traffic – protecting road users from construction and maintenance works (speed control at work sites – information boards, cameras and sensors mounted on trailers in rural renovation areas.
	border control of passengers and cargo	– "one–stop concept"
Traveler information systems	services to travelers	– Pre-trip information, – information an route, – route mapping, trip matching and booking, – information on services for travelers.
Public transport systems	public transport systems	– public transport management, – route information, personalized public transport, – public transport safety.
Commercial vehicle applications	improving private sector fleet management, streamlining governmental/regulatory functions	– electronic clearance of commercial vehicles, – in-vehicle safety monitoring, – streamlining of administrative processes for commercial vehicles, – information and incidents involving hazardous materials, – communication between drivers – dispatchers and intermodal transport providers.
Vehicle safety applications	vehicle safety applications	– collision avoidance, – Pre-Crash, – self-driving vehicles.
Maintenance and construction management applications	maintenance and construction management	– tracking and monitoring the condition of maintenance and construction vehicles, – winter maintenance operations support, – traffic management in work zones, – infrastructure condition monitoring.
Emergency management	management of sudden emergency situations, e.g. sudden severe storms	– portable changeable message signs, – temporary radio stations.
Archived data management	Archive Data Management System (ADMS)	archiving, merging, organizing and analyzing infrastructure and incident data

Source: own elaboration based on: [Shadeed et. al. 2007, Shah et al. 2007, Mikulski 2010, Kammoun et al. 2011, Karoń and Mikulski 2011, Tam et. al. 2011, Karoń and Mikulski 2012, Ashokkumar et al. 2015, Mfenjou et al. 2018, Javed et al. 2019, John et al. 2019, Leblanc et al. 2019, Zaheer et al. 2019, Kulińska and Masłowski 2020, Pastori et al. 2020, Balasubramaniam et al. 2021].

A smart city is a city that uses the previously mentioned information and communication technologies to increase the interaction and efficiency of the urban infrastructure with its component parts, as well as to increase the social awareness of its inhabitants [Ismagilova et al. 2019]. A "smart" city is created, when administrators invest appropriately in human and social capital as well as in transport infrastructure to promote sustainable economic development and above all a high quality of life [Azkuna 2012, Lai et al. 2020].

A smart city can also be defined as an intelligence that deals with the combination of increasingly effective digital telecommunications networks with ubiquitous intelligence and with sensors, tags or software [Silva et al. 2018].

Nicos Komninos writes in one of his publications that a smart city is an area made up of four main elements [Komninos 2008]:

- a creative population implementing knowledge-intensive activities or a cluster of such activities [Ghazal et al. 2021],
- effectively functioning institutions and procedures for knowledge creation, enabling its acquisition, adaptation and development [Ruhlandt 2018],
- developed broadband infrastructure, digital spaces, e-services and online tools for knowledge management [Ullah et al. 2020],
- proven ability to innovate, manage and solve problems that arise for the first time, as innovation and management under uncertainty are key to assessing intelligence [Mohamed et al. 2020].

It should be borne in mind that smart cities are created mainly by smart people, where the effect of smart management of the city are various undertakings ensuring above all: general access to information about the city, development plans, etc.; efficient dealing with matters in city offices and institutions; favorable conditions for investing in the city; efficient communication; effective operation of city services; care for the state of the environment; safety of residents; many opportunities to spend free time (cultural events, sports events, etc.); active participation of residents in improving the city through cooperation with the administration [Bogobowicz and Domański 2015, Pereira et al. 2018, Ismagilova et al. 2019, Kummitha et al. 2019, Lai et al. 2020].

The aim of this paper is to analyze the existing telematics solutions used in the city and to propose smart solutions in order to qualify the city as a smart city.

Research methods

The subject of the study is the city of Opole, which is the central part of the Opole agglomeration. The city borders with eight areas of Opole County. In addition to this, the city is a county seat in south-western Poland, it is also the seat of the authorities of Opole Voivodeship and Opole Zone. Opole is one of the historical capitals of Upper Silesia and one of the oldest centers in Poland.

In relation to achieving the objective, the author used the following research tools:

- theoretical:
  - literature analysis of smart city and telematics issues and tools used in cities,
  - generalizations and comparisons of the scope of application of telematics tools;
- practical:
  - surveys addressed to city residents on their knowledge towards the use of telematics solutions,
  - analysis of existing solutions used in the city carried out by means of observation,
  - analysis of statistical data and information taken from Opole City Hall concerning possible places of implementation of potential solutions in order to create smart city,

– SWOT analysis of the use of the proposed solutions in the city's infrastructure.

In order to estimate certain assumptions for the implementation of telematic solutions in the city, public information about them was needed. Because it is the inhabitants who are the main beneficiaries of these improvements. Often, the opinion data of city citizens are omitted, which consequently leads to agitation and an unfavorable image of those who manage these centers.

About 380 respondents took part in the survey. The research concerned the attitude of city dwellers towards telematic solutions. The research was conducted in the middle of 2021 in the city of Opole. The data of the respondents are presented in Table 2.

Table 2. Demographics of respondents
Tabela 2. Dane demograficzne respondentów

Respondent's data	**Percentage share [%]**
Gender	
Woman	61
Male	39
Age	
<18	7
18–25	45
26–35	25
36–50	12
>50	11
Education	
Basic	8
Professional	7
Averages	60
Higher	25

Source: own study.

Through the analysis of data from city managers and own observation it was possible to propose solutions that could positively influence the functioning of the units, which would lead to reclassifying the city as a SMART unit.

Current smart solutions applied in Opole

Telematics systems within the city are divided into the following areas: traffic control, mobility management and public transport management. Traffic flow control includes ITS, which are intelligent transport systems. At the beginning of 2020, a contract was signed to build ITS by the end of 2022 in Opole, while the budget for this investment amounts to approximately PLN 38 million. The pillar of these systems will be equipment monitoring the intensity of traffic flow at the most frequently used intersections in Opole. With the help of the data obtained, the system will contribute to the reduction of congestion and will have the possibility of manipulating traffic lights in such a way as to ensure smooth and trouble-free traffic flow. The project also includes the introduction of a parking information system to inform and direct drivers to free spaces. A specially designed application will also be available to users to help them find an empty space. The following telematics solutions are currently in operation in Opole:

- weather stations

- LED variable message signs and boards;
- Traffic volume measuring devices;
- devices measuring air pollution;
- Electronic passenger fare collection systems
- intelligent parking charging systems
- intelligent passenger information systems
- remote hot-spots in public spaces.

Weather stations

They are used to provide continuous data on local meteorological and road surface conditions. The weather station is designed to collect and process data related to safety and road use, processing the following data: weather conditions: air temperature, wind speed and direction, humidity and pressure, visibility, type and intensity of precipitation. In addition, the stations can verify conditions on the road surface: thickness of the water layer, road surface temperature, ground temperature, freezing point of the road surface. With the collected data, the stations can calculate values, i.e.: average and maximum wind speed, dew points, etc. [Jaber 2019].

LED variable message signs and boards

They are an essential tool for dynamic traffic management on motorways, expressways and in urban areas. They support the transmission of information and enable the display of a wide range of information. Once the appropriate systems presented in the following section have been implemented, these existing signs can take into account the travel routes and suggest alternative routes to drivers by indicating the time taken to cross particular streets.

Traffic volume measuring devices

Modern radar technology makes it possible to accurately record traffic-related data for statistical purposes and traffic volume analyses. Devices in the urban area record the exact date, time, speed, direction (approaching, departing) and distance to the preceding vehicle. The integrated Bluetooth function, when connected to a mobile device, allows data to be quickly recorded and checked at any chosen location [Szołtysek 2010].

Air pollution measurements

They are measured through sensors placed in different parts of the city and at different heights. The Environmental Inspectorate examines the content of PM10 and PM2.5 in the air using two complementary methods [Liu et al. 2018]:

- the gravimetric (reference) method, which is recognized and applied worldwide as the most accurate measurement method;
- an automatic method having a demonstrated equivalence to the reference method.

Electronic Passenger Toll Collection Systems

Proximity cards, usually based on RFID technology, are most commonly used in electronic toll collection systems. Depending on the type of card used, the ticket can be validated by either directly inserting the card into a reader on the vehicle, or the ticket can be "validated" automatically when boarding or alighting from the bus [Lee et al. 2008].

Intelligent parking payment systems

They now make it possible not only to pay for parking using various electronic tools, but also to use comprehensive solutions, such as a single shared payment for parking and public transport at the same time [Shimi 2020].

Intelligent passenger information systems

The positioning of public transport vehicles is carried out using solutions such as GPS, GSM, sensors and sensors [Anudeep 2019].

Remote hotspots

One of the smart systems used in cities is also a simple Wi-Fi network in public places, where it is often free of charge, e.g. at the railway station or "Karolinka" Shopping Centre.

Table 3 presents a summary of the solutions used in the city with their locations in the urban infrastructure and their benefits for city dwellers.

Table 3. Telematics systems in Opole and their benefits
Tabela 3. Systemy telematyczne w Opolu i ich zalety

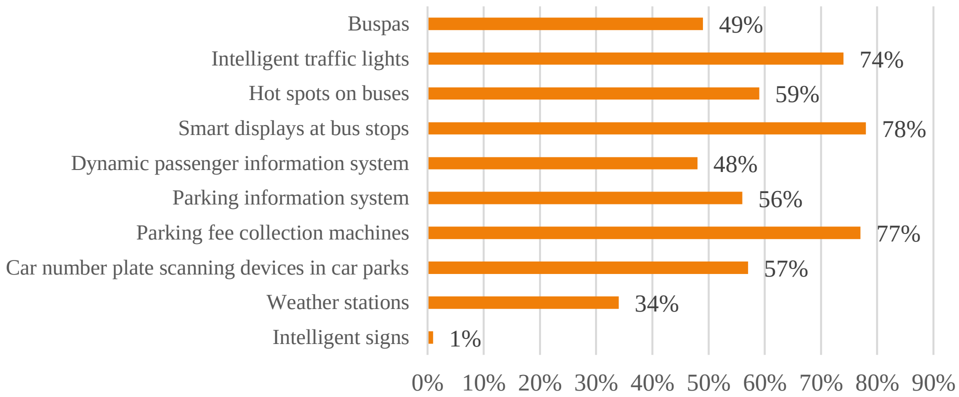
Telematics system	Location in Opole	Benefits
Parking Information System	Car parks belonging to the Solaris shopping mall	More efficient traffic flow in car parks
Variable Message Signs	MZK bus stops	Information on bus arrivals and departures
Buspas	Stanisława Spychalskiego street	Reducing congestion and travel time
Intelligent Video Sensors	Intersections and pedestrian crossings	Improving safety
Parking Fee Collection Machines	Car parks	More free parking spaces in the center
Number Plate Scanning Devices	In front of the entrances to the car parks of the Solaris mall	Improving traffic flow in car parks
Application "KiedyPrzyjedzie"	Internet	Information on bus arrivals and departures
Ticket Machines	MZK bus stops and buses	Possibility to buy a ticket, increase of punctuality

Source: own study.

Empirical study of residents' satisfaction with implemented telematics systems

The 54% of those surveyed said they had heard of the term telematics systems before completing the survey, while 46% had not heard of the term. The survey showed that this is still a new concept for people, they know about the telematics solutions around them but do not know that this is what they are called. 60% of the respondents knew about the existence of the systems described in the paper that operate in Opole, while 40% had no idea about them. However, as many as 95% of respondents claim that there is a need to implement modern solutions already functioning in other larger centers in the country.

From the knowledge of respondents, it can be concluded that the highest number of people noticed boards at MZK stops in the city, informing about the real arrival of the bus (Figure 1).



Fiure 1. Visibility of IT solutions in the city of Opole according to respondents
Rysunek 1. Widoczność rozwiązań IT w mieście Opole według respondentów
Source: own study.

Parking payment machines and intelligent traffic lights counting down to the green light were next most frequently mentioned. This was followed by a parking information system displaying how many parking spaces are available, the possibility to connect to the Internet in MZK buses and devices scanning the car license plate in order to pay for parking. This was followed by the dynamic passenger information system “KiedyPrzyjedzie” and the Buspas located on Spychalskiego street. Weather stations were noticed by 34 respondents, which was 6%, and intelligent signs were noticed by 1 person.

The majority of respondents stated that telematics systems are easily accessible/visible, accounting for 80%. On the other hand, 20% of the respondents think that the systems are not easily accessible/visible. Furthermore 94% of the respondents say that the current telematics systems used in Opole are useful. According to 6% of respondents they are not useful. It means that most of the respondents think that these solutions fulfill their function in Opole.

The graph (Figure 2) shows that 57% of the respondents are satisfied with the operation of the telematics systems in Opole, 21% are moderately satisfied, 17% are very satisfied, 3% are very dissatisfied and 2% are dissatisfied. According to 84% of the respondents the telematics systems used in Opole improve the traffic flow, while 16% of the respondents claim that the above-mentioned systems do not improve the traffic flow in the city. Thus, it can be concluded that in the opinion of the majority the traffic in Opole is smoother thanks to these systems.

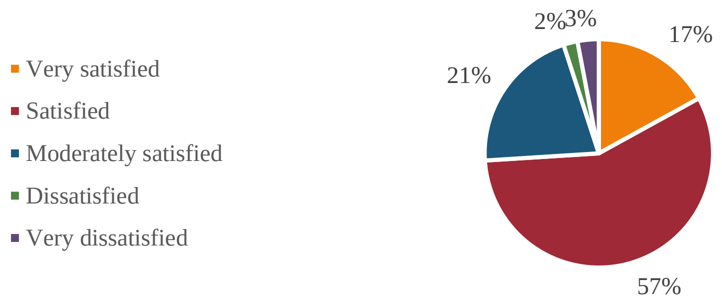


Figure 2. Graph showing the level of satisfaction with existing solutions in the city of Opole
Rysunek 2. Wykres pokazujący poziom zadowolenia z istniejących rozwiązań w Opolu
Source: own study.

As many as 75% of the respondents think that they get to their destination faster thanks to telematics systems and 25% say the opposite. The dissatisfaction of the respondents may be due to the fact that they believe that there are still no solutions in Opole that would improve the traffic flow around the city.

Proposals for applying intelligent solutions in Opole

Improvement is a process characterized by actions aimed at improving the functioning of a specific entity or area. Current telematics systems operate in most urban agglomerations around the world. The questionnaire research has shown that Opole residents overwhelmingly believe that the telematics systems currently operating in the city are easily accessible and visible. According to the respondents there are places in the city where there are no telematics systems. Figure 3 shows the respondents' opinions on the places in Opole where there are no telematics systems.

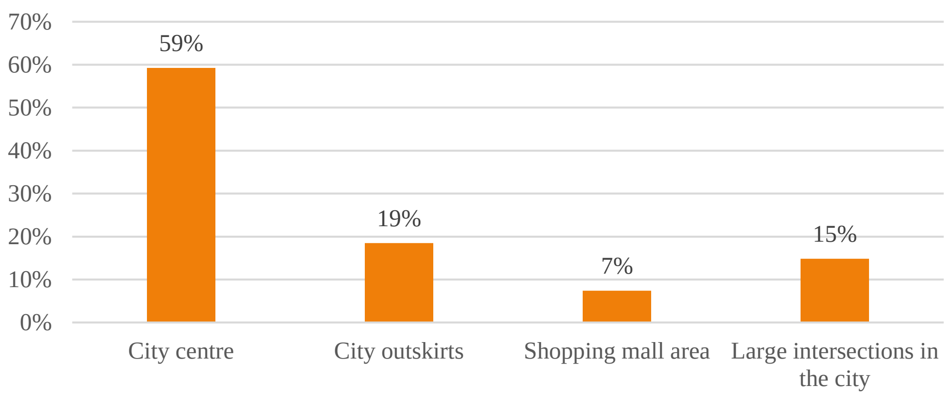


Figure 3. Respondents' opinions on the places in Opole that lack telematics systems
Rysunek 3. Opinie respondentów na temat miejsc w Opolu, w których brakuje systemów telematycznych
Source: own study.

It can be seen from Figure 3 that respondents most often indicated the city center as an area lacking telematics systems. The next most frequent places are the outskirts of the city and large intersections. The areas belonging to shopping malls (Solaris, C.H. "Karolinka") were mentioned the least frequently.

