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Environmental Issues in Logistics and Manufacturing

Katarzyna Grzybowska
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Rapinder Sawhney *Editors*

Sustainable Logistics and Production in Industry 4.0

New Opportunities and Challenges

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Preface

Changes are becoming faster and more unpredictable. The rapid development of more new technologies have been introduced in logistics and production. Accordingly, logistics and production have become more intelligent, more automated and more complex. Material handling, maintenance, exploitation and supply chains, become an integral part of manufacturing driven by sustainability. Industry 4.0 creates many new opportunities, but at the same time brings several challenges. Sustainable logistics and sustainable production are a systemic concern that can be examined from a variety of perspectives. Sustainable logistics and sustainable production are also highly contextual concepts.

The book provides interdisciplinary approaches to sustainable Logistics and Production in Industry 4.0. Sustainable Logistics and Production are vital for business growth, social coherence and environmental impact reduction. This publication concerns the multidisciplinary set of studies, researches and projects. The objective of this book is identify current and future research issues. Challenges and future perspectives are identified and discussed.

The objective of chapter "Literature Review on Sustainable Logistics and Sustainable Production for Industry 4.0" is to depict a landscape of the scientific literature on the concept of the Sustainable Production and Sustainable Logistics. This concept in recent years is gaining more and more attention from academics and practitioners. The authors identified a sample of 892 internationally published papers and conducted a citation analysis to examine the connections between the many scientific papers and to explore the most influential works.

In chapter "Evaluation of Key Skills Supporting Industry 4.0—A Review of Literature and Practice", review of literature targeting Industry and Education sectors is performed. Canadian manufacturing and service industries and Polish automotive and pharmacy sectors are investigated.

In chapter "The Role and Impact of Industry 4.0 on Business Models", the authors try to answer the question: what new forms will business models adopt? The aim of this chapter is to identify the challenges related to the adaptation of business models to the Industry 4.0 concept.

The purpose of the chapter "Smart Industry—The Digital Gap in the Process of the Smart Supply Chain Competitive Advantage?" is analyse the role of digital technologies ecosystems usage by the Smart Industry sector in gaining competitive advantage. The main part of the analysis concentrates on the concept of Smart Industry development.

Chapter "Sustainable Supply Chains Versus Safety and Resilience" focused on the investigation of the main concepts of supply chain resilience, vulnerability, risk and safety in the relation to the supply chain sustainability management. The conducted analysis gives the possibility to highlight the necessity of performing the multidimensional analyses performance in order to properly manage sustainable supply chain.

Chapter "Digitalization of Supply Chain Transparency: The Case of ChainReact" aims at empirical anchoring of the theoretical assumptions that the newest technological solutions, particularly those connected with the lump idea of Industry 4.0. will substantially contribute to sustainability of supply chains. The authors use the example of an advanced tool created by the Horizon 2020 project ChainReact.

While observing global trends, one could notice that more and more suppliers are monitored in terms of the principles of sustainable development. The purpose of the chapter "Sustainability as Criteria of Evaluation of Suppliers" is to present the use by international corporations of sustainability concept as criteria for initial and periodic evaluation of suppliers.

Next chapter "Sustainable Supply Chain Management in the Perspective of Sharing Economy" presents reconstruction and interpretation of the key assumptions of the sharing economy and the concept of managing the sustainable supply chain.

Many of the supply chain issues affect the sustainability performance of companies. Since supply chains are complex adaptive systems, appropriate modelling methods. The chapter "Simulation Modeling and Analysis for Sustainable Supply Chains" presents guidelines for the construction of coherent and consistent simulation models that would enable multilayered and multifaceted analysis of common supply chain management problems (e.g. eliminated unnecessary waste).

The chapter "Identification of Logistics 4.0 Maturity Levels in Polish Companies—Framework of the Model and Preliminary Research" presents the framework of Logistics 4.0 maturity model (L4MM) developed to provide companies with opportunity to assess current status with respect to Logistics 4.0 and develop a roadmap for improvement process.

The chapter "Dynamic Organisation of Traffic Flows in the Transport Network in Terms of Sustainable Mobility and the Development of Industry 4.0" presents a concept for the method of traffic flow organization in the transport network. The aim this chapter is to promote sustainable mobility. Data acquired undergo complex processing and modification according to the Industry 4.0 concept.

Next chapter "Attractiveness of the Region in Connection with Intermodal Transport Development" presents evaluate the criteria shaping the attractiveness of the near-border region from the intermodal transport development point of view.

The evaluation was based on statistic indicators, description data and estimates of experts.

The concept of sustainable development goal is to increase economic value while reducing environmental impact and improving the quality of life for humans. The next chapter "Smart Glasses in Sustainable Manual Order Picking Systems" tests the potential of smart glasses use in manual order picking systems, as an example of production system, through the perspective of sustainability.

The chapter "Solutions Dedicated to Internal Logistics 4.0" presents methodological arrangement of internal logistics in the context of Industry 4.0. In desk–research methodology was used for this contribution.

The innovative model becomes a standard in the development of contemporary businesses. The purpose of the chapter "Manager's Maturity as a Derivative of Competencies and Dynamic Capabilities—Vivisection in the Context of Industry 4.0" is attempted assessment of maturity of managers being an answer to the upcoming fourth industrial revolution.

Planning at the company's strategic level is as an opportunity to imply organizational development. The aim of the chapter "Partner Sales Networks as Determinants of Road Maps for the Development of the Telecommunications Industry in Poland" presented is the presentation of the potential development path.

The outlooks of the authors are methodical and firm based on their own experiences during their carrier. I hope this book will be extremely useful to the researchers who are working on the development of newer and sustainable strategies for logistics and production management as a source of valuable information.

Poznan, Poland — Katarzyna Grzybowska
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Contents

Literature Review on Sustainable Logistics and Sustainable Production for Industry 4.0

Katarzyna Grzybowska and Anjali Awasthi

Abstract Sustainable Production and Sustainable Logistics has been discussed extensively in the scientific literature. The objective of this chapter is to depict a landscape of scientific literature on the concept of the Sustainable Production and Sustainable Logistics. This concept in recent years is gaining more and more attention from academics and practitioners. We identified a sample of 892 internationally published papers and conducted a citation analysis to examine the connections between the many scientific papers and to explore the most influential works.

Keywords Sustainability · Eco-logistics · Eco-production · Bibliometric analysis · Eco-efficiency · Knowledge structure · Visualization of science

1 Introduction

Dynamic development of manufacturing Industry 4.0 is inevitable. In a globalized world with highly interconnected processes, companies are facing an increasing number of challenges to cope with (Hecklau et al. 2016). The approach of Industry 4.0—the "Fourth Industrial Revolution"—may be also confirmed by reviewing leading domains in publications (Gudanowska 2017; Lasi et al. 2014; Mrugalska and Wyrwicka 2017; Stock and Seliger 2016). The discovery of new technologies has escorted industry development from the early adoption of mechanical systems, to support production processes, to today's highly automated assembly lines, in order to be responsive and adaptive to current dynamic market requirements and demands (Lee et al. 2014). With these new integrated systems, it is possible for the factory of the future to be adaptive with respect to the production of individualized products in

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small batch sizes. Automation will be increasingly important. The 'Smart Factory' constitutes a key feature of Industry 4.0, i.e., the Fourth Industrial Revolution (Drath and Horch 2014). Factories become smarter, more efficient, safer and more environmentally sustainable, thanks to the combination and integration of production technologies and devices, Information and Communication systems, data and services in network infrastructures (Strozzi et al. 2017). Sustainability is playing an increasingly significant role in planning and management within organizations (Grzybowska and Kovács 2014).

A number of companies have proactively acted in favor of a more sustainable development. Among those, a group also perceived the economical potential of environmentally friendly logistic networks (Frota Neto et al. 2008). Sustainable logistics network has attracted growing attention with the stringent pressures from environmental and social requirements (Lee et al. 2010).

The following research questions were asked:

Question 1. To what extent does the idea under research concern individuals?
Question 2. Which researchers are the most influential figures in relation to the idea under research?
Question 3. Which areas of knowledge concern the idea under research?
Question 4. Which research centers are leaders in terms of the idea under research?
Question 5. What have been the international research trends over the years?
Question 6. What are the most important conceptual clusters created on the historical–graphical map of scientific publications, in the scope of the concept of Sustainable Logistics and Sustainable Production, which were cataloged in WoS in 1980–2018?

This chapter is structured as follows. In Sect. 2 materials and methods are presented, while in Sect. 3 research methodology the results. In Sect. 4, the results of the analysis. In Sect. 5, results are discussed and research directions are identified. Final remarks conclude the chapter (Sect. 6).

2 Bibliometric Analysis

Bibliometric analysis is a dynamically developing method of evaluating research results and comprehensively capturing scientific achievements. It allows you to observe the development of science on a national and international scale. This analysis uses information system tools that are used to comprehensively search for relevant scientific publications. The bibliometric analysis focuses on scientific work, which is often cited by other researchers over time and indexed in the largest databases indexing scientific work. This is due to the fact that only these publications can be considered as the basis for a given field or discipline. The reference of one researcher to the knowledge of another scientist is interpreted as a phenomenon of diffusion of knowledge.

Bibliometric analysis consists of the application and quantification of quantitative data referring to scientific publications and the use of quantitative indicators of various databases. These indicators reflect the state of science or selected areas (Marszakowa-Szajkiewicz 2009). She also adds that sometimes a large number of citations of the indicated scientific work can be a determinant of a new idea, method, or discovery. And a group of scientific publications often referred to by other researchers in a given field or scientific specialty, can be treated as a concrete carrier of its paradigm. In order to examine the structure, characteristics, as well as the models underlying science and technology, both mathematical and statistical techniques were used in the bibliometric analysis (Du et al. 2015). Bibliometric techniques are often used by scientists, public institutions, and enterprises, but relatively little known in Poland (Klincewicz et al. 2012).

Observation of scientific research in selected fields is practiced by scientists around the world and is a key tool for managing knowledge diversity. Examples include bibliometric analysis regarding the concept of supply chain sustainability (Taticchi et al. 2013); research on flexibility (Seebacher and Winkler 2013); green supply chains (Fahimnia et al. 2015); the Smart Factory concept (Strozzi et al. 2017); considerations on reverse logistics (Wang et al. 2017); City Logistics (Kaur and Awasthi 2018b); green supply chain management (Kaur and Awasthi 2018a).

3 Research Methodology

As a method of bibliometric analysis, the method of dynamic analysis of the literature network (SLNA) was introduced by Colicchia and Strozzi (2012), which combines a systematic literature review (Systematic Literature Review, SLR) and analysis and visualization of the bibliographic network. The adoption of such an approach allows the identification of trends in key issues that affect the development of knowledge in a given field in a more scientific and objective manner than descriptive reviews that are based on subjective criteria for selection of work and classification of research contributions.

In the first phase, a Systematic Literature Review (SLR) is performed, and the definition of the scope of the study is identified by means of three steps (Strozzi and Colicchia 2012):

(1) Scope of the analysis.
(2) Locating studies ‘keywords, time, type of documents, language’.
(3) Study selection and evaluation.

In this chapter, the concepts of Sustainable Logistics and Sustainable Production were studied. Sustainable logistics network research and practice have swung from the search for win–win solutions to the search for solutions smartly compromising business and the environment (Frota Neto et al. 2008). In a logistic network, a number of actors will influence business costs and corresponding environmental impact. Suppliers, manufacturers, consumers, logistics operators, as well as third parties operating in testing, refurbishing, recycling, and energy production for the end-of-life products are the main players. These players perform the majority of the activities impacting business and the environment (Frota Neto et al. 2008, 2009).

4 Bibliometric Analysis

The search for scientific publications was carried out using the Core Collection of Web of Science (WoS). This database provided by Clarivate Analytics earlier for managing the platform was answered by Thomson Reuters). It is an interdisciplinary (multidisciplinary) research platform that records the content of over 12,000 major journals and over 160,000 conferences from around the world. It allows researchers to search multiple databases simultaneously using a single interface—through the Web of Science™ Core Collection. The WoS database provides many bibliometric indicators and contains literature from most disciplines. This database includes a number of databases and tools necessary to establish bibliometric indicators, parametric evaluation, and bibliography creation. It is also the most commonly used database and citations for scientific purposes. An important advantage of the Web of Science database is its transparency and organization. The Web of Science database is one of the most coherent databases of scientific publications. Compared to the Scopus database, Web of Science has a smaller range (Zhao and Strotmann 2015). The main disadvantage of Scopus, however, is the quality of the data that is not "clean", like those from WoS. This means that some publications are not uniquely identified. Therefore, the Web of Science database was used for research purposes.

It can be observed that the knowledge base related to research on sustainable development is widely disseminated (Fig. 1). All the time we can observe a growing trend of publishing scientific papers, which indicates that research is the focus of scientists and researchers. Therefore, the current state of knowledge requires research

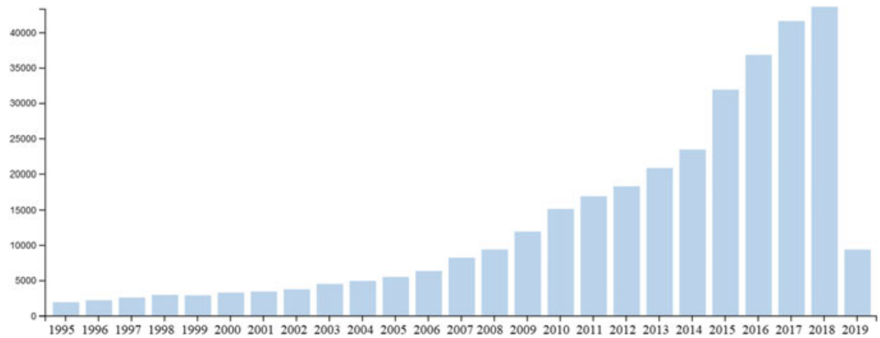

Fig. 1 Number of publications in the area of research on sustainable development from the Web of Science database. *Source* Own study based on Web of Science

Table 1 Initial search results

A set of keywords	Search results
Sustainability or Sustainable and Industry 4.0	243,802
Sustainable Production	4,126
Sustainable Logistics	112

Source Own study based on the Web of Science

to systematize and rationalize the knowledge generated on this subject. For this purpose, it would be ideal to study the process of creating, transferring, and developing knowledge from a dynamic perspective, to reveal its evolution in time.

In connection with the above, it was decided to narrow the subject of the undertaken analysis. The aim of this chapter is to present the area of scientific literature on the concept of sustainable logistics and sustainable production for Industry 4.0.

As a result of preliminary literature works, a set of keywords was selected that will be used to collect metadata obtained from selected scientific databases. As a result of this action, a set of concepts has been identified. The basic concept was identified in the collection: "Industry 4.0" AND "Sustainability" AND "Sustainable Logistics" OR "Sustainable Production". Identification of keywords is a critical stage of analysis. Its results may change if different keywords are used.

Finally, the search was conducted in January 2019 in the Web of Science database using selected keywords. Scientific publications from the years 1980–2018 were found, containing in its title, abstract, or words "Sustainable" or "Sustainability". Initial search for defined terms encompassed 328,910 literature items, without supplementary words and identification of the type and type of publication.

Then the search was narrowed down to the set of key words indicated earlier. Table 1 shows the search results.

The first publication for the concept of Sustainable Production was published in 1987 by researcher R. Repetto entitled *Economic incentives for sustainable production*. The author presents activities into sustainable patterns that preserve the productivity of natural resource assets. Incentive problems now arise both from market failures, such as externalities and common property problems, and from policy failures, such as price distortions. The author indicates opportunities are available to improve policies in ways that promote resource conservation, reduce environmental damage, and simultaneously raise economic productivity, decrease government budget deficits, and ameliorate rural poverty.

Sustainable Logistics is a new area of research. The first publication for the concept of Sustainable Logistics was published in 2004. This is a collective publication under the title *Environmental logistics for circular economy & eco-industry*. In this article on modem sustainable logistics, he presented the concept and connotation of eco-industry and circular economy. Analyzed theories and key technologies of environmental logistics in detail. Denoted that environmental logistics is the foundation of the eco-industry and circular economy (Zhang et al. 2004).

The most frequently cited publication is *Designing and evaluating sustainable logistics networks* by N. Frota, J. Quariguasi, J.M. Bloemhof-Ruwaard, A.E.E. van

Table 2 Scientific publications in the years 1980–2018

Scientific publications in the years 1980–2018
Number of records = 892
The number of researchers = 2 846
Number of source titles = 626
Number of countries = 91
Number of scientific centers = 1,205

Source Own study based on the Web of Science

Nunen, and E. van Heck. The article applies redesign logistic networks in order to mitigate negative environmental impacts. The objective in the design of logistics networks has changed, therefore, from cost minimization only, to cost and environmental impact minimization. In this paper, the authors reviewed the main activities affecting environmental performance and cost-efficiency in logistic networks (Frota Neto et al. 2008).

The scope of the search for scientific publications was reduced to four terms: “Sustainability” OR “Sustainable” AND “Sustainable Logistics” OR “Sustainable Production”. In total, 892 scientific publications were published in the years 1991–2018.

As a result of the conducted activities, basic statistics regarding the created bibliometric database were presented (Table 2). A total of 892 scientific publications, compiled by 2,846 scientists, were collected for analysis. They were published jointly in 626 source titles—scientific magazines, conference materials, and monograph chapters. The authors of the scientific publications identified and analyzed come from 91 countries and represent a total of 1215 units and research centers from around the world.

After the analysis of the 892 papers, we were able to identify 626 scientific journals (70%) and 205 conference volumes (23%) and 61 chapters from monograph books (7%). All recorded citations refer to these sources. The journal with the largest number of published articles was the *Journal Of Cleaner Production* with 85 record count, comprising 9.417% of all publications. The Journal of Cleaner Production is an international, transdisciplinary journal focusing on Cleaner Production, Environmental, and Sustainability research and practice. *Sustainability* has been identified as the second most important scientific journal. Sustainability is an international, cross-disciplinary, scholarly, peer-reviewed, and open-access journal of environmental, cultural, economic, and social sustainability of human beings. It was cited 35 record count or 3.924% of all publications (Table 3). It is evident that many articles were published in only a small number of journals.

We analyzed a sample of 892 academic papers to identify articles with high impact on the scientific research on “Sustainable Logistics” OR “Sustainable Production”. The most important papers were cited more than two hundred times, all of them dealing with research with the beginning up to the state-of-the-art of scientific research. Table 4 presents an overview of the most influential scientific papers, starting with high citation frequencies and ending with papers of low scientific impact.

Table 3 Top 10 most important scientific journals with the largest number of articles "Sustainable Logistics" OR "Sustainable Production"

Source titles	Record count	% of 892 (%)
Journal of Cleaner Production	85	9.417
Sustainability	35	3.924
Acta Horticulturae	22	2.466
Journal of Manufacturing Technology Management	16	1.794
Procedia CIRP	10	1.121
Renewable Sustainable Energy Reviews	10	1.121
International Journal of Production Economics	9	0.991
Agronomy for Sustainable Development	8	0.897
Aquaculture	7	0.897
Ecological Indicators	7	0.897

Source Own study based on the Web of Science

Table 4 Most influential scientific papers

Publications	Years	Total citations
Expanding the utilization of sustainable plant products in aquafeeds: a review By: Gatlin D.M.; Barrows F.T.; Brown P.; et al.	2007	804
The biorefinery concept: Using biomass instead of oil for producing energy and chemicals By: Cherubini F.	2010	604
A literature and practice review to develop sustainable business model archetypes By: Bocken N.M. P.; Short S.W.; Rana P.; et al.	2014	471
Biotechnology—a sustainable alternative for chemical industry By: Gavrilescu M.; Chisti Y.	2005	307
Constraints to commercialization of algal fuels By: Chisti Y.	2013	274
The spread of Conservation Agriculture: justification, sustainability and uptake By: Kassam A.; Friedrich T.; Shaxson F.; et al.	2009	262
Nitrogen removal techniques in aquaculture for a sustainable production By: Crab R.; Avnimelech Y.; Defoirdt T. et al.	2007	256
Transitioning to sustainable production—Part I: application on machining technologies By: Pusavec F.; Krajnik P.; Kopac J.	2010	216
Towards sustainable production of biofuels from microalgae By: Patil V.; Khanh-Quang T.; Giselrod H.R.	2008	207

Source Own study based on Web of Science

On the basis of the Web of Science database, the ranking of researchers can also be distinguished, according to the number of scientific papers published by them indexed by the database. Taking into account the authors and co-authors as well as the number of their scientific publications, it should be emphasized that research into supply chains, for the keywords “Sustainable Logistics” OR “Sustainable Production” was/is dealt with by 2,846 scientists from around the world.

Due to the number of publications among researchers, attention is drawn primarily to three whose scientific achievements include more than 5 scientific publications from the studied area (Table 5). They constitute 0.05% of the researched population of scientists. On the other hand, 2,646 scientists, which account for 93% of the surveyed population, have in their output 1 scientific publication from the studied area.

The results presented in Table 5 confirm the law of scientific productivity, commonly referred to as Lotka’s Law. It says that a small number of researchers publish a large number of scientific papers, while most scholars can boast of a small number of publications (Fig. 2).

Table 6 presents seven leading people of science, who most often published scientific papers in the studied area. This group of researchers has published a total of 32 scientific papers. Among the published works were three, which were elaborated independently—A. Azapagic (1) and L. Hunt (2). Other scientific papers were developed as co-authored works, in which three co-authors participated on average.

For the studied population of 892 identified scientific publications, statistics show that the analyzed collection of scientific works is dominated by researchers from the United States. It is a leadership that contributes significantly to the development of the studied area. They have published a total of 128 scientific papers (Table 7). This gives an indicator equal to 14.350%. In the second place, there is Germany with the number of published works equal to 94 items.

The Web of Science database provides detailed insight into the types of knowledge areas of selected scientific papers (Table 8). For the concept of Sustainable Logistics and Sustainable Production, a total of 78 areas of knowledge were detailed, which were then grouped. This shows that the subject is characterized by a multidisciplinary specificity, which is related to the complementarity of issues and concepts from different areas of science.

Table 5 Number of published scientific papers

Number of authors	Number of published scientific papers
1	6
2	5
4	4
37	3
156	2
2,646	1

Source Own study based on Web of Science

This approach allows you to get a comprehensive approach to research. The analyzed area is also characterized by a wide range of studies; derives knowledge about the methodology of research, methods, and tools from many sciences. The studied area cannot be clearly subordinated to any of the sciences according to the classification of sciences. In the database, no scientific publication and scientific journal about the "one-character" nature was found.

It should be noted that the total number of scientific papers corresponding to particular areas of knowledge does not add up to the identified population of 892 scientific publications. It results from the possibility of qualifying the publication simultaneously to several different fields and subfields of knowledge.

The developed statistics show that in the analyzed set of sophisticated scientific works, four leading scientific institutions dominate. These are institutions whose

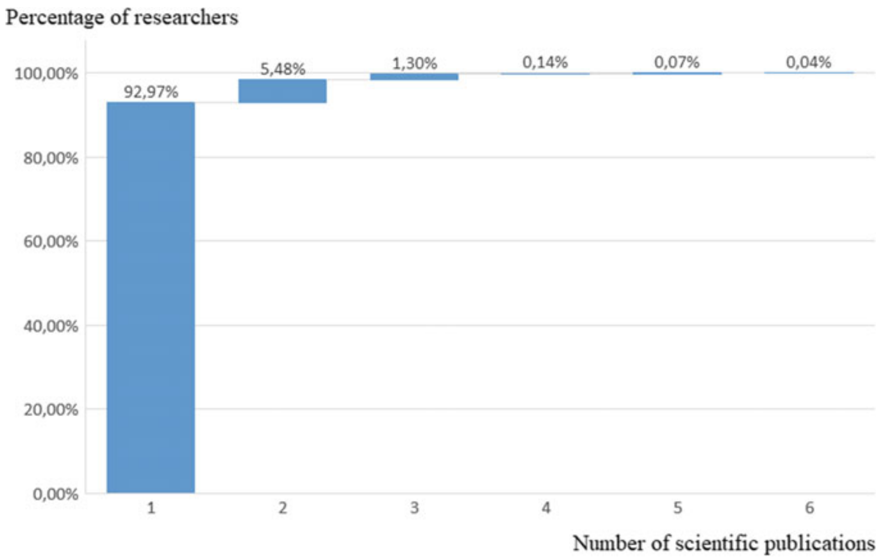

Fig. 2 Scientific productivity of researchers. *Source* Own study

Table 6 Most influential researchers

Authors	Record count	% of 892 (%)
Pusavec F.	6	0.673
Kopac J.	5	0.561
Sala S.	5	0.561
Azapagic A.	4	0.448
De Boer I.J.M.	4	0.448
Forslund H.	4	0.448
Hunt L.	4	0.448

Source Own study based on Web of Science

Table 7 Scientific contribution divided into countries and geographic regions

Countries/Regions	Record count	% of 892 (%)
USA	128	14.350
Germany	94	10.538
Italy	76	8.520
Netherlands	72	8.072
England	71	7.960
Peoples Republic of China	48	5.381
Brazil	47	5.269
India	43	4.821
Spain	43	4.821
Australia	41	4.596

Source Own study based on the Web of Science

Table 8 The most popular areas of knowledge for identified scientific papers

Research areas	Record count	% of 892 (%)
Engineering	262	29.372
Environmental Sciences Ecology	250	28.027
Science Technology Other Topics	208	23.318
Agriculture	187	20.964
Business Economics	95	10.650
Energy Fuels	65	7.287
Operations Research Management Science	53	5.942
Computer Science	43	4.821

Source Own study based on the Web of Science

scientists published 8 and more scientific papers indexed in the Web of Science base and were affiliated in a given scientific unit (Table 9). It was found that scientists

Table 9 The most popular organizations for identified scientific papers

Organizations	Record count	% of 892 (%)
Wageningen University & Research Centre, Netherlands	23	2.576
Ghent University, Belgium	13	1.456
Cornell University, USA	8	0.896
Utrecht University, Netherlands	8	0.896

Source Own study based on Web of Science

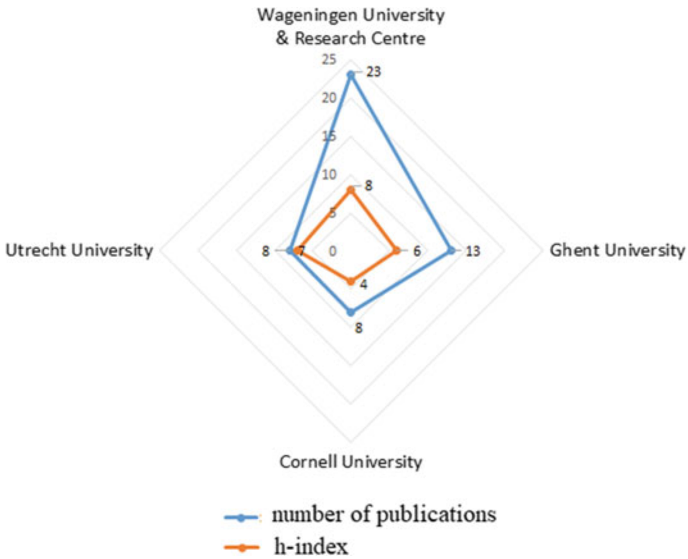

Fig. 3 Comparison of selected scientific centers. *Source* Own study

from these distinguished scientific centers published a total of 52 scientific papers, which is 5.83% of all published papers from the studied area.

A detailed analysis showed that among the four dominating research centers, two are located in the Netherlands. Two hundred academic papers affiliated with Wageningen University & Research Center obtained h-index at level 8 (Fig. 3). Thirteen scientific papers affiliated with Ghent University obtained h-index at level 6. Eight scientific papers affiliated with Cornell University obtained h-index at level 4. The Utrecht University is noteworthy. Eight scientific papers affiliated with this university received an h-index at level 7. It is a center aspiring to the leading.

The review of the dynamics of the number of published scientific papers from the studied area in the years 1980–2018 allowed to identify three periods:

1. Activation period (1980–2006), in which 88 scientific publications were published
2. Growth period (2007–2015), this period includes 425 scientific publications
3. Expansion period (2016–2018), this period covers 379 scientific papers.

5 Semantic Maps

The visualization of knowledge includes, among others, such issues as visualization of the results of scientific research. It allows you to create excess value and extract new knowledge from datasets. It also supports the process of creating new sources of information (Motylińska 2014). The visualization is to provide a more effective understanding of the data as well as the discovery of new facts and dependencies that have been hidden so far. Taking into account the explosion of literature in recent years, using digital tools to analyze disciplinary formation is not just a novel tool, but a key tool (Flis and van Eck 2017, p. 7).

The use of analyses results in the creation of maps and science atlases. The use of mapping and visualization opens up new research perspectives in the inter- and transdisciplinary fields (Osińska 2012, p. 209). Thus, the analysis allows you to explore the structure of science, or the field or discipline, and show its future trends.

The most commonly used unit for mapping or visualization of knowledge documents, understood as scientific works, patents, etc. Maps that visualize knowledge are developed for various purposes. Examples include: mapping the evolution of entrepreneurship as a field of research in 1990–2013 (Chandra 2018), analysis of trends in the circular economy (Homrich et al. 2018), analysis of security culture research (van Nunen et al. 2018).

As a result of the conducted works, semantic maps are created and subject to analysis. They are based on keywords (Börner et al. 2005). Semantic maps are generated from various text sources, based on individual words extracted from scientific papers, descriptive terms or descriptors assigned by the publisher provided by the database provider (e.g., ISI keywords) (Börner et al. 2005). These maps are used to understand the cognitive structure of the field (Salvador and López-Martínez 2000).