Respondents also gave their opinions on what should be improved in order to make telematics systems in the city work better. The respondents were mainly in favor of too few bus lanes and suggested increasing their number in Opole. The reason for this is that there is only one bus lane in the city on Spychalskiego street. Residents also claimed that the countdown to the green light should be located at all intersections in the city. They also believe that the coordination of traffic lights at intersections should be improved. This may be due to the lack of smooth traffic flow at street intersections. Figure 4 shows the telematics systems that, in the opinion of Opole residents, should be introduced in the city.

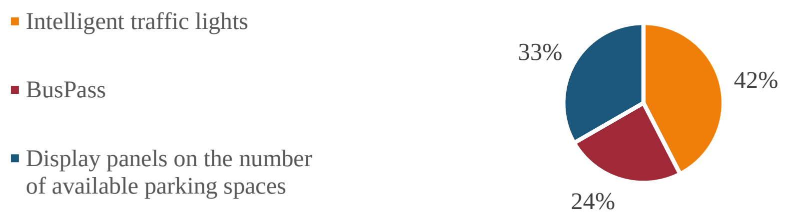


Figure 4. Telematics systems that respondents think should be introduced in Opole
Rysunek 4.. Systemy telematyczne, które zdaniem respondentów powinny zostać wprowadzone w Opolu
Source: own study.

On the basis of the chart above, it can be concluded that according to the inhabitants of Opole the most desired telematics system in the city is intelligent traffic lights. This is probably due to the fact that congestion is quite frequent in Opole. The implementation of intelligent traffic lights can significantly contribute to the improvement of traffic flow in the city, and thus to the satisfaction of users of individual and collective transport. The second most frequently mentioned telematics system that should be implemented in Opole are boards located at car parks to inform about the number of free spaces there. According to residents, the need to implement such a system may be caused by the fact that there are practically no such boards in Opole (except for the Solaris shopping mall).

A second aspect may be the need to quickly find a free space in a particular car park, which is often impossible without entering the car park zone. The last-mentioned telematics system in demand according to the respondents is bus lanes. The reason for implementing this system may be that there is only one in Opole. Bus lanes are very necessary, they help to significantly improve traffic in the city, because in this way city buses have their own separate lane for their efficient movement.

Based on the respondents' suggestions, specific telematics solutions were proposed in the following locations. The first proposal is to implement more bus lanes. Currently there is such a system in Opole only on Stanisława Spychalskiego street. Until recently, a bus lane was also located on the bridge in memory of the Sybiraks on Nysa Łużycka street. Based on observations, it is known that congestion often forms there, impeding the smooth flow of traffic. In order to improve this, a separate lane for public transport vehicles could be re-established at this location.

On the basis of information taking into account the cost of busway implementation on the Łomianki-Warsaw route, which is about 17.8 km long, the estimated cost of implementing the above telematics system in the specified location in Opole was calculated. According to rough calculations, the cost of implementing a busway located on the extreme lane of Nysa Łużycka street is PLN 182 thousand. The busway starts at the crossing of national road No. 94 with voivodeship road No. 435, while its end is at the point of crossing of Nysa Łużycka, Wrocławska and Niemodlińska streets. In turn, the length of the busway is approximately 372 meters. Figure 5 shows the beginning and end of the road on which the busway would be built.

Figure 5. Start and end of the road where a BusPas should be introduced
Rysunek 5. Początek i koniec drogi, na której należy wprowadzić BusPas
Source: own study based on Google Maps.

The second proposal is to implement intelligent traffic lights. At the moment there is no such solution functioning at any intersection in Opole. Therefore, it is necessary to implement such technology in the city. It undoubtedly contributes to increasing the capacity of streets, improving air quality by reducing emissions, shortening travel time and reducing the number of collisions and accidents on the roads.

Having analyzed the respondents' answers, it was concluded that intelligent traffic lights are missing mainly in the city center. Therefore it is suggested to install such a solution at the intersection of Ozimska street and Plebiscytowa street. There is a very big traffic flow there, and intelligent traffic lights will contribute to decrease it significantly. Figure 6 shows the intersection of Ozimska street and Plebiscytowa street. Another intersection where such a solution can be implemented is in the central part of Opole and it crosses Niemodlińska, Wrocławska and Nysa Łużycka streets. It is necessary to install this type of telematics system there because of the high traffic density, which creates a lot of congestion.

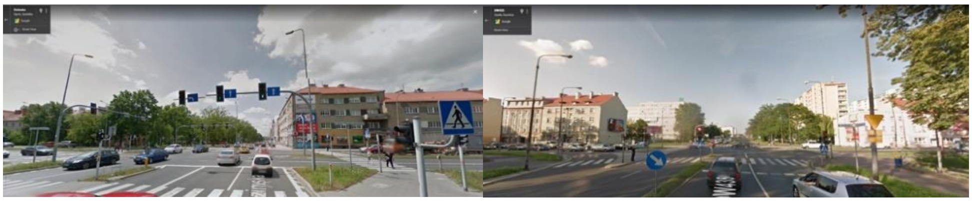


Figure 6. The intersection of Ozimska and Plebiscytowa street in Opole where intelligent traffic lights should be built
Rysunek 6. Skrzyżowanie ulic Ozimskiej i Plebiscytowej w Opolu, gdzie powinna powstać inteligentna sygnalizacja świetlna
Source: own study based on Google Maps.

The third and last proposal for the introduction of telematics systems in the city are boards located at large car parks in Opole, informing about the number of free spaces in them. At present, boards informing about the number of free spaces are located in a multi-stored car park and in an underground car park belonging to the Solaris shopping center. This facilitates traffic in the car parks and reduces congestion in them. The car park that needs this type of solution is located next to the C.H. "Karolinka" shopping center. This is a huge area for parking and by using the above telematics system it will make finding a parking space easier and save time. Figure 7 shows a car park located on the premises of the C.H. "Karolinka" shopping center. The proposed telematics system improvements will first and foremost have a positive impact on more efficient traffic and parking, and will increase the satisfaction of the city's residents.

Figure 7. Parking in Karolinka Shopping Centre to be managed by a parking management system
Rysunek 7. Parking w Centrum Handlowym Karolinka będzie zarządzany przez system zarządzania parkingiem
Source: own study based on Google Maps.

The proposed improvements in telematics systems will primarily benefit more efficient traffic flow on streets and car parks and increase the satisfaction of the city's residents. Therefore, in addition to the surveys and the residents' perspective on the need for telematics systems in the city, the following solutions can be proposed: Intelligent Incident Management System; Traffic Light Control System – Green Wave; Over-height Vehicle Detection System; Intelligent Lanes; Kiss & Ride; Park & Ride; C2I (Car to Infrastructure) system; GSM connectivity; CANARD system; Radio Communication System using DAP and RDS-TMC technology.

Intelligent Accident Management System

Such a system would greatly improve traffic flow and make it much easier for emergency services to get to the scene of an incident. Application of this system in Opole could take place at the following intersections:

- Opolskie Princes Roundabout,
- The intersection of Nysa Łużycka street with Wrocławska street,
- the intersection of Niemodlińska street with Stanisława Spychalskiego street,

- the intersection of Piastowska street with Zamkowa street,
- the intersection of Wojciecha Korfantego, Krakowska, 1 Maja and Armii Krajowej streets,
- the intersection of 1 Maja with ul. Władysława Reymonta streets,
- the intersection of Władysława Reymonta with Ozimska streets,
- Pileckiego Roundabout by the Solaris Shopping Centre,
- the intersection of Oleska with Batalionów Chłopskich streets,
- the intersection of Ozimska with Plebiscytowa streets,
- intersection of 1 Maja, Plebiscytowa and Fabryczna streets.

Traffic signal control system – green wave

The synchronization of traffic lights, sometimes called a "green wave", means that vehicles travelling at a certain speed have their path open to them at each passing intersection.

This makes traffic flow smoothly, without the need to wait long periods for the lights to change. Vehicles do not have to change speed abruptly, which results in higher fuel consumption, and the average speed on a given section of road is increased, which makes it go faster.

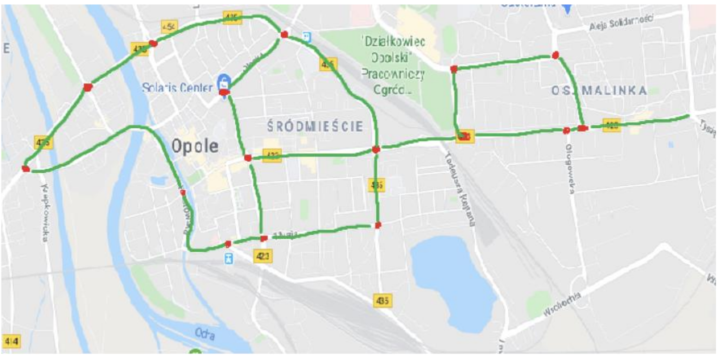
While it is technically easy to synchronize the lights so that they change at precisely defined intervals, adapting these cycles to the constantly changing traffic flows is a major problem. The capacity of intersections and arterial roads is limited, so that when more vehicles are on the road, some of them will not manage to cross the route "on the green wave". In order to fully adapt the traffic light cycles to the traffic flow at any given moment, it is necessary to analyze the situation on the road, supported by constant measurement of traffic flow. It also requires the cooperation of drivers who should adjust their speed so as to arrive at subsequent junctions exactly on time. Not all traffic lights in large cities can be synchronized with each other, but the main traffic routes are usually set up in such a way that a car travelling at the permitted speed (50 km/h in built-up areas) hits a sequence of green lights at each subsequent intersection. The green wave could run through:

- Ozimska street until its intersection with Tysiąclecia street, Częstochowska street and Witosa Avenue,
- from the Reagan roundabout to the intersection of General Kazimierz Sosnkowski, Szarych Szeregów and Horoszkiewicza streets.

Such a deployment of intelligent devices would significantly support the operation of the Intelligent Accident Management System and facilitate access to strategic points on the map of Opole, where there are often large concentrations of people, which directly affects the risk of fire and other events requiring rapid intervention of services.

Such a system would connect, among others, the Provincial Fire Brigade Headquarters – whose headquarters are located at the roundabout of Nysa Łużycka; the Provincial Police Headquarters, located at Wojciecha Korfanty street and the University Clinical Hospital, which is located directly at Witos Avenue.

Apart from the advantages mentioned above, another important thing is that it would be easier for the inhabitants of Opole to move around the city center and get to places such as the Solaris Shopping Centre, the Main Post Office or bus and railway stations more quickly. Below is a graphic plan of the system layout (Figure 8).



Legend:

- Intelligent Incident Management System-enabled devices

------ **Green wave**

Figure 8. Graphical layout plan for traffic signal control system.
Rysunek 8. Graficzny plan zagospodarowania systemu sterowania sygnalizacją świetlną
Source: own study based on Google Maps.

Over-height vehicle detection system

Devices such as the HISIC450 detector detect vehicles that are too high. In combination with the LMS511 2D LiDAR sensor, the device also determines in which lane the vehicle is too high. This means that only the relevant lane needs to be blocked. Compared with other technologies, this solution enables a much more precise adjustment of the monitoring area to the lane width. Examples of places where this technology can be used in Opole (Figure 9).

Figure 9. Possible use of a high vehicle detection system – Crossing under the viaduct – Głogowska street with East street
Rysunek 9. Możliwość zastosowania systemu wysokiego wykrywania pojazdów – przejście pod wiaduktem - ul. Głogowska z ul. Wschodnią
Source: own study based on Google Maps.

This place was chosen because in its vicinity there are large transport and trading companies such as Kano, Zott and the warehouse of Agata Meble, which use truck transport.

The device could also be located in an extremely dangerous place such as an overpass, because Tabor Szynowy Opole SA is also located nearby and transport of goods to this place is also done by delivery trucks or lorries (Figure 10).

Figure 10. Possible use of a high vehicle detection system – viaduct from Ozimska street to Rejtana street
Rysunek 10. Możliwość zastosowania wysokiego systemu wykrywania pojazdów – wiaduktu od ul. Ozimskiej do ul. Rejtana

Source: own study based on Google Maps.

Figure 11. Intelligent Lane System in Opole
Rysunek 11. Inteligentny system pasów ruchu w Opolu

Source: own study based on Google Maps.

Intelligent lanes

Smart lanes are a system that would work on the principle of "Smart Motorways". This is a section of road where speed limits are changed in real time, and lanes are opened and closed. An important element of the system is also the shoulder, which can be used as an additional road lane. All this is done to make traffic flow as smooth as possible.

The whole process is automatic, decisions are made by a computer on the basis of data from devices constantly monitoring the congestion of vehicles on the road. Information on speed limits and the availability of lanes, including the shoulder, is shown on luminous panels suspended above the roadway (Figure 11).

This solution could be applied on the route located on the streets: Niemodlińska; Nysa Łużycka; Batalionów Chłopskich; Bohaterów Monte Cassino; Plebiscytowa; Fabryczna.

This road is very congested both in the morning, when everyone goes to work or school – and in the afternoon, when everyone walks back along the same road to their homes, which has bothered residents on more than one occasion.

Smart lanes could work here by designating the appropriate number of lanes in a given direction so that in the morning more lanes would be open for people heading towards the center, and vice versa in the evening.

Kiss & Ride

Kiss and Ride (Kiss & Ride, K&R, K+R) – designated places for a short stop (about 1–2 minutes), especially found at railway stations, airports, transfer centers and schools. They are intended to facilitate the rapid transfer of the vehicle occupant to another mode of transport or facility.

A Kiss and Ride system could be used at the current PKP station and the newly built PKS station (Figure 12). This relatively simple system would considerably improve the traffic flow around these stations and save time for drivers, as at present many people, due to the high price of parking around the station, stop in places not designated for this purpose, thus paving the way for other vehicles.

Figure 12. Possible use of the Kiss & Ride system – Main railway station – Opole
Rysunek 12. Możliwość zastosowania systemu Kiss & Ride – Dworzec Główny – Opole

Source: own study based on Google Maps.

Park & Ride

A park and ride system could also significantly support the functioning of the city by e.g. significantly decreasing the traffic in the city and consequently the air would be cleaner, people could leave their cars at car parks located on the outskirts of the city and use public transport to get to the center. Such a project would also strengthen an enterprise already operating in Opole such as MZK Opole as they would have to significantly increase the number and frequency of their courses and thus have better revenues (Figure 13).

Figure 13. Selected locations for the Park & Ride system
Rysunek 13. Wybrane lokalizacje dla systemu Park & Ride
Source: own study based on Google Maps.

System C2I (Car to Infrastructure)

This system is based on the integration of vehicles with the road infrastructure in the car after installing the On-Board Unit (OBU), which will enable communication and localization of other vehicles thanks to radio waves sent, with OBU units in the car it would be possible to use the Car-to-Car concept. On the other hand, at intersections in Opole, it would be enough to place Road Side Units (RSUs), with which OBUs would connect, which would also give great opportunities for controlling city traffic and significantly improve its safety.

Connectivity GSM

The use of GSM communications to locate events and/or road users allows for more precise determination of their location or place of crash. GPS could also be used for this purpose, but unfortunately it will be relatively easy to jam and will not work in places sheltered from the sky, e.g. in tunnels, buildings, containers, etc. On the other hand, a radio signal, e.g. from GSM base stations located in a city, will easily reach that place and enable accurate location. A GSM device (e.g. a phone or a GPS locator) that moves in the monitored object (e.g. in a car) is always within the range of radio waves transmitted from the stations that could be located in several places in Opole or placed on the roofs of buildings. Thanks to all this, localization would become simpler and much more accurate.

System CANARD

Automatic recording of traffic offences (CANARD). CANARD uses state-of-the-art technologies, both in terms of the control and measurement infrastructure and in terms of IT solutions.

The Central Processing System is to ensure maximum automation of the data flow path related to traffic offences. Modern speed cameras automatically send information on offences to the Central Processing System using wireless technology. The system verifies them in terms of compliance with formal assumptions and possibility of further proceedings and then reads the vehicle registration number. On this basis, the data of the owner are automatically downloaded from the Central Vehicle Register. The system supports the process of generating documentation of misdemeanor proceedings, including summonses and fines, as well as court proceedings. In addition, appropriately configured, the system can also monitor the city as a "red light system" – i.e. monitoring controlling entry through red lights and can cooperate with the GITD equipment. The system can also classify vehicles thanks to its connection with the central register of vehicles and drivers in order to identify all traffic participants more quickly (Figure 14).

Figure 14. Examples of intersections in Opole covered by the CANARD system to increase safety
Rysunek 14. Przykłady skrzyżowań w Opolu objętych systemem CANARD w celu zwiększenia bezpieczeństwa
Source: own study based on Google Maps.

Technology-Based Radio Communication System DAP I RDS-TMC

A technology that uses radio communications is the Traffic Message Channel (TMC) system. The driver receives information in the chosen language, which is played on the radio and heard through speakers. The data is transmitted via specially coded FM waves using the RDS FM-System, via satellite or Digital Audio Broadcasting. This system, when properly configured with navigation, can also be used for alternative routing to avoid traffic jams or other obstructive situations.

Every traffic incident is sent as a TMC message. The message is encoded to Alert C standards and contains precise information about the place and time of the incident. With a unique code for each area on the map, the receiver distributes the information in the appropriate language to users.

Such a system could cover the entire Opole area, as it propagates through radio waves and thus can have a very large operating range without infrastructure limitations.

Conclusion

Opole is a city very poor in telematics systems. The telematics solutions included in the study aim to make life easier for the average Opole citizen by easing traffic congestion in the most congested places. These proposals should significantly improve safety and make moving around the city easier and more pleasant. The proposed systems have already been applied in many more modern cities, so there is no doubt that they will also work very well in Opole. The goal of the study was achieved by a thorough analysis of existing telematic solutions functioning in the city and by surveying the respondents' opinions on telematic systems.

Figure 15 presents a proposal of functioning of a potential ITS system, which in its actions covers practically the whole city. The proposed solutions will contribute to changes in the public perception preferences of the city of Opole and its preliminary qualification as a Smart City. Of course, it cannot be stated unequivocally that after the introduction of such solutions the city will be reclassified as intelligent, for which an effective implication is still needed, but to a large extent it will make a great step in that direction.

To verify the proposal, the author used a simple SWOT analysis comparing the four main decision fields of the implemented solutions (Table 4).

Table 4. SWOT analysis of the telematics solutions in Opole proposed in the study
Tabela 4. Analiza SWOT rozwiązań telematycznych w Opolu zaproponowana w opracowaniu

S (strengths)	**W (weaknesses)**	**O (opportunities)**	**T (threats)**
• Good system organization • Highly advanced technology • Unification of databases for the entire transport system • Improvement of communication in the city • Reduction of travel times • Increase in revenue from fines • Simplification of travel by public transport • Increased freedom of movement in the city center	• Potential problem in finding a service • High investment and depreciation costs • Need to create a city model before implementing systems	• Increased number of traffic participants • Extension of roads in the city • Increased attractiveness of the city • Inflow of tourists • Extension and modernization of the city • Development of industrial zone	• Newer and more telematics solutions entering the market (proposed solutions may become obsolete) • Migration of residents • System failure

Source: own study.

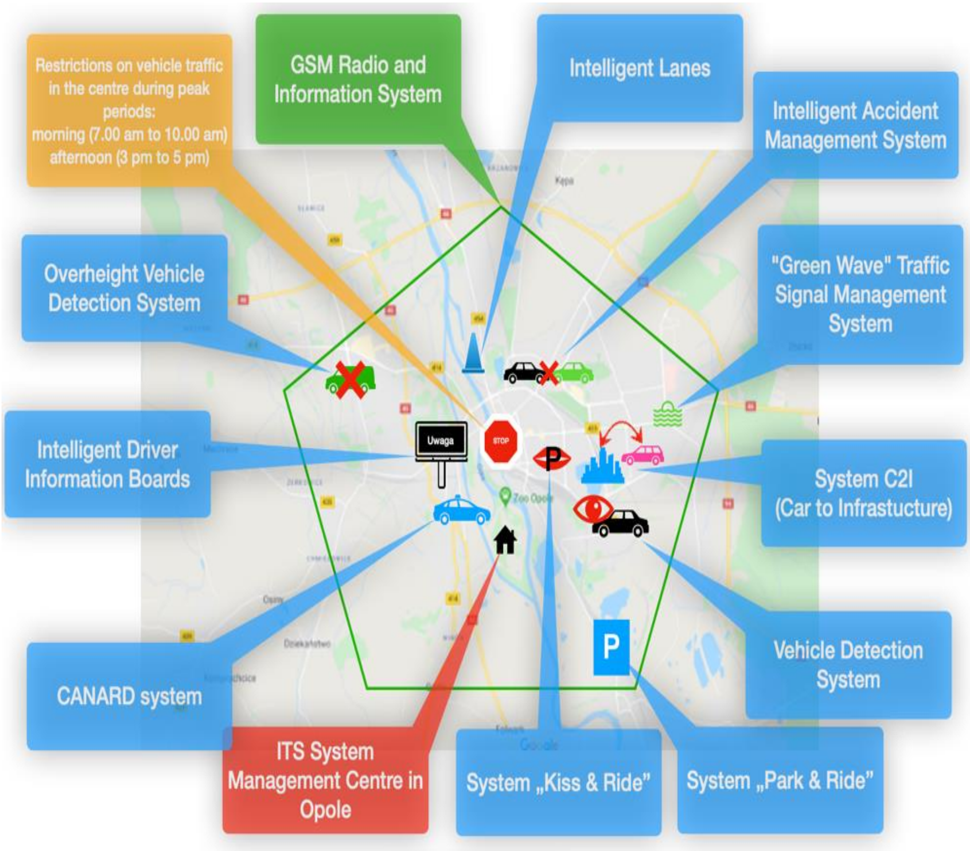


Figure 15. Map of Opole showing proposed solutions operating under one ITS system
Rysunek 15. Mapa Opola przedstawiająca proponowane rozwiązania działające w ramach jednego systemu ITS
Source: own study.

The main conclusion from the research is that telematics solutions can turn cities into Smart Cities. However, whether such functioning will bring only benefits, it cannot be clearly determined due to the fact that potential benefits are noticeable only in a longer period of time. However, as far as the city of Opole is concerned, it should undertake all activities to integrate the society with IT solutions in order to catch up with the leading cities in Poland and Europe. Despite many efforts it is potentially within the reach of the analyzed entity.

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Acquisition, transmission and management of data in industrial practice in the digital age

Pozyskiwanie, przekazywanie i zarządzanie danymi w praktyce przemysłowej w erze cyfrowej

Abstract: Digital technologies permeate all aspects of industrial production and Logistics systems, accelerating the generation of large amounts of industrial data. Industry 4.0 and Industrial Internet of Things offers great development opportunities, new perspectives, a new paradigm of autonomous and decentralized production control. The information on the current status of industrial processes is invaluable in present times. Among others, it enables deliberate and rational management of available resources. Therefore, acquisition, transmission and management of data is an important issue in the systems for collecting data from production lines and a key element in the decision-making process. In industrial practice, the data acquisition process uses the information obtained from various sensors placed directly in production lines. The current level of microelectronics development enables acquisition and transfer of data from technological processes in real time. This article presents selected popular methods of automatic acquisition and transfer of data directly from production lines in the course of implementation of manufacturing processes. A review of all the issues discussed is supported by examples. Particular attention is paid to the nature and importance of data acquisition in the decision-making process. It was emphasized that the information itself is very important, but the value of information and the way it is processed and managed are also important. Data management in the unit optimizes the decision-making process and the work of the entire unit. On the other hand, data is a resource, the loss of which may result in the loss of competitive position or the loss of development opportunities.

Key words: digital technologies, data acquisition, data management, production, management, decision-making process, Industry 4.0, automation, sensors, wired network, wireless network

Synopsis: Technologie cyfrowe przenikają wszystkie aspekty produkcji przemysłowej i systemów logistycznych, przyspieszając generowanie dużych ilości danych przemysłowych. Przemysł 4.0 i Przemysłowy Internet rzeczy oferują ogromne możliwości rozwoju, nowe perspektywy, nowy paradygmat autonomicznej i zdecentralizowanej kontroli produkcji. Informacje o aktualnym stanie procesów przemysłowych są nieocenione w dzisiejszych czasach. Umożliwia m.in. przemyślane i racjonalne gospodarowanie dostępnymi zasobami. Dlatego pozyskiwanie, przekazywanie i zarządzanie danymi jest

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ważną kwestią w systemach zbierania danych z linii produkcyjnych i kluczowym elementem w procesie decyzyjnym. W praktyce przemysłowej proces pozyskiwania danych wykorzystuje informacje uzyskane z różnych czujników umieszczonych bezpośrednio na liniach produkcyjnych. Obecny poziom rozwoju mikroelektroniki umożliwia pozyskiwanie i przekazywanie danych z procesów technologicznych w czasie rzeczywistym. W artykule przedstawiono wybrane popularne metody automatycznego pozyskiwania i przesyłania danych bezpośrednio z linii produkcyjnych w trakcie realizacji procesów produkcyjnych. Przegląd wszystkich omawianych zagadnień jest poparty przykładami. Szczególną uwagę zwraca się na charakter i znaczenie pozyskiwania danych w procesie decyzyjnym. Podkreślono, że sama informacja jest bardzo ważna, ale ważna jest również wartość informacji oraz sposób jej przetwarzania i zarządzania. Zarządzanie danymi w jednostce optymalizuje proces decyzyjny i pracę całej jednostki. Z kolei dane są zasobem, którego utrata może skutkować utratą pozycji konkurencyjnej lub utratą możliwości rozwoju.

Słowa kluczowe: technologie cyfrowe, pozyskiwanie danych, zarządzanie danymi, produkcja, zarządzanie, proces decyzyjny, Przemysł 4.0, automatyzacja, czujniki, sieć przewodowa, sieć bezprzewodowa

JEL codes: L16, L26, O32, O39

Introduction

Today, digital technologies permeate all aspects of industrial and production systems, accelerating the generation of large amounts of industrial data. Industry 4.0 offers great development opportunities, new perspectives, a new paradigm of autonomous and decentralized production control. From an IT perspective, this means a new level of networking, data integration and data processing in production, and new possibilities for data management. Data management trends and challenges reveal the impact of developing new models and architectures that incorporate the Internet of Things, Cloud Computing and Big Data at different levels of integration to enable intelligent analytics. Data management covers all the plans, processes, policies, and practices that a company uses to collect, store, control, deliver, and modify data and information in the systems of a business organization. Proper data management is one way business can proactively improve the quality, efficiency, effectiveness and reliability of its data [Tupa and Steiner 2019].

Changing market conditions and increasing competition force manufacturing companies to use organizational, technological and IT innovations which enable flexible production planning and increasing efficiency of management of processes. Appropriately collected and presented data from production lines make it possible to specify which of the manufacturing processes reduces productivity and at what point it should be improved.

Data acquisition in industrial practice consists in remote reading data through measuring systems as well as transmission of the data obtained using a transmission medium. The data acquired in this way are usually sent to an acquisition server (Figure 1) or a DNC computer. The constantly growing level of industrial automation causes the dynamic growth of the amount of transmitted data. It should be noticed at the same time that the requirements related to the increase in the amount of the data processed and the reduced time of their acquisition affect parameters of industrial enterprises. The data acquisition is one of the most important issues of distributed real-time systems. Modern computer systems used to support manufacturing processes allow for real-time visualization, processing, downloading and making available the data collected. In the context of the vast amounts of data on processes, the tasks specified pose a serious problem to be solved by the systems of industrial databases used currently [Cupek 2021].

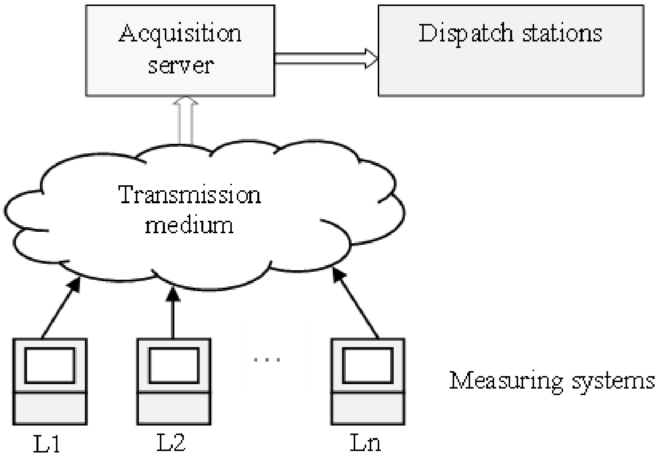

Figure 1. Example of a remote reading system
Rysunek 1. Przykład systemu zdalnego odczytu
Source: [Bogacz and Krupanek 2021].

There are many methods for collecting process data from production systems. In general, it can be said that the choice of an appropriate method depends on specific characteristics and the level of automation of manufacturing processes [Ćwikła 2011]. Acquisition of data from manufacturing processes can be manual, semi-automatic or automatic. The manual acquisition is a process onerous for employees, vulnerable to manipulations and many errors resulting, among others, from the human factor. Moreover, the data in the process of manual acquisition is collected with a huge delay. This is due to the fact that they must be entered manually into the system and forwarded. The semi-automatic acquisition is based on the cooperation between a man and a machine. The semi-automatic mode enhances the process of data acquisition significantly but does not eliminate all deficiencies of the manual mode. The automatic data acquisition may be applied in automated production lines or at workplaces intentionally equipped with various types of data acquisition sensors. Therefore, an automatic data acquisition system must be appropriately built. It is usually the most expensive method of date collection for implementation. However, it is the most efficient and the most reliable of all the methods mentioned above [Sade et al. 2019].

It is obvious that fully automated production systems due to the large amount of the key data on processes affect taking decisions on controlling manufacturing processes. However, the data collected from the sensors require proper analysis and interpretation [Ćwikla 2011]. Finally, it is a man who takes decisions on controlled processes on the basis of the current data.

The aim of this paper is to present selected popular ways and methods of automatic acquisition and transfer of data directly from production lines of enterprises, accentuation the differences between the discussed methods and presenting the essence of data management as the key to the success of many enterprises.

Materials and methods

The purpose of this paper is to present an analysis of selected methods and approaches to automatic data acquisition and transfer directly from the production lines of enterprises, to highlight the differences between the discussed methods and to present the essence of data management as a key to success of many enterprises in the era of digitalization of Industry 4.0. Based on the literature and available data on the acquisition, transmission and management of data, an analysis and evaluation was carried out, resulting in the conclusion that in all manufacturing enterprises, the acquisition and management of data from the production layer serves to increase production efficiency and reliability, and data acquisition is a key element in the decision-making process and at every level of enterprise management. The analysis also covers current technological developments that are increasing the possibilities of wired as well as wireless ways of transferring data from technological processes, accelerating the pace of analysis in the decision-making process, as new technologies used in Industry 4.0 are also enabling the development of enterprises whose main objective is to gain a competitive advantage. Without appropriate support of modern digital technologies, the amount of data/information generated in technological processes, is impossible to process and use in further development of enterprises.

Industry 4.0 and Industrial Internet of Things

Industry 4.0 stands for the integration of intelligent machines, systems and the introduction of changes in production processes to increase manufacturing efficiency and introduce the possibility of flexible product range changes. In line with the idea of the future, data acquisition and archiving are of great use in production processes. The analysis of production data allows for the early elimination of process errors and strategic line failures. The archiving of data allows the creation of historical analyses and direct process tracing of the product at each production stage and supports future production planning [Akwizycja i transmisja…].

The basic execution elements necessary to move production into the digital era are digitalized control systems. It is about controlling automation systems, production nests, automatic transport or human communication systems. Industrial computers are responsible for the operation of all these devices and they are the main element allowing to build the Industrial Internet of Things, Digital Factory or, finally, to create an enterprise management and control system compliant with Industry 4.0. In industrial installations, measuring devices generate huge amounts of information, e.g., about the condition of machines or environmental conditions. Until now, this data was hardly used because it was not transmitted to the control systems. Nowadays, they can be transmitted via digital techniques to the cloud, where they are available to all systems operating in the plant. This makes it possible to continuously monitor the condition of the equipment and to plan maintenance activities well in advance.

It also makes it possible to optimize production processes, depending on information about conditions, location and availability of individual devices. This results in savings of raw materials and media used during production [Bieńkowski 2018].