The so-called clusters are configured on the created knowledge maps. Clusters are created using Cluster Analysis (CA). The result of cluster analysis is the division of a finite set of objects into clusters (subsets). During the grouping, a set of clusters is created (Jain and Dubes 1988).

As a result of cluster analysis, it is possible for

(1) identification of clusters by separating a group of similar objects that intensively coexist and attempt to generalize their features
(2) designation of objects with isolated values that do not match other objects
(3) the discovery of the unexplored and unknown structure of the analyzed data.

VOSviewer version 1.6.9 was used for the job, which was released on August 29, 2018. The main advantage of VOSviewer, which decided about choosing this, and not another IT tool, is the continuous process of updating the software functions and a relatively easy way of using it. A special positive feature is that the program focuses entirely on the visualization of bibliometric networks, and thus meets the expectations of software.

The big advantage of VOSviewer is also the ability to map and create so-called clusters using cluster analysis. To this end, the VOSviewer software uses the intelligent local algorithm developed by Waltman et al. (2013). On the basis of the previous bibliometric analysis and the obtained local database, a division into four periods regarding the development of the concept was carried out:

1. activation period (1980–2006),
2. growth period (2007–2015), and

Fig. 4 Keywords for activation period. *Source* Own study

3. expansion period (2016–2018).

These periods were covered by the analysis and visualization discussed later.

5.1 Activation Period

For the analysis based on the keywords, the first period was chosen, the so-called activation period. It belonged to 1980–2006. In this period, 88 scientific papers from the studied area were published.

During this period, a total of 477 keywords were identified. Due to the fact that the selection period concerns only 88 scientific publications for the purposes of building a semantic map, the threshold for the minimal occurrence of keywords was set, which is 3. Of the 477 keywords that relate to the identified work, 3 meet the set requirements. These are: sustainability, economics, and management.

For the period under consideration, two clusters are specified, which is a scientific, thematically coherent area. The first cluster contains two keywords: sustainability and management. The second cluster contains one keyword: economics. Within clusters, keywords are internally highly homogenous (Fig. 4).

The evolution of the studied approach began with keyword management, while at the end of the analyzed period there is an expansion to the keywords: sustainability and economics.

5.2 Growth Period

In the specified second period, called the growth period falling in the years 2007–2015, 2,653 concepts have already been identified, of which 67 of them meet the threshold of minimal occurrence of keywords, which was set at level 6.

In the analyzed period, 5 conceptual clusters (Fig. 5) were identified, related to keywords. On the semantic map, the coexistence of keywords is clearly visible. The Sustainability concepts are no longer relevant to the Management keyword, even though they are in the same cluster. In contrast, Sustainability is relatively strongly related to the concept of Sustainable Production, which is located in cluster 2. There is also a relatively strong link to the concept of Sustainable Logistics.

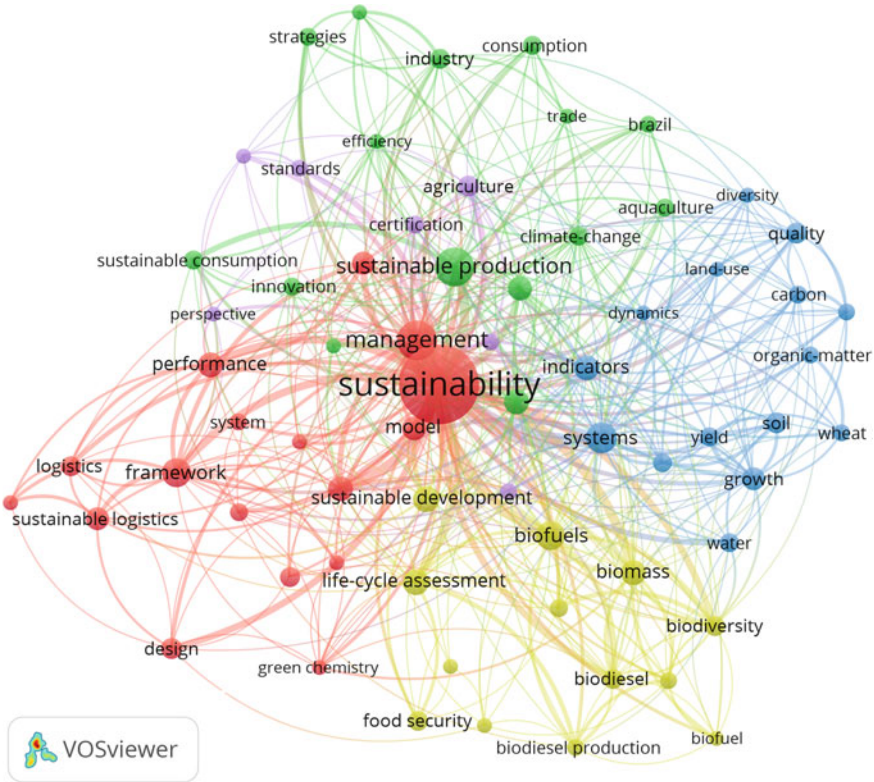

Fig. 5 Keywords for growth period. *Source* Own study

All identified clusters are internally highly uniform and externally highly multi-directional. In Table 10, the first two clusters with grouped keywords are presented.

It should be confirmed that the scientific structure of the studied area is radically changing. It results from the development of concepts and identified problems. In the analyzed period, one can observe a growing interest in the concepts and problems: Sustainable Production and Sustainable Consumption; Sustainable Logistics and Management; Sustainability and Environment; Environmental Management, and others.

5.3 Expansion Period

In the third analyzed period, called the Expansion period falling in the years 2016–2018, 2,533 keywords were identified, of which 72 met the minimum keyword occurrence threshold, which was set at level 6. The analyzed period contains, on average,

Table 10 Two important clusters for growth period

Cluster 1 (17 items)	Cluster 2 (15 items)
Design	Aquaculture
Environment	Brazil
Framework	Cleaner production
Green chemistry	Climate change
Impact	Consumption
Life cycle assessment	Efficiency
Logistics	Energy
Management	Food
Methodology	Industry
Model	Innovation
Optimization	Policy
Performance	Strategies
Supply chain management	Sustainable consumption
Sustainability	Sustainable production
Sustainable logistics	Trade
System	
Technology	

Source Own study

the largest number of scientific publications on average. It should be noted that in the analyzed 2-year period, the number of keywords increased radically.

Based on these identified terms, six conceptual clusters based on identified keywords were specified for the period under consideration. Further changes can be observed (Fig. 6).

The Sustainable Production keyword is given in cluster 2. In the third analyzed period, the concept of Sustainability was assigned to cluster 3, which is less important. The concepts of Management and Sustainable Logistics have been transferred to the 5 clusters. Sustainable Logistics is increasingly being replaced by another Sustainable Supply Chain. Sustainable Supply Chain is the management of raw materials and services from suppliers to manufacturer/service providers to customers and back with the improvement of the social and environmental impacts explicitly considered (Grzybowska 2012). This shows the continuous evolution of the research structure.

6 Conclusion

As a result of the research, international research trends for the period 1980–2018 were identified. They were carried out on the basis of identified scientific publications included in the international Web of Science indexing database. On the basis of

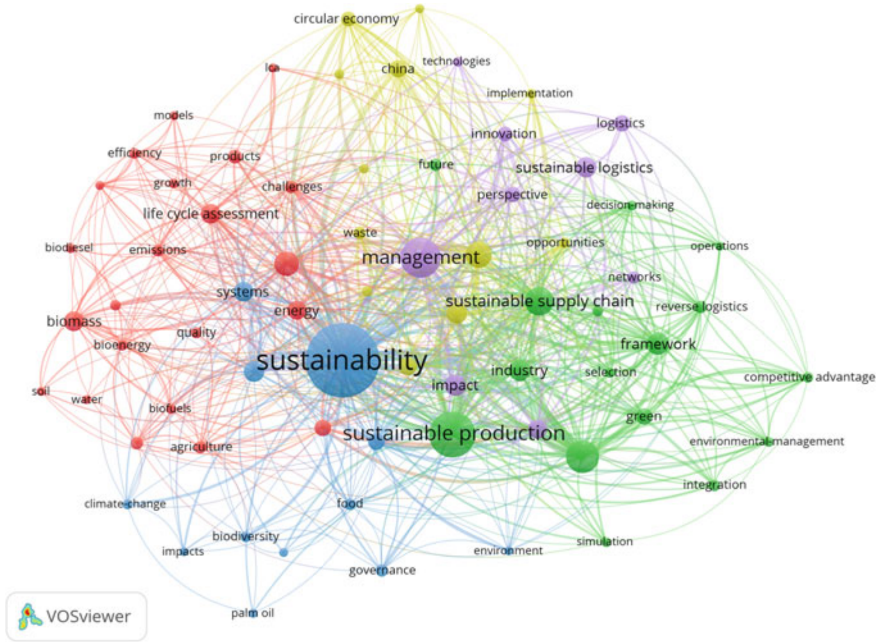

Fig. 6 Keywords for expansion period. *Source* Own study

created semantic maps, one can observe the nonlinear development of concepts and abrupt changes in thinking and conducting scientific research.

The aim of the visualization of knowledge regarding the concept of Sustainable Production and Sustainable Logistics is to answer the following research questions: (1) What are the international research trends over the years? (2) what are the most important conceptual clusters created on the historiographic map of scientific publications in 1980–2018?

The main criticism of the study may be the fact that bibliometric analysis, the effects of scientific productivity and citations cannot completely communicate about the actual contribution of scientific work to the area under study. The choice of a research database, which, despite being a large interdisciplinary and international platform, covers only a fraction of the scientific publications available in the world.

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Evaluation of Key Skills Supporting Industry 4.0—A Review of Literature and Practice

Rupinder Kaur, Anjali Awasthi and Katarzyna Grzybowska

Abstract The proposed study evaluates the key skills needed to support Industry 4.0 from a literature review and practice perspective. A detailed review of literature targeting the Industry and Education sectors is performed. Canadian manufacturing and service industries and Polish automotive and pharmacy sectors are investigated. Decision-making, leadership, team thinking, core skills, and general aptitude emerge as the top skills needed in these sectors.

Keywords Education · Competence · Skills analysis · Workforce planning · Expert interview · Comparative analysis · Canada · Poland

1 Introduction

Enterprises have to react very quickly to challenges and opportunities in the business world (Saniuk et al. 2014). The concept of Industry 4.0 was first used in 2011 at the Hannover Fair—an annual world-leading Fair of Technology and Industry in Germany with the goal to collect recommendations for deploying strategic initiatives of "Industry 4.0" to ensure the future development of German manufacturing industry (Vu 2018). Proposed on a European level, the catchword is "Factories of the Future", "Industrial Internet" in the USA and "Internet +" in China (Mrugalska and Wyrwicka 2017). Industry 4.0 is the digitization of a company's physical assets and the company's integration into digital ecosystems with its value chain partners, from suppliers to customers. It uses smart technology and the use of real-time data to increase flexibility, customization, efficiency, and productivity, and to reduce time, costs, and innovation cycles. Due to disruptive technologies, the digitization of processes, and explosive growth in data, Industry 4.0 will have a major impact on the way products are designed, manufactured, assembled, shipped, and

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repaired, and on the people that have to adapt to these changes. Industry 4.0 focuses on nine technologies: autonomous robots, system integration, the internet of things (IoT), simulation, additive manufacturing, cloud computing, augmented reality, big data, and cybersecurity. Through these technologies, new supply chain paradigms can be achieved, and production and related logistics processes will change. This will require innovation on two fronts: smart products and smart processes. It will also require substantial change to the workforce, which will need to be trained and skilled to work in an Industry 4.0 environment; this is one of the biggest challenges of the fourth industrial revolution.

Due to the implementation of new technologies, the employees need to be trained for the latest and upcoming technologies to be an active member of the competitive market (Kaur 2018).

Roux et al. (2017) revealed that with the introduction of new technologies and new markets there will be an introduction of new job categories with the use of human talent in a different direction. Ho and Frampton (2010) analyzed workforce suitability in response to these technological changes. Lorenz et al. (2015) revealed that there will be a 6 percent increase in employment but at the same time automation will displace the low skilled laborers and there will be an increase in demand of employees in software development and IT technologies. Hecklau et al. (2016) published that with the introduction of new technology companies need to adopt new strategies for the holistic development of human resource management. Barlat et al. (2008) states that simultaneously determining the workforce allocation, i.e., the number of workers with each skill set available during the planning horizon and the workforce utilization or the sequence of tasks scheduled during the planning horizon to meet customer demand is not a trivial task.

In this chapter, we present a detailed literature review on key skills supporting Industry 4.0. Section 2 presents the workforce requirements based on Industry sector. Section 3 covers the education sector. The Canadian and Polish perspectives are presented in Sect. 4 and Sect. 5, respectively. Section 6 summarizes the results and provides directions for future works.

2 Industry Sector

Importance of multi-skills for employees to work in Industry 4.0 has been recommended by several authors (Sitek and Wikarek 2016; Nowakowski et al. 2019). These include the ability to work in different business units, strategic thinking, computer skills, core ability, general aptitude, leadership, culture protection, and security of information. The key areas requiring skills will be ERP implementation, big data and data analytics, cloud system and services, data and cybersecurity, and autonomous manufacturing (Karre et al. 2017).

Gudanowska et al. (2018) identified four key categories of competencies namely social, personal, managerial, and professional in the context of woodworks production, food processing, machine production, production of rubber and plastic products, and metal works production sectors. Social competencies include building relationships, knowledge sharing, and communication. Personal competencies include self-reliance, decision-making, troubleshooting, and innovativeness. The managerial competencies include team building, leadership, strategic thinking, project management, and team management. The professional competencies include IT skills, technical skills, administering, negotiating, and knowledge of foreign languages.

Hecklau et al. (2016) conducted a competency gap analysis and proposed employee readiness level for Industry 4.0. Four categories of required competencies namely technical, methodological, social, and personal are reported. The technical competencies include state-of-the-art knowledge, technical skills, process understanding, media skills, coding skills, and understanding IT security. The methodological competencies include creativity, entrepreneurial thinking, problem-solving, conflict solving, decision making, analytical skills, research skills, and efficiency orientation. The social competencies include intercultural skills, language skills, communication skills, networking skills, ability to work in a team, ability to be compromising and cooperative, ability to transfer knowledge, and leadership skills. The personal competencies include flexibility, ambiguity tolerance, motivation to learn, ability to work under pressure, sustainable mindset, and compliance.

Gehrke et al. (2015) classify the qualifications and skills of workers in a factory of the future into two broad categories: technical and personal. The must be requirements for technical Q&S include IT knowledge and abilities, data and information processing and analytics, statistical knowledge, organizational and processual understanding, ability to interact with modern interfaces (human–machine/human–robot), whereas for the personal Q&S, these are self and time management, adaptability and ability to change, team working abilities, social skills, and communication skills.

Prifti et al. (2017) identified key competencies as communicating with people, IT/Technology affinity, big data problem-solving, life-long learning, work in interdisciplinary environments, network technology/M2M communication, modeling/programming, data/network security, business process management, collaboration, teamwork, decision making, leadership skills, service orientation, creativity, and self-management.

Grzybowska and Łupicka (2017) report the key skills for Industry 4.0 as creativity, entrepreneurial thinking, problem-solving, conflict solving, decision making, analytical skills, research skills, and efficiency orientation.

Longo et al. (2017) advocate ERP implementation, big data and data analytics, cloud system and services, data and cybersecurity, and autonomous manufacturing as key areas requiring skills in Industry 4.0.

Karre et al. (2017) identified process mapping, statistical knowledge for problem-solving, PL/SQL-advanced, and UML-advanced, maintenance and use of stored and retained data, knowledge of servers, working with databases, virtualization and cloud services, analytical and logic thinking, knowledge of security standards and communication standards, off-line and online robot programming, installation of the device into operation, and PLC programmer-machinery programming as the must-have skills.

Benešová and Tupa (2017) recommend language skills, autonomy-responsibility-flexibility-creativity-cooperation-communicativeness-reliability, ability and willingness to learn new things, analytical/logic thinking, knowledge of security standards and communication standards, knowledge of servers (level-administrator) for IT jobs. For production jobs, manual skills, technical skills, language skills (English, German, etc.,), autonomy, responsibility, creativity, knowledge of technical documentation, ability and willingness to learn new things, organized skills, cooperation, media skills, and communication skills are needed.

Pfeiffer (2015) suggests that there will be demand for social media, data, next-generation technology, and automation skills.

Janis and Alias (2017) recommend both technical and nontechnical competencies for Industry 4.0. The technical skills involve state of the art knowledge, manufacturing, IT, computer science, and robotics and automation. The nontechnical skills involve personal, social-human role, professional, and methodological competencies.

Arnold et al. (2016) identified requirements to face digital transformation as standardization, work organization, availability of products, new business models, know-how protections, availability of skilled workers, research investment, professional development, and legal frameworks.

Kinzel (2016) emphasized the importance of human factors in designing the Industry 4.0 concept. No doubt, innovative technologies will be enhancing the use of machines, but the role of the human factor cannot be ignored. Even for supervising and technical maintenance of the machines we need labor force.

3 Education

Sackey and Bester (2016) looked into Industrial Engineering curriculum enhancement initiatives for Industry 4.0. The key skills identified are data science and advanced (big data) analytics, advanced simulation and virtual plant modeling, data communication and networks and system automation, novel human–machine interfaces, digital-to-physical transfer technologies such as 3D printing, closed-loop integrated product and process quality control/management systems, real-time inventory and logistics optimization systems, and teaching and learning demonstration infrastructure.

Benešová et al. (2018) looked into education requirements for electronics manufacturing within concept Industry 4.0 and identified that the cooperation between schools and universities with companies will be very important for Education 4.0. Currently, a lack of qualified employees is one of the highest risks for Industry 4.0 (Devedzic and Bari 2016). For this reason, the new technology trends (virtual learning environment, learning factory or augmented reality) should be included in education.

Vu (2018) proposed innovation of academic curriculum through CDIO (Conceive, Design, Implement, Operate) methodology and standards for the Vietnamese education sector.

Salah et al. (2019) emphasized on virtual reality based engineering education to enhance manufacturing sustainability in Industry 4.0.

Stachová et al. (2019) highlight the importance of external partnerships in employee education and development as the key to facing Industry 4.0 challenges. These include employee training in external organizations, participation in training courses, coaching and development programs provided by external specialists, staff travel to partner organizations, cooperation with research institutions, cooperation with secondary schools and universities, joint business activities with other activities (e.g., development, advertising, logistics), cooperation with competitors (e.g., partnerships in specific projects), a close link in the supply and demand chain, and engagement in knowledge networks, alliances, and joint venture.

Azmi et al. (2018) found a lack of nontechnical skills among engineering students in Malaysia. Communication skills especially in English, teamwork skills, critical thinking and problem-solving skills, entrepreneur skills, and computer skills were identified as key. Universities should expose their students with much more interdisciplinary teaching, research, innovation, and valuable industrial training to meet the current demands of industries.

Motyl et al. (2017) identify culture and education as the main keys to promoting knowledge and awareness about industry 4.0.

4 Canadian Perspective

A survey study with 31 experts from manufacturing and service sectors was conducted to seek their rankings on the following seven criteria:

Computer skills: This category involves skills related to computer proficiency such as programming, robotics, decision support systems, software development, and human–machine interface.
Soft skills: This category involves skills related to empathy and communication.
Multiskilling: This category involves knowledge of interdisciplinary skills, thereby allowing workers to be multi-skilled and multitask in different environments.
Leadership: This category involves skills related to creativity and innovation, generation of new ideas and initiative taking.
Core skills: This category involves core or fundamental skills related to operations engineering and management such as scheduling, resource allocation, and project management.
Team thinking: This category involves skills related to working in teams such as group coordination, conflict resolution, and consensus.
General aptitude: This category involves basic problem-solving skills such as problem identification, diagnostic, and repair.

The experts provided a rating of 1–10 where 1 refers to the least important and 10 refers to most important. Table 1 presents the results for the service sector. 18

Table 1 Study results from the service sector (Canadian sector)

Criteria	Mean	Std. dev
Computer skills (C1)	8.028	1.311
Soft skills (C2)	8.222	1.734
Multiskilling (C3)	7.972	1.337
Leadership (C4)	8.528	1.355
Core skills (C5)	8.500	1.237
Team thinking (C6)	8.444	1.162
General aptitude (C7)	7.889	1.632

Table 2 Study results from the manufacturing sector (Canadian sector)

Criteria	Mean	Std. dev
Computer skills (C1)	7.231	2.619
Soft skills (C2)	7.769	2.278
Multiskilling (C3)	7.231	2.455
Leadership (C4)	8.000	2.549
Core skills (C5)	6.692	2.689
Team thinking (C6)	8.077	2.498
General aptitude (C7)	7.846	1.951

responses were received. It can be seen that Leadership (C4), Core skills (C5), and Team thinking (C6) emerge as the top three skills.

Table 2 presents the results for the manufacturing sector. 13 responses were received. It can be seen that Team thinking (C6), Leadership (C4), and General aptitude (C7) are the top three skills.

Figure 1 presents the comparative analysis for the manufacturing and the service sectors. It can be seen that the skills receive higher scores in service over the manufacturing sector. The general aptitude (C7) scores equally for both sectors while leadership (C4) received the major difference in scores. Leadership (C4) scored the highest followed by Core skills (C5) in the service sector whereas in manufacturing it was Ability to work in different business units (C3) and Soft skills (C2). In the service sector, general aptitude (C7) scored the lowest whereas in manufacturing it was computer skills (C1).

5 Polish Perspective

A questionnaire survey was conducted amongst 20 selected experts in the automotive and pharmaceutical industries (Grzybowska and Łupicka 2017). These experts are highly qualified managers employed in transnational companies. There were 10 experts in each industry sector, who filled in the questionnaire. Respondents were asked to indicate their rankings on the following seven criteria (competencies):

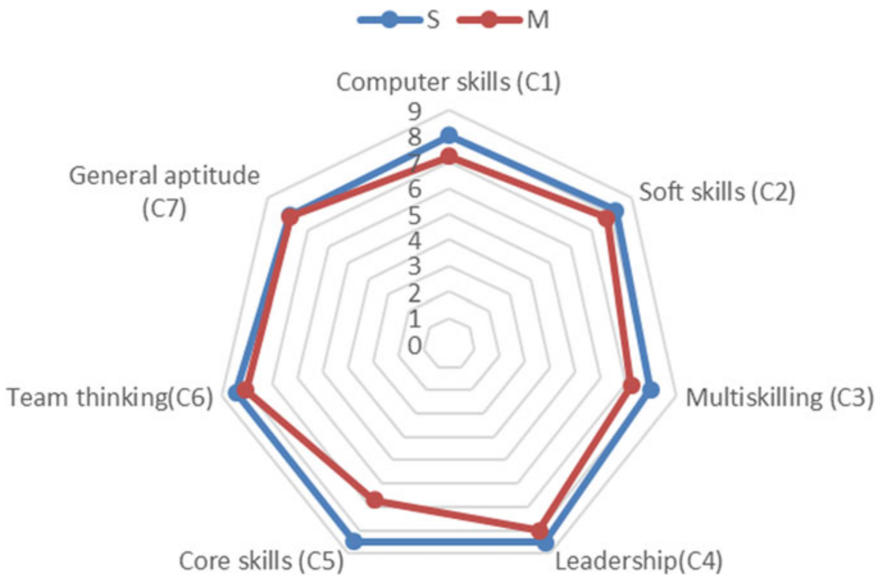

Fig. 1 Industry 4.0 competencies comparative analysis (Canadian sector)

Creativity: is becoming a key focus area for employers looking for the twenty-first-century employee. Creativity is characterized by the ability to perceive the world in new ways, to find hidden patterns, to make connections between seemingly unrelated phenomena, and to generate solutions. We are naturally creative and as we grow up we learn to be uncreative. Creativity is a skill that can be developed.

Entrepreneurial thinking: skills refer to the ability to identify marketplace opportunities and discover the most appropriate ways and time to capitalize on them. It is more like a state of mind that opens your eyes to new opportunities.

Solving problems: involves both analytical and creative skills. Analytical or logical thinking includes skills such as comparing, evaluating and selecting. It provides a logical framework for problem-solving. Creative thinking is a divergent process, using the imagination to create a large range of ideas for solutions. Problem-solving is an essential skill in the workplace and in personal situations.

Conflict solving: Resolving conflict is a key part of a manager's role. Managing and resolving conflict requires emotional maturity, self-control, and empathy. Resolving conflict in a positive manner is a skill that can be developed and practiced.

Decision-making: is the process of making choices by identifying a decision, gathering information, and assessing alternative resolutions. Decision-making is an integral part of modern management. Essentially, rational or sound decision making is taken as a primary function of management. According to the Oxford Advanced Learner's Dictionary, the term decision making means—the process of deciding about something important, especially in a group of people or in an organization.

Analytical skills: are the thought processes required to evaluate information effectively. Analytical skills are the ability to visualize, gather information, articulate, analyze, solve complex problems, and make decisions.
Research skills: can be from the need to be able to use reliable sources for continuous learning in changing environments. Being able to provide in-depth information and advice on a given topic is an important skill. Doing research in the world of work is all about stepping back from your day-to-day work and looking at ways you can improve. The most successful people tend to develop research skills early and use them consistently.
Efficiency orientation: an 'efficiency' approach is one that stresses the efficient use of resources as the main determinant of decision and action. Efficiency orientation is inevitable.

The experts provided a rating of 1–10, where 1 refers to the least important and 10 refers to most important. Table 3 presents the results for the automotive sector. It can be seen that entrepreneurial thinking (P2), decision-making (P5), and efficiency orientation (P8) emerge as the top three skills.

Table 4 presents the results for the manufacturing sector. It can be seen that decision-making (P5), problem-solving (P3), and conflict solving (P4) are the top three skills.

Table 3 Study results from the automotive sector (Poland)

Criteria	Mean	Std. dev
Creativity (P1)	7.420	1.840
Entrepreneurial thinking (P2)	9.140	1.060
Problem-solving (P3)	8.500	1.420
Conflict solving (P4)	8.500	1.420
Decision-making (P5)	9.140	1.840
Analytical skills (P6)	8.260	0.700
Research skills (P7)	4.760	3.020
Efficiency orientation (P8)	9.000	1.060

Table 4 Study results from the pharmacy sector (Poland)

Criteria	Mean	Std. dev
Creativity (P1)	5.140	1.080
Entrepreneurial thinking (P2)	7.140	1.580
Problem-solving (P3)	9.720	0.760
Conflict solving (P4)	9.420	0.980
Decision-making (P5)	10.000	0.000
Analytical skills (P6)	8.280	1.800
Research skills (P7)	4.580	2.760
Efficiency orientation (P8)	8.860	1.060

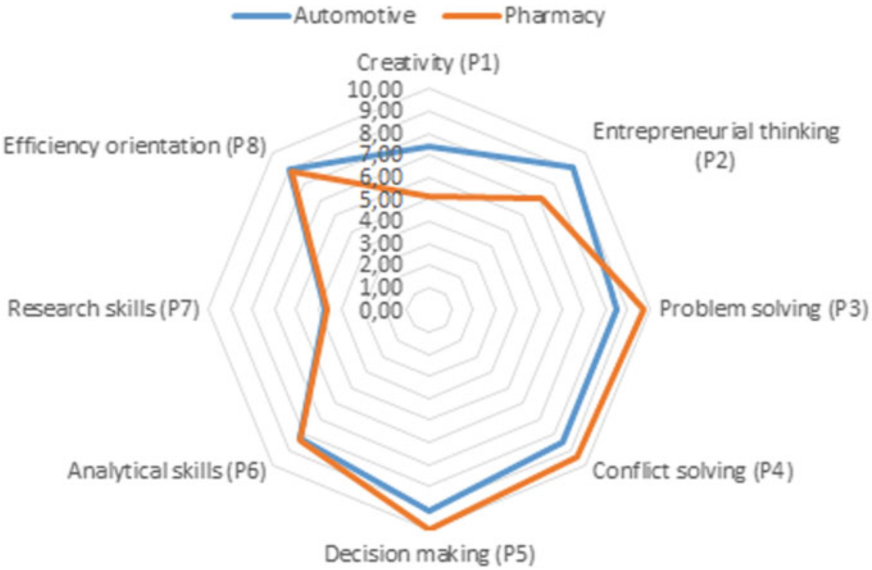

Fig. 2 Industry 4.0 competencies (Polish sector)

Figure 2 presents the comparative analysis for the automotive and pharmacy sectors. Knowledge becomes a key determinant of the development potential of enterprises (Grzybowska and Łupicka 2016). Employees with entrepreneurial thinking skills stand out because they tend to think creatively and take ownership of their jobs as well as performance. This is recognized by experts from the automotive sector. Experts (practitioners) attach a very high value to competencies related to decision-making. Such thinking probably arises from the view that the ability to make optimal and effective decisions is the only way to increase efficiency and win a strategic advantage (Grzybowska and Łupicka 2017).

6 Findings and Directions for Future Works

In this chapter, we conducted a detailed literature review on key competencies and skills for Industry 4.0. Industry and Education sectors were investigated. Perspectives from the Canadian manufacturing and service sector and Polish automotive and pharmacy sectors are discussed. The results of our study yield decision making, leadership, team thinking, core skills, and general aptitude as the top skills needed in these sectors.