Data acquisition – an essential element of the decision-making process

It is in all manufacturing companies that the data acquisition from production processes and the management of the data are aimed at improving productivity and reliability of the processes. Data acquisition is a key element in the decision-making process at every level of business management i.e. from operational services and maintenance through departments of engineering to administrative units. These levels also have their reference in the hierarchical structure of an enterprise. It is at the lowest level that there are the sensors, actuators and various industrial automation devices having a direct connection with the production level. A level above, there are control and data acquisition systems as well as all sorts of industrial control systems. These systems operate in real time and, besides collecting data, are responsible for control of machinery, equipment and components of production lines [Pękala 2012]. The decision-making process consists mainly of stages of identification and analysis of all the information available on the existing problems, then assessment, decisions and selection of an optimal solution [Sala 2007]. Efficient and accurate decision making within a reasonably short period is the basis for the proper functioning of any enterprise [Bolloju et al. 2002]. The complexity of decision-making processes involves many determinants affecting their course. The process itself can be characterized as a set of different elements defining the context and the circumstances of decision-making. The efficiency of decision-making processes depends on the organization of activities and the course of the planned cycle and the need to isolate individual stages results from the complexity of processes themselves [Kisielnicki 2006]. The analysis of the decision-making process enables thorough understanding of the problem and the entire process as well as generates new knowledge [Bolloju et al. 2002].

Data acquisition in the decision-making process is a fundamental prerequisite for solving most problems that occur in the enterprise. In a rational analysis of alternative decisions, an important element is a careful comparison of benefits and costs and possible courses of action and behaviour. Current changes in the surrounding reality, digitalization and Industry 4.0 set new goals and directions that organizations will strive for.

Methods for collecting data from production lines

In the process of data collection from production lines, it is very important that the process data acquisition itself is not burdensome for an operator and does not slow the production process. In industrial practice, the data acquisition process uses many sensors positioned directly in the production line [Xu et al. 2020]. An example of sensors' classification is shown in Figure 2.

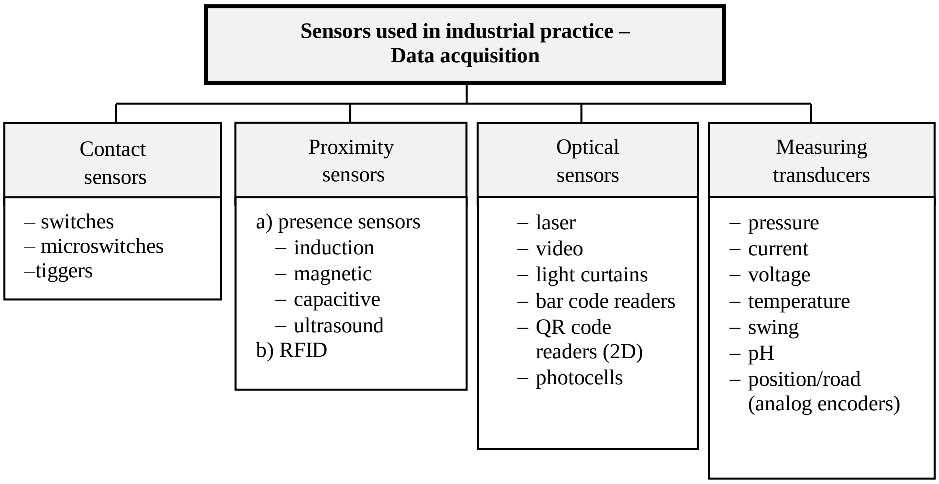

Figure 2. The division of sensors used in industrial practice for collecting data
Rysunek 2. Podział czujników stosowanych w praktyce przemysłowej do zbierania danych
Source: own study based on [Fraden 2010].

For obvious reasons, sensors are necessary and are an important element of most machines, equipment and technological lines. They are usually very small and inconspicuous. However, it is without them that it would not be possible to detect the presence of objects, define their characteristics, control work of machinery and equipment as well as processes. Therefore, well-selected sensors largely decide on the accuracy and reliability of production processes [Fraden 2010].

The sensors listed in the Figure 2 usually work together with PLC controllers (PLC – Programmable Logic Controller) (directly connected to input modules, bus connection – ProfiBus, MPI, ANSI, SPI, I2C, CAN or through an industrial network – Profinet). Acquisition of data from production lines generally consists in collecting data from PLC controllers [Fraden 2010, Blokdyk 2020].

The PLC controllers integrate entire hardware controlling technological processes. Their outputs are connected to executive systems, to inputs – different types of sensors and measuring systems. It is through fast buses that they communicate with other controllers (often specialized for specific tasks). At the same time, they are also equipped with a number of interfaces allowing for communication with data networks, may also be equipped with hardware modules for recording data process directly to standard of databases [Ćwikła 2012].

Contact sensors are mainly used as "limit switches" (position switches), however, due to the presence of mechanical parts in their construction, they are prone to crushes, which causes that they are used less often in industrial practice. Contact sensors are used mainly for detection of the presence of objects which are not deformed by contact. They are also used as triggers – devices starting machines [Fraden 2010].

Proximity sensors belong to main elements of many industrial automation systems. They are used primarily to detect the presence of objects, their count and even to define their certain physical characteristics. The use of proximity sensors allows for automatic control of machinery and production systems through controlling levels of certain liquids and bulk material, and even for providing personnel with security when they are used in the safety systems [Karbowniczek 2015].

Optical sensors are part of control devices, whose operation is based on sending a light beam by a transmitter which is received by a receiver and recording objects which cross the light beam sent by the transmitters. Optical sensors are characterized by a high resolution which enables to record very small objects, a large detection zone from a few centimeters to several meters, a short response time and high resistance to noise and air pollution. Optical sensors are very widely used in industry. They are used, among others, for [TWT Automatyka]:

- identification of objects within the range of their operation,
- controlling the position of the moving parts of machinery,
- counting passing objects or number of revolutions,
- specifying for example: the level of liquids and bulk material,
- in addition to typical industrial applications, they are also used for control of comings and goings, at gates and security systems.

Measuring transducers convert a tested physical unit (temperature, weight, pressure, pH, moisture) to another one. It is usually that the output unit is current or voltage – a signal read by industrial automation systems [Fraden 2010]. Examples of sensors used in industrial practice are shown in the Figure 3.

Sensors provide a wide range of information on the state and course of the manufacturing process as well as on the condition of machines and devices allowing for automatic manufacturing process control. The main task of sensors used in production lines is collecting data from production paths as well as detecting irregularities occurring in production processes [Fraden 2010]. The data, which can be obtained, cover executed tasks (progress of executed orders), material flow (parts, work in progress, finished products), use of machinery and equipment (performance, downtime, failures), quality of products and the data on persons/workers involved in the production process (type of operations performed, breaks etc.). Selection of types and location of sensors in the automatic process is individual for each production line (specificity of production) and depends on the type of the production process [Xu et al. 2020].

The larger the number of sensors, the more comprehensive may be the control algorithm of the manufacturing process. The most commonly used sensors for data acquisition in industrial automation are inductive sensors (metal detection), capacitive sensors (responding to approach of any active medium to the surface) and photoelectric sensors (allowing for detection of foreign bodies in the operating area, light or color detection) [Heimann et al. 2001].

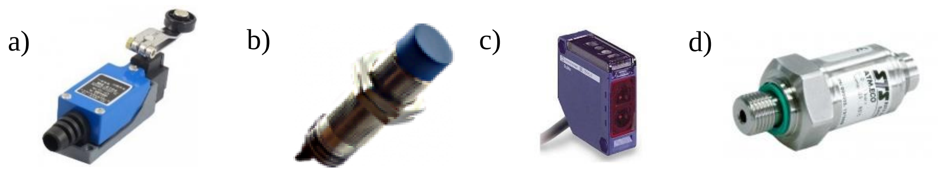

Figure 3. Exemplary sensors used in the industrial practice: a) a contact sensor (a limit switch); b) an inductive proximity sensor; c) an optical sensor; d) a pressure transducer
Rysunek 3. Przykładowe czujniki stosowane w praktyce przemysłowej: a) czujnik kontaktowy (wyłącznik krańcowy); b) indukcyjny czujnik zbliżeniowy; c) czujnik optyczny; d) przetwornik ciśnienia

Source: a – [Kontratech]; b – [Karbowniczek 2015]; c – [Automatyka – sklep]; d – [ACSE].

The cooperation of an enterprise resource management system with a production subsystem of the company requires certain and unambiguous acquisition of data on the manufacturing process. The data are passed through different types of data networks from the source to the place of their analysis and storage, whose load changes in time. Another problem is the diversity of technical solutions crated as universal or customized solutions. Characteristics essential for the effective data acquisition are consistency of the information, reliable collection and storage, effective access to information and keeping chronology of the events recorded [Cupek 2021].

Methods for transferring data from production lines

The modern methods for transferring data available today offer immense, new opportunities in the processes of automation of technological lines. The data are exchanged via industrial networks, local computer networks, wireless networks or a global computer network. The possibility of connecting via drivers, distributed inputs/outputs modules, transducers, frequency converters, operator panels or PC-es installed locally or anywhere in the world offers a user great opportunities for the full integration of the extensive, distributed industrial processes [Naskręt et al. 2005]. Nowadays, the huge amount of processed and collected data has led to an increase in digital demand using methods and tools that can process data quickly enough and extract valid, relevant, useful and meaningful information from it.

The modern manufacturing companies constantly strive after reduction of production costs, improvement of quality and enhancement of the efficiency of technological processes. Currently, there are many interfaces for data transmission used in processes of production control [Tupa and Steiner 2019, Xu et al. 2020].

Transfer of data from measurement points and from elements in their production process can be carried out either by wire or wirelessly (Figure 4). Network infrastructure is currently an indispensable part of machinery, equipment and production lines allowing for control of machinery, technological processes, data transmission and communication with computer systems of a company [Blokdyk 2020].

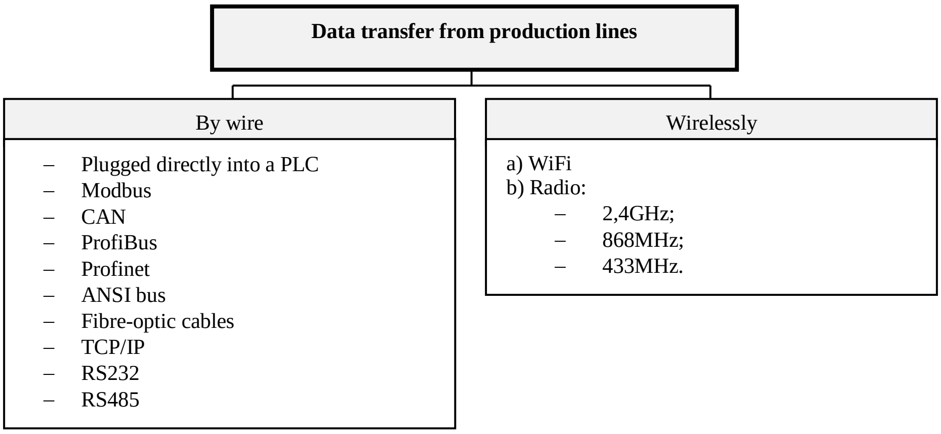

Figure 4. Popular methods for transferring data from production lines usedin industrial practice
Rysunek 4. Popularne metody przesyłania danych z linii produkcyjnych stosowane w praktyce przemysłowej
Source: own study based on [Blokdyk 2020].

The optimal efficiency of the data transfer from production lines can be achieved by providing adequate quality of the wired infrastructure, which is a key element in the operation of all machinery and equipment, control systems and industrial automation. Wired data transmission is one of the most popular ways to exchange data in technological processes. The data transmitted in this way can be sent in either analog or digital form with appropriate frequency. This technology is considered to be the most reliable and offers a number of advantages i.e. it is not susceptible to radio interferences, has a higher throughput, ease of diagnosing damage, resistance to serious failures, expandability and can be effectively optimized [Yekini et al. 2015].

Among the many possibilities of transferring data from production lines in a wired way, the ProfiBus network (developed by Siemens), which is used in the distributed control systems, is noteworthy [Mamo et al. 2017]. The network structure is based on the efficient transfer of large amounts of data in real time (data transmission in the network takes milliseconds). Analog and digital (input/output) devices, sensors, actuators, PCS and PLC controllers or operator terminals can be primary stations – controlling stations (Master). The attached substations (Slave) include different systems (i.e. inputs/outputs, cylinders, transducers). The ProfiBus can be operated in either Master-Slave or Multimaster mode. The structure of the ProfiBus protocol is based on the Open Systems Interconnection module (OSI) according to ISO (International Standard Organization). The maximum transmission speed is 12Mbs, the transmission speed is inversely proportional to the length of the bus. There can be up to 127 devices in one network [Mamo et al. 2017].

The Profinet is another noteworthy network. The Profinet network integrates IT networks in enterprises with office networks without modifying existing devices. The basic operation mode is compatible with the TCP/IP protocol. The Profinet network is used, among others, in the systems of the MES and ERP class [Mulaosmanovic 2015].

Moreover, it should be also noted that the standards intended for multipoint transmission lines, i.e. RS232 and RS485, are very important. Both standards are communication buses intended for serial data transmission, the RS232 has a voltage output and RS485 has a current output. Both buses (RS232 and RS485) can work both in full-duplex and half-duplex mode [Mulaosmanovic 2015]. In the full-duplex mode, transmission and reception of data are performed simultaneously; only two devices are connected with each other (Figure 5). The half-duplex mode (Figure 6) consists in transmitting and receiving data alternately (one pair of wires, which is bi-directional).

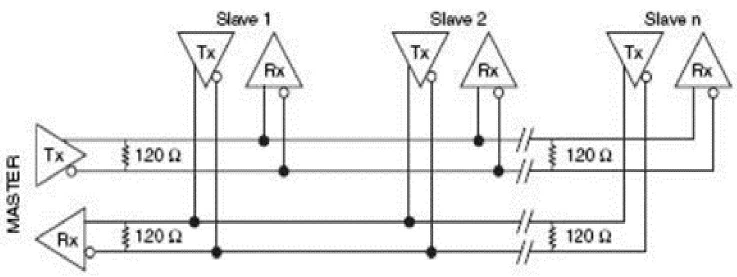

Figure 5. A bus in the Master Slave mode full-duplex
Rysunek 5. Magistrala w trybie Master Slave full-duplex
Source: [Engineer Ambitiously].

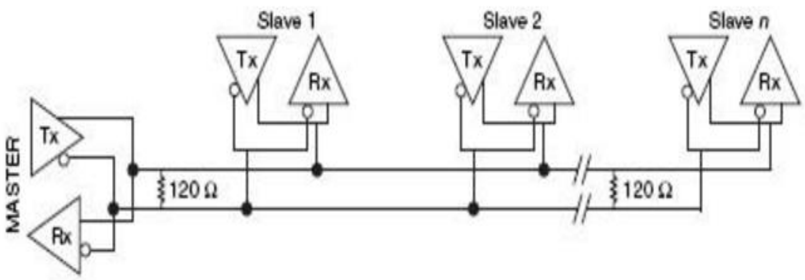

Figure 6. A bus in the Master Slave mode half-duplex
Rysunek 6. Magistrala w trybie półdupleksowym Master Slave
Source: [Engineer Ambitiously].

However, the transmission speed drops with the increase in length of the bus (wire). This phenomenon is graphically illustrated in the Figure 7.

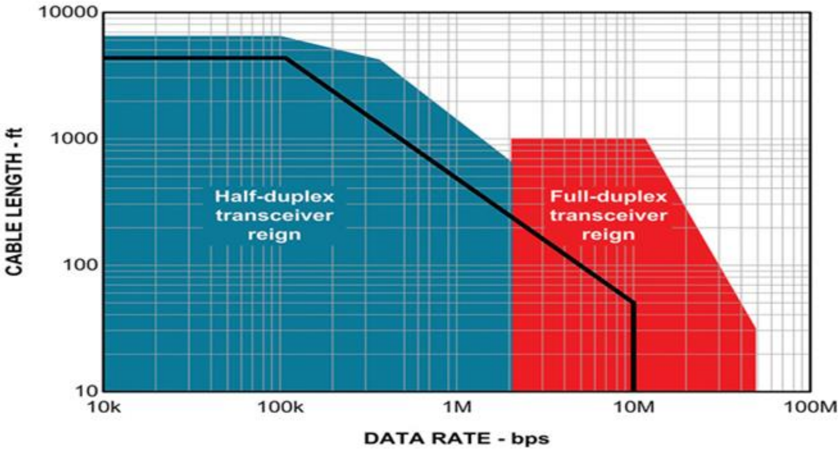

Figure 7. The dependence of the transmission speed on the length of the bus (wires) for the RS485 full-duplex and half-duplex

Rysunek 7. Zależność prędkości transmisji od długości magistrali (przewodów) dla RS485 full-duplex i half-duplex

Source: [Kugelstadt and Devlin-Allen 2014].

Currently, wireless networks are an alternative to conventional wired networks. They are used everywhere, where wired connections are difficult to create or too expensive; they give users easy access to resources regardless of place and time. Wireless data transmission has many advantages, which include the ease of installation and flexibility, monitoring device parameters, range (from several meters in buildings to several kilometers), fast expansion and modification of the network structure. Among disadvantages, there are a high level of external interferences, the requirement of additional security systems, which reduces the speed transmission, unauthorized access, as well as the relatively large energy dissipation [Pawar and Sawant 2014].

There are many possibilities for transferring data wirelessly. One of the most popular network is Wi-Fi, which transmits data on distances to several dozen or several hundred meters and is executed in the IEEE 802.11 standard. Wi-Fi is a technology that is used properly without any modification in the case of industrial applications. Wi-Fi uses the frequency ranges of 2.4 GHz and 5 GHz and the main advantage of this type of transmission is relatively high throughput [Piątek 2021].

Wireless networks are becoming increasingly popular. This technology allows for creation of networks in a variety of different configurations. The most popular and most commonly used is a temporary network (ad hoc) or a network with infrastructure. An ad hoc network is a temporary connection (usually for a short period) amongst devices and computers established for a specific purpose e.g. for direct exchange of files (Figure 8). A network with infrastructure has a fixed master station, in which all devices (in a wireless network) communicate with each other via access points AP (Figure 9) [Pawar and Sawant 2014].

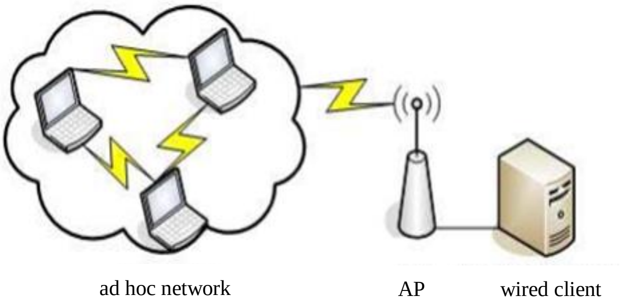

Figure 8. An ad-hoc temporary network (ad-hoc network, wired customer)
Rysunek 8. Tymczasowa sieć ad-hoc (sieć ad-hoc, klient przewodowy)
Source: [Laboratorium lokalnych…].

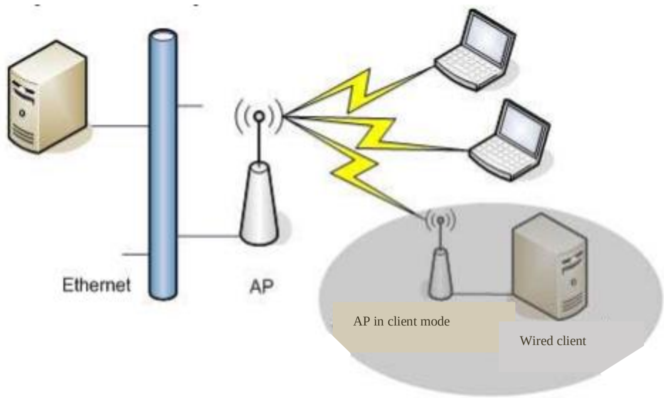

Figure 9. A Network with infrastructure (AP in customer mode, wired client)
Rysunek 9. Sieć z infrastrukturą (AP w trybie klienta, klient przewodowy)
Source: [Laboratorium lokalnych…].

Moreover, other types of networks should be listed such as a bridge point-to-point. This solution is used to connect remote segments of a wired network using radio (Figure 10). It is in practice that a bridge point-multipoint is also used. It is a structure similar to a bridge point-to-point, with the difference that there can be more segments of a wired network connected in this way in this case (Figure 11).

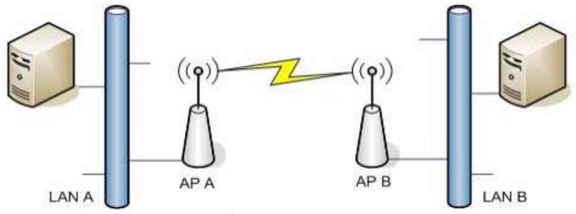

Figure 10. Bridge point-to-point
Rysunek 10. Most z punktu do punktu
Source: [Laboratorium lokalnych…].

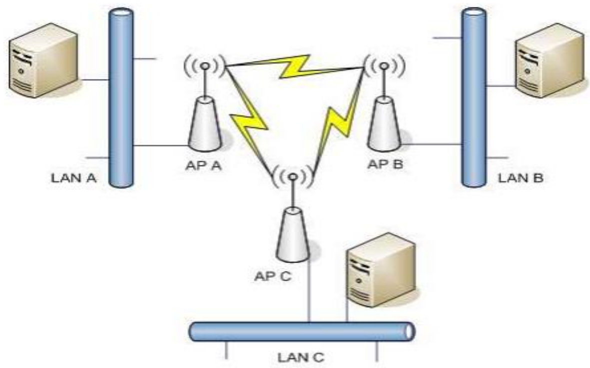

Figure 11. Bridge point to multipoint
Rysunek 11. Most z punktu do wielopunktu
Source: [Laboratorium lokalnych…].

In addition to the different wireless networks mentioned above, it is the MESH network that is noteworthy. This network is considered a smart network. Its intelligence is imbedded in routing algorithms which provide information on the possibility to reach a specific node (Figure 12). MESH networks integrate fully with Internet. Then the IP protocol is accepted as a network layer protocol. However, it should be mentioned that routing protocols in the case of MESH networks are completely different from those used in wired networks [Folga 2006].

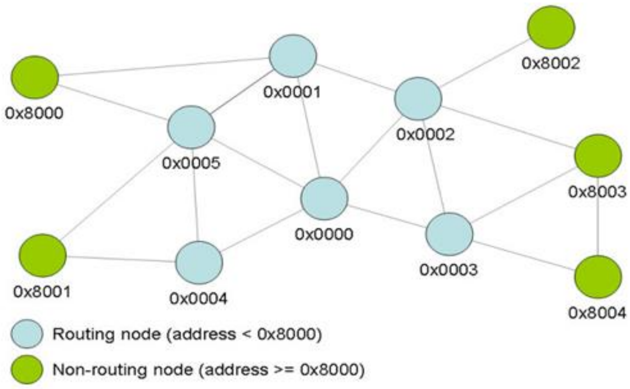

Figure 12. A MESH network
Rysunek 12. Sieć MESH
Source: [Rudnicki 2014].

Automated production lines are constructed on the basis of distributed control structures more and more often and therefore require advanced data transmission networks [Antons and Arlinghaus 2021]. The use of the wireless technology based on the Wi-Fi network allows for greater mobility and elimination of wires. The wide availability of technical measures and their differentiated capabilities allow for creation of any form of a network for data acquisition. A comparison of technical characteristics of the selected types of data transmission is shown in the Table 1.

Table 1. A comparison of technical characteristics of the selected types of data transmission
Tabela 1. Porównanie charakterystyk technicznych wybranych rodzajów transmisji danych

Type of transmission	**Data transfer speed**	**Distance**
RS232C	from 300 to 19200 bit/s	max. 15m
RS485	up to 35 Mbit/s	up to 1200m
CAN	up to 1 Mb/s	From 40 m to 1 km
USB	up to 480 Mbit/s, (actual transfer speed depends on the design of the device)	2 to 5 m, with the possibility of extension
Ethernet	from 10 Mbps to 10 Gb/s	from 500 m to 80 km
Wi-Fi	up to 300 Mbit/s	from a few meters to a few km

Source: own study on [Chaładyniak 2011, Kruszyński 2015, Tomaszewski 2018].

To sum up, it should be noted that both solutions wired and wireless can support and complement each other offering a completely new quality of control and monitoring in production processes [Cisco Systems 2007]. They may create so called hybrid systems of transmission networks sending data from technological processes. It is also possible to create redundant networks, in which information may arrive from a sender to a recipient in many ways (a network automatically chooses the shortest one). The redundancy of transmission paths makes that the network is extremely resistant to failures as in the case of damage to one route, the network selects a different path.

Currently, the development of technology increases possibilities of both the wired as well as wireless data transfer from technological processes and speeds up the pace of analysis in the decision-making process. New technologies used in industry also allow for development of companies, whose main purpose is to generate profit by gaining a competitive advantage. Without proper support of the information technology, the amount of data/information generated in technological processes could not be processed.

Data management – a responsible and complex set of processes

Data collection and management are the foundation for the good functioning of every enterprise. Currently, data is one of the most valuable resources, and their potential is growing. The data obtained is key in the activities of modern enterprises. Thanks to them, all company management processes are optimized [Tupa and Steiner 2019]. However, it is not the information itself that determines their value, but the ways to manage it. How an enterprise uses data determines the quality of data and affects the good (or bad) prosperity of the individual. Data management processes extract all potential from the information. Awareness of the importance of proper data usage currently encourages entrepreneurs to invest in the most effective data management systems. Thanks to detailed analyzes, not only the company's excellent performance is achieved, but also the information flow along with the distribution of access to authorized persons is improved, the offer is perfectly adapted to the customer's requirements and expectations, and the relationship between the company and the customer is improved by improving the service system and communication [Raptis et al. 2019]. Data management also enables accurate analyzes of entire data streams flowing through a given organization, which are subjected to processes recognizing data diagrams. Thanks to the analysis of the stream, the data is immediately filtered and subjected to preparatory activities to use them for a specific purpose. The key to business success is therefore good data management [Integral Solutions].

Conclusion

The aim of the paper was to present selected ways and methods of the automatic data acquisition and transfer directly from production lines, in the course of manufacturing processes and emphasize the importance of the data acquisition in the decision-making process.

Implementation of solutions compatible with the concept of Industry 4.0 gives many benefits, including easy access to data, or the ability to process and present them in a clear and accessible form. Interoperability of devices of Industry 4.0 allows to connect them to the Industrial Internet of Things (IIoT) in any factory environment [Bieńkowski 2018].

The efficiency and cost-effectiveness of production depend on its organization to a large extent. In this sense, the automation and reliability of data collection measurement is of particular importance. It contributes, among others, to reduction of production costs and increase in productivity, shortening the production cycle, reduction of unplanned and planned downtimes, identification and minimization of errors and inefficient operations. The use of a wide range of different types of sensors allows for acquisition and transfer of data directly from production lines. However, it is not the information itself that provides value, but also the processing and management of data quality. Data management in the organization facilitates not only every data activity, but also optimizes the work of the whole unit. Data is a resource whose potential is in continuous development, which is why companies do not cease to collect them. As it is well known, the knowledge on the current status of the production process is of great importance in the decision-making process. Moreover, the possibility to monitor in the online mode contributes to increasing the productivity and reliability of production.

In conclusion, it should be noted that without consistent high-quality data, companies are exposed to threats such as loss of revenues, loss of valuable development opportunities and damage to their reputation, which can lead to a serious weakening of their market position.

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The value chain in the digital age

Łańcuch wartości w erze cyfrowej

Abstract. The fourth industrial revolution causes changes in the organization and functioning of many enterprises. Digital transformation is a multi-threaded process covering practically all areas of life and economy. Digital transformation means implementation information technologies in all areas of business functioning. Businesses, both large and small, must adapt to the standards of digital "reality". Digitalization is the driving force that will shape the industry of the future. The potential of digitization can be seen throughout the value chain, from product design, manufacturing and business processes, a fully digitized customer path, to new customer acquisition and customer service, to supply automation. The implementation of digital technologies of Industry 4.0 has a huge impact on the entire value chain, streamlining production and processes, improving management and quality of products and services, optimizing relationships between customers and organizations, bringing new business development opportunities and many benefits. The value chain in the era of digitization is becoming an important element generating noticeable profits. The aim of the study is to present the value chain in the era of digitization in the context of Industry 4.0, including the identification of its most key elements, including the formulation of strategies based on digital resources that bring added value, allowing to compete in the market and at the same time set new standards and business models, and to show the significant benefits of digitization of the value chain.

Key words: management, value chain, enterprise, digitalization, Industry 4.0, digital technologies, supply chain

Synopsis. Czwarta rewolucja przemysłowa powoduje zmiany w organizacji i funkcjonowaniu wielu przedsiębiorstw. Cyfrowa transformacja to proces wielowątkowy obejmujący praktycznie wszystkie dziedziny życia oraz gospodarki. Transformacja cyfrowa oznacza wdrożenie technologii informatycznych we wszystkich obszarach funkcjonowania przedsiębiorstw. Przedsiębiorstwa zarówno duże, jak i te małe muszą dostosować się do standardów "rzeczywistości" cyfrowej. Cyfryzacja jest siłą napędową, która będzie kształtować przyszły przemysł. Potencjał cyfryzacji zauważalny jest w ramach całego łańcucha wartości, począwszy od projektowania produktów, procesów produkcyjnych i biznesowych, w pełni scyfryzowanej ścieżki klienta, poprzez pozyskiwanie nowych klientów i ich obsługę aż po automatyzację dostaw. Wdrożenie cyfrowych technologii Przemysłu 4.0 ma ogromny wpływ na cały łańcuch wartości, usprawniając produkcję i procesy, poprawiając zarządzanie i jakość produktów oraz usług, optymalizując relacje między klientami i organizacjami, przynosząc nowe możliwości rozwojowe biznesu oraz wiele korzyści. Łańcuch wartości w dobie cyfryzacji staje się istotnym elementem generujacym zauważalne zyski. Celem opracowania jest przedstawienie łańcu-

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cha wartości w dobie cyfryzacji w kontekście Przemysłu 4.0, z uwzględnieniem wskazania jego najbardziej kluczowych elementów obejmujących formułowanie strategii na podstawie zasobów cyfrowych, które przynoszą wartość dodaną, pozwalając konkurować na rynku i jednocześnie wyznaczać nowe standardy i modele biznesowe oraz ukazanie istotnych korzyści płynących z cyfryzacji łańcucha wartości.

Słowa kluczowe: zarządzanie, łańcuch wartości, przedsiębiorstwo, cyfryzacja, Przemysł 4.0, cyfrowe technologie, łańcuch dostaw

JEL codes: L16, L26, O14, O32

Introduction

The economic development that can currently be observed is caused by many factors. Among them, an important role is played by the phenomenon of digitization of the economy, enterprises and social life. The fourth industrial revolution causes changes in the organization and functioning of enterprises, the foundation of which are new information technologies based on Big Data, Internet of Things (IoT) and Artificial Intelligence (AI). These new technologies open up tremendous opportunities for companies to increase productivity, increase competitiveness, and create and capture value. Implementation of artificial intelligence to manage business and manufacturing processes, including new generations of intelligent robots create the foundations for the development of smart factories and introduction of the Industry 4.0 concept [Łobejko 2018]. Digitalization makes it possible to collect and analyze various types of data not only faster but also with greater precision. Thanks to this, the data provided are much more objective, the processes can be dynamically controlled and ultimately optimized, and the decisions based on them are much more accurate. This enables even more efficient use of available resources, for example in order and delivery planning, quality assurance, better tool management or maintenance. Process data is recorded online, transparently prepared and accessible to the public [Arburg].

Digitization is impacting businesses in every industry by removing barriers between people, businesses, and things. Removing these barriers allows new products and services to be developed and more efficient ways to operate to be found. Change affects all types of organizations and all industries. However, they have several things in common: They provide opportunities for better management of processes and resources, lead to new forms of contact with customers, contribute to the transformation of business models and stimulate innovation among employees [Streżyńska 2020]. Digital transformation is a multi-threaded process. Carried out holistically and skillfully, it should be based on wide use of IT technologies in handling all, or at least most, of the processes carried out in the course of daily functioning of a company, such as production, sales, customer service, finances or distribution [Arburg].