Directions for future work include the following:

- Extension of the current study with more data and across more sectors.
- Cross-sector comparison of key skills and competencies for Industry 4.0.

- Impact of various cultures on Industry 4.0 skills gaps.
- Identification of training programs for Workforce 4.0.
- Design and development of university programs for Education 4.0.

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The Role and Impact of Industry 4.0 on Business Models

Sandra Grabowska, Bożena Gajdzik and Sebastian Saniuk

Abstract Development of the concept Industry 4.0, dictated by the need to reverse the downward trend in industrial production of European enterprises, forces modern enterprises to adapt quickly and flexibly. These adaptations affect demand conditions, production costs, and the search for new business solutions. The dynamic development of industrial digitization and telecommunications technologies allows for better integration of processes, machines, employees and individual products within the framework of intelligent network structures. Industry 4.0 facilitates data collection and analysis, evaluation of productivity and continuous improvement of processes. The development of the Industry 4.0 concept was needed to develop new competitive business models. These business models need to be based on cooperation and better use of the available resources. As a result, enterprises could achieve a competitive advantage through the personalization of products and low production costs. This fourth industrial revolution affects the operational activity of enterprises and results in new strategic thinking. The basis of new business models modified value chains within the network of cooperating enterprises. Supply chains equipped with the latest cyber–physical solutions ensure fast reorganization of logistics processes and a very flexible adaptation of commercialization. These new forms of supply chains offer the most personalized customer expectations. With the development of the Industry 4.0 concept, questions arise: what new forms will business models adopt? What will the cooperation of enterprises that are inherently competitors be? What tools will be able to support network cooperation of enterprises? The aim of this study is to identify the challenges related to the adaptation of business models. The Industry 4.0 concept, includes issues such as reconfiguration of value chains, customization and sharing resources in the network of companies operating under flexible supply chains.

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1 Challenges for the Cooperation of Enterprises in Industry 4.0

Strong competition and growing customer expectations in today's markets mean production efficiency and product customization. Product customization means that the price should be close to the mass production cost. The Industry 4.0 concept provides for a close relationship between these two factors, Industry 4.0 assumes a fully integrated system with the suppliers, producers, and clients. This system forms the Cyber–Physical Systems (CPS). CPS is an open socio-technical system composed of communicating mechatronic products (machines, devices, robots, means of transport, etc.). The issue of creating intelligent production plants (smart factories) is associated with the use of digital transformation and intelligent robotics. Industry 4.0 is not only technological changes, but it is also changed in the business models, strategic thinking and in value and supply chains. Dynamically changing the business environment, the rapid development of new production technologies (CPPS—Cyber–Physical Production System), intensity of the competition and globalization of market present entrepreneurs with new and much more difficult conditions. (Therefore, enterprises are planning to invest in cyber–physical systems in the future.) This will also be reflected in the creation of new business models, which will allow for a fast reorganization of processes and very flexible production (smart production) (Saniuk and Saniuk 2018).

The logistics industry in Industry 4.0 (CPPS) is a system for collecting and processing data in the area of the entire value chain, including the means of production, storage systems, and suppliers' networks. Information in the supply chain is exchanged between CPPS elements through standardized communication interfaces, but it also becomes available globally, for human use in operational or maintenance activities. CPPS systems are integrated, inter alia, in communication solutions known as the Internet of Things (IoT) and the Internet of Services (IoS) (Ashton 2009). Modern supply chains are smart value chains, which are so flexible and innovative that their participants provide customers with personalized value (Kaliczyńska and Dabek 2015).

In new forms of business relations with digital resources, large amounts of data, access to distance communication systems and the ability to build relationships within the Internet of Things (IoT) and Services (IoS), new systems of cooperative value chains are created. In relation to the value chain in terms of M. E. Porter, in which a product or service moves in one dimension to subsequent organizational units (and each adds value), new network realities are created in the new industrial reality, a network of values, multidimensional structure, unlimited space and time, flexible, mobile built for a specific customer (Kaliczyńska and Dabek 2015; Chui et al. 2010;

Clarke and Clegg 2000). The source of value is the combination of links of the network, based on cooperation in the broad exchange of data, digitization, access to cloud computing (computer), automation and robotization activities online customer service and the availability of services shortening the order completion time to 24 h or even shorter. The network systems are dominated by technical solutions belonging to the physical world and the virtual world. There is an integration of Information Technology (IT, office) and OT (operational and production) systems (Nanterme and Daugherty 2017). IT systems in industry are used for logistics planning, customer relationship management and support making key decisions about the way the company operates. Operational systems are used to monitor the operating conditions of devices, to control the devices and to control processes. In modern business models, there is a combination of these two worlds. This requires action in the form of the modernization of technology and the realignment of digitization. The value chain consists of a process, which is a set of activities and technology based on the technology used (Szymańska et al. 2017). The participants of the chain are characterized by mutual trust. Communication in value chains of cooperating enterprises is carried out without any time limit and from any place (Gajdzik and Grzybowska 2012).

2 Evolution of the Competitiveness of Enterprises in Terms of CPS

Competition in the cyber–physical economy plays a significant role. Cyber–physical systems (CPS) set the direction for the development of enterprises that strives to be a smart factory. The continuous market competition of enterprises results in the constant search for sources of competitive advantage and maintaining or improving an existing position on the market. In the case of Industry 4.0, this source is CPS (Sahay 2003).

Observing the competition processes in recent years, it has been noticed that enterprises richly equipped with the factors and means of production have a strong market position. They build the competitiveness of companies in the industry or market segment. There is the competitiveness of economies, enterprises, and people (Afuah and Tucci 2001; Grabowska 2016). The number of definitions proves the complexity and ambiguity of the concept of competitiveness. Porter (1990b), analyzed the concept of competitiveness in relation to national economies. Porter assumes competitiveness is defined as productivity which is determined by factory conditions, demand conditions, related and supporting industries, as well as regulations affecting the creation, organization, and management of companies (Chui et al. 2010). These skills are divided into two categories: operational competitiveness and system competitiveness (Casson 1991; Grabowska and Furman 2015). The main indicator of competitiveness is the results of foreign trade. Competitiveness is understood as the ability to design, produce and sell goods whose prices, quality, technical and utility values are more attractive than those offered by competitors (Teece 2010). Points out the company's distinctive abilities such as reputation, innovation, and enterprise structure form the basis of the company's competitiveness. In his concept of economic development (Jabłoński 2019; Wirtz et al. 2016; Afuah 2004). These factors are production and commercial solutions, or innovations (Afuah 2004) Prahalad and Krishnan (2010) highlight concepts of key skills. For them, the competitive feature is a set of human skills and the application of technology. The key feature of competitiveness meets three criteria. Those criteria value for the client, differentiates from the competitors and create opportunities to expand the market. In a different manner and in a different approach, the competitive advantage is inseparably connected with the company's strategic model and with the business processes of the company (Copeland et al. 1990). The competitive advantage is treated as the most important conceptual dimension of the business model. It is the most important attribute. The other elements constitute important sources of creation and maintenance in the model or are perceived as factors of its application.

Nowadays, the intensification of competition in the industry is observed. By observing the changes taking place at the Industry 4.0 level, there is a steady increase in the importance of information resources in relation to material and financial resources. The need to adapt business models in connection with a personalized value for the customer and the development of cyber–physical production systems is becoming a reality. Industry 4.0 introduces new areas of business competitiveness known as "smart". Competitiveness in new business models includes modern materials and personalized products manufactured by CPPS, giving a new quality to products and services, accuracy, speed, precision, availability, individuality, convenience, ease, flexibility, etc.

3 Industry 4.0 at the Core of New Business Models

The dynamic growth of competition, largely associated with the globalization of the economy, makes it necessary to create a business concept that can meet the challenges of Industry 4.0. Their theoretical detailing, and at the same time the application option is the concepts of business models. Their characteristics are important because it is an important element of the business processes being carried out, which constitute value by satisfying the clients' expectations. In Industry 4.0, it is particularly about providing products that are maximally personalized while productively using the resources of enterprises operating in flexible supply chain structures on the global opportunity market.

3.1 Business Models—A Definitional Approach

Business models are a kind of philosophy of action which is treated as essential for business development. The business models implemented by enterprises determine the profitability and competitiveness of the organization (Porter 1990a, pp. 71–72). Analyzing the essence, structure, and determinant helps to decide the shape and types of strategic models which are important cognitive elements of the sphere of development and functioning of enterprises. At the same time, such research may serve to improve or build new business models that are necessary for the face of economic, social, and technological changes (Porter 1996a, pp. 61–78).

In one of the most extensive and interesting works devoted to the construction of business models, Afuah (2004, pp. 9–10) presents the business model of the company as a set of activities, methods, and time to carry them out, using its resources to create the highest value for the client and ensure a position to take on value. He states that virtual innovations can be applied in all its elements and are necessary for creating value for the client (Porter 2002, pp. 1–50).

The concept of a business model is closely related to processes, such as business processes and business management. A business model is a tool containing a set of elements and relationships between them, in a schematic way of presenting a business idea (Porter 1996a, b). The model is a static description of the phenomenon through its mathematical or descriptive mapping. Economic (business) models are considered as a reflection of how to achieve the right economic results, expressed by the relation of revenues, costs, and profit in the organization (enterprise) structures. Business models correspond with performance models through the structure of the sector in which enterprises operate and due to the intensity of competition and behavior of enterprises, that is participants of the sector on the market in relation to competitors.

Business models are based on a strong combination of the strategy adopted by the company with its implementation. Implementation of the strategy takes place by building a value chain that ensures both the effective use of resources and skills as well as their renewal. Partial innovations involve changes within the existing business model. They express themselves in the creation of an advantage, e.g., in the area of product quality, distribution network, sales network, research and development, customer relations and production processes. In more detail, the elements of the business model, as well as the interrelations between them and the construction of the business model of enterprises in industry are shown in Fig. 1.

3.2 Competitiveness of M. E. Porter in Business Models

In a different way and in a different approach, competitive advantage is inseparably connected with business models. Competitive advantage is treated as the most important conceptual dimension of the model, is its attribute. The other elements of it constitute important sources of its creation and maintenance in the model or are perceived as factors of its application.

The achievements of Porter (2002), Saniuk and Saniuk (2018, Porter (1985), Liker (1997) in the field of competitiveness are used to conceptualize business models. It should be noted that the focus has been on the theoretical achievements, which concern the microeconomic view of enterprise competition. Therefore,

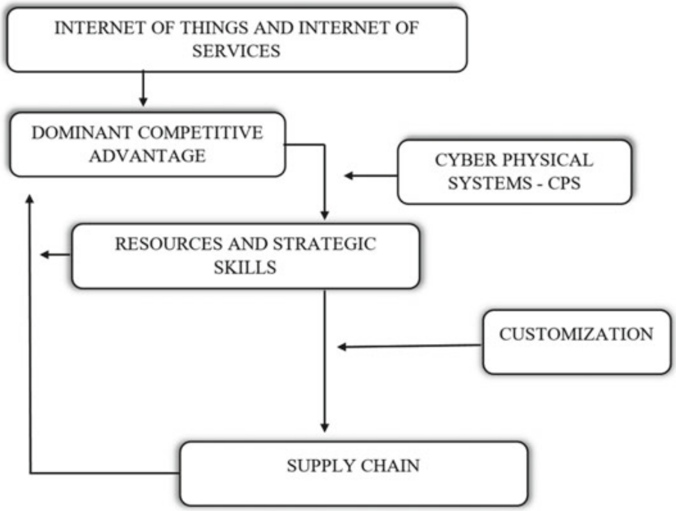

Fig. 1 The system of determinants of the business model in Industry 4.0

the example of a model determining national competitive advantages called the "national advantage diamond" or "national competitive advantage diamond", was not considered. It is certainly worth presenting, even in a synthetic way, the views of this author which directly concern shaping a competitive strategy and operational efficiency. This model of the company's activity ensures its economic success.

Presentation of Porter's (1996a, b) views on this issue can begin with his thesis of strategy and operational efficiency as conditions for obtaining the most important goal of the enterprise. The most important goal is an economic success. This author states, however, that each of these conditions (strategy and operational efficiency) have a different impact on the achievement of this goal. The introduction of the issue, which is an important issue for the transparency of the presented concept, is to distinguish strategy and operational efficiency. Analysis of Porter's (1985) views on strategy and operational efficiency allows us to formulate useful guidelines for building business models since the source of competitive advantages are all activities carried out by the organization. Therefore, business models should include the following:

– typical activities (like their competitors),
– ways to modify those activities,
– different performance of such activities,
– activities other than competitors conducted exclusively by the given company.

An example of competition through the increase in operational efficiency is the consolidation of sectors through mergers and acquisitions. In the era of Industry 4.0, such thinking should be abandoned. The key indicator of the company's success will be the ability to cooperate with other entities. The decisive role in creating and implementing an effective strategic model of a company is played by managers. In the opinion of Porter (2002), they are too focused on improving operational efficiency at the expense of the strategy. This situation, among other things, results from the fact that the pursuit of operational efficiency is attractive. Operational efficiency is specific and it can be based on actions leading to measurable improvement of efficiency, which is required of managers. Operational efficiency programs, as stated by the author, lead to immediate progress and higher, long-term profitability without defining a strategy that may turn out unattainable for the company. Such a strategy enables the company to achieve a lasting competitive advantage.

Assessment of the presented approach of Porter (1985), conducted in the aspect of creating business models at the level of the fourth industrial revolution, should start with the observation that an effective, long-term profitability business model of an enterprise should be based on:

– a strategy to achieve sustainable competitive advantage,
– a management system that ensures operational efficiency.

Industry 4.0 is a big challenge for enterprises, but it also has huge prospects for future development. Companies must completely change their strategy and overcome many barriers. Initial research indicates that the most important barriers are as follows:

– technical infrastructure—demand for machines and devices,
– automation of machines and devices and communication between them,
– cooperation with other companies—building relations and
– competences with other companies.

Elimination of these barriers (as shown in Fig. 2) will enable the joint production of products in the network of companies creating smart factories in the future and employees' competences (the skills of employees needed to control an automated production system) (Womack and Jones 2003).

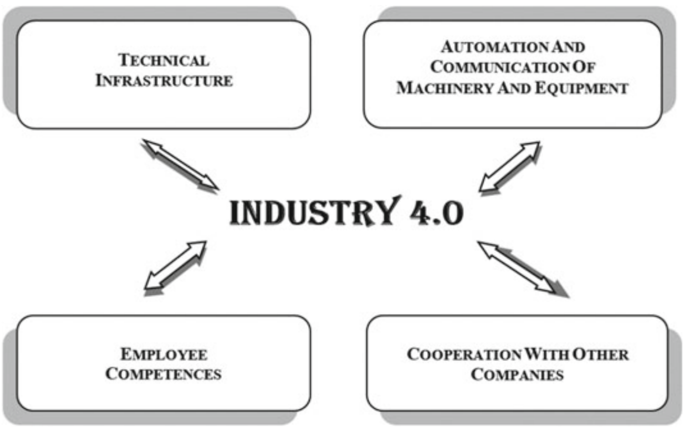

Fig. 2 Key areas for building a competitive advantage in Industry 4.0

In each of these areas, strategic goals can be identified which must be implemented in order to effectively implement the assumptions of the Industry 4.0 concept. Based on preliminary pilot studies and literature analysis, a general implementation scheme for the proposed concept can be built in network-oriented enterprises (Fig. 3).

A condition for the development of network forms of cooperation is the development of a model of cooperation of companies creating future cyber–physical systems (CPS). The main task of CPS will be to ensure the collection, processing of data required during physical flow processes taking place in the created network. Unlimited network connections of intelligent mechatronic resources allow the human role to be reduced to the supervisory and/or the coordinator function. The creating of the network model requires the development of a number of conditions related to the enterprise's modus operandi in the production network. Particular attention should be paid to the selection of partners oriented towards a joint production execution, the manner of production flow planning within available resources and the financial settlement of the partners providing resources for production. The selection of a partner for the network functioning within the framework of the Industry 4.0 concept

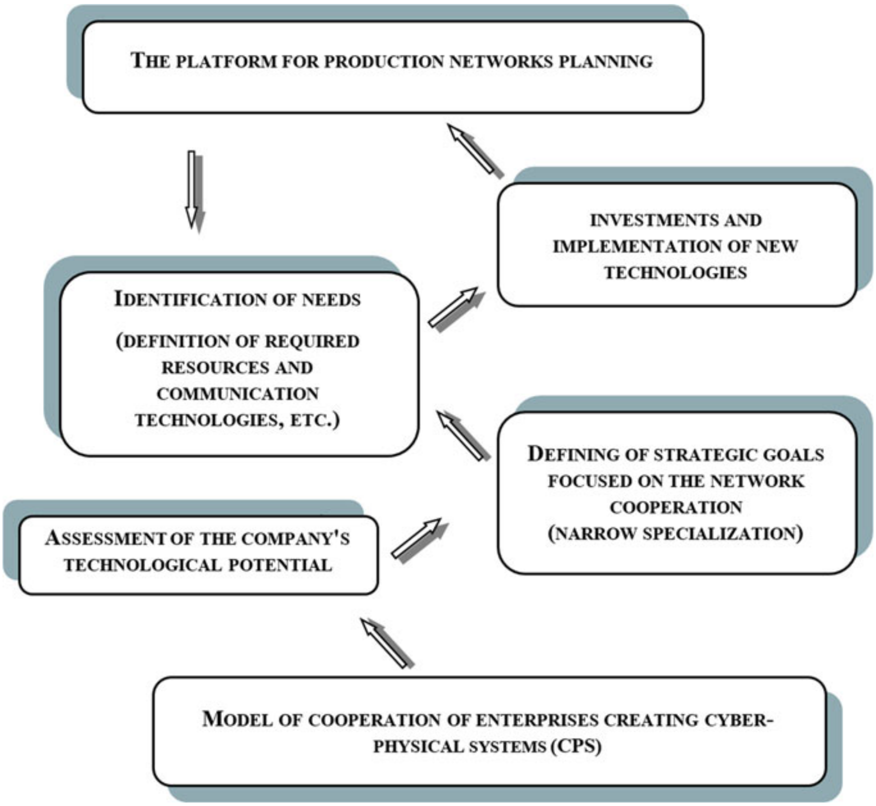

Fig. 3 The integration model of enterprises oriented to cooperation with Industry 4.0

requires an initial assessment of the technological potential of partners, know-how, employee competencies and the possibilities and skills of cooperation. This process is also aimed at creating in the company the ability to reduce the technological gap to the extent required by Industry 4.0. This technical gap reduction includes ensuring the so-called technological readiness, which will allow for the creation of a competitive advantage base (based on CPS) and to create within the managerial staff an internal capacity to absorb and adapt innovation at the level of 4.0.

In the next stage, the company should decide to limit very high infrastructure costs, in its area of specialization to provide for network cooperation. This will allow the company to focus its attention only on those resources which guarantee a high level of use and ensure the competitiveness of the company. The adoption of strategic objectives oriented to the implementation of technology requires a further stage related to the identification of needs and the determination of the required resources and technologies capable of cooperating within CPS systems. The last stage is an investment in the required resources and joining a common platform responsible for receiving orders from the client and organizing temporary networks composed of enterprises providing mechatronic resources for the needs of the platform. The process of creating a network together with a prototype of computer implementation is described in more detail in the work (Kuczyńska-Chałada and Furman 2018). The platform is a tool facilitating the exchange of information between a broker who is responsible for supervising the collection of data on a production order and offer(s) from enterprises.

Data from enterprises will be automatically transferred to the platform from machines and devices using the Internet of Things technology. Based on the information gathered in the system, a set of network variants capable of timely order completion is generated as well as a schedule showing the burden of individual company resources in the selected option for the implementation of a new order. Each variant is characterized by a set of selected enterprises with an indication of the resources used, the cost of implementation and the date of commencement and completion of the production order. Ultimately, this allows the individual company to choose the best variant in the system and available resources to be reserved for the production. Data on company resources is only provided to the broker. This means that there is no access to confidential data from other companies, which increases security against unfair competition. Each of the companies registered on the platform has access to information about orders and planned tasks. In the modern industry, a competitive advantage is built by enterprises that cooperate effectively with each other. To this end, the company combines in a business ecosystem modeled on natural networks. The mutual relations of entities, the use of shared resources and flexibility allow for effective competition with large players in the global market. The strength of companies in the network grows with an increase in the number of participants. On this foundation, companies can build their modern business models.

4 The Value Chain of M. E. Porter in Industry 4.0

The existing system of connections within the value chain of M. E. Porter allowed systematizing basic and auxiliary activities aimed at creating more value for the client. The sum of the nine strategically important activities creates the added value of the economic activity. The five basic activities are directly related to logistics, production, and sales. The four auxiliary activities include management, financial and personnel services, R&D, and procurement (Korena et al. 2015, pp. 64–71).

The first basic activity in M. Porter's chain is entry logistics. Entry logistics is related to supply. Raw materials and semi-finished products must be delivered to the producer who uses them in the process of manufacturing products. The logistics for supplying resources needed at the entrance to the production system are improved. Manufacturers' expectations at the developmental level of Industry 4.0 result in increased flexibility of supply, greater diversification of forms of delivery and more use of transport services using IoT. Time is of great importance. Delivery on time reduces the costs of storage of raw materials as well as the storage of semi-finished products on the production site (Bakkari and Khatory 2018). The resources go directly to production, so the warehouse may be unnecessary. The solutions used in the Japanese production systems (TPS—Toyota Production System) are still valid. At the smart factory, they are verified quantitatively and qualitatively using computer-IT control devices (Domingo Galindo 2016). Both raw materials and semi-finished products must physically cross the gate of the plant and are delivered to the production halls by autonomous vehicles, unmanned overhead cranes, conveyors, drones, etc. During production operations, they are processed or assembled on cyber–physical production lines (CPPS). Cyber–Physical Production Systems operate without the participation of production workers. At the beginning of level 4.0, employees will only be needed to monitor the process (Bauernhansl et al. 2014).

A new product is created. It is a highly personalized product. At the beginning of entry logistics, the customer participates in product design. An intelligent chatbot (robot at the level of trade assistants) can be virtual consultants who inspire the customer to personalize the order and help in its realization by assigning individual utility and non-use features of the products, e.g., aesthetic (Jones and LeBaron 2002).

Customers use sales platforms. Access to the sales platform is unlimited in time and space. The commercial offer on remote systems is updated continuously. A personalized order is a package of information coded and assigned individually for each ordered product (so-called product memory). In addition, manufacturers assign products to all necessary technical information in terms of production requirements. The memory product communicates with cyber–physical production systems throughout the course of the implementation using RFID technology (Gajdzik and Grzybowska 2012).

The output logistics process organizes the dispatch of goods according to orders. So far, all these activities have been monitored by the Marketing and Sales Department, which in practice is also called the Sales Department. At level 4.0, customer service is unmanned as part of the mobile service and availability of sales platforms (B2B). In the M.E. Porter value chain, the Sales Department was an extremely important cell in the company because employees' skills in acquiring and retaining customers translate into orders placed. In Industry 4.0, business platforms and sales platforms replace supply and sales cells. Access to online services eliminates the need for access to employees dealing with customer service. Virtual advisors advise in many industries, e.g., tourism, aviation, clothing, household appliances, and pharmacology.

A common feature of the classic supply chain and its modifications at level 4.0 is the pull-based process approach from the customer's order to production (Gajdzik 2014; Kagermann et al. 2011). The difference is that the customer affects the characteristics of the ordered product to a greater extent now. The individual processes are followed by a total value orientation for the customer who is served online. Production in Industry 4.0 is flexible and quickly changes to realize a new customer order, which is another challenge for cyber–physical production systems.

The value chain in Industry 4.0 is varied in terms of products. Its participants focus on the needs of a virtual client (supported by sales platforms). Satisfying every customer's need is a prerequisite for competitiveness in business models. The individual orders carried out through personalized products create a set of serviced clients that exceeds hundreds of millions (Mrugalska and Wyrwicka 2017, pp. 466–473). The created set of satisfied individual customer needs is treated as a form of mass individualization due to overcoming spatial, time, communication, technological, cultural, financial barriers, etc.

The last basic activity in the classic value chain of Porter (2002) is an additional service. The scope of these services is particularly significant and extensive since the product must be adapted to the individual (imaginary) needs (expectations) of the client. Access to services that enrich the value of products is implemented through virtual service platforms as well as physical storage and service centers. In the value chain, you can see integration with the environment, both IT and physical. IT integration is mainly about joining the logistics system with e-commerce systems. These logistics systems ensure the ability to control the availability and purchase of goods and devices communicating directly with each other via the internet. (This applies to such concepts as the Internet of Things or M2M—Mobile To Mobile). Physical integration is primarily a streamlining of logistics processes, e.g., automatic loading and unloading, fast stock replenishment in the warehouse, picking individual customer orders and quick paths for picking processes (Krykavskyy and Mashchak 2017).

Resource flow management will be made easier by reflecting the movement of products in the virtual supply chain (Bijańska et al. 2016, pp. 128–134). During ancillary activities (support activities) within the value chain, several derogations from the original M. E. Porter concept can be considered. Even Porter was tempted to make a significant change (Grzybowska 2012).

Procurement previously implemented by the supply department in the enterprise gives way to supply platforms, commodity exchanges, online auctions, etc. The virtual nature of supply enters many types of raw materials and materials. It also takes into consideration the supply relation to energy, water, gas, etc. However, it should be emphasized that natural resource deposits are limited. The strong bargaining power of suppliers and market availability will continue to apply traditional forms of supply guaranteed by contracts that are negotiated between the supplier of raw materials and the producer.

At the level of enterprise infrastructure and technology development, there will be changes towards mobile automation and robotization in cyber–physical systems of manufacturing and in unmanned warehouses with autonomous vehicles. In Industry 4.0, production processes are considered as innovative solutions in which production (manufacture of products) is carried out using robots and industrial manipulators. It also seems justified at the level of management to emphasize the importance of the Maintenance Department, which will be replaced by learning devices, learning machines and the people who supervise them. The communication of solutions between a human and machines will use the Internet and computer systems to support production. Learning machines (machine learning) use the processing of current data from cloud data (cloud computing) and learn to perform their tasks optimally with the simultaneous calibration of adjustable operational parameters (Zhu et al. 2007; Hamprecht 2006).

The level of human resource management will also be reduced. Its significance will be lower in the value-level system at level 4.0. In Industry 4.0, due to the high level of automation and robotization of activities, the demand for employees will decrease. It will also be possible to eliminate many errors originating from a human being, and which bring certain consequences for the efficient delivery of the product to the market. At the same time, the demand for employees with competence in handling information traffic between elements of the production process and the final product will increase. The smart factory employs mainly IT specialists, automation specialists, service staff, maintenance staff, cybernetics, and analysts. The basic tools for increasing demands on human resources are creativity support tools (Gajdzik 2014).

The level of the company's infrastructure according to the value chain of M. E. Porter includes activities such as general management, planning, finances, accounting and quality management (Porter 1996a, b). Planning and management activities will continue to be implemented in the role of securing the course of basic activities. However, their form and methods are changing. New names will appear, such as digital business strategy, data-driven planning, and management. Gradually, new business rules will be built between virtual organizations in connection with the use of ICT in business management. The importance of monitoring, testing and analyzing the course of operations, i.e., IoT, is growing in the smart factory. Figure 4 shows an example of the IoT value chain.

With the development of Industry 4.0, the value chain will evolve due to the impact of computer science, automation, and robotization on the course of basic and auxiliary processes. The share of individual auxiliary and support activities in creating value for the client will change. The value is personalized and strongly individualized. Therefore, the competitiveness of enterprises will be related to technological capabilities in meeting customer requirements. The value chain will be subject to

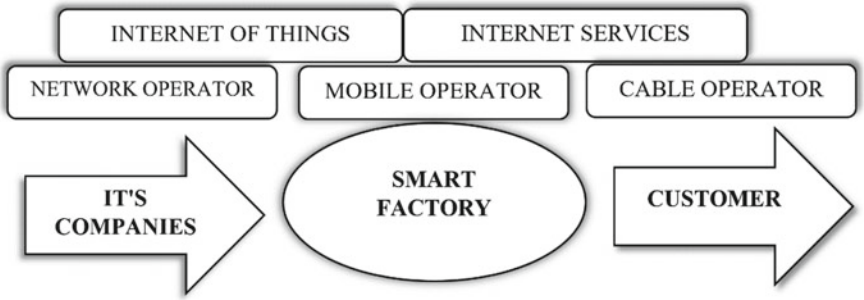

Fig. 4 An example of an IoT value chain

configuration depending on the degree of adaptation of entities to the requirements of Industry 4.0 participants. "Default", wise technology (Baden-Filler and Haefliger 2017), occurs in production and logistics.

5 The Supply Chain in Industry 4.0

The process of controlling devices through Internet access goes beyond production. This process includes means of transport, ordering systems and warehouses (material control) within the supply chain (Womack and Jones 2003). Logistics implemented under Industry 4.0 generates capabilities that allow effective implementation of the tasks required for it in relation to a wide group of clients, contractors and other stakeholder groups using the latest communication solutions in cyber–physical systems (Kaliczyńska and Dabek 2015). Horizontal integration through value networks is a term used in production, automation and IT and means the integration of various IT systems used in various stages of production and planning, including the flow of materials, energy, and information both within the company and on the outside in value networks. In the Industry 4.0 concept, horizontal integration is based on digitization where information flows in the network from the customer to the supplier and vice versa. Product memory is essential for horizontal integration. Horizontal integration includes both components of the value network within the company as well as the network of subcontractors. The exchange of information concerns not only the flow of goods but also data defining the reliability of deliveries and the degree (level) of customer satisfaction (Krykavskyy and Mashchak 2017). Existing trends of nowadays put new challenges to supply chain management.