Digital transformation is a comprehensive process that is developing new ways and practices for managing businesses and conducting the entire spectrum of business in the digital world. At the same time – it is also the acquisition of new digital skills by the company's employees, enabling them to better collaborate with technology for optimal business results. It is simply changing the entire operating model of the company [Cyfryzacja według…].

We are currently witnessing unprecedented changes across industries. After the third industrial revolution, which involved the automation of individual processes, came the fourth

– enabling the interconnection of devices within digital ecosystems, and deepening integration across horizontal and vertical value chains. The global trend that made the next revolution possible was primarily the increase in the amount of data available and the computational capabilities to process it. They have made it possible to better manage company resources, plan production, and manage the entire product lifecycle. Data analytics has given companies the opportunity to deepen cooperation with suppliers and better respond to customer needs. What does this process consist of? It is based on automatic collection and processing of large sets of data, coming from devices or directly from people. Analysis of this data allows for cost and product optimization [PWC 2017].

The value chain in the era of digitization is becoming an essential element to generate noticeable profits. However, redesigning business systems, improving value chains, and delivering new value propositions require companies to adopt new approaches and fundamentally change their business systems. The potential of digitization can be seen throughout the entire value chain, from product design, manufacturing and business processes, a fully digitized customer path, new customer acquisition and customer service to delivery automation. Digital solutions facilitate the integration of the entire value chain.

The aim of the study is to present the value chain in the era of digitization in the context of Industry 4.0, including the identification of its most key elements, including the formulation of strategies based on digital resources that bring added value, allowing to compete in the market, while setting new standards and business models, and showing the significant benefits of digitization of the value chain.

Materials and methods

The subject of the study is the presentation on the basis of the conducted literature studies of the subject, the value chain in the era of digitisation in the context of Industry 4.0, to identify its most key elements, including the formulation of strategies based on digital resources bringing added value, allowing to compete on the market setting new standards and business models, as well as to indicate the significant benefits resulting from the digitisation of the value chain. Based on the literature on digitisation and Industry 4.0, an analysis and evaluation of the scientific literature was carried out, which shows that digitisation is more than just the purchase of new computer hardware and IT systems. It is about using the opportunities provided by new technologies and the data collected with them to rethink all aspects of business processes. The analysis covered the area of digital strategy. It highlighted the important aspect of how an organization formulates and implements a strategy based on digital assets that add value to the organization, allow it to compete in the market and set new standards and business models. The analyses conducted have also identified the significant benefits of value chain digitization in Industry 4.0 at many stages of its operation. The aim of the presented study is to broaden the knowledge and also to contribute to a deeper understanding of the relevance of value chain digitization.

The value chain

The competitive environment for organizations of all shapes and sizes – and in all industry verticals – is more challenging than ever before. Technological advancements have enabled businesses to design and build more quickly, sell across multiple channels, react instantly to changing demands, and cut costs simply by outsourcing an activity. To achieve competitive advantage, an organization ultimately delivers more value at an equal or lower cost. Value chain analysis is the method for determining the critical path to enhance customer value while reducing costs [Eby 2017].

The concept of value chain was developed by M.E. Porter as a mechanism of value creation in an enterprise. According to it, every organization has two types of activities: primary and secondary activities. The core business includes input logistics, production activities, output logistics, marketing and sales, and service. Supporting activities, on the other hand, include procurement, technology, human resource management, and company infrastructure (e.g., management, planning, financial activities, accounting) [Figure 1]. In light of contemporary knowledge, the value chain is considered to describe the full range of activities that are necessary to make a product or service available from the concept stage, through the intermediate stages of production, to delivery to final consumers. Fragmentation of production processes and the related dispersion of tasks and activities on an international scale leads to the emergence of cross-border production systems, consisting of a sequence of chains or networks that operate on a global or regional level or cover only two countries. Due to the described scope of activities, these systems are commonly referred to as Global Value Chains (GVCs). The question of terminological differentiation between global value chains and supply chains is also an important issue. Supply chains are the physical embodiment of value chains - a network of interconnected organizations engaged in various processes and activities with the goal of providing a full range of products and services to the ultimate customer. Global value chains have a direct economic impact on value-added generation, including jobs and income. For developing regions, they are also an important avenue for development in building productive capacity, which occurs through technology and know-how transfer, acquisition of new skills, and industrial upgrading. The value chain analysis allows identifying and defining action strategies for economic sectors that have a key impact on the development of the region [Łańcuchy wartości…]. The value chain concept refers to the concept of an economic path to trace a product from raw material sources through all economic links to the final user. Each enterprise is a link in a broader value chain, but it also creates an internal chain consisting of various processes, activities and resources that need to be managed. Using the value chain model, an enterprise can be simplified as a sequence of activities, successive transformations of raw materials, materials, purchased technologies, services into final products, called core functions. These functions cannot be performed well without the existence of management and consulting activities referred to as support functions. The integrated operation of the core and support functions and their linkage to the value chains of suppliers and buyers allows the company to make a profit and grow. Value chain management is therefore not a one-off act, but a process of refining the business model to increase value for the end user, while capturing the financial benefits of doing so as much as possible [Rojek 2014].

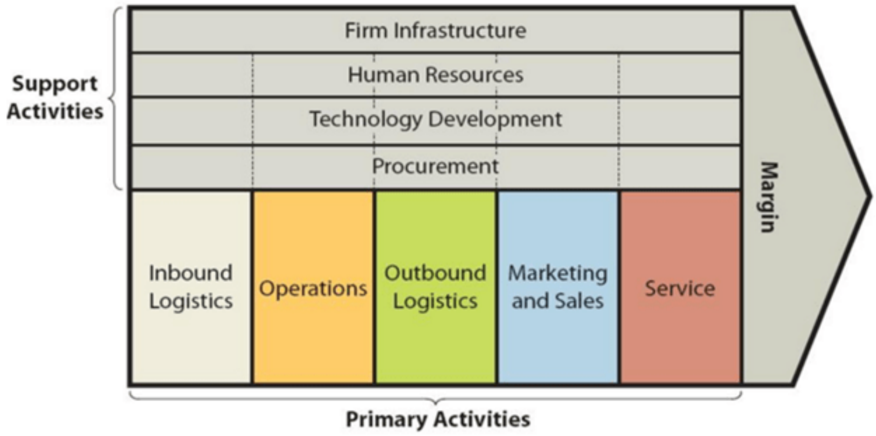

Figure 1. Porter's value chain
Rysunek 1. Łańcuch wartości Portera
Source: [Dudovskiy 2016].

Main activities consist of processes that add value to the product or service offered by the company, while auxiliary activities define the organizational culture of the company and resources unrelated to the production process [Szareck 2021]. Value chain through the sequence of activities (primary and secondary) in it participates in the generation of profit. But not every activity has a significant impact on the competitive advantage and efficiency of the company's operation. The selection of activities to be implemented in the company and the identification of those to be improved is therefore of fundamental importance for the company [Walas-Trębacz 2013].

To summarize, in general terms, the value chain represents the process of "adding" value to a product, beginning with the activities associated with a company's purchase of raw materials, supplies, semi-finished products, etc., necessary for the production process. The value chain then includes design, production, logistics activities, marketing, and ends with the provision of value-added services to customers. Thus, it becomes necessary to distinguish strategically important "carriers" of value creation within the enterprise. These are the subsequent activities related to the creation and delivery of value to the customer and the creation of value of the entire entity. Therefore, the concept of the value chain has entered both the stream of strategic management, through its reference to the construction of strategic advantage and competitiveness of the enterprise, and has become one of the tools of enterprise value management, actively participating in this process [Rojek 2014]. It should also be remembered that the nature and effectiveness of the created relationships in the value chain is influenced by many factors, such as It should also be borne in mind that the nature of the relations established in the value chain is influenced by many factors, including: the type of sector, the scope and scale of operations, product complexity, the number of participants in the value chain, partners' goals and expectations, partners' choices, the level of trust between partners, ways of cooperation and ways of competition between partners, coordination mechanisms in the chain, the degree of integration of the chain, the business model adopted, access to information and knowledge, the degree of internationalisation of enterprises, cultural differences, partners' experience in existing relations, the level and scope of key competencies, the place and position of partners in the value chain, the level of risk in establishing relations, the scope and frequency of changes in technology, the progressive process of globalisation, etc. [Walas-Trębacz 2013]. It should also be remembered that in modern value chains, especially thanks to the introduction of the Industry 4.0 concept, companies no longer function as isolated islands connected to suppliers and subcontractors but are part of a whole chain of information exchange and analysis, whose processes are no longer merely internal but have an impact on processes in other entities. This coordination can be seen, for example, in production and logistics processes – in order to work more efficiently, logistic processes are managed and coordinated properly, but also resources, allowing for delivery of raw materials and certain finished products at the right time (according to the "Just-In-Time" concept). This allows for more efficient use of raw materials and energy. These two elements are of particular importance in the situation created by the COVID-19 pandemic, where supply chains have changed significantly. Old ones were disrupted or heavily modified and new, local ones emerged. This is also not without significance for the environment and its protection and energy efficiency, as well as for delivery times. It reduces the distance between actors in the supply chain and thus directly contributes, for example, to reducing the carbon footprint of the entire manufacturing process, including logistics processes. Another example of strong interconnectedness within a value chain is cyber security. When entities are so strongly connected to each other, the lack of adequate security at one point along the chain, which may be a small business for example, the consequences of a cyber-attack can affect all related entities, including customers.

Digital strategy in the value chain

A company that wants to build a digitization strategy must understand what digitization is all about. Without digitizing processes and creating a data warehouse, one cannot think about digital transformation at all. More and more Polish companies choose digital transformation. Its course, scope and role depend on the goals set. Digital transformation is a series of broad, holistic activities that should be linked by a common vision and a unified strategy. Although each company carries it out in its own way, the motivation is similar: without such a change there is no way to compete in the market [Smoliński 2019]. Digital transformation is a key component of an overall business transformation strategy, and while it is not the only component, it is fundamental to the success or failure of the effort. The right technologies, as well as people, processes and operations, enable you to respond quickly to disruptions and opportunities and meet new and changing customer needs. They prepare organizations for future growth and foster innovation – often in unexpected ways [Na czym polega…].

Digital strategy means that the organization formulates and implements its strategy based on digital resources that bring it added value, allow it to compete in the marketplace and set new standards and business models. Such a situation means, among other things, going beyond traditional thinking about IT strategy, going beyond systems and technologies (understood in a narrow sense) and basing the entire operation of the company on a resource-based approach (Resource-Based View) and intangible resources (information, knowledge, tacit knowledge, intellectual capital), linking digital strategy to the creation of value for business and operational and energy efficiency. Digitalization is also a tool which does not serve only to digitalize processes for the sake of digitalization itself. On the one hand, it is supposed to increase the efficiency of process management, and on the other hand, the efficiency of raw materials use, including energy, which translates directly into a reduction in its consumption, and its effective management, and as a result, the reduction of contribution to CO2 emission. Value creation in traditional business models is rather understandable and the issue has been widely described within various strategic management theories [Olszak 2015]. Digital strategy highlights additional dimensions that change the nature and manner of value creation. These include the use of diverse information, the use of multi-party business models, the coordination of models across networks, and the control of network architecture [Bharadwaj et al. 2013].

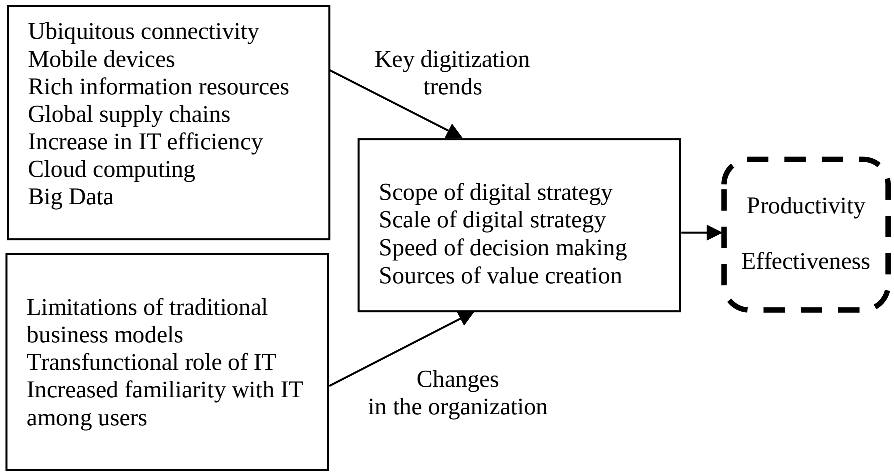

Figure 2. Key elements that shape an organization's digital strategy
Rysunek 2. Kluczowe elementy kształtujące strategię cyfrowa organizacji
Source: [Bharadwaj et al. 2013].

The fourth industrial revolution describes a complex process of technological and organizational transformation of enterprises that includes the integration of the value chain, the introduction of new business models, and the digitalization of products and services. The implementation of these solutions is made possible by using new digital technologies, collecting and analyzing data resources, and providing communication in a network of machines, devices, and people working together. Keep in mind that the primary value in digitization is objective data, the analysis of which allows humans to make the best possible process management decisions based on it. The driver of the transformation is the increasingly individualized needs of customers and the growing trend of personalization of products and services [MBF group 2021].

Keep in mind that the primary value in digitization is objective data, the analysis of which allows humans to make the best possible process management decisions based on it. The driver of the transformation is the increasingly individualized needs of customers and the growing trend of personalization of products and services. The first is vertical integration, which affects all systems in the traditional automation pyramid: from the field level and control level to the production level, the operations level or the enterprise planning level. Vertical integration makes the traditional view of the automation pyramid disappear. The same applies to several systems and applications that are currently at different levels. Other systems, such as ERP, for example, will change completely. This will happen when they are replaced by rapidly emerging applications in terms of Industrial Internet of Things platforms. Specifically, these will be production platforms that serve a variety of tasks and use cases in many aspects of the industry. They are gaining more and more features and are being connected in a way that requires systems, digital transformation platforms and business applications to work together. In addition, they also need to integrate with the aforementioned IoT platforms and all their functions. The second integration is horizontal integration, which is not about a hierarchical view of several systems (as in vertical integration), but a comprehensive value chain. It breaks down from the supplier and processes, information flows and IT or IoT systems as early as product development and manufacturing to logistics, distribution and the ultimate customer. This also has a significant impact on the many different systems used in industrial markets. Ultimately, however, it is all about data and how, what and where it is used [Innowacyjność w Przemyśle…]. The last element is the digital end-to-end engineering along the entire value chain, which means the mutual synergy associated with the development and manufacturing of the product offered by the company. All these elements, thanks to the use of the latest technological solutions, can be interconnected and managed in order for the company to function optimally in the market. Also of key importance, according to experts, is the change of mentality and consumer profile, the form of all goods – from cars to cell phones and electronics. Also important for the development of the idea of Industry 4.0 is the influence of universities and research institutions in the context of developing new solutions to improve business processes [Bondyra and Zagierski 2019]. It should be mentioned that an extremely important element is the increasing use of cloud computing and the transfer of data processing systems to external infrastructure. Many entities are not able to provide on their own the appropriate tools and infrastructure for processing and secure storage of data. On the one hand, this has an impact on expanding the number of stakeholders in the digitization process, and on the other hand it has an impact on increasing the level of security while reducing costs.

An additional element that should also be mentioned is the ability for companies to make semi-independent and fully autonomous decisions. However, these are proving to be cornerstones in both Industry 4.0 and Logistics 4.0 [Innowacyjność w Przemyśle…]. The integration and increasing digitization of industrial production will lead to more complex and digital market models, increasing competitiveness by eliminating barriers between information and physical structures [Pereira and Romero 2017]. This requires companies to review their operating models. When technology leaders introduce new advanced products, they offer new product quality and functionality, which contributes to changing customer expectations. This, in turn, must be responded to by other businesses by changing their existing business models. This process is certainly not an easy task [Li et al. 2017].

Industry 4.0 covers the entire value chain: from placing orders and supplying components for ongoing production to shipping goods to customers and after-sales services. Based on complex products, value networks will be created in which IT systems and production lines of manufacturers and suppliers automatically exchange data with each other. This will take the “Just-In-Time” production model to the next level. Within the value network, companies will share data with each other to increase production efficiency across the value chain. What does this mean in practice? Only those manufacturers who prepare for Industry 4.0 solutions at the right time will be able to integrate into the value network and retain customers and suppliers in the long run. Whether we want it or not, Industry 4.0 is the next inevitable step in the overall global economy. Companies that implement digital solutions from the beginning even in small steps, learn new technologies and take an active part in shaping the changes. In the process, these companies gain a competitive advantage and secure their future [Piątek 2017].

Digitalization of the value chain in Industry 4.0

Industry 4.0, encompassing many modern automation systems, data exchange and manufacturing technologies, represents a potential for development in many fields. The implementation of digital technologies of Industry 4.0 has a huge impact on the entire value chain, streamlining production and engineering processes, improving management and product and service quality, optimizing customer and organizational relationships, bringing new business opportunities and economic benefits, changing educational requirements and transforming the current work environment [Ślusarczyk 2019]. Industry 4.0 is a collective term for the techniques and operating principles of value chain organizations collectively applying or using cyber-physical systems, the Internet of Things (IoT), and cloud computing [MBF group 2021].

Digitalization contributes to productivity growth in four ways: through process optimization, market expansion, product innovation, and more efficient use of human capital [McKinsey & Company and Forbes Polska 2016]. Digitization is also a tool for better resource management and is inextricably linked to building a green economy. Digitalization is the driving force that will shape the industry of the future. Digital solutions open up new opportunities to streamline operations from a sustainability perspective, but also lead to improved profitability [Bieńkowska and Lalka 2021].

Digitization of the value chain in Industry 4.0 affects the entire value chain, streamlining production and engineering processes, improving product and service quality, optimizing customer and organizational relationships, bringing new business opportunities and economic benefits, changing educational requirements, and transforming the current work environment. Digitalization is leading to profound changes in industrial and manufacturing sectors, having a strong impact along entire value chains and providing a range of new opportunities in terms of business models, production technologies, job creation and work organization [Ślusarczyk 2019].

In summary, it should be noted that there will no longer be classic value chains with clearly defined boundaries between internal company functions and external areas within Industry 4.0. Thanks to modern applications and their ubiquitous exchange of information, internal and external boundaries will merge and the classic boundaries of individual companies will be shifted. Industry 4.0 digitizes and integrates processes vertically across the organization, through all functions, from product development and purchasing, to manufacturing, logistics and after-sales service. Besides, horizontal integration goes beyond internal operations. Here, suppliers, customers and all key value chain partners are also integrated

[Blunck and Werthmann 2017]. The full digitization of these chains has the potential to increase productivity levels, but it requires precisely the aforementioned integration of vertical and vertical information sharing and decentralization of decision-making [Santos et al. 2017].

Significant benefits of value chain digitization

Digitalization brings benefits at many stages of the value chain. One of the first might be the digital design of entire production lines using the Digital Twin. It allows to design the entire plant or production line in the form of digital simulation of all production and logistics processes, and thus to identify potential hazards, weak points, increase the level of ergonomics, facilitate the functioning, optimize the time of performed operations and significantly increase the level of safety for employees and equipment. A similar area is the design of products using the same technology, which allows, already in the design phase, with the use of Artificial Intelligence and analysis of large data sets to optimize the construction of a single component to ensure on the one hand the best functional parameters, and on the other hand safety, durability or production optimization. What is more, digitalization and introduction of intelligent systems of data collection and analysis based on the Internet of Things allow for real-time analysis of the functioning of products and entire systems. This translates, on the one hand, into the use of advanced predictive analytics and the ability to react quickly in the case of an anticipated failure and not only in the case of an actual one, but also to use the data concerning the parameters of product operation to improve and develop it.

In business processes digitalization is also of paramount importance. Data collected by intelligent production systems make it possible to collect and analyze information and report objective data showing the functioning of systems, their parameters, energy and raw material consumption, as well as machines and equipment themselves. This allows for making optimal management decisions in the area of production, which also translates into business decisions and allows for a better and more flexible response to changes, micro- and macroeconomic conditions. In Industry 4.0, however, the processes of data collection and analysis go beyond a single entity and become part of a much broader ecosystem of information collection, exchange and analysis. Thanks to this, all processes, including production and logistics processes also between ecosystem entities, can be optimized in order to reduce costs, the level of consumption of raw materials and resources, increase the efficiency of all processes – from production, through logistics, to business – which directly translates into environmental protection, but also into improved quality and working conditions. This system and sample tools can work in any industry. Individual systems and processes and tools may differ due to the nature of the business. Nevertheless, the general concept and principles of functioning of Industry 4.0, areas of digitalization and values achieved thanks to its introduction, such as objective data and optimization of decisions based on them, are unchangeable for all entities.

Conclusion

The aim of the study was to present the value chain in the era of digitization in the context of Industry 4.0, including the identification of its most key elements, including the formulation of strategies based on digital resources that bring added value, allowing to compete in the market and at the same time set new standards and business models, and to show the significant benefits of digitization of the value chain.

Revolutionary changes in the business environment of enterprises caused by progressive digitalization pose many challenges to enterprises. Each enterprise nowadays, wishing to remain competitive in the market, is forced to introduce innovative solutions of Industry 4.0 increasing quality and production efficiency. Industry 4.0 forces technological, IT and organizational changes caused by the intensive process automation and in-depth digital transformation of industry.

Digitalization has become a necessity at the present moment. Nowadays, digitization, automation as well as real-time management cover almost all operations and processes of enterprises. Digitalization increases competitiveness and enterprise value, leads to profound changes in industrial and manufacturing sectors, and exerts a strong influence along entire value chains. Digitalization of each element of the value chain in Industry 4.0 affects the entire value chain. The value chain in the era of digitization is becoming an important element that generates noticeable profits and savings. In addition, digitalization brings many significant benefits to many stages of the value chain. By digitizing the value chain, companies can increase revenue, optimize costs, improve cash flow and working capital management, increase efficiency of operations, improve organization and management and quality.

In summary, the presented study aims to enhance readers' knowledge and also to contribute to a deeper understanding of the importance of value chain digitisation.

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Industry 4.0 smart technologies in workplace safety logistics

Inteligentne technologie Przemysłu 4.0 w logistyce bezpieczeństwa pracy

Abstract. Safety logistics in the age of digitization of industrial plants is complex because it embodies the technologies of Industry 4.0 by integrating people and machines and individual processes. New technologies allow them to manage machines and equipment based on communication and mutual data flow. This creates a network of connections between products, value chains and business models. The activities associated with the implementation of the Industry 4.0 concept include human interaction and occupational safety logistics in addition to technology. Digitalization creates new options for the organization of work areas and thus new opportunities for work safety logistics. Modern digitalization has an extremely positive impact on occupational safety and productivity. Intelligent work safety management requires the use of new Industry 4.0 technologies and solutions developed for the work environment area. The purpose of this paper is to present a systematic literature review covering the area of intelligent Industry 4.0 technologies in occupational safety logistics, including an indication of the importance of safety in the work environment, in the context of the continuous digital transformation of enterprises.

Key words: management, intelligent systems, logistics, work safety, Industry 4.0, digitalization, new technologies

Synopsis. Logistyka bezpieczeństwa w dobie cyfryzacji zakładów przemysłowych jest złożona, ponieważ ucieleśnia technologie Przemysłu 4.0 poprzez integrację ludzi i maszyn oraz poszczególnych procesów. Nowe technologie pozwalają im zarządzać maszynami i urządzeniami na podstawie komunikacji i wzajemnym przepływie danych. Tworzy to sieć powiązań między produktami, łańcuchami wartości i modelami biznesowymi. Działania związane z wdrożeniem koncepcji Przemysłu 4.0 obejmują interakcję międzyludzką i logistykę bezpieczeństwa pracy oprócz technologii. Cyfryzacja stwarza nowe możliwości organizacji obszarów pracy, a tym samym nowe możliwości logistyki bezpieczeństwa pracy. Nowoczesna cyfryzacja ma niezwykle pozytywny wpływ na bezpieczeństwo i wydajność pracy. Inteligentne zarządzanie bezpieczeństwem pracy wymaga zastosowania nowych technologii i rozwiązań Przemysłu 4.0 opracowanych dla obszaru środowiska pracy. Celem artykułu jest przedstawienie systematycznego przeglądu literatury obejmującego obszar inteligentnych technologii Przemysłu 4.0 w logistyce bezpieczeństwa pracy, w tym wskazanie znaczenia bezpieczeństwa w środowisku pracy, w kontekście ciągłej transformacji cyfrowej przedsiębiorstw.

Slowa kluczowe: zarządzanie, inteligentne systemy, logistyka, bezpieczeństwo pracy, Przemysł 4.0, cyfryzacja, nowe technologie

JEL codes: J01, J28, J81, L16, L26

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Introduction

Nowadays, you can see an increase in the number of solutions and smart devices that are managed using the Internet. What is important is that not only the item and the computer are connected, but also there is integration in the area of access to the network. Such solutions are used more and more often in everyday life. They can be seen in smart homes and cars, which are slowly becoming something normal and common. They are also appearing in other areas, for example in the economy – automation and digitalization is being introduced on an increasing scale. The concept of Industry 4.0 is put into practice by integrating people, machines and individual processes. Thanks to it, intelligent production systems can flourish in industrial plants, having not only their own autonomy, but also capable of self-configuration, self-control, and even self-repair. In this way, the company can improve production efficiency and save money by quickly eliminating defects and preventing production stoppages. The company will not have to spend a lot of money on repairs and will not have to think about how to compensate for the losses incurred by the interruption of production [Staleo 2018].

Robots, data storage technology, affordable high-performance computing and increased computing power have become widely available in recent years. The expansion of broadband coverage is particularly conducive to the use of new technologies [CIOP-PIB]. New technologies mean not only faster and more efficient work, greater effectiveness or easier estimation of productivity and better profitability, but also saving money and protecting the environment by reducing CO_2 emissions [Zadania dla rolnictwa…].

It is important to note that there are many high-risk work areas in industrial practice. Intelligent systems and a digital network that connects people, workplaces, and safety, logistics, and security logistics solutions can use real-time information, real data to protect workers from risk and improve emergency response [Inteligentne BHP…].

The purpose of this paper is to present a systematic literature review covering the area of intelligent Industry 4.0 technologies in occupational safety logistics, including an indication of the importance of safety in the work environment, in the context of the continuous digital transformation of enterprises.

Materials and methods

Based on the a systematic literature review covering the area of Industry 4.0 the subject of this paper is to present the intelligent technologies of Industry 4.0 in occupational safety logistics, including the indication of the importance of the importance of safety in the work environment, in the context of the continuous digital transformation of enterprises. Based on a systematic literature review covering the area of Industry 4.0, the topic of this article is to present the intelligent technologies of Industry 4.0 in occupational safety logistics, including an indication of the importance of the importance of safety in the work environment, in the context of the continuous digital transformation of enterprises. Based on the literature on digitalization, Industry 4.0 and digitalization, a literature analysis and evaluation of the information and results of the scientific research conducted by many authors was carried out, which concluded that digitalization creates new opportunities for the organization of execution areas in the work environment, and thus new opportunities for work safety logistics. Modern digitalization has an extremely positive impact on safety and productivity at work. Intelligent work safety management requires the use of new Industry 4.0 technologies and solutions developed for the work environment area. The importance of the value chain in the era of digitization was also highlighted. The analysis covered the areas of Industrial Internet of Things in industrial practice, Industry 4.0 smart technologies and occupational safety, and Smart Work Environment in Industry 4.0. This paper presents a literature review and the impact of digital innovations available in the market. The aim of the presented paper is to enhance knowledge, as well as to contribute to a deeper understanding of the relevance and importance of the importance of safety logistics in the work environment, in the context of the continuous digital transformation of enterprises.

Industrial Internet of Things in industrial practice

In recent years, the fourth industrial revolution accelerated by the industrial Internet of Things (IIoT) has raised a global upsurge [Da Xu et al. 2014]. The safety logistics infrastructure of modern industrial plants is complex and highly sensitive. Legal requirements and standardized processes form the basis of modern safety concepts. At the same time, the digitization of data offers new opportunities to optimize processes and procedures, to better assess risk situations with more information, and – through data aggregation and analysis - to obtain conclusions that could not even be imagined before [Inteligentne BHP…].

In today's constantly digitally transforming manufacturing world, smart manufacturing and technologies based on the IIoT have created new opportunities for manufacturing companies to improve their business efficiency and enhance their operational process capabilities. IIoT technology in industrial practice enables machines to communicate with each other Machine to Machine (M2M) and collect and share large amounts of data. Manufacturers need to capture this data, process it into actionable information, and then, based on that information, locate the root causes of situations that occur (e.g., impending or occurring failures). Manufacturers can then use this data, collected and processed in real-time, to optimize their processes and reduce costs [Clemons 2021].

Digital transformation is a multi-threaded process. Carried out holistically and skillfully, it should be based on wide use of IT technologies in handling all, or at least most, of the processes carried out in the course of daily functioning of a company, such as production, sales, customer service, finances or distribution [Arburg].

Industry is currently investing heavily in the potential of modern, personalized safety technologies offered by the Industrial Internet of Things. It may soon be possible to use artificial intelligence to analyze collected data to predict accidents. One can also imagine the use of continuous monitoring systems that recognize serious health problems in employees [Inteligentne BHP…].

The IIoT enables specific data processing tasks. It is also important to note that by successfully implementing IIoT in enterprises, the connectivity gap between legacy systems and industrial IoT or cloud platforms can be bridged. IIoT devices can either provide low-latency processing when connected to older heavy equipment or send data captured from these systems to the cloud, ideally both. The IIoT is a very attractive group of technologies for changing the organization of manufacturing. Transformation, however, requires classification and ordering of processes within the plant. Thanks to these procedures we can be sure that the company will be properly organized. It will also be equipped with the infrastructure that allows it to build its way to Industry 4.0, and thus its market advantage [IIoT w przemyśle…].

The IIoT supports manufacturing with a network of sensors, advanced analytics and intelligent decision-making. The IIoT technology allows process manufacturing to collect data from equipment, sensors and devices and combine it with data and intelligence from back-end systems. The manufacturing process often depends on hundreds of variables that must be taken into account to produce a perfect, repeatable batch. The IoT sensors provide detailed visibility to optimize and adjust processes in real time. This allows process engineers to fine-tune control practices to increase repeatability. The IoT solution can also optimize overall equipment efficiency, compare and calculate production costs of equipment, systems, and production lines, monitor energy profiles of machines and systems, and trigger automatic alerts on operational parameters that will initiate system defense actions [Przemysłowy internet…].

Implementing the Internet of Things in an enterprise provides the ability to respond quickly to emergencies and operate within entirely new global markets. This is especially beneficial for companies with advanced technology and know-how, while lacking an extensive international distribution and service network. In view of the many benefits of using the IoT, it is important to remember about the necessary investments in cyber security (to protect your data, exposed to potential hacker attacks) and in staff development (to effectively implement and maintain modern installations). In summary, investments in the Internet of Things are investments in the development of the enterprise, in line with the increasingly popular trend of the Fourth Industrial Revolution. They undoubtedly contribute to increasing the flexibility and potential of the plant, allowing also to strengthen the position and increase the competitiveness and efficiency of the entire company. Therefore, it is worth investing in development of your valuable resources: time, money and people [Iwański, 2021].

To sum up, today, in the era of the fourth industrial revolution, it is enough to connect key machines to the cloud. On the basis of signals from controllers, sensors we are able to analyze data from the actual production process. With real data, we can focus on the biggest problems of production lines, which translates into increased productivity and more efficient use of employees' and machinery's time. You can't fully control a process without the right information about its progress [Zabój 2021].

Industry 4.0 smart technologies and occupational safety logistics

The enormous development and progress of new technologies in the field of IT (Information Technology) effectively support the functioning of enterprises in many areas. The application of innovative solutions of Industry 4.0 technology brings many benefits to enterprises, because after their application, companies operate more efficiently and faster, which translates into effective execution of orders, customer satisfaction and, as a result, higher revenues. Digitisation and automation of processes occurring in enterprises change the way they function at all levels and in many areas, and enterprises introducing these innovations have a great opportunity to gain a significant competitive advantage on the market [Rut and Ostafil 2020].