Through the supply chain management, to improve the productivity of social, environmental and economic activities of the company, the business is working for itself and its stakeholders, and SSCM is an important factor in the growth of indicators of all its participants. And, although the actions of the company, in accordance with the principles of sustainable development, may have a higher initial cost, it is important to take into account the entire life cycle of products and services. The more energy-efficient and eco-friendly equipment and process the company has, the smaller is its impact on the long-term operating costs. Enterprises and society must develop common values. So, first of all, the supply chain managers must respond to new challenges: to find suppliers who adhere to the principles of sustainable development and to minimize the use of non-renewable resources with parallel limitation of the company's costs (Bijańska et al. 2016, pp. 128–134).

In the transformation of the supply chain to Industry 4.0 standards, an important aspect will be its sustainable development. Sustainable supply chain management (SSCM) is the management of the economic, social, and environmental impact of the supplying process in the whole product life cycle to create, health and long-term development of the economic, social and environmental value for all interested parties in the process. According to SSCM, three groups of criteria are taken into the account:

1. Economic criteria—fair conditions of contracts, timely adjustment of debts, transparency in establishing business contacts between participants of the supply chain, prevention of corruption.
2. Social criteria—fair practice in the field of employment (compliance with labor laws and human rights, fair compensation to employees, adherence to the principles of equality, concern for health and safety) and practice focused on cooperation with local communities.
3. Environmental criteria—the aspects of the environment that relate to the entire product life cycle (design, transportation, use of raw materials for production, recycling) (Zhu et al. 2007).

In the supply chain at level 4.0, as before, there is a requirement to quickly deliver the product to the customer. Along with the increase in the speed of data flow and the growing availability of commercial offers on the Internet, the emphasis on the pace of deliveries is growing. With a high level of competition on the market, the struggle to deliver product innovation to the market consists of accelerating the manufacturing processes and logistics operations such as time compression. The customer can easily search the Internet for alternative offers in terms of their speed of implementation. Delivery of the goods within a short time from placing the order by the customer is a development of the Just-in-Time delivery system (Hamprecht 2006). In the 1990s, the products delivered in a relatively short time to the customer were mostly homogeneous and constituted the standard offer (ings) of the company. Industry 4.0, offerings are personalized. The companies strive to shorten the delivery time from the moment the order is placed by the customer to the maximum personalized order delivery (Liker 2004). There are already companies appearing on the market which are testing solutions based on deliveries within one hour of placing an order, e.g. Amazon. However, this time compression applies only to certain regions with high population density, such as Manhattan in New York City.

Apart from time compression, which in the supply chain at level 4.0 becomes stronger, an important feature describing changes in the supply chain is the need to achieve a stronger and more positive synergy effect (Saniuk and Saniuk 2017). Therefore, the effect of their interaction is greater than the sum of the results of individual processes. The concept of "Smart Factory" offers such a combination of machines that enables smooth synchronization of the technological process. A positive example of the synergy effect is matching the cyber–physical systems of individual participants in the supply chain. Intelligent devices as referred to in Industry 4.0, communicate with each other and transmit data to user management systems that have access to cloud computing. Participants in the supply chain have access to cloud computing, which facilitates their adaptation of supply and warehouse processes in combination with maintaining inventories, production processes, distribution and supply to the customer's personalized expectations (Moden 1998). The flow of information between all links in the supply chain is optimized. Reconstruction of the interface between successive processes to make the information run faster is a prerequisite for building a competitive advantage.

The necessity of compatibility of system-computing solutions between individual participants of the supply chain is also important. In order to ensure the flexibility of the installation, IT systems must work seamlessly with the new network component requirements for data transmission. New standards are created, which will be introduced gradually, and will allow these two groups of solutions, e.g., Time-Sensitive Networking, developed in IEEE by companies such as Cisco and Intel, to allow synchronization of devices connected to one classic Ethernet network. This solution will eliminate the need for using such industrial equivalents, such as Ethernet routers. Using the new standard, it is possible to transmit data in industrial networks (IT) that connect to office networks (OT) (Wicher et al. 2015, pp. 703–706).

Control and measurement solutions used in Industry 4.0 constantly analyze the processes in terms of their efficiency and cost-effectiveness. These solutions eliminate unnecessary activities due to the purpose of operations, as well as time-consuming and overly expensive operations. Therefore, activities that do not directly create value for the recipient are the first to be eliminated. Cost analysis is a basic process control panel in the aspect of eliminating "waste". This is understood very broadly as "muda" in Japanese. Data in the supply chain are special because they are available in real time. By reliably reflecting the physical flows of resources in the supply chain, the producer can increase the level of control over the processes occurring in it. The use of IT technologies allows for the sharing of data at warehouse sites, vehicle locations and other means of transport for partners in the supply chain. IT technologies analyze data on an ongoing basis, eliminating unprofitable operations at a given time and having a lower impact on the value for the recipient than base operations (Franke 2001).

The value network (net of the value chain) as a new network structure was created by the evolution of the M. E. Porter value chain. Porter's concept, in which the product or service moved one-dimensional to subsequent organizational units and each added value, is multidimensional and flexible in the new industrial reality. The source of value is the combination of network links, based on interoperability using business platforms. Participants in the supply chain network participate in the expansion of the data exchange network in real time. Technologies of wireless data transfer with tags operating in the RFID (Radio-Frequency Identification) system enable control of the location of the goods in the warehouse as well as control of the location during transport. The dissemination of this technology is also associated with the anticipated development of the Internet of Things (Liker 2004).

New chain structures enrich the relationships between participants by increasing the coordination of activities using IT technology, increasing the precision of implementation and shortening the production cycles of personalized products. The common parts of the integrated supply chain in Industry 4.0 is access to IoT, the virtual world of solutions. The basic and auxiliary activities typical of the chain value of M. E. Porter imply an added value in the combined value chains (supplier value chain, enterprise value chain, value chain of sales routes and value chain of recipients). In the integrated industry, the term used for the form of the product line using mobile automation solutions in many smart factories and integrated logistics creates an integrated supply chain in which virtual connections override physical connections (strategic alliances, capital links, etc.) (Tadejko 2015).

6 Summary

The chapter presents an introduction to the discussion of changing business models in Industry 4.0. It is an attempt to answer the following questions: what new forms will business models adopt? What will be the cooperation of companies that are competitors by nature? What tools will be able to support the network cooperation of enterprises? The publication does not present specific model solutions. It describes the conditions that will be placed on business models in Industry 4.0. Industry 4.0 is a new concept of economic development which was initiated by the non-German government in 2011. The first smart factories are projected to be operational around 2030. The current level of change can be defined as the adaptation of enterprises to the new challenges posed by Industry 4.0. Enterprises are testing cyber–physical production systems. The enterprises are also trying to understand how to control these systems. From the perspective of adapting enterprises to the smart factory, the independence of cyber–physical systems is assumed. Business models describing cyber–physical smart businesses are being predicted to appear in a decade or two. Currently, any attempt to copy a smart business is only an approximation of the initiated changes which are not yet fully understood by everyone.

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Smart Industry—The Digital Gap in the Process of the Smart Supply Chain Competitive Advantage?

Katarzyna Nowicka

Abstract Smart Industry plays a crucial role in the system of smart supply chains. Those kinds of supply chains are based on digital technologies ecosystems concentrated on supporting all types of flows to increase competitive advantage. Therefore, decisions taken within a particular company concerning its innovations, technology usage or B and R activities impact the whole level of value developed and delivered by the supply chains. The crucial role in the supply chain is played by small and medium enterprises (SME) as their level of digitalization impacts on ability to compete by smart supply chain idea. The aim of the chapter is to analyze the role of digital technologies ecosystems usage by the Smart Industry sector—understood as a part of the smart supply chain model—in gaining competitive advantage. The special attention is put on SME as their role in the supply chain and economy is vital. The main part of the analysis concentrates on the concept of Smart Industry development in terms of its innovation and digitalization level in Poland. Analysis is based on empirical researches conducted by Kantar Millward Brown among Polish SME in 2017 and 2018 on behalf of the Siemens company and Ministry of Entrepreneurship and Technology (in 2017—Ministry of Development) in Poland. Additionally the reports on Industry 4.0 (Smart Industry) were revised and used for research purposes.

Keywords Industry 4.0 · Technologies ecosystem · Smart supply chain · Digital technologies · Ecosystems · Small and medium enterprises

1 Introduction

No discussion on the disruptive, uncertain or unpredictable economic environment should take place any more. It's a fact that surrounds the companies and their supply chains from decades. Now the understanding of how these aspects could be omitted or rather used as an opportunity by the company is a must. Digital technologies are transforming all end to end steps in production and supply chain business models in

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most sectors of the economy to add more flexibility and efficiency to meet customers' demand fluctuations. Today they play a basic role in gaining competitive advantages not only from the perspective of a single company but mostly from the perspective of the system they have been used for. This is mainly due to the features of these technologies—or better the ecosystem they are element of—to support information flow between the partners in the system—namely: the supply chain. Smart Industry (or Industry 4.0) is a part of smart supply chains. It plays a crucial role in the system as the producer and it is the main partner responsible for fulfilling the pipeline with the products according to the information received on-line. Smarty Industry covers the supply side in the smart supply chains warranting, i.e.:

- constant flow of the products according to the demands' fluctuations,
- decreasing level of lost sales due to the lack of inventories,
- directly impacting the system flexibility in terms of supplying different combinations of the products during its personalization process.

All of these assumptions covering the role of the Smart Industry's impact on smart supply chains' competitive advantage. Therefore, understanding of being a part of the system by the producers is one of the most important aspects heling them to identify accurate technologies for the investments in the innovative technologies supporting integration and information flow for value creation and delivery for the customers.

The aim of the chapter is to analyze the role of digital technology ecosystems usage by the Smart Industry sector in gaining competitive advantage. In the second chapter, the idea of Smart Industry (understood also as Industry 4.0) and its relation to the smart supply chain is introduced. The IT ecosystem as a base for the introduction of Smart Industry within the concept of smart (or digital) supply chains is the subject of the third part of the study. The main part of the analysis concentrates on the Smart Industry development in terms of its innovation and digitalization level in Poland. Analysis is based on empirical researches conducted among Polish SME in 2017 and 2018 in cooperation with Siemens company and Ministry of Entrepreneurship and Technology (in 2017—Ministry of Development) in Poland.

2 Smart Industry—The Phase in the Smart Supply Chain

Currently, the so-called fourth industrial revolution being today the broadly described stage of socioeconomic development. The concept of Industry 4.0 (or Smart Industry) has become its element. This revolution is connected with the following three phenomena (Paprocki 2016):

- universal digitization and ensuring constant communication between people, people with devices, and devices among themselves,
- increasing the implemented innovations of subversive character (disruptive innovations), allowing for a stepwise increase in the efficiency of the socioeconomic system,
- the development of machines capable of autonomous functioning through the use of artificial intelligence.

Smart Industry, or Industry 4.0, is currently widely described in the scientific literature and popular term used in the business world. It is defined as the application of the cyber-physical systems (CPS) within industrial production systems, which can be equivalent to what has been introduced as industrial internet by General Electric in North America (Posada et al. 2015). However, Industry 4.0 can be better identified based on its design principles and technology trends (Gilchrist 2016; Liao et al. 2017; Santos et al. 2017; Ustundag and Cevikcan 2017; Vogel-Heuser and Hess 2016; Grzybowska and Lupicka 2017). Also, the broader approach can be revised,. i.e., German Federal Ministry of Economics and Energy (Bundesministerium Für Wirtschaft Und Energie) (2015) introduced the idea of "Industry Platform 4.0" and described as: "The term Industrial 4.0 stands for the fourth industrial revolution, a new stage in the organization and management of the entire value chain over the life cycle of products. This cycle addresses the increasingly individualized customer requirements and extends from the idea of the development and manufacturing, the delivery of a product to the customer up to the recycling, including Industry 4.0 associated services. The basis is the availability of all relevant information in real time through the networking of all entities involved in the value creation as well as the ability to derive from the data the optimal value flow at any time. By linking people, objects and systems, dynamic, real time and self-organizing, cross-company value-added networks emerge, which can be optimized according to different criteria such as cost, availability, and resource consumption." One can observe two main aspects that are covered by this definition. One is that it is built on features of digital technologies and the second is that it might be mainly dedicated to the big companies that are able to implement the idea in the entire value chain. However, not only big companies compete by the supply chains. And more—the technologies are getting cheaper and diffused within the supply chains.

Therefore, it is interesting to analyze the Smart Industry idea acceptance within SME. Especially that they play an important role in the economy. First of all because they cover around 95% of the companies operating in Poland and 30% of them are registered in the production sector (GUS 2018). The second point is that producers are one of the most important nexus in supply chain as they used to have a strong bargaining power even if they are not a big companies but only supplies big companies.

From the supply chain perspective, Smart Industry might be understood as one of the nexuses in the network of information, products, and money flow. According to Christopher (2011) supply chain is "the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer". The most important aspect when analyzing competitiveness of the supply chains is the integration that allows taking and implementing strategic decisions in the whole system. Integration becomes a vital factor for the effective functioning of supply chains to meet the performance objectives like cost, responsiveness, serviceability, and agility. Stevens and Johnson (2016, p. 22) described supply chain integration as "the alignment, linkage and coordination of people, processes, information, knowledge, and strategies across the supply chain between all points of contact and influence to facilitate the efficient and effective flows of material, money, information, and knowledge in response to customer needs". Today those "alignment", "linkage" and "coordination" can easily be supported by digital technologies (Nowicka 2019) creating smart supply chains.

Smart supply chains are based on digital technologies (and thus are also called "digital supply chains"—Michel (2017), Straub et al. (2004), The Center for Global Enterprise (2016) have a set of characteristics which distinguish them for traditional—linear-based solutions (Nowicka 2016). These characteristics create systems that are Wu et al. (2016):

- instrumented: information in the next generation supply chain is overwhelmingly being machine-generated, for example, by sensors, RFID tags, meters, and many others;
- interconnected: the entire supply chain, including business entities, and assets, IT systems, products, and other smart objects are all connected in a smart supply chain;
- intelligent: smart supply chains make large-scale optimal decisions to optimize performance;
- automated: smart supply chains must automate much of its process flows by using machines to replace other low-efficiency resources including labor;
- integrated: supply chain process integration involves collaboration across supply chain stages, joint decision-making, common systems, and information sharing; and
- innovative: innovation is the development of new values through solutions that meet new requirements, inarticulate needs, or even existing needs in better ways.

The smart supply chain is a system that ensures full interoperability and which uses the potential of technologies, namely the features of IoT, Cloud Computing, 3D printing, Big Data and big data analytics, artificial intelligence, and automation or robotization. A vast range of these technologies is already impacting production systems and supply chains. Combined and connected into the joint ecosystem, these technologies will open up new opportunities for creating value across multiple dimensions—across the competitive supply chains of the future. The ongoing digital transformation of industries also brings new opportunities for innovative business models. The majority of companies in the manufacturing sector (79.9%) and the logistics industry (85.5%) see positive effects resulting from digital transformation (Kersten et al. 2017).

Such an ecosystem of technologies and appropriate use of data analytics makes it possible to take decisions in near real time of events taking place in the physical world at various levels of the supply chain. This requires integration processes which consist of Wang et al. (2016), PwC (2016):

- Vertical integration, which involves internal processes of a company, ranging from design and purchase to customer and after-sales services;
- Horizontal integration, which takes into account collaboration with suppliers, customers, and cooperators in the value chain.

3 The Technology Ecosystem—The Holy Grail in Gaining on the Competitive Advantage?

According to the World Economic Forum (2017), there is a correlation between the relevance of new technologies and the speed of implementation of novel business model solutions. Change in current supply chains is driven by operating the new technologies. Five key technologies, which are currently at different stages in terms of level of readiness and adoption across industry sectors, are expected to significantly impact supply chains, they are internet of things, artificial intelligence, advanced robotics, enterprise wearables, and additive manufacturing. It must be underlined that they cover solutions for all types of enterprises in the supply chain.

The internet of things (IoT) is the virtual interconnection of intelligent assets and devices to achieve improved user experience and/or usability. The opportunities will only grow with the growth of intelligent interconnected assets and devices in the global supply chains. Connected devices ensure the availability of real time data, enable the geographic distribution of operations and manufacturing, and result in improvements in operational efficiency, processing time, and operating and management costs for the whole system.

Artificial intelligence (AI) or self-learning systems is the collective term for machines that replicate the cognitive abilities of human beings. Within the broader technological landscape predictive maintenance in the cognitive era has the potential to transform global production systems. Machine-generated insights will pave the way for greater precision and accuracy. Physical assets replace low-skilled labor, which requires investment in and upskilling of the existing workforce.

Advanced robotics is defined as devices that act largely or partially autonomously, interact physically with people or their environment and are capable of modifying their behavior based on sensor data. Robotic innovations have been used for recursive manufacturing processes. Robotics and automation technologies result in shorter cycle times while achieving better floor space utilization and higher levels of productivity.

Enterprise wearables are permanently switched on, interconnected computing displays that are worn on the human body. Applications of enterprise wearables are multifarious. Design augmentations and manufacturing processes are key areas of use.

3D Printing (additive manufacturing) is the fully automated manufacturing process of building three-dimensional objects from a digital blueprint or model. It paves the way for new designs, manufacturing concepts, and logistical services. Additive manufacturing is considered a disruptive technology that adds new diversity to products and manufacturing strategies while also creating opportunities for new business models.

All the above technologies, as well as other introduced into the supply chain according to its needs and specifics are integrated into the one system or the platform, might be called the technology ecosystem (Berttram et al. 2017). The technology ecosystem is an enabling ecosystem that covers IT architecture and interfaces as well as digital technologies and drives or supports improvements and breakthroughs in the smart supply chain. According to Desmet et al. (2017) "integrating a company's IT with third-party capabilities creates opportunities to capture substantial new sources of value. But until IT expands to become technology ecosystem, the vast majority of those opportunities will remain out of reach".

That technology ecosystem should be understood as a developing process since new technologies are arising and constantly impacting different aspects of managing the business and developing new supply chain business models. So the pointed technologies are important now, but might not be so important for gaining competitive advantages in the next decade or even years. This might be also an important argument to consider implementation of technology solutions together with the most important stakeholders—partners in the integrated supply chain since the decision plays a strategic role for more than just one company.

4 Smart Industry—The Role of Digital Technology in the Competitive Advantage of SME in Poland

As the idea of Smart Industry implementation can be the first step to develop smart supply chains that are able to gain extraordinary competitive advantage, there is a need to analyze the current status of the Smart Industry concept by understanding and implementing within production companies. Thus, there were two surveys conducted in Poland to diagnose recognition of Smart Industry concept within SME. Both of them were carried out on representative sample of SME registered in the industrial sector in Poland.

The survey of Smart Industry Polska (2018) was aimed at examining the motivation and barriers associated with the implementation of innovative technologies in industrial enterprises belonging to the SME sector related to the Industry 4.0 revolution. The study was carried out in April 2018 on behalf of Siemens Sp. z o.o. and the Polish Ministry of Entrepreneurship and Technology (former Ministry of Development). CATI telephone interviews were conducted on a nationwide sample of 200 companies from the industrial or production sector with the number of employees up to 250. The respondents were carrying out production activities in Poland, i.e., having a factory or production plant operating in Poland. The sample included micro, SME in the following sizes: $N = 60$—micro-companies (1–9 employees); $N = 90$—small companies (10–49 employees); $N = 50$—medium-sized companies (50–250 employees). The respondents in the study were decision makers/competent informers, i.e., managers responsible for implementing innovations, new technologies or company development (directors, production or development managers or managing directors/business owners). Results presented in this study are additionally supported by the previous study's results. The previous study was carried out in March and April 2017 also by Kantar Millward Brown on behalf of Siemens Sp. z o.o. and Ministry of Development. It was conducted on a nationwide sample of

SME from the industrial sector conducting manufacturing activities in Poland. The representative sample size consisted of 251 SME ($N = 76$—micro-companies, $N = 100$—small companies, and $N = 75$—medium companies). As mentioned before SME was chosen due to the fact that they cover about 95% of production companies registered in Poland (Statistical Yearbook of Industry—Poland 2017).

First of all, companies were asked if they plan to implement the concept of Smart Industry in their strategic activities now or in the near future. However, in 2018 60% of entrepreneurs have not even heard of the Industry 4.0 concept. And only 15.5% of enterprises included the idea of Industry 4.0 in their strategy (Smart Industry Polska 2018) (Fig. 1).

Among that 15.5 % of companies (30 out of 200 respondents) who have implemented the concept of Industry 4.0 in their strategy or plan to do so within the next three years, the factors having the most important impact on such a decision were

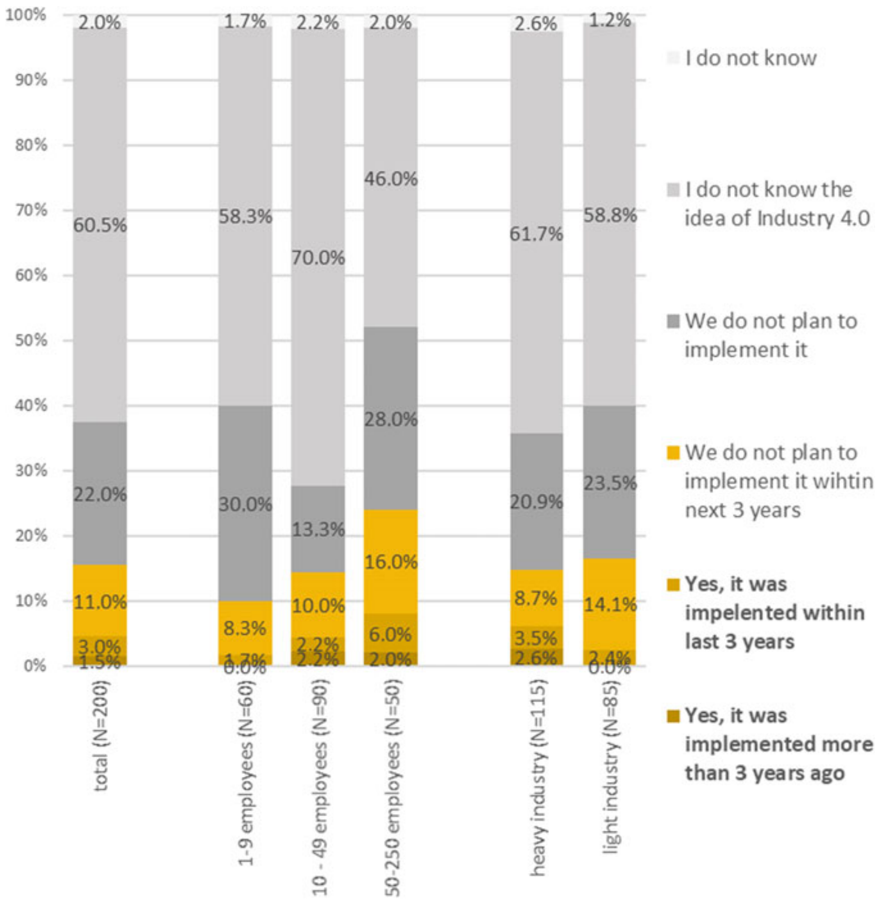

Fig. 1 Place of the Smart Industry in the companies' strategy

diagnosed. As the most important determinants of such choices respondents included the need to reduce production costs (35.5% of responses) and the need to obtain a competitive advantage on the market (22.6%). The third very important factor was the expectations of customers with regard to the increase in the quality of the products offered, so the value proposition, (9.7%), and then the expectations of customers with lower prices of products—this could also be understood as a value proposition—(6.5%) (Smart Industry Polska 2018). The indicated responses are among the factors shaping the level of company's competitiveness on the market (Fig. 2).

However, the low level of the Industry 4.0 (or Smart Industry) concept knowledge is not synonymous with the nonuse of modern technologies by these companies. SME in Poland uses different types of technologies and more than half of them use automation of production lines and data analytics. About one-third uses software helping to reduce costs of prototyping of new products and Internet of Things, 25% use robotization of production lines and less than one-fifth use other digital technologies that are in particular shown in Fig. 3. All of them illustrate the ecosystem of technologies used in Smart Industry in Poland in 2018.

The implementation of new solutions in running a business is usually accompanied by the expectation of improving the competitive advantage of the company on the market. Therefore, respondents were asked to indicate the impact of particular technologies that they use to build their market position. Based on the answers received,

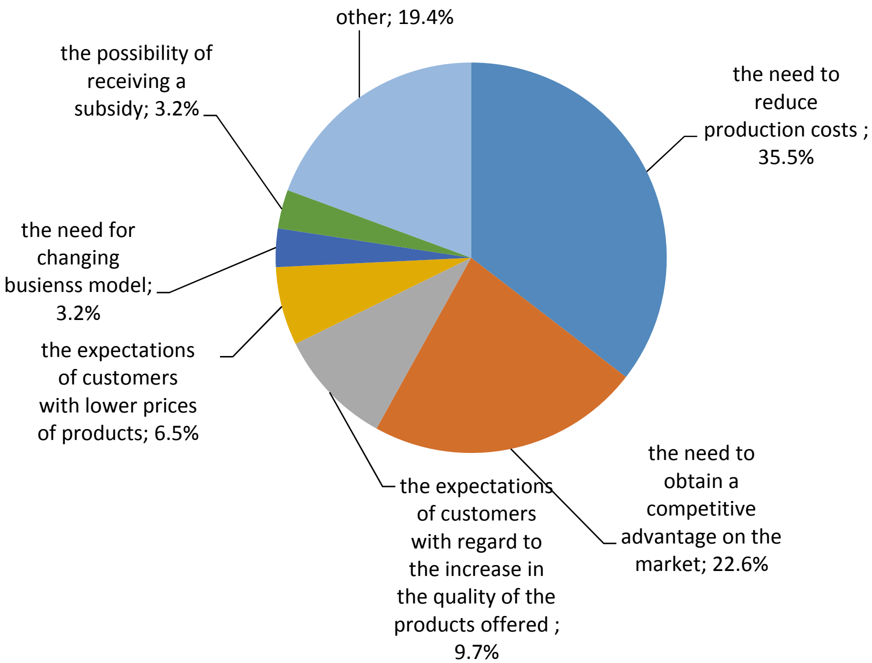

Fig. 2 Determinants of Smart Industry concept implementation

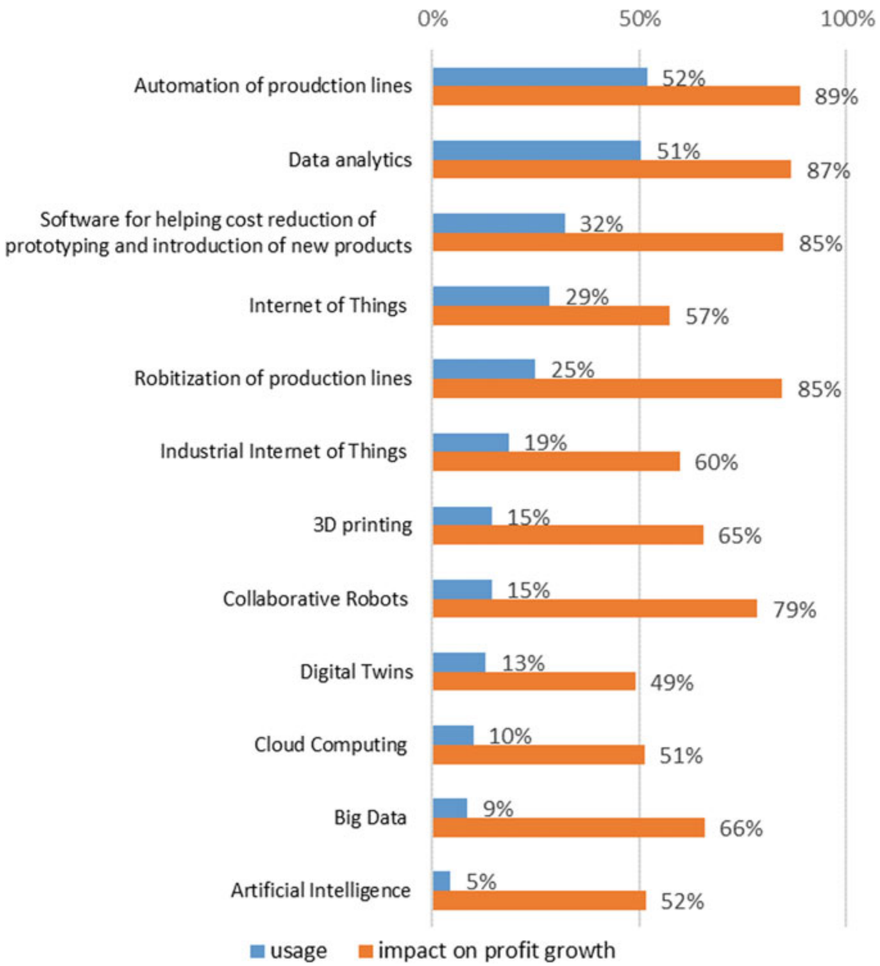

Fig. 3 Ecosystem of technologies used by the SME in Poland in 2018

it can be stated that the technologies supporting the innovativeness of the enterprise, of the greatest importance for building a competitive position, are the automation of production lines (76% respondents admitted that this solution impact on competitive advantage) and data analytics used to optimize production activities (67%). Indication of the important order of these technologies to the impact on competitiveness is the same as the frequency of their application by entrepreneurs declared. At the same time, it is interesting to indicate by the respondents the robotics of production lines as a solution with a strong impact on the market position (in total 63% consider this technology as affecting the competitive advantage) with a relatively small percentage of companies using this solution (25% on average) (Smart Industry Polska 2018).

In addition, respondents were asked about the direct role of individual technology solutions in improving the profitability of the company. The level of utilization of particular technologies (ecosystem) by companies was compared with their opinions regarding the impact of these technologies on their economic activities (Fig. 3). This comparison might serve for in-depth analyses to diagnose the low level use of technologies indicated as those whose impact on profitability is significant. From the production side it might be important to study costs of robotization of production lines introduction in the factory as the impact of this solution is rather high. The other—however more specific for particular industry and product characteristics—is 3D printing. 3D printing, however, is a technology that strongly impacts on supply chain business model that might be reconfigured or even reduced from intermediaries for direct distribution and the connection remains only between producer–consumer. The other important technology that impacts whole supply chain management is Internet of Things that is used by one-third of the companies and has quite a high impact on their profitability. Wider usage of this solution might bring even more value when considering its other features as impact on time to market, level of inventory turns or rate of replacing damaged products at the different levels of supply chain product's flow.

By pointing out in more detail areas of the impact of technological solutions in the context of competitiveness, the respondents recognized the possibility of improving the quality of products offered, increasing productivity or improving the efficiency of resource use. By the application of digital technologies, 85% of respondents expect an increase in production profitability and over 82% increase in revenues. These results show the key role of technological solutions that they can play when competiing by innovations.

Due to the innovative nature attributed to digital technologies, one could assume that the research and development departments of production companies will play an important role in the field of decision-making in these areas. However, it is not. The percentage of indications for these departments as a decisive factor in the implementation of new technologies was slightly above 21%. In addition, 45% of enterprises do not have such departments in their organizational structures (Smart Industry Polska 2018).

Additionally, the results of the study conducted in 2017 among a similar group of respondents showed that 58.6% of companies implemented innovations over the past year (Smart Industry Polska 2017). Most often they consisted of introducing a completely new or significantly improved product or service (37.8%), i.e., they were a product innovation. In the second place, they relied on the use of a completely new or significantly improved method or technology of production or delivery (32.7%), which was a process innovation. On average—in companies that introduced innovations—it was not one isolated initiative. The larger the company, the more innovation there was—on average from 1.52 in microenterprises to 1.7 in medium-sized companies (i.e., employing from 50 to 250 employees). Looking at the type and number of digital technologies implemented recently by the SME in Poland one can conclude that those results show that SME from industry sector are neither innovative within their core business activities nor in terms of using digital technologies supporting their role in smart supply chains. The opportunity given by the features of digital technologies is not used yet.

5 Conclusions

Smart Industry started to be an important concept connected directly with the fourth industrial revolution that changes not only business models of the corporation but whole economy migrating its development in the direction of further servicization. The most important driver for this migration is the digital technologies that started to be broadly implemented by innovative companies and their followers. Digital technologies are currently the basis for business model reconfiguration that leads to leveraging competitive advantages. However, not a single technology is a reason for solving problems with the competition and not even single company can win the race. First there is a need to analyze the type of technologies in terms of their features that in connection with the other technologies' features could create the best ecosystem that fits into the need of the company. The second important aspect is that the company should be understood as a system—the connected network of the companies that cooperates within the supply (value) chain to maximize competitive advantage by integration of the flows in the end to end perspective (Grzybowska et al. 2014; Awasthi et al. 2014). Thus, Smart Industry should be analyzed as a part of the smart supply chain that cooperates in an integrated manner based on digital technologies ecosystem and driven by customers' demands fluctuations.

It is important to understand the role of SME in the supply chain. First of all, they cover 95% of the companies which means that they are strong partners in each of the supply chains supporting big companies and innovators. The second aspect is that the weakest link testifies to the strength of the entire chain. Therefore, whenever there is an idea to compete with new solutions, i.e., digital technologies it must be diagnosed if the partners in the supply chain are ready to take the challenge and introduce new solutions.

The idea of the Smart Industry is starting to gain importance also among enterprises located in Poland. Still, it is not a commonly known concept and included in a strategic perspective for the development of micro and small and medium-sized industrial enterprises. It is worth noting that among those for whom Industry 4.0 is a strategic element of the market game, the main factors motivating this decision was the need to reduce production costs and the need to gain a competitive advantage. At the same time it should be underlined that SME in Poland uses different types of digital technologies that support their ability to integrate (or even create) smart supply chains. Respondents recognized even their impact on profitability. The results might be a base for further studies on how the low-level innovation companies (also not even supported by any research and development activities) could gain competitive advantages by integrating different types of flows based on digital technologies implementation or interconnection within their (smart) supply chains. The results also show the potential to introduce smart supply chain ideas within big companies as in most of the cases they also built their supply chains in cooperation with SME.

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Sustainable Supply Chains Versus Safety and Resilience

Tomasz Nowakowski, George Scroubelos, Agnieszka Tubis, Sylwia Werbińska-Wojciechowska and Maciej Chlebus

Abstract This chapter is focused on the investigation of the main concepts of supply chain resilience, vulnerability, risk, and safety in relation to the supply chain sustainability management. Moreover, the fundamental differences between these definitions are discussed. Thus, in the introduction section the authors discuss the main definitions of sustainable supply chain management and define the main relations between the investigated concepts. Later, the disruption event definition is explained. In the third section, the literature review on supply chain resilience, vulnerability, risk, and safety is given. The authors underline the main perspectives and contexts of these concepts definitions. The performed state of the art gives the possibility to define the main relations between these concepts and sustainable supply chain management. The case study conducted in the automotive company presents the main classification of disruption events that can occur during the production processes performance. The conducted analysis gives the possibility to highlight the necessity of performing the multidimensional analysis performance in order to properly manage sustainable supply chain. The work ends up with conclusions and directions for further research.

Keywords Supply chain management · Resilience engineering · Risk analysis · Hazard event

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1 Introduction

Nowadays, globalization, challenging market, demand uncertainty, and recent economic competitiveness cause that supply chains sustainability performance issues are of immediate importance (Ansari and Kant 2017). The topic of sustainability in the context of supply chain management has been discussed using a number of terms in the literature. Based on this and following (Gulati et al. 2010) the term sustainability is defined as *a development that meets the needs of the present without compromising the ability of future generations to meet their own needs*. The business sustainability is usually perceived in the context of *creating resilient organizations through integrated economic, social, and environmental systems* (Bansal 2010). The author in Wolf (2011) define the sustainable supply chain management (SSCM) as *the degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organization processes for sustainability*. A different view is provided by the authors in (Closs et al. 2011), where SSCM is defined as *a reflection of the firm's ability to plan for, mitigate, detect, respond, and recover from potential global risks*. The definition of sustainable supply chain management based on life cycle approach implementation is given in (Haake and Seuring 2009). The authors define the SSCM as *the set of supply chain management policies held, actions taken, and relationships formed in response to concerns related to the natural environment and social issues with regard to the design, acquisition, production, distribution, use, reuse, and disposal of the firm's goods and services*. However, in the most commonly approach to SSCM, the sustainable development of supply chains is *usually comprehended in an economic, an environmental, and a social dimension* (Ciliberti et al. 2008; Font et al. 2008; Grzybowska et al. 2014; Grzybowska and Lupicka 2017; Seurig 2013; Seurig and Muller 2008).

Taking one step further, requirements for successful SSCM implementation include organizational culture, strategy, risk management, and transparency (Alexander et al. 2014). As a result, meeting environmental and social standards along all stages of the supply chain gives the possibility to assess the minimum sustainability performance. Thus, there is made an assumption that logistic flows in many industries strive to be lean, responsible, and agile (Svensson 2000).

However, in today's uncertain environment, supply chains may be disrupted in many ways in their daily operations. This situation takes place in all sectors of the economy, regardless of the level of chain integration. The only difference is the type of adverse events that should be subject to risk analysis prepared for the needs of cooperating business participants. For this reason, it is currently difficult to effectively manage the supply chain without regularly analyzing the existing hazard events and implementing solutions aimed at risk management. This approach becomes particularly important when we talk about supply chain management in accordance with the concept of sustainable development. The performed risk assessment must be focused in this case not only on the risks related to economic aspects that are the goal of the business. In the center of attention of persons identifying adverse events, it is equally important to study risks affecting the environment and people. The need to adapt the

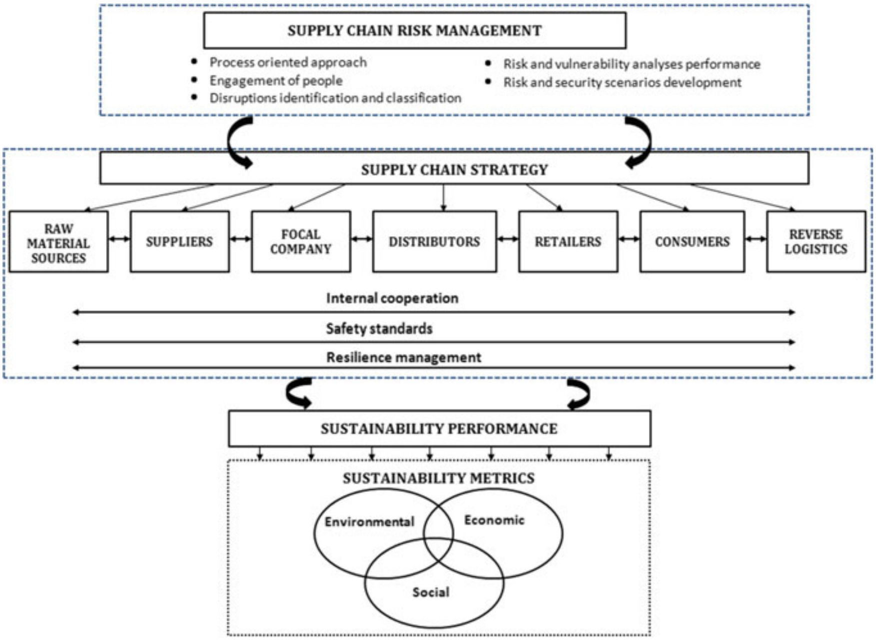

Fig. 1 The supply chain sustainability in relation to resilience, vulnerability, safety, and risk *Source* Own contribution based on Ansari and Kant (2017), Quorri et al. (2018), Seurig and Muller (2008)

operation of supply chains in such an uncertain and volatile environment has caused the need to formulate new characteristics, like vulnerability, safety, and resilience. The main relations between these concepts are presented in Fig. 1.

Consequently, the aim of this paper is to present and discuss the main terms of supply chain resilience, vulnerability, risk, and safety by giving some explanations of the fundamental differences between the mentioned concepts. The authors also focus on the main relations between the mentioned concepts and SSCM.

The structure of the paper is as follows: In the introduction section, the authors present the main definitions of a sustainable supply chain and defines the main relations between the investigated concepts. In the next section, the disruption event definition and its classification in terms of company's performance level are explained. In the third section, the literature review on supply chain resilience, vulnerability, risk, and safety is given. The performed state of the art gives the possibility to define the main relations between these concepts and SSCM. The case study conducted in the chosen company from automotive industry is presented. The work ends up with conclusions and directions for further research.

2 The Disruption Definition and Classification

Supply chain vulnerability, resilience, risk, and safety have become a field of research over the past 15 years, and a number of definitions have been made (Berle et al. 2011; Sheffi 2007). In order to properly explain these concepts, first the disruption definition and disruption profile should be explained.

Any threat which could cause an interruption in the flow from raw material to the end user is a supply chain risk and any interruption in the flow of material is a supply chain disruption (Sapna Isotupa et al. 2014).

Disruptions can be divided into three categories to facilitate estimating their likelihood (Sheffi 2007): natural disasters, accidents (faults, failures), intentional attacks, and the methods of estimating their likelihood are different.

Moreover, based on Chapman et al. (2002), Mascaritolo and Holcomb (2009), Singhal et al. (2011), main supply chain disruptions may arise from such sources as:

- natural disasters, such as earthquakes, cyclones, epidemics,
- terrorist incidents,
- accidents, like the fire of supplier's factory, or
- operational difficulties, connected, e.g., with variability in supply, demand uncertainties, price variability.

Svensson in his work (2000) considers them in terms of analysis inbound logistic vulnerability and divides them into direct and indirect sources of disturbance. Moreover, following Longo and Oren (2008), terrorist attacks, wars, politic problems or natural disasters should be considered as risks external to the supply chains. Risks related to processes and activities should be considered as internal to the company, and risks coming from the market or from suppliers should be considered as external to the company and internal to the supply chain.

When supply chain disruptions are defined in terms of unexpected events occurrence, they can be described as having uncertainty in logistic process operation (Werbińska-Wojciechowska 2013). Uncertainty in the process is connected with definition of perfect operation of logistic system and may be described by 7R formula: Right product, Right quantity, Right quality, Right place, Right time, Right customer, and Right price. Thus, different aspects are taken into consideration, such as (Werbińska-Wojciechowska 2013):

- time (in the sense of duration of activity/process, starting/ending moment of activity realization, frequency of activity/demand occurrence),
- quantity (of supply, demand or physical transfer of goods),
- location/place (where activity starts/ends),
- quality (of service/products),
- cost (fluctuation, occurrence).

However, not every disruption occurrence leads to a logistic system failure appearance. The critical factor which determines the logistic system failures is time. In a situation, when disruption (connected with, e.g., improper delivery quality/quantity, improper location) occurs, there is a necessity to find out if we have enough time to correct the problem. When the spare time lets us remove the disruption—logistic system is not defined as failed. In other words, time redundant system has the ability to tolerate interruptions in their basic function for a specific period of time without having a negative impact on the system task performance.

Typically, the time redundant systems have a defined time resource that is larger than the time needed to perform the system total task (Werbińska-Wojciechowska 2013). Time redundancy is to take additional time to complete the task (in relation to the time necessary for its execution), which can be used to restore the state of the system or improve its technical characteristics. This means that the system with time resource tolerates faults with a short (usually specified) duration.

Any significant disruption will have a typical profile in terms of its effect on company performance. The performance is measured by sales, production level, profits, customer service or another relevant metric (Sheffi 2007).

Following this, in the next section, the main definitions and literature review on the analyzed supply chain concepts are provided.

3 Resilience, Vulnerability, Risk, and Safety of Supply Chains—Definitions and Literature Review

Currently, in the literature on resilience, vulnerability, risk, and safety of supply chains one can find a lot of ideas, definitions, and methods that can be implemented to manage sustainable supply chain (Sheffi 2006, 2007). Therefore, it is worth discussing each of these concepts separately in the first step.

3.1 Concept of Resilience of Supply Chains

The importance of supply chain resilience issues may be confirmed, e.g., by the Supply Chain Resilience Reports in which the challenge of developing resilient supply chains are considered since 2009 (Supply Chain Resilience reports 2009, 2010, 2011, 2012, 2013). The reports highlight the level, range, and cost of disruptions that organizations face, and demonstrate how a disruption in one organization can spread out over the entire supply chain (Supply Chain Resilience report 2013). One of the most important key findings results from the last report (Supply Chain Resilience report 2013), is that about 75% of respondents still do not have full visibility of their supply chain disruption levels (survey of 579 respondents from 71 countries).

The concept of resilience is now widely analyzed in many research areas, such as engineering, social sciences, and economics (Elleuch et al. 2016). Therefore, one common definition of this concept cannot be presented for different technical systems or organizations. The Online Compact Oxford Dictionary (2014) defined resilience as *the (a) ability to withstand or recover quickly from difficult conditions; (b) the ability to recoil or spring back into shape after bending, stretching, or being compressed*. For example, in work (Fiksel 2006) resilience is defined as *the ability of enterprises to survive, adapt, and develop in the light of changes and uncertainty*. For technical systems, resilience generally means *the ability to recover from some shock, insult, or disturbance, the quality or state of being flexible* (Bouchon 2006). Later, in Bukowski and Feliks (2011) the definition of technical systems resilience was determined *in the context of readiness for safe and acceptable performance in abnormal (rare) working conditions (e.g., disruptions, attacks, accidents, and catastrophe).*

One of the articles devoted to the review of literature in the field of resilience engineering (RE) is work (Patriarca et al. 2018), where the authors analyze publications from a given scientific area from the period 2004–2016. Based on the assumptions of the meta-analysis (Shafique 2013), the authors select 472 publications, including articles from scientific journals, conference materials and chapters in books. They focus on five studied scientific issues—the need for RE, RE for modeling, defining and exploring RE, reflecting on RE, and RE managing and improvisation. In the next paper (Nowakowski 2013a), the author discusses the concepts of vulnerability and resilience and examines the relationship between these concepts, reliability, and risk. A broad review of the literature in the area of defining the concept of resilience is also presented in the works (Francis and Bekera 2014; Hosseini et al. 2016).

With regard to supply chains, the concept of resilience is defined in terms of—their flexibility, agility, speed, transparency, and redundancy (see e.g., Creating a Resilient Supply Chains: A practical Guide. Cranfield School of Management 2003). In Ribeiro and Barbosa-Povoa (2018), the authors present a broad overview of the definition of this concept in relation to four perspectives: focus event, performance level, speed, and adaptive framing. The problem of supply chain resilience in the context of risk management for the chain infrastructure and the ability to reconfigure chain resources is discussed in detail in Ambulkar et al. (2015).

Some of the recent literature reviews in the field of supply chains resilience can be found, among others, in the works (Briano et al. 2009; Brusset 2013; Carvalho et al. 2012; Chowdhury and Quaddus 2017; Christopher and Peck 2004; Haffenen et al. 2012; Kamalahmadi and Parast 2016; Longo and Oren 2008; Ponis 2012; Schoon 2005). On the other hand, in the work (Levalle and Nof 2017), the authors focus on research on the resilience of logistics networks.

At the same time, Table 1 presents the chosen definitions of supply chain resilience proposed in the literature.

3.2 Concept of Vulnerability of Supply Chains

Currently, there are a lot of works covering issues of vulnerability of technical systems (critical infrastructure, transport systems, etc.). At the same time, the term vulnerability is defined in various ways, depending on the research area or research methods used by the authors. In work (Schoon 2005) author identifies trend in the definitions of vulnerability, resilience, and adaptation concepts, providing a short

Table 1 Chosen definitions of supply chain resilience

Sources	Definitions
Berle et al. (2011)	*'the ability of the supply chain to handle a disruption without significant impact on the ability to serve the supply chain mission'*
Christopher and Peck (2004)	*'is the ability of a system to return to its original state or move to a new, more desirable state after being disturbed'*
Jüttner and Maklan (2011)	*'the apparent ability of some supply chains to recover from inevitable risk events more effectively than other'*
Pereira et al. (2014)	*'the ability of the supply chain to react quickly to unexpected events, to restore operations to the previous functional level, and even to a new, better one'*
Rice and Caniato (2003)	*'the ability to respond to unexpected disturbances and restore normal operations of the supply network'*

historical overview of their developments. Later, the author of the paper (Haimes 2006) analyzes the concept of vulnerability in the aspect of measuring and assessing the risk of operating systems. In turn, the authors of the paper (Johansson and Hassel 2010) present three perspectives for the analysis of technical systems vulnerability—an approach to assess vulnerability of global system threats, assess vulnerabilities to system components, and examine the system in terms of geographic location of its elements and its impact on the vulnerability level for threats. The proposed vulnerability assessment model has been implemented in the area of operation of the electrified railway network. In the next work (Tixier et al. 2012) authors present thirty-seven definitions of vulnerability term depending on the source and scientific area. Moreover, in work (Nowakowski and Valis 2013) the author tries to specify how to understand and define terms vulnerability, dependability, and risk. The state of the art on vulnerability issues may be found also in, e.g., Nowakowski (2013a, b), Nowakowski and Werbińska-Wojciechowska (2014), Nowakowski and Valis (2013), Proag (2014), Restel (2015), Taylor and D'Este (2007), Valis et al. (2012).

The term supply chain vulnerability also has been studied and defined by researchers in various ways. For example, supply chain vulnerability can be defined as *an exposure to serious disturbance, arising from risks within the supply chain as well as risks external to the supply chain* (Chapman et al. 2002). Svensson, one of the most widely cited authors in this field, placed vulnerability and related concepts, such as risk, uncertainty, and reliability, within the context of the wider concept of contingency planning (Svensson 2002a, b, c). In his work (Svensson 2002a, b, c), he defined vulnerability as *the existence of random disturbances that lead to deviations in the supply chain of components and materials from normal, expected or planned schedules or activities, all of which cause negative effects or consequences for the involved manufacturer and its subcontractors*. This definition was the base for developing a model consisting of three principal components, namely: source of disturbance, category of disturbance, and type of logistics flow. Later, in Svensson (2002a, b, c), author constructed the vulnerability consisting of the two components:

disturbance and the negative consequence of disturbance. This approach referred to the focal firm's inbound and outbound logistics flows and corresponded to the direct source of disturbance in the model of vulnerability introduced in Svensson (2002a, b, c). In the next work (Svensson 2002a), author investigated vulnerability consisted of two components, namely time-dependence and relationship dependence, which can occur in marketing channels. The higher the dependence the higher is the level of perceived vulnerability. Following this, author in his next work (Svensson 2004) based on the assumption that the gap between perceived dependence and perceived trust influences, and has an impact on, companies' perceived vulnerability in business relationships towards suppliers and customers. The present research studies are typically surveyed perceptions of supply chain-related risk in an organization's purchasing department or its first-tier supplier base.

To sum up, some of the researchers studied supply chain vulnerability, e.g., conceptually (see, e.g., Peck 2006; Svensson 2000, 2002c), or mathematically (see, e.g., Aleksic et al. 2014; Bogataj and Bogataj 2007; Huang 2012). There are also some works which are aimed at investigation of supply chain management issues in the view of their vulnerability and resilience characteristics (see, e.g., Kurniawan and Zailani 2010). Moreover, in the last 10 years there are few developed research works presenting some empirical study for the concept definition, measurement, and investigation of the relationships between supply chain vulnerability and its performance level (see, e.g., Svensson 2002a; Wagner and Neshat 2012) as well as the supply chain risk management practices (see, e.g., Thun and Hoenig 2011).

Most of the known supply chain vulnerability definitions are consistent that this concept in a multidisciplinary approach is determined by certain characteristics, supply chain design variables, and environment (Wagner and Neshat 2012). Some summary of vulnerability definitions in the context of supply chain performance was presented, e.g., in works (Briano et al. 2009; Longo and Oren 2008; Nowakowski 2013a; Nowakowski and Werbińska-Wojciechowska 2014).

Moreover, it should be underlined, that several scientific research works on supply chain vulnerability were developed considering specific supply chain sectors or technical systems. There were articles on supply chain risk/vulnerability, which dealt with aspects of, e.g., maritime transportation system (see, e.g., Berle et al. 2011), transportation systems (see, e.g., Klibi and Martel 2012; Lupicka et al. 2018; Walkowiak and Mazurkiewicz 2013), power systems (see, e.g., Hofmann et al. 2012), or critical infrastructures (see, e.g., Kroger 2008; Zio and Kroger 2009).

Table 2 provides some recent definitions of supply chain vulnerability.

The nature of the disruption and the dynamics of the system response can be characterized by the main eight phases presented, e.g., in Nowakowski and Werbińska-Wojciechowska (2014). Key parameters of vulnerability are the stress to which a system is exposed, its sensitivity, and its adaptive capacity (Adger 2006). When reducing vulnerability, one reduces the likelihood of a disruption occurrence and increases resilience. Thus, supply chain managers need to have the ability to measure and quantify the vulnerability of their supply chains (Wagner and Neshat 2012). The main questions being involved in vulnerability assessment include: What can go wrong? What is the likelihood of that happening? What are the consequences if it does happen?

Table 2 Chosen definitions of supply chain vulnerability

Sources	Definitions
Christopher and Peck (2004)	*'an exposure to serious disturbance, arising from risks within the supply chain as well as risks external to the supply chain'*
Jüttner et al. (2003)	*'the propensity of risk sources and risk drivers to outweigh risk mitigating strategies, thus causing adverse supply chain consequences'*
Svensson (2002b)	*'condition that is caused by time and relationship dependencies in a company's business activities in supply chains. The degree of vulnerability may be interpreted as proportional to the degree of time and relationship dependencies and the negative consequence of these dependencies, in a company's business activities towards suppliers and customers'*
Wagner and Neshat (2012)	*'is a function of certain supply chain characteristics and that the loss a firm incurs is a result of its supply chain vulnerability to a given supply chain disruption'*

3.3 Concept of Risk of Supply Chains

In the literature one can find many different definitions and meanings of the concept of risk (Aven 2012; Hampel 2006), methods of its analysis and evaluation (e.g., Aven 2010; Brown and May 2003) and procedures for using the effects of risk analysis in the decision-making processes carried out by managers. In colloquial language, the risk is usually associated with the measure of hazard/threat, which is a consequence of random events that are independent of us (Serafin 2013). According to the PN-ISO 31000 (2010) standard, risk is defined as *the effect of uncertainty on objectives*. The development of this definition can be found, for example, in Aven (2016), where the authors state that the existing definitions of risk express essentially the same idea, adding the dimension of uncertainty to events that may occur and the consequences that this entails. On the other hand, Wilson in his work (2005) defines the risk as *an assessment, significance, size, and essence of the loss, which may be the result of a specific action, regardless of whether the action is initiated by the organization or whether the organization is subject to its influence*. In the frame of this definition, risk is a measurable effect of uncertainty. A broader overview of the risk definition can be found, among others, in the works (Aven 2012; Goerlandt and Montewka 2015).

The carried out literature review allows to state that the risk is a combination of the probability of an event occurring with its consequences. The risk is closely related to the uncertainty of the effects of a given action. The effects can have a serious impact on the achievement of the objectives set for a given organizational unit. It is important that the risk can take on two levels. This is due to the fact that the occurring events are either negative with signifying a loss or positive with creating a certain value.

Table 3 Chosen definitions of supply chain risk

Sources	Definitions
Bogataj and Bogataj (2007)	*'potential variability of results that affect the decrease of value-added in any activity in the supply chain'*
Juttner et al. (2003)	*'any risks related to the flow of information, materials, and products from sources of supply to the place of delivery of the final product to the end user'*
Zsidisin and Richie (2008)	*'the probability of occurrence of an incident related to the delivery supply process resulting from the failure of a single supplier or supply market, in which its results cause the inability of a distribution company to meet customer requirements or pose threats to the customer's life and safety'*

Currently, there is no single common definition for determining the concept of supply chain risk or Supply Chain Risk Management (SCRM) (Sodhi et al. 2012). In the literature, one can find works that define the concept of supply/delivery risk (e.g., Ellis et al. 2010) or supply chain risk (e.g., Bogataj and Bogataj 2007; Jüttner et al. 2003; Zsidisin and Richie 2008). The exemplary definitions are presented in Table 3. These definitions usually refer to a specific area of the logistics chain performance, the risk related to the implementation of information or material flows. In the paper (Ho et al. 2015), the authors propose a more comprehensive definition of supply chain risk *as the probability and impact of unexpected events or conditions at the macro and or micro level that negatively affect any part of the supply chain, leading to operational, tactical or strategic failures*.

An extensive review of the literature on supply chain risk is given in (Rao and Goldsby 2009), where the authors classify existing literature on the typology of risk sources, consisting of environmental factors, industry factors, organizational factors, problem-specific factors and related to the decision-making process. This problem is also continued, for example in Vilko and Hallikas (2012), where the authors map the processes and structure of the multimodal marine supply chain and present the risk classification framework in terms of the main risk factors. In addition, the authors analyze the influence of risk in terms of delays occurring in the chain by Monte Carlo simulations use. Moreover, the analysis of the issue of designing supply chains in the aspect of the decision-making process affected by uncertainty and risk is presented in the work (Ivanov et al. 2016). The paper presents a review of the literature analyzing the possibilities of using selected quantitative methods in the aspect of analysis and assessment of various types of risk as well as measures assessing the resilience of chains.

To sum up, in order to prevent vulnerability, it is essential to manage risks in chains through creating more resilient supply chains that are able to respond to disruptions and adapt themselves to necessary changes (Christopher and Peck 2004). Risk managing in supply chains is the function of supply chain risk management, according to the definition presented, e.g., in Christopher and Peck (2004). More information can be found, e.g., in Singhal et al. (2011), where authors provide a comprehensive review and classification of supply chain risk management literature. In addition, literature reviews in the area of risk management in supply chains can be found, among others, in works (Ceryno et al. 2013; Ghadge et al. 2012; Qazi et al. 2015; Ouabouch and Paché 2014; Singhal et al. 2011).

3.4 Concept of Safety of Supply Chains

The last concept that needs comprehensive investigation is system/object safety. *The safety of objects/systems is a complex issue and should be considered in a multidimensional sense* (Huczek 2015). Therefore, many definitions of safety can be found in the literature, depending on the research area in which the issue is addressed. In the aspect of crisis management, the following are safe: *an individual, a social group, a nation, an institution, a state, when they do not feel threatened for their being and their existence, are calm and confident in their interests, do not need someone to look after them* (Huczek 2015). In terms of system analysis, safety is captured in two dimensions:

- as the property of an object characterizing its resilience to dangerous events (threats),
- the system's ability to protect internal values against external threats.