Today's businesses are facing the fourth industrial revolution, which offers a lot while demanding a lot. It is a challenging time for manufacturing companies. They need to integrate where disparate systems and technologies previously operated. There is a lot of excitement about integrating technologies into a unified cyber-physical system. Companies that were accustomed to a degree of independence from digitization are now raising concerns about keeping production and organizational management running smoothly in the event of a disaster. For many, having the hardware, software, and modern data visualization systems integrated into a single panel is both a challenge and a threat. On the other hand, the Industry 4.0 era offers enormous opportunities. Companies that are able to exploit them gain an advantage in the market. New technologies allow them to manage machines and equipment based on communication and mutual data flow. This creates a network of connections between products, value chains and business models. It involves constant exchange of information, which results in increased efficiency of production plants and simultaneous reduction of production costs. Industry 4.0 contributes to the emergence of Smart Factory, or intelligent factory. This type of factory is based on cyber-physical systems, their integration using the IIoT and new methods of production organization. One of the basic success factors of a smart factory is communication between all elements of the system (Figure 1) [Przemysł 4.0…].

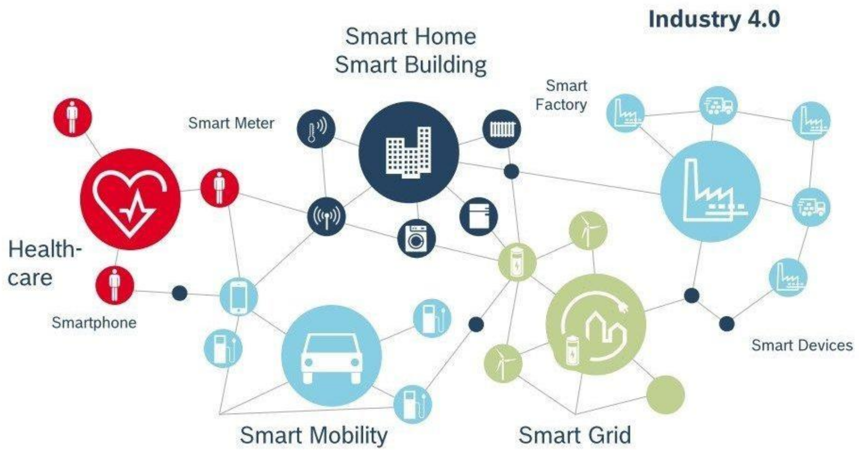

Figure 1. Industry 4.0
Rysunek 1. Przemysł 4.0
Source: [Piątek 2017].

Industry 4.0 is a complicated technical pattern characterized primarily by connection, integration, and industrial digitalization, highlighting the possibilities for integrating all components in a value-adding system. Digital manufacturing technology, network communication technology, computer technology, and automation technology are all included in this approach. Industry 4.0 technology breakthroughs are blurring the lines between the digital and physical worlds by merging human and machine agents, materials, products, production systems, and processes [Santos et al. 2018].

At the core of the fourth industrial revolution are nine technological pillars. These innovations blur the line between the physical and digital worlds, paving the way for intelligent and autonomous systems. Some of these technologies are already being used by companies and supply chains, but the full potential offered by the fourth industrial revolution is only seen when they are applied together. Industry 4.0 technologies include Big Data and AI-based analytics, horizontal and vertical integration, Cloud computing, Augmented Reality (AR), Industrial Internet of Things, Space/3D printing, Autonomous robots, Simulation/digital twin, Cyber security. As a result of this transformation, sensors, machines, machined objects, and IT systems will be connected in a value chain [Kaliczyńska 2018]. The value chain represents the process of "adding" value to a product, beginning with the activities associated with a company's purchase of raw materials, supplies, semi-finished products, etc., needed for the production process. The value chain then includes design, production, logistics activities, marketing, and ends with the provision of value-added services to customers. Thus, it becomes necessary to distinguish strategically important "carriers" of added value creation within the enterprise. The value chain refers to the concept of an economic path to follow a product from its raw material source through all economic links to the end user. Each company is a link in a broader value chain, but also creates an internal chain consisting of various processes, activities and resources to be managed. Using the value chain model, an enterprise can be simplified to represent a sequence of activities, successive transformations of raw materials, materials, purchased technologies, services into final products, called core functions. These functions cannot be performed well without the existence of management and consulting activities called support functions. The integrated operation of the core and support functions and their linkage to the value chains of suppliers and buyers enables profit and business growth [Rojek 2014]. Value chain through the sequence of activities (primary and secondary) in it participates in the generation of profit. But not every action has a significant impact on the competitive advantage and efficiency of the company's operation. Selection of activities that will be implemented in the enterprise and identification of those subject to improvement is therefore of fundamental importance for the enterprise [Walas-Trębacz 2013]. Thanks to digitalization, automation and robotization of industrial processes associated with the use of the latest Industry 4.0 technologies, it is much easier to create a company that is adapted to the realities of the modern world and at the same time quickly respond to the need for changes, e.g. in technological processes, in the implementation of work safety logistics, in the functioning of the company, management and quality of services [IMI Polska].

Activities related to the implementation of the Industry 4.0 concept include, in addition to technologies, also interactions with people and work safety logistics (Figure 2). It is an unquestionable fact that the Industry 4.0 is mostly related to automation. However, it is essential that there is a clear acceptance that humans in the production process will never be redundant. In fact, one of the main beliefs about Industry 4.0 is that people are key players in it. Connectivity between people and machines, along with the integration of information technology (IT), is fundamental to the success of the Industry 4.0 concept. In a traditional manufacturing environment, where lines or cells are often tailored to produce a single product, the safety of people working in the plant is generally simple to monitor. A risk assessment of all aspects of the operations performed, from individual components to the operator's "points of contact" with the equipment, will create a guide that, in theory, should remain valid until the use of the production line changes or changes are made to the equipment on the line. As long as proper procedures are implemented, hazards and risks to operator logistics safety can be avoided [Minturn 2021].

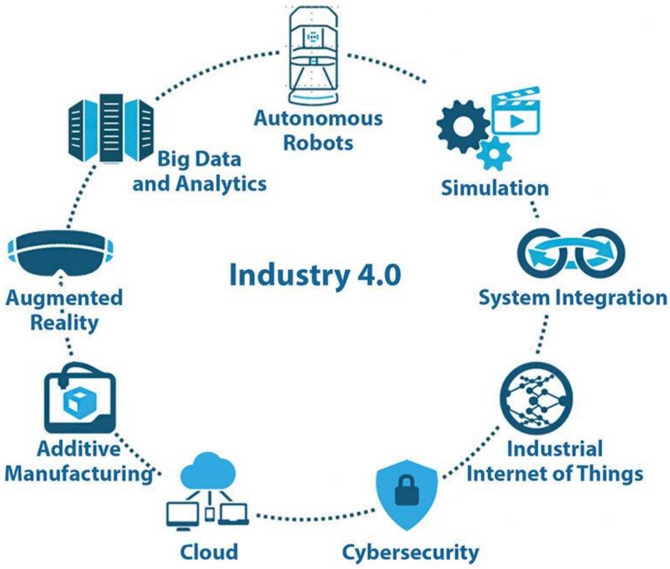

Figure 2. Industry 4.0 Key Technologies
Rysunek 2. Kluczowe technologie Przemysłu 4.0
Source: [Kaliczyńska 2018].

Digitalization creates new options for the organization of work performance areas and thus new opportunities for work safety logistics. Modern digitalization has an extremely positive impact on safety and productivity. Connected intelligent safety technologies speed up processes, facilitate decision-making and improve the safety level of employees and plants [Dräger]. The autonomization of processes, whether manufacturing, logistics or processing, is taking industry to the next level. Ensuring the safety and health of workers in 4.0 factories and warehouses is a relatively new and interesting challenge. Especially since we are talking about safety not only in one, but in two aspects. On the one hand, safety is of course understood as occupational health and safety, i.e. issues related to protecting health and life and ensuring employee comfort. Here, first on the list of things a company should take care of in terms of ensuring the physical safety of its employees is, of course, the verification of their skills. In the context of modern equipment working autonomously, the type of worker responsible for the actual production of the product with their own hands is de facto eliminated. What is more, this type of processes does not involve workers who take part in, for example, the transfer of products from one nest to another. Instead, we are dealing here with a large group of supervisors, i.e. people who verify whether the entire machine system works properly, is well calibrated, and does not require repair or maintenance. It is therefore a kind of hybrid of the tasks of the maintenance department, engineering and production or logistics, depending on the profile of the company. The first step towards ensuring their safety is therefore a properly designed verification of their knowledge and skills during the recruitment process. Paradoxically, this particular process is very difficult to autonomize. Each person is different, has a different professional background and different goals. Hence, recruitment is an extremely difficult task, based on a thorough understanding of each candidate. The challenges faced by the candidate should match or even exceed those they will face on a daily basis [Hyla 2020].

Intelligent Work Environment in Industry 4.0

Another technological leap is taking place in the world's industry, exploiting the potential of Internet-connected machines and equipment. Giving this idea the name Industry 4.0, many countries are talking about the so-called fourth industrial revolution. A new approach to intelligent occupational safety management requires the use of new Industry 4.0 technologies and solutions developed for the work environment area. Changes in the markets, both local and global, caused by short product life cycles, new technologies, innovations and the increase of individualized customer requirements in terms of product functions, increase the level of competitiveness of companies. This state of affairs forces manufacturers to seek advanced technologies and solutions – guaranteeing shorter production times and unconventional possibilities of reducing costs, while improving the quality of products. Changes in the markets, both local and global, caused by short product life cycles, new technologies, innovations and the increase of individualized customer requirements in terms of product functions, increase the level of competitiveness of companies. This state of affairs forces manufacturers to seek advanced technologies and solutions - guaranteeing shorter production times and unconventional possibilities of reducing costs, while improving the quality of products [Gralewicz 2021]. This new approach will allow the improvement of productivity and efficiency, carrying enormous potential effects, and it will support a set of economic and social opportunities among the companies that are adopting this new manufacturing paradigm [Pereira and Romero 2017]. Industry 4.0 has a huge potential impact in many areas and its application will transform the working environment. Industry 4.0 leads to potential in three dimensions of sustainability for example smart factories, M-2-M, smart robots etc. [Abdelmajied 2022].

Companies operating under Industry 4.0 principles potentially present a very different and more intricate set of challenges. Re-configuring and abruptly reconfiguring production areas, involving very rapid changes in tooling and even physical movement of equipment, can present a range of occupational safety challenges, while the very large number of configurations possible to meet potential customer requirements may entail performing a risk assessment separately for each. But when it comes to another key feature of Industry 4.0, the security of personnel and data in a secure value creation network, these considerations cannot be ignored if compliance with regulations – local, state and international – is to be maintained. Fortunately, with the help of various technologies, these issues can be countered, and it is no exaggeration to say that Industry 4.0 offers an opportunity to further enhance workplace safety and the ability to collect data in real time and then use it before potential danger becomes a reality. For example, a set of devices can be installed on equipment in a factory that can detect and report on such operator behaviors that may pose a threat to workplace safety. This equipment can take a number of forms, the most common being smart digital cameras that take pictures or video, which they then send to a central control point, which automatically signals any abnormal behavior, such as a worker entering a no-go area. Many system designers also advocate equipping machines with safety sensors that can immediately detect when an operator enters a hazardous area or gets too close to a specific machine or piece of equipment in the factory. In such cases, the default response is usually to shut down the machine, or in the case of a collaborative robot, to slow the machine down to a safe speed, giving the worker time to move away from the source of danger [Minturn 2021].

The idea of Industry 4.0 is not only based on the use of modern technologies. It is realized through knowledge, tools, optimization and monitoring of all production systems. Also important is the interaction of people with machines, therefore it is so important to provide them with appropriate working and safety conditions. With help come technological innovations that are able to protect workers from accidents and thus loss of health or life, and also increase the comfort of work. The concept of Industry 4.0 is put into practice by integrating people, machines and individual processes. Thanks to it, industrial plants can prosper from intelligent production systems that not only have their own autonomy, but are also capable of self-configuration, self-control, and even self-repair. In this way, companies can improve production efficiency and save money by quickly eliminating defects and preventing production downtime. The company will not have to spend a lot of money on repairs and will not have to think about how to compensate for the losses incurred by the interruption of production. Introduction of new technologies often goes hand in hand with a discussion about the importance and necessity of human labour. However, the currently developed concept of Industry 4.0 assumes (it is in its assumptions, by the way) that people are an indispensable link in the production process. This can, of course, cause complications and difficulties in industrial plants. Indeed, in advanced manufacturing areas, it is a challenge to ensure the safety of workers performing their duties. However, new technologies and intelligent systems are also conducive to solving this problem. Developed technologies based on Industry 4.0 basically support like never before in providing adequate safety to employees. Our machines are equipped with the right hardware and software to prevent danger, e.g. laser machines have special cabins to protect the operator from being hit during material processing and also to prevent the laser beam from escaping. Automatic loading and unloading systems, on the other hand, are equipped with intelligent light barriers and barrier nets. To avoid accidents and breakdowns it is very important to collect data in real time. Therefore, special sensors are installed in the machines to detect and analyze any disturbing and life-threatening behavior of the worker. As soon as a dangerous situation arises, the machine suspends or slows down operation until the risk is eliminated. In addition to this method, smart cameras are also used that can take pictures or videos while the operator of the machine is doing the work. The footage collected in this way is sent in real time to the control room that manages the machine and if the situation becomes dangerous, they are immediately notified of the incident. Another very commonly used solution are safety protocols. This tool, which is used in the field of Industry 4.0, was created as an extension of older wired systems. It allows the machine to be switched off and enables a greater flow of information. This ensures maximum uptime - the machine is only shut down as a last resort. IoT devices and hybrid solutions also allow for monitoring and sending security information along with employee biometrics. As a result, companies can reduce insurance costs and improve workplace safety in an efficient and intelligent way. The development and collaboration of IoT technologies is important for businesses because safety in the workplace is paramount [Staleo 2018].

Conclusion

The purpose of the study was to present a systematic literature review covering the area of intelligent Industry 4.0 technologies in occupational safety logistics, including an indication of the importance of safety in the work environment, in the context of the continuous digital transformation of enterprises.

Industry 4.0 has enormous potential effect in many areas, and its application will have an impact across the entire value chain, improving production and engineering processes, improving product and service quality, optimizing customer-organization relationships, bringing new business opportunities and economic benefits, changing educational requirements, and transforming the current work environment [Abdelmajied 2022].

Digitalization offers enormous development opportunities and offers solutions to many problems, as well as new options for the organization of work areas and thus new possibilities for work safety logistics. Digitalization has an extremely positive impact on work safety and productivity. However, the intelligent management of occupational safety in a logistical work environment requires the use of new Industry 4.0 technologies and solutions individually tailored to the needs of companies, including the work environment. It is important to remember that digital transformation is a multi-faceted topic with a major impact on safety logistics, the work performance area, and the work environment as a whole.

Availability of new technologies and ubiquitous digitalization requires from enterprises the ability to adapt and readiness for changes. The concept of Industry 4.0 is realized on the basis of knowledge, tools, optimization and monitoring of all production systems. It is based not only on technology, but also on direct interaction of people with machines, which in turn is associated with ensuring adequate safety in the plant. Modern solutions not only significantly increase the comfort of work, but, what is important, they can often protect an employee from losing their health or even life. Nowadays, there are more and more smart devices and solutions that are managed via the Internet. This is done not only by connecting the item and the computer, but also by integrating them in the area of network access. We deal with such solutions almost every day – examples are smart homes or cars. They can also be seen in other sectors, e.g. economy, where automation and digitalization are introduced on an increasingly wider scale. They fit into the idea of Industry 4.0. by integrating people, machines and individual processes. Implementation of this concept into the industrial plant allows for the prosperity of intelligent production systems, which in addition to their own autonomy will have the ability to self-configure, self-control or even self-repair. This brings many benefits to the enterprise such as increased production efficiency or significant savings due to the elimination of defects and downtime in production. With many opinions on the introduction of new technologies into manufacturing, a debatable issue is human labor. With the evolving concept of Industry 4.0, one of its main tenets is that people in the process will never be redundant [Główny Mechanik 2019].

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