Thus, safety means the absence of critical/dangerous events while security is focused on protecting system environment against the effects of these damages. Safety is measured generally by risk—two-dimensional combination of probability of an undesirable event and possibility of loss (consequences). Risk assessment consists of the process of risk identification related to threat, includes its possibility (likelihood or probability), impact, and consequences (Nowakowski and Werbińska-Wojciechowska 2014).

After the attacks of September 11, 2001, safety issues in supply chains have gained significant importance (Williams et al. 2008). Since then, the concept has been rapidly developing in the context of risk management in supply chains (Williams et al. 2008).

One of the more frequently cited definitions of supply chain safety is that proposed by Closs et al. (2004) (Table 4). This definition is multidimensional and refers to both

Table 4 Chosen definitions of supply chain security/safety

Sources	Definitions
Closs et al. (2004)	*'managing supply chain safety means applying policies, procedures and technologies to protect supply chain resources (products, equipment, information, and personnel) against theft, damage or terrorism and preventing the entry of smuggling and unauthorized people or weapons of mass destruction into the supply chain'*
ISO 28000:2007 (2007)	*'resilience to intentional unauthorized actions aimed at causing damage or failure to the supply chain'*

material and information flows, being carried out in the logistics chain. A similar context of understanding the concept of supply chain safety is presented in Rice and Caniato (2003), where the authors define three groups of tasks related to the safety of supply chains including physical security, information security, and freight security. Moreover, the author (Huczek 2015) defines the security of the logistic system as a non-threaded state of logistic objects, connections (external and internal supplies), an environment and users. The analysis and classification of the main threats to supply chain safety are presented in Huczek (2015).

A detailed review of the literature from the studied research area can be found, among others, in the works (Acciaro and Serra 2013; Colicchia and Strozzi 2012; Gould et al. 2010; Williams et al. 2008). Table 4 presents examples of supply chain safety definitions given in the recent literature.

4 Sustainable Supply Chains and Main Relations Between the Concepts of Resilience, Vulnerability, Risk, and Security

The concepts presented above form the basis for developing various vulnerability scenarios for supply chains. These scenarios have been discussed in more detail, among others, in work (Nowakowski 2013b). In available models, global chain capability focused on three elements (Kroger and Zio 2011):

- the degree of loss and damage as a result of the threat occurrence;
- the degree of exposure to hazards; vulnerability of the element to the risk of loss and damage;
- the degree of resilience; the ability of the system to anticipate, deal with, absorb, rebuild, and recover from the impact of a threat or disaster.

At the same time, the growing need to ensure safety and increase the resilience of operating logistics systems to emerging threats has translated into the need to develop standards that will allow standardization of the procedures conducted by participants in supply chains in the area of risk management. There are currently various standards defining the ways of risk management. The most well-known standards include COSO (corporate risk management—integrated framework structure); Risk management standard FERMA—AIR-MIC/ALARM/IRM; Australian Standard AZ/ZNS 4360; Standard PN-ISO 31000: 2012 Risk management—principles and guidelines; ISO 28000 standard—Safety management system in the supply chain.

Therefore, based on existing models of vulnerability (e.g., presented in Bouchon 2006; Kroger and Zio 2011; Scheffi and rice 2005), it is possible to determine the basic relationships between the analyzed concepts (Fig. 2). The proposed in the Fig. 2 framework systematically integrates four major components (vulnerability analysis, resilience measurement, risk management, and supply chain performance metrics) in order to provide sustainable supply chain.

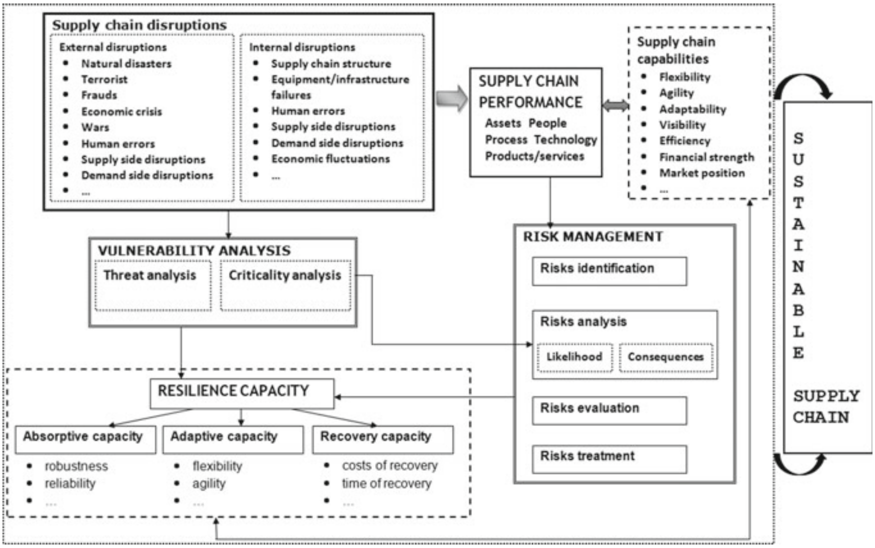

Fig. 2 Relationships occurring between the analyzed concepts in the aspect of supply chain operations—framework for creating a sustainable supply chain

The starting point for the development of SSCM is to identify, classify, and analyze the existing and possible to occur hazard events. During this phase, managers should also group the defined disruptions (and classified according to vulnerability theory) into three main areas—economic, environmental, and social. The obtained results from vulnerability analysis are the basis for resilience measurement system development and supply chain performance assessment. First, supply chain practitioners should develop a supply chain and resilience management aims and scope, including the definition of resilience policy or scope of measurement. They should:

- identify major performance processes and decompose them into sub-processes and activities (the process decomposition can be performed according to the guidelines given in, e.g., Chan and Qi 2003),
- set objectives with resilience and supply chain performance measures selection,
- aggregate individual metrics into one performance system,
- measure and track resilience and supply chain performance level,
- report results.

The obtained results are the base for risk management performance. The main steps for the risk management process should be compatible with known standards, mentioned above. The results in the form of guidelines, risk assessment, risk scenarios are implemented into supply chain sustainability strategy.

After this process is finished for the focal company, the same processes can be repeated for other supply chain members to identify sustainability goals, policy, and measures for the inter-organizational processes performed.

Although this framework does not provide specific sustainability solutions (e.g., metrics), it should be used as a guide on how and what needs to be done to provide/create sustainable supply chain with taking into account uncertain performance conditions.

5 Case Study

The problem of hazard events supervising and managing is presented in the case of a production company from automotive industry. The analyzed production company is focused on the production of automotive parts, which are mostly elements of trucks. The offered products are designed to provide adequate protection for the driver and improve his control over the vehicle being driven. In addition, the introduced technological novelties are used by the company's customers for the production of trailers, coaches, and roadsters. Increased driver control is ensured, inter alia, by improving the braking system, innovation in the area of gear changes and suspension improvement. The company is constantly developing newer technologies that are to further improve the driving experience.

The company currently cooperates with over 500 foreign and local deliveries of components. The company offers more than 4000 products that are delivered to customers. The company's headquarter is located in Europe. The facility described at the Chapter is located in Poland, in the Lower Silesia Voivodship.

In the described enterprise are two main production halls. There are six departments in the company: there are two departments in hall no. 1, and four sections in hall no. 2, which deals with the production of, among others, main and auxiliary valves. The department described in the work is located in hall no. 1 and is the largest department in the company. It has over 40 production lines and occupies about 1/3 of the entire production hall.

The plant produces large-scale products. This is mainly the assembly of components that are delivered. On the production line, operators in specific positions deal with the assembly according to a specific instruction and production plan that is currently in force on the line. Then the product is tested. The next stage is quality control, later the product is packaged according to the packing plan prepared for this product. Each product is packed in a plastic bag, then goes to the carton, where it is separated by spacers. The package contains a specific number of layers of the product. The production is organized according to three-shift work.

The production process is presented in Fig. 3.

Fig. 3 The main steps of the analyzed company's production process

The operational performance of production processes is possible due to the efficient operation of the IT system. It is used, among others, for ordering components from the supplier and Kanban parts, verifying Kanban tables, verifying parts in the factory and their availability in the warehouse, as well as verifying Kanban movements. In addition, the analyzed case company uses the Just In Time system supported by Kanban cards to ensure the right flow of materials, without the need for stockpiling.

Moreover, in the enterprise, great attention is paid to the evaluation of the effectiveness of the processes carried out through the prism of emerging disturbances. Of particular importance are the problems appearing on production and their impact on the level of so-called Lost Time management index.

Currently, there are defined 16 types of so-called disturbances that mostly regard to social and environment factors:

1. Production break (unscheduled and scheduled breaks during the working shift)
2. Meetings (meetings of production workers)
3. PM1 (Preventive maintenance action performance)
4. 5S (all actions connected with 5S implementation and maintenance)
5. Conversion (all production plants conversions during the working shift)
6. Failure events (instrumentation)
7. Failure events (tester)
8. Lack of parts (due to quality)
9. Lack of parts (due to logistics)
10. Training
11. Settings/regulations
12. The line is taken by an engineer
13. Error analysis
14. The accuracy and lubrication of parts
15. Measurement of moments
16. Others

The exemplary results showing the level of time loses in the company for 2018 (for working weeks 1–44) for the selected production line of division no. 1 are given in Fig. 4. Figure. 5 presents the details of production lost time in 35 weeks of 2018 according to the selected group of hazard events occurrence.

Monitored disturbances presented in the form of such defined indicators do not allow to identify the source of the threat in a direct way. At the time of major delays caused by the occurrence of a given disturbance, managers are forced to undertake additional analyses examining the actual reasons for its occurrence. An example can be a disturbance no. 9. The source of the unwanted events can be an IT system, an employee of the logistics department or a supplier. For each of these defined reasons, the manager managing the process can react in various ways. The introduction of hazard assessment indicators at such a high level of generality does not allow to monitor the effectiveness of the improvement actions undertaken. Changes in the purchasing process at a given supplier, aimed at improving the timeliness and completeness of deliveries, may mean the implementation of new solutions.

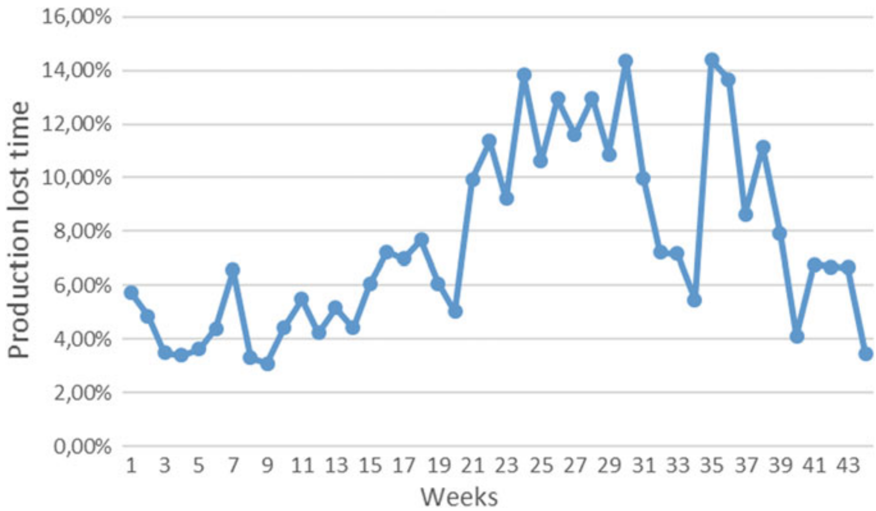

Fig. 4 The lost time level (%) for the chosen production line in the division no. 1 during the 44 working weeks of 2018 of the selected production company

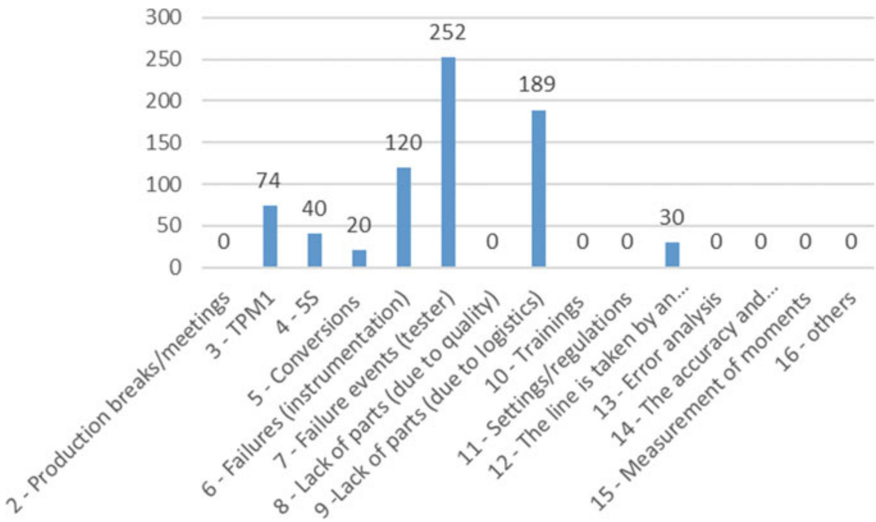

Fig. 5 The lost time (in minutes) in the 35 weeks of 2018 in the production company—Pareto diagram for the defined groups of disturbances

These new solutions in the first months of operation may generate errors caused by the employee of the logistics department, which will affect further occurrence of missing materials on production. In this way, the assessment of the effectiveness of the implemented solution may be incorrect.

Such a defined risk measurement system may also lead to erroneous inferences. If the occurring delays result from the occurrence of the event no. 2 or no. 10, managers may limit the number of meetings and trainings in order to reduce the occurring delays. Such action is in contradiction with the concept of sustainable development. Both meetings and trainings have a developmental character and influence the quality, safety, and comfort of the team's work.

It should also be noted that not all events defined by the company as a disturbance are negative. Their occurrence may decide about occupational health and safety provision (e.g., event no. 3 or 4) and, in this way, they should not be limited.

In the frame of the concept of sustainable development, the company should, therefore, significantly modify the scope of monitored disturbances in the production process, which would be aimed at improving the process, taking into account social and environmental aspects, not only economic in terms of time delays.

6 Summary and Conclusions for Research Work

When assessing the risk for logistic processes performed in accordance with the concept of sustainable development, managers should monitor not only events that introduce delays in production, but above all they should analyze adverse events that affect the safety of employees, the environment and the economic stability of the enterprise. Numerous concepts of safety, resilience, and risk in supply chains can be found in the literature. However, there is a lack of a structured set of measures and indicators aimed at measuring risks specific to individual sectors of the economy and taking into account sustainable development. Examples of solutions used in the surveyed enterprises indicate that also managers see the problem related to the measurements being carried out, which do not correspond to the concept of sustainable development. However, they point out in interviews that they lack access to good practices that they could use in their processes performance. The development of a performance measurement system based on literature studies, guidelines of European organizations operating in the area of sustainable development (e.g., OSHE) and case studies from enterprises representing various sectors of the economy could provide solutions for enterprises operating under specific market conditions. Thanks to this, managers could use the developed solutions that would adapt flexibly to the needs of the processes they manage. The development of such a system, taking into account the specificity of the industry, will be the subject of further research carried out by the authors.

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Digitalization of Supply Chain Transparency: The Case of ChainReact

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Abstract Industry 4.0 revolves around digital augmentation of production processes—from design to utilization. It promises new business models, business–customer relationships, product innovations, but also unprecedented transparency and control, translating into new levels of sustainability in various areas (environmental impact of production, human rights in supply chains, etc.). The current vision, derived from technological advances in big data, cloud computing, IoT, distributed ledgers, suggests that the satisfactory levels of sustainability will emerge almost "magically", by the sheer concentration of transparency and reporting capable technical solutions. The case of WikiRate.org, and its ChainReact program, nuances these assumptions. First, it demonstrates that technology can be used already to promote business social responsibility without the full Industry 4.0 in place. Even more importantly, it shows that technology alone is not likely to assure sustainability. ChainReact process shows that promoting transparency, empowering various stakeholders of production processes, and eventually pushing for positive change are as much about building production and supply chain data ecosystem, as about getting companies' buy-ins, organizing research groups, and working with legislators. The current WikiRate experience can update our thinking on how promoting sustainability could realistically look like in a fully realized world of Industry 4.0.

Keywords Sustainable supply chain · Digitalization · Supply chain transparency · Supply chain data ecosystem

1 Introduction

Even the reluctant economists from IMF and World Bank admit that we are experiencing the next turning point in the modes of industrial production, which adds to the transformation of society, economy, and politics under the impact of information

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and communication technologies (IMF, Measuring the Digital Economy 2018). The chapter aims at empirical anchoring of the theoretical assumptions that the newest technological solutions, particularly those connected with the lump idea of Industry 4.0. will substantially contribute to sustainability of supply chains. We use the example of an advanced tool created by the Horizon 2020 project ChainReact to bring out the opportunities stemming from the refined integration of data and its presentation in a clear and concise manner. The data may be then used by media and NGOs in order to track the activities of large corporations in their supply chain ecosystems.

2 Why Sustainable Supply Chain Must be Transparent?

The concept of sustainability is well-grounded in macroeconomic debates concerning the activities of both public institutions and industries. The growing awareness of the social and environmental problems accumulated over the years through irresponsible resource management and human rights abuses have raised expectations that companies will seek more ethical ways to achieve their goals. But the intermittent progress of globalization borne out an important conceptual problem: a company wielding a specific brand may be only the cap of a wide and geographically scattered chain of suppliers and subcontractors. Hence the attention of both activists fighting for sustainable development and researchers delving into theoretical intricacies of the term is being redirected to supply chains (Rajeev et al. 2017; Ansari and Kant 2017).

A sustainable supply chain (SSC) allows for environmentally and socially responsible management of its economic and noneconomic areas. One of the exemplary definitions describes the SSC as "the creation of coordinated supply chains through the voluntary integration of economic, environmental, and social considerations with key interorganizational business systems designed to efficiently and effectively manage the material, information, and capital flows associated with the procurement, production, and distribution of products or services in order to meet stakeholder requirements and improve the profitability, competitiveness, and resilience of the organization over the short- and long-term" (Ahi and Searcy 2013). Regarding environmental issues, it deals with such challenges as effective management of natural resources, efficient waste management, CO_2 emission, new product development, and closing economic cycles. Social aspects cover the problems, in particular, of human rights and workers' rights. Both dimensions are analyzed from local and global perspective and in intra- and interindustrial relations.

Sustainability is closely dependent upon transparency, although, as pointed out by Gardner et al., the linkages between those phenomena are rather poorly understood (2019) Some scholars equate supply chain transparency with disclosure of sustainable conditions provided by the suppliers; others underline the importance of traceability—the ability to track the product through the production process and supply chain (Egels-Zandén and Hansson 2016). The latter understanding is shared by some of the representatives of the industry sector: e.g., for Leslie Johnston, executive director of the C&A Foundation, transparency is tantamount to "disclosure of information in a standardized manner that enables comparison", and traceability—to the "ability to discover information as to when and how a product is made" (Newbold 2018). The aforementioned Gardner et al. argue that "in the context of corporate accountability, transparency refers to the ability of businesses not only to 'know internally' that they are exercising due diligence but also to 'show externally' that this is the case" (2019). They strongly advocate for linking information transparency with sustainability governance, and go as far as to propose a concise framework for information gathering that may improve sustainability of supply chain: traceability information (associations among actors and between actors and places); transaction information (purchasing practices and investment decisions of actors in supply chain); impact information (social and environmental impacts and risk along the production process); policy and commitment information (as introduced by supply chain actors); activity information (actions taken by the supply chain actors to reach the targets set in their policies); and effectiveness information (progress by each actor or place).

The essential question concerns the structure of accountability when it comes to sustainability in supply chains; in other words, who is responsible for and entitled to monitoring the supply chains and checking their sustainability? We will return to it later, now turning to another key problem of how to extract such multilevel information from a complex supply chain, often scattered geographically over several political and economic institutional frameworks. Traditional reporting and monitoring do not measure up to the need for timely and accurate information about the activities of supply chain stakeholders. Much more promising are the technological developments forming the basis of a brand new concept of Industry 4.0 (Kamble et al. 2018; Smit et al. 2016).

3 The Promising Flood of Data

The ongoing technological revolution is much more combinatorial in character than the previous ones, meaning that the new inventions spurt a plethora of subsequent ones, and the technological pace is unabashedly described as exponential (Schwab 2017) Miniaturized computer (that is fit to stand on a desk, not in the three adjoining rooms) together with the Internet supplemented by the World Wide Web introduced the era of connectivity in everyday life and business. Yet for the manufacturing industry, the key change came quite recently with the introduction of miniaturized, but intelligent sensors equipped with effective microprocessors and signal conditioning circuitry. The most common types of sensors gather acoustic, chemical, electrical, environmental, image, motion and force, and touch inputs. They are able to monitor their environment, collect rudimental data, process them with embedded computational resources, and communicate with other devices (Deloitte 2018). Their spread was obviously facilitated by their dropping prices: in 2004, an average price oscillated around 1.3 USD per sensor, in 2017—around 50 cents. In 2006, there were 2 billion intelligent sensors, in 2020, their number is predicted at 200 billion (Ennomotive industrial IoT 2017).

Naturally, sensors are important, but not sufficiently so to start a new industrial revolution. The other crucial components are faster communication, geared by the introduction of new connectivity standards (and it will become even more faster with the implementation of 5G), and the rapidly growing uptake of cloud computing together with the data processing mechanisms based on AI. Taken together—sensors, connectivity, AI-based processing, and learning)—opened quite new possibilities for the progress of automation. The manufacturing robots are becoming more agile and more mobile, making human–machine interfaces more indispensable in factories (Sirkin et al. 2015). The network connecting sensor-equipped objects that enable the flow of data forms the Internet of Things. When integrated with people and systems on the factory floor and beyond it, the Industrial IoT gives rise to a new mode of manufacturing and marketing, elegantly dubbed Industry 4.0 (Popkova et al. 2018) The authorship of the notion is commonly attributed to the proponents of the Federal Government High Tech Strategy, first presented publicly during the Hanover Technological Fair in 2011, and it was meant to signify a process of transformation of global value chains stimulated by intermittent progress in information and communication technologies (Kagermann et al. 2013; Thoben et al. 2017). The 4.0. denominator alluded both to the enumeration of previous industrial revolutions (the first one precipitated by the invention of steam machine, the second one—by the electrification, the third one characterized by automation and computerization), and to the stages of development of the Internet (Web 1.0. of e-commerce explosion, Web 2.0. of interactive content generation, semantic executing Web 3.0. and emerging mobile Web 4.0., connecting the real and the virtual).

Introduced in factories, fleets, and embedded products, the more and more ubiquitous and super connected sensors allow for monitoring of the machinery and counteracting unexpected breakdown by real-time maintenance; they make it possible to automate transport and logistics; they optimize inventory practices, making it possible to intermittently analyze the stocks and alert the managers when they are getting low. Additionally, the implementation of sensors in the product life cycle may add to its personalization in response to the customer's needs, as signalized by his or her real-life usage and behavior (Pilloni 2018) Perhaps most importantly, IoT solutions may greatly facilitate asset and product tracking down the supply chain (Supply Chain 4.0 2016; Müller et al. 2018). Already in 2014, nearly half of global 593 companies surveyed by Forrester hoped that IoT will help them to locate objects, containers, transactions, and people, resulting in supply chain optimization, visibility, and loss prevention (Internet of Things 2014) They harbor hopes that taken together the solutions inscribed in the concept of Industry 4.0. will revolutionize the production processes, sharing the sentiment voiced by Erskin Blunck and Hedwig Werthmann that "Within Industry 4.0, physical production processes and information and communication technology grow more closely together (…). Through this development, production processes get transparent and easily influenceable" (Blunck and Werthmann 2017) The same applies to the whole supply chain. The question is transparent to whom and influenceable by whom?

3.1 Quis Custodies Ipso Custodes?

Never before business had access to some much data to be utilized in order to raise the productivity, to enhance product personalization, to tailor the marketing offer and expand to the new markets, and to optimize the management and introduce the real-time decision-making. The already somewhat clichéd saying goes that for the new digital economy, data is what coal and steel were for the industrial economy in the nineteenth-century and oil in the twentieth-century economy, namely a new production factor, determining not only the business effectiveness but also the development of the new business models and economic relations (Internet of Things 2014). This new abundance of data and information begets managerial knowledge about the functioning of the companies together with their complex supply chain, which is used by the decisive nodes of the supply chain for their internal and external goals. The sheer fact of there being more data does not mean that the companies will be willing to open all of them; rather, they will compromise the transparency necessities according to their interests. As noted by the researchers studying the apparel industry "the Industry 4.0 guiding principle was not initially focused on providing solutions to the ecological problems faced by production, but on boosting productivity, revenue growth, and competitiveness" (Egels-Zanden and Hansson 2016). Some of this information will be shared with customers in order to build the brand image, e.g., in order to show the ecological breeding of the chicken, the person has to consume in a fancy restaurant or the decent working conditions in the apparel factory in Bangladesh to somebody buying a T-shirt (McDermott 2018). Yet, there is growing awareness that the corporations use the cleverly selective presentation data to whitewash their activities for the benefit of their PR messaging. For example, the corporations often claim to work toward transparency through introduction of common auditing procedures. Craig Carter and Dale Rogers venture that such procedures "adopted by an industry coalition can allow a single, effective supplier sustainability audit to be performed, which increases transparency and supplier sustainability while lowering transaction costs for both the supplier and the multiple buying organizations that might do business with that supplier" (Carter et al. 2008). Still, a 2016 study by Genevieve LeBaron and Jane Lister from University of Sheffield found that with the willing support from the growing audit industry, the global corporations "have designed a system of self-regulation that allows their suppliers to cover-up abuses and easily cheat a weak inspection system" (LeBaron and Lister 2016).

Here enter the actors of the civil society, such as the media and nongovernmental organizations. Only a strong ecosystem of external stakeholders who may play the role of both watchdogs and engaged partners to companies strive to develop their CSR. The essence of transparency, in addition to two-side communication, is the involvement of various groups of stakeholders who have diversified information important for sustainable supply chain management. On the other hand suppliers, employees (including employees of suppliers), clients, and nongovernmental organizations expect the availability of supply chain data for their decision-making processes (Pieters 2013). Yet the access to data is not all: the data produced by plethora of suppliers, subcontractors, and increasingly by sensors are often unstructured and come in diverse and inconvenient formats. The key to sustainability lays in transforming data into actionable information that may be used to change the negative situation. And that is the vision of ChainReact project: "So long as public data on corporate supplier networks remain poor and scarce, stakeholders are powerless to remedy the networks' faults" (ChainReact 2018).

4 ChainReact—Toward Transparent Relations in Supply Chains

4.1 From Sustainable Corporations to Sustainable Supply Chain

ChainReact is a project funded by the European Commission's Horizon 2020 framework as a part of CAPS ("Collective Awareness Platforms for Sustainability and Social Innovation") topic. The project consortium comprises of six partners from four countries, led by Wikirate foundation (Berlin). The explicit core premise of ChainReact project is that working toward improving the sustainability of supply chains is a multi-stakeholder process. Leaving it only to the companies to fix the issues in their supply chains and monitor their sustainability performance is likely to underrepresent the interests of employees, clients, and general public, affected by production and distribution process. In order to address all the dimensions of sustainability of global supply chains, the information about them needs to be made transparent and actionable.

This approach is inherited from Wikirate.org, the project and platform ChainReact extends. The original Wikirate is concentrated on crowdsourcing sustainability information about singular entities—companies. Its "theory of change" states that the improvement of companies in the area of sustainability is driven by the feedback of informed stakeholders. In order for the stakeholders to be informed, the transparency of ESG data needs to be achieved. The main problem Wikirate tries to resolve is the quality of sustainability-related data: they are closed in corporate databases or buried deep in official reports, messy, isolated from the context and other data, and often presented in unengaging ways. Wikirate.org is an open research platform, where the data is gathered, structured, integrated and related to other entities, and presented in a way that makes it easy to analyze and use. Its activity revolves around the concept of a "metric". Each metrics is one data point per company per year, answering a concrete research question (e.g., what was company's "X" CO_2 emission in 2018?). The metrics are concrete, standardized (hence, comparable) with metadata about methodology and idea behind given Table 1.

ChainReact applies this framework to supply chains. While the Wikirate approach concentrates on a singular company, ChainReact sets out to map entire supply chains and to provide information on their sustainability performance. The project relies

Table 1 How Wikirate can improve the metrics of sustainability in supply chains

Without Wikirate	With Wikirate
Closed/Expensive: ESG data are often proprietary and prohibitively costly and thus only useful to the privileged few	**Free and Open**: data access—via web or API; community—anyone can join and contribute; methodologies—includes derivatives; source software—available at GitHub
Messy: Companies produce abundant reports in PDFs, which can't be queried or easily interpreted by machines, making it difficult to compare one company with another	**Structured**: WikiRate contributors are structuring data into standardized Metrics via scraping, API, and crowd research
Isolated: Data silos, high-level ratings without sources, and low-level data without analysis combine to make ESG data almost impossible to navigate	**Interconnected**: WikiRate brings together metrics from many different researchers and makes answers easy to navigate, interpret, improve, and recombine
Dull: Often, reports are produced for a narrow audience of experts and are inscrutable to those unfamiliar with jargon	**Engaging**: WikiRate will make data more digestible so that more people can engage and demand better metrics, better data, and better companies

Source WikiRate (2018)

on the basic infrastructure Wikirate has been built upon and uses metrics already present on the platform, but adds important aspects of network mapping and providing contextual, supply chain related information about network nodes/companies. A special class of metric has been developed: relationship metric, which stores information about ties between companies in supply chains and other hierarchical relations between firms. These metrics answer question whether two companies have a tie between them or not.

4.2 ChainReact Supply Network Map

To date, 16 different relationships have been defined. For a given company, they indicate the ties having a specific supplier or owning a specific factory. The snapshot of the most recent network state comprises of almost 67,000 various relationships, mapped for over 16,500 companies. The graphical representation of this network is shown in Fig. 1.

The most prominent features of this graph are hubs of companies and their suppliers ("supplied by" relationships) and, in the middle, a complex component comprised of the relationships of using minerals smelted at a given facility, related to the "conflict minerals" issue and advocacy. Remarkably, in spite of the fact that the relationships that make the network have been obtained through different methodologies and mechanisms (both automatic and manual), and that they map various industries, the network is not fragmented. 99% of companies belong to the main component. This shows that the need to use different strategies in order to "feed"

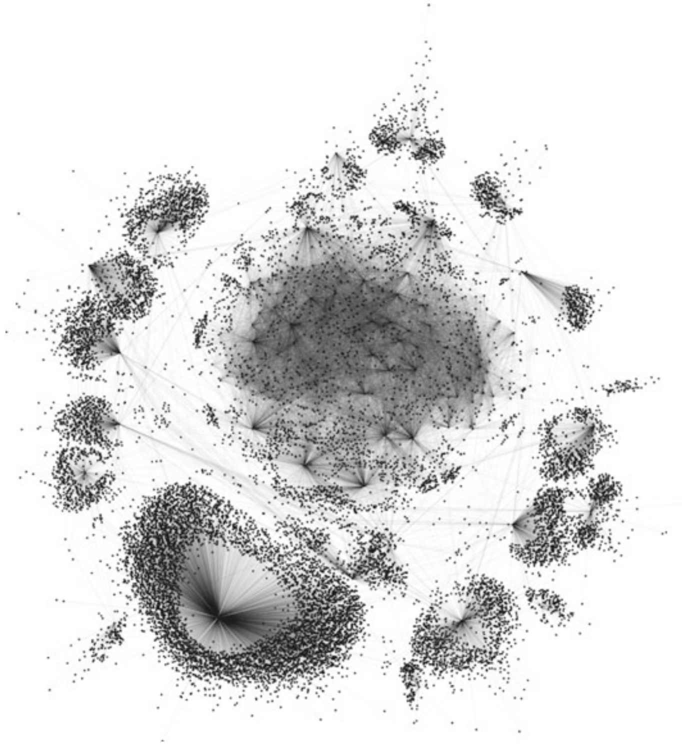

Fig. 1 ChainReact supply network map

the database (described below in more detail) still is able to yield a global, systemic view of companies' interdependence in the context of supplier networks.

There are some interesting structural features emerging in the network after assembling the network out of merely dyadic relationships. One of them would the dependence of suppliers on more than one customer. The network close-up below shows how tightly integrated the network customers (bigger node) and their suppliers (small nodes at the end of arrows) can be (Fig. 2).

This illustrates the highly complex nature of contemporary supply chains systems. One of the consequences of this complexity is making the design and execution of advocacy actions in supply chain areas (e.g., trying to influence the improvements of working conditions) complicated due to the number of actors and institutions with interwoven interests.

Another interesting structural feature is a certain amount of "transitivity of authority", illustrated in Fig. 3.

Here, we can see the network of suppliers of a major company (Columbia Sportswear, the big node, its suppliers being at the end of orange arrows). This company is at the same time "at the receiving end" of a number of "is shareholder of" relationships (green arrows). Again, this kind of structure has consequences for

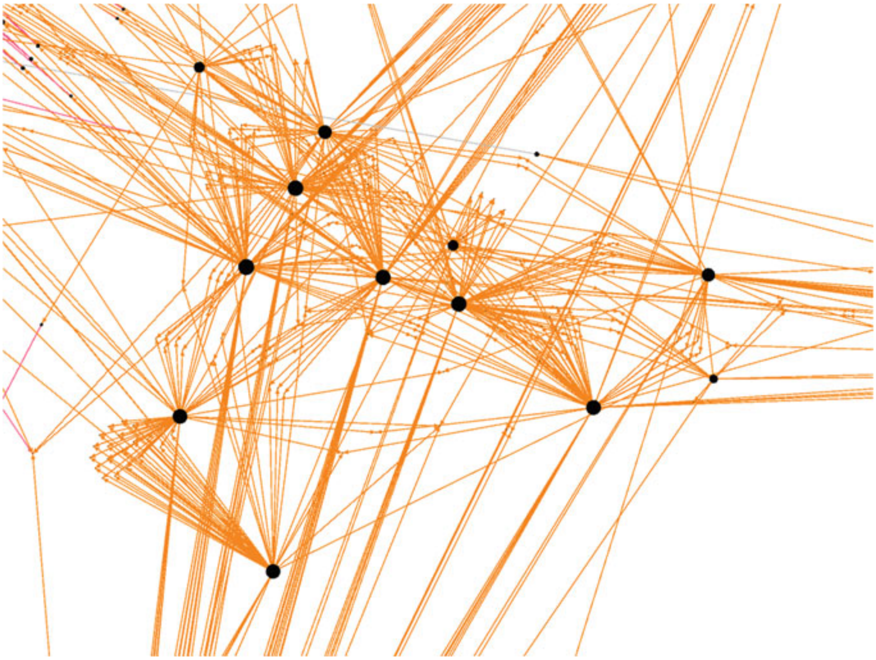

Fig. 2 Close-up on "supplied by" network

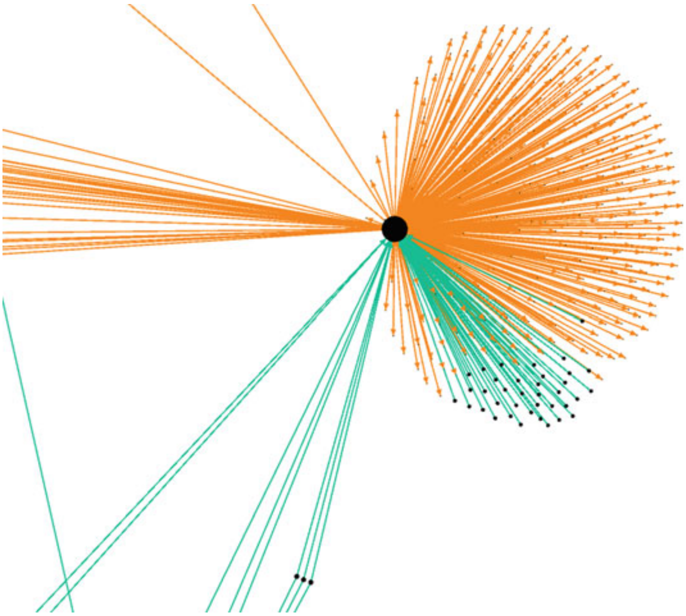

Fig. 3 Example of "transitivity of authority" in supply network map

the way the issues of sustainability in supply chains can be addressed. Influence over what is going on at the "edges" of the network (e.g., in factories in economically and socially challenges regions) extends beyond the immediate customers of factories and other categories of suppliers. The entities such as shareholders or subsidizers, also have their role to play in the efforts to improve sustainability of supply chains. ChainReact's goal is to make this kind of structural relationships visible and actionable.

Connecting Issues "At The Edges" of the Network

The other aspect of expanding Wikirate.org with network dimension is adding data to the supply-related network. Partially, this data had already been present on WikiRate.org: company profiles and their individual metrics which can be readily integrated with structural data. However, there are specific information that are to be supplied by ChainReact project. They are, for example, derived from the Whistle, a tool developed by the University of Cambridge as a part of ChainReact initiative, allowing specialized NGO to run reporting campaigns on human and employee rights abuses in production facilities at the edges of supply networks. The reports can be integrated with structural network data on WikiRate.org. The other enrichment of relational data is "network-aware metrics". The ordinary WikiRate.org metrics inform about sustainability performance of a singular company, e.g., showing the percentage of women on board of directors of this company. The network version of the same metric would show this percentage in the entire network of firms comprising the supply chain of a company. This shows how major companies affect sustainability in the entire web of their influence over other business entities.

Challenges and Remedies

Creating a publicly available relationship map and performance database of supply networks is a challenging task. The biggest obstacle is, of course, obtaining the data. The ultimate source of information about sustainability of company's supply chain, as with any other sustainability measures, is company itself. However, in case of information about supply networks, there appear additional obstacles to disclose them. First, corporate reporting obligations regarding supply chains are still not as wide as in case of traditional sustainability areas. More importantly, the owner of much information about given aspect of sustainability in company's supply chain is not the company itself, but its supplier, an independent business entity. Finally, the disclosure of information about the structure of supply chain itself can be seen as much more threatening to companies than making available only traditional sustainability-related information; the relationships with suppliers are, after all, vital for competitive advantage.

If we consult the sustainable supply chain maturity model (Rudnicka 2016), we will find out, what ChainReact requires from companies, if they are to be a source of information on supply chains, is for them to score the highest (5) level of maturity at least on the "communication dimension", and as high as possible on other dimensions (knowledge, impact, social risk, environmental risk, and cooperation). The highest level of maturity assumes "two-side flow of information, clients, and users included in the process (feedback), social and environmental KPIs publicly available, different channels of communication available" (205). The ChainReact consortium's experiences with trying to understand companies' operations show that many of them stop at "4.5" level of maturity: they have their supply network mapped, influence its conduct as a part of their business model (including whistleblower support), they communicate and cooperate with their suppliers in order to minimize social and environmental risks—all of it without fully disclosing the relevant information to the public.

In order to overcome difficulties in obtaining supply chain data, the ChainReact project worked out several specific approaches, both direct and indirect.

Direct approaches involve various ways of engaging companies. In order to understand the drivers and barriers to supply chain information disclosure, a number of research activities took place. The interviews, surveys, and workshops with representatives of firms, often involving officers responsible for sustainability, showed that indeed the PR and strategic considerations keep them from releasing much of supply chain related information to the public. One of the things that could make them more receptive to the idea of information disclosure is to present companies with clear advantages of making information available through a platform like WikiRate.org/Chainreact, helping them connect with stakeholder groups relevant to them (investors, students, and clients).

In order to encourage companies to disclose their data, a number of features of WikiRate platform have been developed. The company accounts introduce a way for companies to participate in creating and researching supply chain datascape officially, as verified entities. This way they can disclose their information in more controlled way (while still under scrutiny of the wider open-source WikiRate.org community), and easily compare their performance with that of their competition, with the use of dashboarding tools. Benchmarking is another way to make comparison of companies more straightforward. Two pilot benchmarks have been developed. The first one has been prepared in the cooperation with Corporate Human Rights Benchmark and brings CHRB methodology to the platform. The second one aims at comparing the top 100 companies in India with cooperation with Oxfam India, using India Responsible Business Index extended with environmental performance indices. Finally, The WikiRate Index of Transparency intends to measure companies' data profiles on WikiRate in terms of their completeness and hence to encourage more data disclosure. The higher the score, the more information about a company is available in terms of number of answers to important metrics (metrics often used or upvoted by WikiRate community).

In the face of difficulties in obtaining supply chain disclosures from companies themselves, the **indirect approaches** to feeding data into ChainReact ecosystem are vital. There are many sources on intercompany relationship data—the problem is the data profile, fragmentation, and quality. One of the partners of ChainReact consortium is OpenCorporates, organization operating the world's biggest database of corporate entities and relationships (such as being a stakeholder or voting control). There is a bidirectional communication between OpenCorporates and WikiRate.org database. The new companies that enter into the database through ChainReact efforts are matched with OpenCorporates entities so that the details of those companies can be imported from the latter to WikiRate. The relevant relationships from the point of view of supply chains (mainly having to do with hierarchical control) are also imported into ChainReact framework. On the other hand, the data from WikiRate is made available to OpenCorporates as well. The initial technical problem with this cooperation is that both organizations use different ideas of "company". OpenCorporate uses a "legal entity" definition, while WikiRate/ChainReact "companies" can be also brands, physical factories, etc. Special algorithm had been developed in order to accurately map entities from both databases. This kind of categorization problem will be constantly present as infrastructure of Industry 4.0 which makes data integration across fields and organizations more feasible from the technical point of view.

The important sources of information on supply chain networks are various published documents such as company annual reports and public directories. Many of them are presented in the form of pdf documents, unstructured and without metadata, and in order to utilize them, one of the Consortium partners developed the pdf-extractor tool, the usage of which yielded a sizable amount of relationship metrics in ChainReact database (Gkatziaki et al. 2018). Even if supply chain and sustainability data are made available, their quality and structure are often very low, and they require a great deal of cleaning and normalizing. In order to facilitate the usability of disclosed supply chain data, ChainReact and Open Apparel Registry formulated the Open Standard for Supplier Disclosure, which, if widely adopted, should help immensely with data integration. The Open Standard for Supplier Disclosure has been published under the umbrella of Transparency Pledge Coalition, the goal of which is to drive further disclosures of information from companies. The Coalition managed to persuade 70 companies to pledge to disclose information about their suppliers.

All of the above strategies and methods are the means of obtaining supply chain network data in the face of more or less pronounced companies' reluctance to disclose this information themselves. On one hand, the strategies involve efforts in building "collective advocacy" groups, a network of alliances and cooperation, to pressure corporate entities to share data important from the point of view of public interest. At the same time, a lot of technical development needs to take place in areas of data integration, processing, and analyzing. In other words, ChainReact, in its pursuit to make supplier data transparent gets involved in typical "heterogeneous engineering", trying to establish a techno-social web of relations, strong enough to be able to work toward more sustainable supply chains.

5 Conclusions

We started the chapter with a somewhat exaggerated description of the opportunities that the steady development of the technical solutions connected with Industry 4.0. may bring into the area of monitoring the sustainability of supply chains. Undoubtedly, more data will enable the companies to see better through the complex network of their supply chains and hence make decisions concerning production and marketing faster and more efficiently. However, truly sustainable supply chains may exist only in open ecosystem of internal and external stakeholders other than the dominant (brand) company itself, who have open access to supply chain data and are able to understand them in order to act on their basis.

Does WikiRate/ChainReact case cast some light on the emerging possibilities of technological solutions to be used for better monitoring of sustainability of supply chains by stakeholders other than the companies themselves? Several points are worth making. First of all, a huge conceptual and analytical effort is needed to make information out of data—even the fully realized Industry 4.0. will not automatically make corporate data instantly actionable (open, connected, and engaging), mainly due to their incompatible formats. But the essential lesson the project drew from the efforts to collect data and make use of them is that companies will act as gatekeepers to the data and information they deem important. Without the cooperation of the business world, the civil society actors' efforts will be ineffective. There is a need for consistent and persevering political and civic pressure to create and develop common standards such as Open Standard for Supplier Disclosure. Ideally, the data-driven policy should be integrated into material fabric of Industry 4.0, so that there is a constant pressure for sustainability improvement, similar to "on-chain governance" mechanism of blockchains governance so that there is no further need for constant social advocacy.

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Sustainability as Criteria of Evaluation of Suppliers

Maciej Urbaniak

Abstract The purpose of the article is to present the use by international corporations of sustainability concepts as criteria for initial and periodic evaluation of suppliers. In recent times, one may have noticed that global companies are increasingly implementing their strategies based on the concept of sustainable development, and are evaluating and selecting their suppliers based on the sustainability concept. While observing global trends one could notice that more and more suppliers are monitored in terms of the principles of sustainable development. This concept includes the economic aspects (requiring high technical quality, the reliability of supply, price competitiveness), environmental aspects, as well as social ones (rules based on the idea of the Global Compact) Requirements for the implementation of this concept are transferred to suppliers by issuing rules of conduct and ethical standards. The analyses, presented here on practical examples of the chemical, electronics, and pharmaceutical manufacturers show that buyers define specific standards for ethical conduct to their suppliers. Multinational enterprises which are buyers do not limit themselves to putting stringent requirements on suppliers. They also offer their providers support programs for the implementation of the sustainability concept.

Keywords Sustainability · Supplier requirements · Supplier evaluation · The chemical · Electronics and pharmaceutical manufacturers · International corporations

1 The Process of Building a Relationship with Suppliers

Supply chain partnership in the result of some kind of evolution of buying processes from the repetitive transactions based on the loyalty of B2B customers to the source of purchase. Many recurring transactions are often transformed into long-term win-win relationships based on trust (Lee et al. 2013). They can lead to many mutual benefits for the partners such as development product quality, shorten order cycles, improvement of process efficiency, effective communication between the supplier,

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and the clients or joint research and development projects. The observation of business practice shows that many companies improving the processes in a supply chain focus on the implementation of quality, environmental, health, and safety (QEHS) management systems conform to organizational standards issued by International Organization for Standardization (ISO). Many enterprises often define individualized requirements for their suppliers through specifications to determine not only the issues related to quality assurance (safety of products and processes) but also organizational performance related to achieve cost reduction as well as reducing the negative impact on the environment (Sancha et al. 2016).

The process of building relationships with suppliers can be summarized in ten phases. These are:

Setting the expectations and requirements for suppliers in terms of technical quality and service (before and after the sale), the frequency of orders, organizational systems (implementation of QHSE management standards, technical and technological capabilities as well as financial conditions;

- Identification of potential suppliers;
- Assessment of potential suppliers (through self-assessment questionnaires, analysis of submitted bids, auditing factories owned by providers);
- Supplier classifications;
- Negotiating the terms of deliveries with the supplier;
- Choice of the supplier;
- Contract agreement;
- The ordering (establish order, handling order);
- Performance of the contract realization;
- Evaluation of cooperation and development of partnerships, including periodic rating of suppliers (through the scoring or indicators), assessing the impact of cooperation with the supplier to improve the efficiency of processes in the supply chain (design, purchasing, warehousing, manufacturing, maintenance, environmental and safety management, and compliance with best practices in the field of ethical conduct) (Urbaniak 2015).

A partnership comprises a process in which the customer and the supplier gradually build strong and extensive social, economic, and technical relationships. If the parties are satisfied with keeping to the arrangements set out in the agreements, their cooperation may transform into a close partnership (Wagner 2011). The benefits enhance the positive images of the partners. In some cases, a connection between the supplier and the customer may transform into a strategic alliance that is based on the joint achievement of specific long-term goals (Su and Yang 2017). Positive evaluation of these activities is essential to maintain these relationships and a sign of readiness for further cooperation alliances, by which each client and supplier can perceive the number of measurable benefits (Forkmann et al. 2016). The condition of their feelings is effective communication in the form and content of communication should meet the expectations of each partner. The activities of multinational corporations, which introduced the concept of sustainability are heavily focused on collaboration with its partners in the supply chain (suppliers and customers). Large corporations are increasingly offering their support through joint ventures, such as deployment projects operational improvement tools (environmental and safety management systems), or develop concepts for new products. Build partnerships with customers and suppliers, can bring the supply chain many important benefits such as:

- To ensure business continuity, which is based on methodology of the risk management concept (identification, analysis, and hazard mitigation associated with the product and the processes);
- Increased flexibility, efficiency, and effectiveness of the operations;
- Promotion of ethical behavior in economic activity (Goebel et al. 2012).

Many companies also assess suppliers on the basis of their level of management focusing on the guidelines of ISO 9001 and ISO 14001 organizational standards. Many international companies publish their own holistic requirements (in the form of Supplier Quality Requirements Manuals, Supplier Quality, and Excellence Manuals, Customer-Specific Requirements) which are relevant to a wider range than those of international standards. Compliance with these requirements the clients are verified by the client through the audits and self-assessment of suppliers. Auditing suppliers and their implementation of an environmental management system are particularly noticeable in the case of large business entities, companies with foreign capital, and firms offering products in B2B sector. An organization that purchases all kinds of materials, equipment or tools should specify precisely the subject of order and place it with a qualified supplier. When developing cooperation with suppliers, companies monitor them using audits and regular evaluation (based on the analysis of requirements meeting). During the audits, particular attention is paid to the identification of risk connected with operational processes and products, work safety, as well as management of environmental aspects.

2 Requirements for Suppliers in Terms of the Sustainability Concept

2.1 The Methodology of Supplier Evaluation in the Field of Sustainability

International companies more and more often, in addition to technical requirements (contained in relevant regulations and technical specifications concerning products), also give suppliers their specific expectations related to the implementation of the concept of sustainability (Guenther et al. 2015). Corporations provide these requirements by publishing guidelines, guides, and codes of conduct for suppliers. The degree of meeting these requirements is verified by providing Self-evaluation Questionnaires to the suppliers. These questionnaires are used to assess counterparties to the extent they are able to meet technical and organizational requirements. Suppliers interested in cooperating with international corporations fill out self-assessment questionnaires to provide evidence that these requirements have been met. Verification of this evidence is carried out through audits. During the audits, checklist scoring lists are very often used to determine the scope and degree of compliance of potential suppliers (Nakajima et al. 2015). The next step is screening the supplier and analyzing the collected data from the self-assessment reports (including the degree of possibility to meet the client's expectations), observations collected during the audits (Burritt and Schaltegger 2014).

The legal and financial situation (legal structure and shareholding, legal titles to tangible and intangible assets), fulfillment of liabilities (financial/tangible/intangible assets, indebtedness, profitability, liquidity) is also important for the initial evaluation of suppliers, financial resources, shares in other enterprises, the type and scope of insurance, and financial guarantees) that may determine the stability and sustainability of these relationships in the future. The above-mentioned criteria are not taken into account only in the initial assessment and qualification of suppliers. Many international corporations concluding contracts with suppliers oblige them to sign a statement obliging them to introduce a concept of sustainability by applying the principles contained in the Statement on Business Practices and the Supplier Social and Environmental Responsibility Agreement, e.g., Hewlett-Packard. Periodic assessment of suppliers taking into account the criteria related to social responsibility is most often carried out using self-assessment forms. They are used to assess the improvement of these activities using appropriate measures to verify the level of objectives set in the way of achieved indicators (current results). The supplier sustainability report data provided by suppliers are then verified by second party audits (performed by auditors and experts of the client enterprise) or third party audits (performed by auditors and experts from independent certificate bodies). These reports take into account data based on economic, environmental and social indicators (paying particular attention to elements such as hiring practices, respect for human rights or product liability) (Kumar et al. 2014).

The results of audits (both second and third parties) are documented in the relevant reports. If any nonconformities and/or remarks are found in the reports, suppliers are obliged to implement appropriate (effective) corrective and/or preventive actions (CAPA). A special form of assessment of the degree of implementation of the concept of social responsibility IS the certification audits. Some of the international concerns honor the results of certification audits in order to confirm the requirements of international standards in the area of sustainability as part of the initial and interim evaluation. The most recognizable certification is the assessment of compliance with the guidelines published by Social Accountability International. However, the suppliers' interest in the certification of management systems for compliance with the requirements of the SA 8000 social responsibility standard is rather moderate.

2.2 *Code of Conduct for Suppliers*

Observing the global trends, one could note that in recent years more and more suppliers are monitored by their clients for the fulfillment of the principles of sustainability concept which are guided by the economic aspects (requiring high technical quality of the products, reliability of supply, price competitiveness, service support), environmental aspects, as well as social aspects based on the idea of the Global Compact (Mani et al. 2018). Analyzing global trends, it can also be observed that more and more international corporations take into account the criterion related to sustainability activities when assessing the initial and periodic suppliers (Kumar and Rahman 2015; Khan et al. 2018). Business entities that are buyers often publish their requirements in relation to suppliers in documents in the form of guidelines such as the Supplier Corporate Social Responsibility Guidelines (like Toyota, Mazda, Subaru, and Renault-Nissan) or the Supplier Code of Conduct (like ABB, Apple, Bayer, BASF, Deutsche Post DHL, Microsoft, Nestlé, Siemens, and Skanska). Both the guidelines and codes of conduct are based on the principles of the Global Compact, which refer to respect for human rights, ensuring labor standards, protection of the environment, and counteracting corruption. These guidelines and codes also related to other international documents such as: OECD Guidelines for Multinational Enterprises, International Labor Standards, guidelines of the International Standardization Organization like ISO 9001 (quality management standard), ISO series 14000 (environmental management standards), ISO 26000 (social responsibility standard), and other management standards like Social Accountability 8000, or AccountAbility 1000, requirements of the Occupational Health and Safety Assessment series 18,000, as well as reports GRI (Global Reporting Initiative) guidelines. One could also observe increasing number of rules of behavior and ethical standards for suppliers (Supplier Conduct Principles, Principles, and Standards of Ethical Supply Management Conduct), guides for CSR implementation (Supply Chain CSR Deployment Guidebook, Purchasing Way, Supplier Sustainability Program Manual), organizing programs (Supply Chain Social Responsibility programs), and checklist which are used for self-assessment Supply Chain CSR Checklist. Requirements for suppliers in the implementation of the concept of corporate social responsibility included in the literature and codes of ethics.

The analysis of literature and reports on corporate social responsibility shows that many international companies, when evaluating suppliers, develop criteria, which are included in codes of ethical conduct. These codes most often refer to:

- Carrying out activities strictly adhering to all legal requirements;
- The respect of the Declaration of Human Rights accepted by the United Nations, the fundamental rights established by the International Labor Organization and the Global Compact;
- Running the business in accordance with the adopted corporate governance principles;
- Preventing discrimination based on sex, age, race, ethnic origin, sexual orientation, religious or national affiliation or disability;

- Providing reliable information to stakeholders (in financial, environmental and social responsibility reports);
- Environmental protection through the implementation of Cleaner Production programs, or an environmental management system compliant with the requirements of the ISO 14001 standard or the EMAS directive;
- Providing employees safe and harmless health as well as ergonomic working conditions (Kannan 2018).

Enterprises that are clients obliging suppliers to implement ethical codes of conduct also monitor their compliance by reporting and by conducting audits. The analysis of literature and business practice indicates the activities of enterprises in the field of standardization of codes of ethical conduct, especially within certain sectors. This can be seen in the sector of chemical producers, electronic products, pharmaceuticals, toy manufacturers, and jewelry products. It can also be observed that more and more Original Equipment Manufacturers (OEMs) wanting to shape their image as credible customers are developing the purchasing code of ethics or customer good practice guides. Such companies include Philips, Rentokil Initial. These CODs are business customers' obligations to equal treatment of suppliers (not to impose financial conditions) of compliance with contract terms (in particular, deadlines for settling liabilities and pricing arrangements), arrangements for stable planning cooperation with regard to technical quality, volume, and frequency of deliveries (Vahidi et al. 2018).

2.3 The Role of Environmental Management in the Evaluation of Suppliers in the Implementation of the Sustainability Concept

Increasingly, international enterprises require their suppliers detailed evidence of the determining environmental aspects, establishment of environmental objectives and programs, limiting the use of materials and energy, establish procedures for emergency preparedness and response, training employees, reducing environmentally harmful factors (greenhouse gas such as carbon dioxide, noise, vibration, wastewater, solid waste), as well as dissemination of information on the results of activities related to environmental protection. In conducting audits to assess the functioning of the environmental management system vendors frequently pay attention to such elements as:

- Identification of significant environmental aspects and specifying the environmental objectives, targets, and programs;
- Met environmental legal requirements;
- Establish, implement, maintain, and continually improve the environmental management system;

- Determinate and provide resources (infrastructure, technology, processes, information systems, and relevant qualifications of employees);
- Determinate and achieve environmental indicators (related to energy consumption, raw materials, waste management, and pollution);
- Establish criteria for the qualification and monitoring of suppliers in the field of ecological performance (Govindan et al. 2018; Ghadimi et al. 2017; Neutzling et al. 2018; Gallego-Álvarez and Ortas 2017; Li et al. 2016).

An implementation of an environmental management system is for many enterprises one of the main criteria (like ensuring product quality, timeliness, and flexibility of supply as well as the ability to reduce costs) for initial and periodic evaluation of suppliers. Emphasis on the implementation of the requirements relating to environmental management is linked to compliance with legal provisions, especially in the Directives and Regulations of the European Union, such as:

(1) RoHS (Restriction of Hazardous Substances) Directive EU 2003/95/EC,
(2) WEEE (Waste Electrical and Electronic Equipment) Directive 2001/96/EC,
(3) EuP (Eco-design for Energy using Products) Directive 2009/125/EC,
(4) Battery and Accumulator Directive 2006/66/EC,
(5) Packaging Directives 94/62/EC, 2004/12/EC, COM Decision 97/129/EC,
(6) REACH (Registration Evaluation Authorization and Restriction of Chemicals) Regulation 1907/2006/EC.

The implementation of these EU directives is often required of suppliers from outside the European Union and especially of large multinationals producing high-tech products (mainly from the United States and Japan), such as Dell, HP, IBM, Motorola, Fujitsu, NEC, Panasonic, Sony or Toshiba.

More and more multinational companies require their suppliers to reduce the negative impact of products and processes on the environment through the implementation of the concept of Life-Cycle Assessment (LCA, based on ISO 14040 series of standards) and Eco-design approach. This concept focuses on analyzing and reducing the negative impact of each product on the environment in all phases of their life cycle (design, manufacturing, distribution, installation, use, maintenance, disposal/destruction, and dematerialization), or reuse of materials (recycling). These activities aim at:

- Improved material efficiency (by minimizing consumption of materials, use of materials with low impact on the environment, use of renewable raw materials and/or use of materials recovered);
- Improved energy efficiency (by reducing energy consumption, use of energy sources with low impact on the environment, use of energy from renewable resources);
- Designing (products and processes) for cleaner production and safe use of products (through the use of cleaner manufacturing techniques and avoiding the use of hazardous materials);

- Designing for durability (considering in this respect the length of the operation and the improvements of maintainability of a product, resulting from the emergence of new technologies);
- Designing for reuse of products, recovery, and recycling (Grzybowska 2012; Kammerl et al. 2017; Vahidi et al. 2018).

The Eco-design approach is based on Environmental Effect Analysis (EEA) and takes into account: the identification of legal requirements, design planning, conceptual design, the construction and evaluation of a prototype, production, and packaging).

LCA is a complex process involving the analysis of the profitability of investment projects with simultaneous emphasis on reducing a product's negative impact on the environment. This concept takes into account measures to determine the quantities of used materials, energy, and waste generated at each process (starting with raw material extraction, through manufacturing, distribution, use, and reuse/recycling, to final disposal).

Many companies are adopting a system for collecting information on measures to reduce the negative impact on the environment by analyzing the incurred expenditures (costs) and the benefits achieved as a result of the activities of the organization. For these reasons, it may be noted that in recent years, many enterprises implemented an environmental accounting system (environmental management bookkeeping), using in this respect, inter alia, international guidelines such as Environmental Management Accounting Procedures and Principles by the United Nations Division for Sustainable Development. Environmental accounting is taken into consideration for business units (branches, departments, processes) and particular products. Environmental accounting is not limited to individual business units, but increasingly it includes in its scope the relationships between partners in the supply chain. Enterprises implementing environmental cost accounting introduce the concept of MFCA—Material Flow Cost Accounting (Hänninen and Karjaluoto 2017).

In 2007, Japanese managers suggested a definition of global guidelines on the implementation of the concept of Material Flow Cost Accounting (MFCA) in the form of an international standard of management within the group of standards for environmental management, in particular the ISO 14040 series, concerning the assessment of the life cycle of the product, and ISO 14064, specifying guidelines in terms of the quantifying and reporting of emissions and the removal of greenhouse gases. Guidelines for the implementation of this concept have been included in the ISO 14051 standard (Environmental Management—Material Flow Cost Accounting—General Guidelines), which was published in 2011 (Jia et al. 2018). This standard establishes guidelines for the identification and quantification of individual components of the product (weight, quantity) and the measurement of costs in the analysis of maps of flow values. The collected information helps to identify types of waste (losses in the form of waste, energy loss, and implementation of measures that are not effective) occurring in the flow of materials (raw materials, parts, components), and opportunities for the reduction of the negative impact on the environment (by reducing the amount of waste, emissions, etc.) in the operational processes related to the implementation of the product (design, purchase, production, packaging, storage, delivery, use and withdrawal from use). It can also help to identify potential savings, optimize the quantitative flow of materials, and exploit the potential of infrastructure (Lo et al. 2018). By identifying waste, one can limit the purchase of necessary materials (by optimizing the norms of consumption), the level of waste resulting from non-compliance of the product, and the level of energy losses, emissions, and wastewater. Currently, the concept of MFCA is increasingly being implemented in the supply chain of the automotive industry, the chemical and rubber, metal, textile, food, and timber industries, as well as office equipment and medical devices.

2.4 The Role of Ethical Conduct in the Evaluation of Suppliers in the Implementation of the Sustainability Concept

Many multinational companies have entered into contracts with providers require them to sign the statement, obligating them to implement the concept of sustainability through the application of the principles contained in the Statement on Business Practices and Supplier Social and Environmental Responsibility Agreement. Statements regarding business practices are associated with the strict observance of the applicable laws, regulations and ethical standards (no practices to combat corruption and bribery of officials of national and international institutions, non-discrimination of workers, protection of international human rights) and environmental liability. More and more companies wanting to develop an image as a reliable partner (client) develops a purchasing code of ethics and customer and supplier good practice guides. These code of good practice most often refer to such issues as:

- Conducting business strictly observing all legal provisions;
- Performing business activities in accordance with the adopted corporate governance principles;
- Avoiding corrupt practices (bribery or commission payment) in contacts with clients, suppliers, government offices and agencies;
- Respect for the confidentiality of information (contracts and data regarding customers, suppliers, employees, marketing plans, financial plans);
- Commit to abide by the principles of fair and open competition (compliance with applicable antitrust and other norms and legal provisions governing competition);
- Respecting for the intangible resources of the organization, especially the protection of information;
- Respecting intellectual property rights;
- Providing reliable information to stakeholders on the financial situation, undertaken investments, limiting the negative impact on the environment (Igarashi et al. 2013; Govindan et al. 2018).

Many companies implement their codes of conduct (CODs) by monitoring their compliance (Ghadimi et al. 2017). They set up committees for compliance with corporate rules, ethics, internal audits, or organizational risk assessment. Companies that have implemented such rules indicate that an employee who encounters difficulties in their application is obliged to inform their superiors or directly the ethics and compliance of the ethics and compliance committee. Some companies have also launched information helplines) in this area of open talk, which allow all employees to raise concerns regarding violations of codes of conduct, in particular regarding employee treatment, abuse or violation of safety standards. Many international corporations that have implemented the concept of sustainability, qualifying their suppliers, are paying particular attention to building relationships with employees. Guided by the Global Compact principles, they develop suppliers' ethical code of conduct, compliance with which is carefully verified through the self-assessment of suppliers and during initial and periodical audits. Particularly during audits are evaluated such elements as:

- Compliance with labor standards (ensuring employees safe and harmless to health as well as ergonomic working conditions);
- Eliminating all forms of forced labor and abolishing child labor;
- The right to the minimum wage and rest;
- Respect for freedom of association;
- Counteracting discrimination in the sphere of employment (based on sex, age, race, ethnicity, sexual orientation, religious or national affiliation or disability);
- Keeping open communication with employees by consulting decisions;
- Recruitment, employment and promotion of employees solely on the basis of the qualifications and skills;
- Respect for employees' right to remuneration, observance of working hours, holidays;
- Keeping open communication with employees by consulting decisions (Neutzling et al. 2018).

3 The Studies of Sectoral Initiatives in the Fields of Supplier Evaluation Related to the Implementation of the Sustainability Concept

3.1 Supplier Evaluation Criteria Established by the Chemical Initiative for Sustainable Supply Chain

The Chemical Initiative for Sustainable Supply Chain was taken in the year 2011 by six international concerns from the chemical sector (such as BASF, Bayer, Evonik Industries, Henkel, Lanxess, and Solvay), is an example of harmonizing the requirements for auditing suppliers with respect to rules to social responsibility.

This initiative is called Together for Sustainability. It was based on the guidelines of the United Nations Global Compact, the Responsible Care Initiative promoted by the International Council of Chemical Associations (ICCA). Its aim is to develop common criteria for auditing and self-assessment of suppliers. It is intended for its members that an audit by one of its members be honored by the others in accordance with the idea: “An audit for one is an audit for all” (Gallego-Álvarez and Ortas 2017). Similarly, the supplier’s self-assessment result carried out by one of the affiliated organizations is to be honored by the others. The initiative is intended to share the results of self-assessment and audits at suppliers, to promote the improvement of their activities in the implementation of the concept of social responsibility and the exchange of good practices in this area. Other chemical concerns such as Akzo Nobel, Arkema, Brenntac, Clariant, Covestro, DSM, DuPont, Eastman, Evonic Industries, IFF, Merck, Sanofi, Syngenta and Wacker also joined this initiative. The evaluation criteria for audits and the self-assessment of suppliers adopted by Together for Sustainability human rights, governance. Self-assessment and reporting of its results take place using the platform administered by EcoVadis (Helin and Babri 2015).

3.2 Supplier Evaluation Criteria Established by the Electronics Industry Citizen Coalition

Another example of unifying the rules for auditing suppliers in terms of criteria related to social responsibility is the initiative of enterprises associated with the Electronics Industry Citizen Coalition (Kumara and Rahman 2015). The organization was founded in the year 2004 to promote a common code of conduct in the electronic, information and communication industry (ICT). Currently, it associates over 100 companies that are manufacturers of ready-made high-tech products (like Acer, Apple, Dell, Eastman Kodak, Flextronics, Hewlett-Packard, Hitachi, HTC, IBM, Konica Minolta, Lenovo, Lexmark, LG Electronics, Logitech, Medtronic, Microsoft, Motorola, Philips, Samsung, Sony, Texas Instruments, Toshiba, Xerox) and their suppliers around the world. Electronics Industry Citizen Coalition promotes innovative practices in the field of activities related to sustainable development at suppliers. These activities are aimed to help deliveries in the scope of:

- The increase of efficiency and effectiveness of processes,
- Improving working conditions and improving staff qualifications,
- Minimizing the risk level of threats in the supply chain in order to ensure the continuity of operations implemented by the partners,
- Reducing the negative impact on the natural environment,
- Promoting ethical activities in relations with stakeholders.

Enterprises associated in this organization develop standards together for self-assessment of suppliers, criteria for their auditing, or guidelines for the EICC Code of Conduct (Mani et al. 2018). The current EICC audit protocol, version 5.1, was ratified in 2016. One of the major EICC assemblies is self-assessment by Self-Assessment

Questionnaire (SAQ) and Validated Audit Process (VAP), the purpose of which is to demonstrate the degree of compliance with the requirements of the Code of Conduct (Torres-Ruiz and Ravindran 2018).

3.3 Supplier Evaluation Criteria Established by the Pharmaceutical Supply Chain Initiative

Another example of the development of common pre-qualification and periodic qualification criteria for suppliers (in the form of self-assessment and audits) is the Pharmaceutical Supply Chain Initiative (PSCI) which is an association of 24 world producers of pharmaceutical products (such as Astra Zeneca, Baxter, Bayer, Boehringer Ingelheim, GlaxoSmithKline, Johnson & Johnson, Merck, Novartis, Novo Nordisk, Pfizer, Roche, Sanofi, Tekeda, or West). The Pharmaceutical Supply Chain Initiative did not develop a uniform code of conduct for suppliers. Only consistent evaluation criteria were defined under this initiative (Crespin-Mazet and Dontenwill 2012). They cover 10 areas:

- General management systems,
- Environment—general,
- Air emissions,
- Water supply, stormwater, and wastewater,
- Waste management,
- Hazardous materials control and reporting,
- Asbestos, PCBs (polychlorinated biphenyl) and ozone-depleting substances,
- Health and safety documentation,
- Labor documentation,
- Ethics.

Particularly noteworthy are the specific requirements of enterprises from the pharmaceutical sector contained in the customer codes of conduct for suppliers. These requirements relate to conducting clinical trials with people (which should be implemented in accordance with the highest medical, scientific, and ethical standards, in particular with the Helsinki Declaration). These requirements also refer to animal tests (which should be implemented in a humane manner, maximally reducing their stress, fear, and pain). Animal studies can only be carried out when there are no scientifically valid and commonly accepted alternative methods.

4 Supplier Development Programs

4.1 Supplier Development Programs in the Field of Sustainability

International corporations are increasingly trying to help suppliers to meet stringent requirements by offering them assistance in the form of consultations and training in implementing the concept of sustainability (Grimm et al. 2016; Liu et al. 2015; Airike et al. 2016). Suppliers are supported by specialist knowledge provided through training and specialist consultancy. An example of this type of program is the ABB's Supplier Sustainability Development Program (SSDP), which pays particular attention to suppliers from Brazil, China, India, Mexico, Colombia, Peru, Turkey, Indonesia, Thailand, Vietnam, and South Africa. The purpose of this program is to help suppliers meet the requirements set out in the codes of conduct focusing in particular on ensuring decent conditions and occupational health and safety, as well as improving environmental impact (https://pscinitiative.org/hom). Support provided to suppliers is provided in the form of training and the participation of experts in conducting internal audits and the use of checklists. Another example of such activities is Volkswagen, which is provided by suppliers as part of the "Sustainability in the Supply Chain" program in the form of training materials available on the VW B2B-Platform platform, which enable self-assessment (Trapp and Sarkis 2016).

Suppliers who are not able to meet these requirements to a high degree can get help in the form of direct coaching, which is run by a team of experts (Ad hoc-Expert-Team), consisting of specialists in environmental protection, human resources, safety management and health at work, purchase security as well as quality assurance. With the participation of experts, they develop plans to improve suppliers in the implementation of the sustainability concept, which assume achieving targets in the form of objectives related to environmental protection (such as limiting the use of harmful substances, carbon dioxide emissions) improving product safety (reducing production defects, reported complaints by clients) and processes (reducing the risk of accidents or emergency situations).

Support programs in corporate social responsibility are offered to the suppliers by companies affiliated to the Electronics Industry Citizen Coalition, which includes manufacturers of high-tech products (such as Acer, Apple, Dell, Eastman Kodak, Flextronics, Hewlett-Packard, Hitachi, HTC, IBM, Konica Minolta, Lenovo, Lexmark, LG Electronics, Logitech, Medtronic, Microsoft, Motorola, Philips, Samsung, Sony, Texas Instruments, Toshiba, Xerox).

Supplier development programs in the area of sustainability efforts are focused on supporting partners to

- Increasing the effectiveness and efficiency of processes;
- The improvement of working conditions and improve employees qualifications;

- The reduction of the risk level in the supply chain in order to ensure the continuity of processes carried out by the partners;
- Elimination of negative impact on the environment;
- Promoting ethical behavior in relations with stakeholders (Rashidi and Saen 2018).

Another project the Electronic Industry Citizenship Coalition, implemented jointly with the Global e-Sustainability Initiative (GeSI—which currently has over 30 members and partners such as Alcatel Lucent, AT & T, Bakrie Telecom, Bell, BlackBerry, BT, Deutsche Telekom, Ericsson, HP, Huawei, KPN, Microsoft, Nokia, Nokia Siemens Networks (NSN), Orange France Telecom Group, Sony Mobile, Sprint, Swisscom, DTC, Tele2, Telecom Italia, Telefonica, Telenet, Telenor Group, Turk Telekomunikasyon, Verizon, VimpelCom, Vodafone, ZTE Corporation.) is an E-TASC (Electronics-Tool For Accountable Supply Chains). E-TASC is an IT solution that allows EICC and GeSI members to analyze data and generate reports relating to the assessment of suppliers in meeting the requirements for labor standards, environmental impact, risk management, and ethical codes of conduct (Yawar and Seuring 2018). The results of these reports allow for more precise and individualized supplier development programs in the implementation of the sustainability concept.

4.2 Monitoring of Development of Suppliers

Many companies monitor activities of suppliers using Supplier Performance Card, collecting data, and conducting appropriate benchmarking rankings take into account their technical quality, timeliness, cost reduction, technological development, the rate of implementation by the supplier of new solutions (adaptation time changes in the process, the product), the possibility of introducing a new product, the reaction rate (for RFQ/preparation of the offer, the complaint/reported a technical problem, the implementation of corrective/preventive), flexibility (adapting to changes in customer orders, changes in the economic context), improving environmental impact (reducing the consumption of materials/energy, reducing greenhouse gases, reducing waste generation and increase the reuse of materials through the introduction of recycling), progress in the implementation of process improvement tools and products (http://www.abb.com; https://www.volkswagenag.com; Hoejmose et al. 2014). Many companies also evaluate their suppliers focusing on the implementation of QEHS management systems. They also audit suppliers periodically. Some international companies require regular reports on progress in the improvement of QEHS management systems while monitoring suppliers. They also keep monitoring them regularly by means of Performance Feedback Reports Cards which contains data on lowering costs, reducing incompatibility, improving process efficiency and effectiveness indicators, reducing energy consumption as well as shorter cycles of process. The above-described behavior may be presented as a cycle of constant improvement (Raj-Reichert 2013; Yan and Dooley 2013; Yoo et al. 2015; Zhang et al. 2015). Companies are implementing QEHS management systems that conform to ISO organizational standards much more often use full sheets and employ periodical evaluation indicators as well as audit. They also require that bidders implement quality management systems and even, more and more often, an environmental management system. Observing world trends, one may notice easily that recently suppliers have been monitored from the point of view of meeting the sustainable development requirements following economic aspects (demanding high technical quality, delivery reliability, price competitiveness, technical support), more and more often also environmental aspects and social aspects (principles based on the concept of the Global Compact). Many OEMs define for their partners supplier the principles of code of conduct. Particular emphasis on environmental protection is put on suppliers by Japanese firms which laid down detailed guidelines for suppliers. They obliged suppliers to adopt principles included in clauses of so-called Statements on Business Practices) which are connected with binding laws and ethical standards, avoiding corruption practices and fighting against attempts to bribe domestic and foreign institutions employees, avoiding employee discrimination, protection of international human rights and responsibility for the environment. It is worth noticing that these requirements are not imposed on one party only (use of forcing suppliers to meet them). More and more companies want to shape their images as reliable partners (customers) and, therefore, draw up purchasing codes of ethics or good practice guides.

5 Conclusions

Recapitulating the considerations presented in this article, it should be stated that the solutions in the field of standardization of criteria for initial and periodic assessment of providers responsible for sustainability in selected sectors in specific sectors strictly rely on the latest international guidelines and global management standards. This criteria strictly focus on legal compliance, anti-corruption and fair competition, respect for fundamental employment rights, health and safety of employees, environmental protection as well as sustainability in supplier management. When comparing the differences between sectors in terms of evaluation criteria, it can be seen that they result from their specificity (processed raw materials, materials and offered finished products in supply chains). An advantage of the presented standardized criteria is their comprehensiveness, regularity of independent assessments, and self-assessment of suppliers. It should, therefore, be stated that the requirements imposed on suppliers by international concerns as well as the programs offered for their development contribute to their sustainability focusing on guaranteeing the safety of products and processes in supply chains, eliminating the negative impact on the environment, improving working conditions, and promoting ethical behavior in economic relations. The implementation of this concept has a significant effect on limiting the risk of threats in the supply chain and contributes to ensuring the continuity of processes implemented by the partners. Improvement of activities by suppliers aimed at achieving sustainability should limit the risk in supply chains and increase their resilience to the disruption that may occur (Wilhelm et al. 2016; Winter and Lasch 2016; Prasanna and Goh 2016).

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Sustainable Supply Chain Management in the Perspective of Sharing Economy

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Abstract In the literature, a notion of managing a sustainable supply chain or sharing economy is current over a decade. The research goal of this chapter is the reconstruction and interpretation of the key assumptions of the sharing economy and the concept of managing the sustainable supply chain, and then, confronting these assumptions with answering the question signaled as a research problem. How can the sharing economy be the theoretical basis for a conceptual reference to supply chain management? Proposed premises to the model building assume that sustainable supply chain management is implemented due to optimization criteria, closely related to the TBL approach, which is correlated with sharing economy.

Keywords Managing the sustainable supply chain · Sharing economy · Categories · Practices · Definitions · Optimization criteria

1 Introduction

The phenomenon of present times is emerging and playing a more and more economically important role in the so-called supply chains. The supply chain is understood as a set of cooperating enterprises located along the sequence of adding utility value to products in subsequent phases of technical and technological operations, starting from companies acquiring resources, to sellers of ready products intended for final consumption. Processes and events related to the emergence, maintenance, and change of supply chains are becoming an increasingly common subject of both economic research and management practice.[1] Both these types of activities usually refer to and derive justifications from some ideological or theoretical concepts. The

[1] In scholar.google, you can find almost 35,000 scientific publications published only in 2018.

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area of interest of this study is a potential theoretical basis for managing a particular variant of the supply chain, namely a sustainable supply chain.

Because you can talk about the hypothesis that the future paradigm of economic activity is so-called sharing economy, therefore the question of whether and how can the sharing economy be the theoretical basis for a conceptual reference to supply chain management is considered the basic problem of the presented study. The study consists of three basic fragments. The first one is devoted to the characteristics of a sustainable supply chain, the second one deals with the issue of sharing economy and its consequences for the management process, and the third points to the relationship between both these concepts The supply chains are in a state of transformation. Sustainability will be of paramount importance in supply chain. A new wave of factory automation (Industry 4.0 and Logistics 4.0) will be supported by the next generation of low-cost robotics. The transformation of the supply chain of today to the supply chain of the future is an enormous task. The better we understand the future needs, the better smart and sustainable supply chain will function.

2 Sustainable Supply Chain Management

2.1 Contemporary Supply Chains in the Context of the Economics of the Sustainable Development

As a result of the progressing process of the liquidation of barriers among enterprises and going beyond traditionally formed relations between contracting parties, the first forms of connections which later were called supply chains started coming into existence. Even though, at first, enterprises focused their attention mainly on the reduction in supplies, quickly other processes occurring between them started optimizing it. Within several dozen years notion "supply chain" waited a lot of diverse definitions, often not very cohesive. Some authors treat the supply chain as the sequence of activities performed one by one by all sorts of enterprises. An example is an European Committee definition for Standardization which is showing that the supply chain is a sequence of processes carrying the value added into the product in the time of its flow and processing from raw materials, through all indirect forms, all the way to form in accordance with requirements of the final customer (Łupicka 2004). Organization APICS (The Association for Operations Management, earlier American Production and Inventory Society Ctrl) bearing in mind the complexity of processes occurring in the supply chain and their sequential, but also parallel character supply chain as (www.apics.org, 2018): processes reaching the consumerism of the ultimate product from the moment of obtaining initial supply materials and combining the supplier and the recipient and functions inside and outside the enterprise which they enable for the value of chain to produce products and to provide customers with services. Some authors treat supply chain as concept, or even philosophy, and they often also add a flow of knowledge and innovations. Implementing new ideas within the confines of the supply chain is connected with transforming of previous model of cooperation between enterprises as a result of the civilizational development of world and the growing threat to the natural environment. The activity aimed at the environment-friendly development is being strengthened in the awareness of societies already for over 30 years. In activities which are supposed to ensure biosecurity, it is possible to distinguish two courses. First one is concentrating on the environmental protection, ordering the need for the elimination or reducing the threats caused by the contamination and environmental pollutions, second is expressing the perspective thinking it is pointing out to the need for the amendment of a hierarchy of values and action which will lead to eliminating of threats (idea of the sustainable development) (Cała-Wacinkiewicz et al. 2010). In our times, a supply chain is not only managing the flow of logistic streams and their physical flow, but also the achievement of the goals associated with environmental and social aspects and with relations which are occurring between individual entities of the supply chain. Apart from decisions concerning orders, environmental aspects should be taken into consideration at the realization of transport functions, stock operations, and the accumulation of waste. The idea of sustainable development in a harmonious way is linking the ecological, economic, and social order in contemporary supply chains. The sustainable development is being defined as "right to fulfill developmental aspiration of the current generation, without limiting rights of future generations to meet their developmental needs". More widely—it is "process of changes, in which using resources, direction of investing, the sense of direction of the technological development, and institutional changes are harmonized and are increasing both current as well as future potential for satisfying the needs and human aspiration" (Short 1992) At implementing of the concept economics in supply chains, one should remember that economy of sustainable development permits in its assumptions a possibility of the market failure and a need for state interferences into various mechanisms of the activity of companies. The given attitude is aimed at stopping action which could be taken by the state and which would force market participants intended for the good in order to resign from the benefit of future generations what is a superior principle of the concept of sustainable development (Rogall 2010). Adam Smith has already written in his works that the development of the economy was possible at the intensive development of infrastructure (communication, education, etc.) through the state. Unfortunately his pupils disregarded his theses and ignoring the activity of the national politics suggested by A. Smith prevented the concept from the development of sustainable development. Many years later with social and environmental increasing problems, the science returned oneself toward sustainable development. The sustainable development became a global strategy, for which the basic challenges are energy saving, limiting harmful broadcastings, effective using all resources, keeping human resources, and proper use of the space and the social agreement. A source of distinguishing sustainable development as the challenge of civilization is a phenomenon of the intensifying imbalance between the social–economic development and the state of natural resources what is bringing a major risk of the economic, ecological, and social and political instability. A measure of this inequality is ecological footprint which is a synthetic indicator of the demand for sources of the earth. This track within 45 last years underwent the reduplication, leaning in 2007 from the level of the ecological balance about close to 50% (Pietrewicz 2011).

2.2 Managing the Sustainable Supply Chain

In the literature, a notion of managing the sustainable supply chain (Sustainable Supply Chain Management—SSCM) is current for over 10 years. In SSCM literature, the inclusion of sustainability into the theory of SCM is most often based on the triple bottom line (TBL) approach which calls for equal consideration of all three pillars of sustainability, namely, economy, ecology, and society. Many different definitions for sustainable supply chain and sustainable supply chain management practices exist, starting from the concept of green supply chain management and related green topics, with evident evolutions and variations over the years, as listed below:

1. Sustainable supply network management (Awasthi et al. 2014)
2. Supply and demand sustainability in corporate social responsibility networks
3. Green purchasing and procurement
4. Environmental purchasing
5. Green logistics and environmental logistics
6. Supply chain revision incorporating the multiplayer concept
7. Satisfying the triple bottom line (TBL) concept (Carter and Rogers 2008)
8. SSC and
9. SSCM (Seuring and Muller 2008).

The main aim of balancing the supply chain is creating the protection and the long-term development of the environmental, social, and economic value in delivering products and services to the market (United Nations 2008). The above purpose initiated the sweep of managing the sustainable supply chain, both in the context of the new business model, as well as indicating managing the supply chain in the closed terminus (close-loop supply chain) and of TBL (Triple Bottom Line) carrying out the earlier approach of sustainable development being based on three areas. Seuring and Mueller used the TBL concept in the sustainable management supply chain model suggested by them. They divided the model SSCM into three stages: strategic values, the structure, and processes occurring in the supply chain (Fig. 1). Of course the model is universal enough, that can be used both in traditional analysis as well as sustainable supply chains. The difference consists of noticing individual categories of processes with respect to sustainable development.

Seuring and Mueller define SSCM as […] the management of material, information, and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental, and social, into account which derived from customer and stakeholder requirements. This definition takes TBL (Triple Bottom Line)

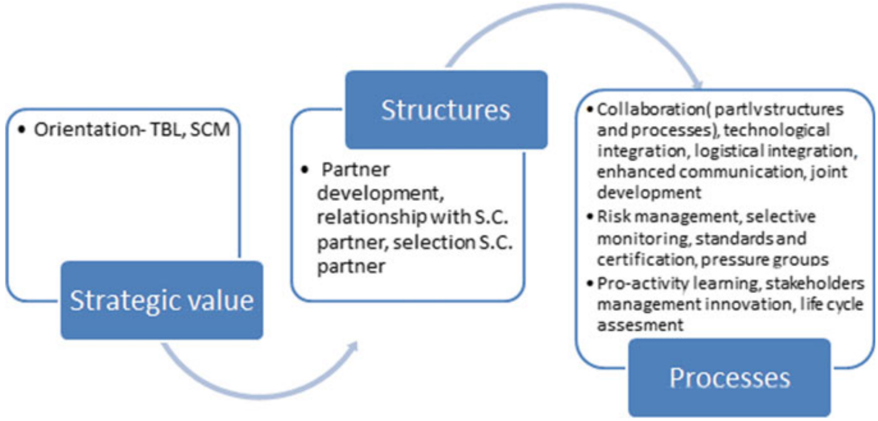

Fig. 1 Sustainable supply chain management categories and practices. *Source* Own study based on Seuring and Mueller (2008, pp. 1–6)

into account, recognizes interorganizational information sharing as a key factor for profound management, and furthermore, specifically includes the stakeholders as an important part of SSCM. Sustainable Supply Chain Management (SSCM) is defined also as the strategic, transparent integration, and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key interorganizational business processes for improving the long-term economic performance of the individual company and its supply chains.

Below a character sketch of individual areas is presented in the context of managing sustainable supply chains.

Environmental values in the sustainable supply chain

From a perspective of enterprises and their supply chains, the concept shows the sustainable development on economically justified, socially using acceptable, and friendly to the natural environment resources in the destination of supporting its development in the long term. A process of using the resources friendly to the environment and transforming them isfound in a sustainable supply chain so that it is possible to improve their incidental properties or to affect the recycling in the existing environment without harming it (Brdulak 2012). Environmental values are for example the following regulations associated with environmental aspects of the conducting business activities. Within the supply chain, it is possible to measure the amount of secreted greenhouse gases, the energy efficiency, or the possibility of new processing materials.

Social values in the sustainable supply chain

Among social values mentioned in the sustainable supply chains, it is possible to distinguish honest employee practice, fair rewarding employees, abiding by labor law and human rights, adherence to the principles of equality of rights, safety among others on-the-job, not using for the child labor, not applying the employee slavery as well as practice set for the cooperation with the local communities.

Economic values in the sustainable supply chain

It is possible to count to economic values fair conditions of contracts, timely paying to the amount due, not using the economic majority toward partners in the supply chain, building the relations based on the confidence, applying fair trade rules, the appropriate spread of risk and liabilities in the supply chain.

Sustainability will be of paramount importance in the supply chain. The goals of sustainability efforts will be materials, manufacturing processes, energy, and pollutants attributed to manufacturing and logistics.

2.3 Causes of the Development of Sustainable Supply Chains

Basic causes of the development of stable concepts of supply chains both in theory as well as in practice of the management are as follows:

1. *Rejecting existing paradigms of economic studies.* In conditions of the contemporary functioning, economy gradual paradigm shifts are happening in the turbulent environment, being characterized by great instability, uncertainty, and a discontinuity of action of economic studies. More and more managers are approaching the business administration in an intuitive way, in which the classical economic theory is only a point of departure for creating new proposals, linking different fields of study such as economics, psychology, sociology or ethics, letting solving contemporary problems, but first of all, enabling building stronger relations with business partners. Many companies such as the Beiersdorf Group, the VW, or the often described coincidence of the Mexican bank Grupa Financiero Serfin are implementing improvements of the training program in the negotiation and the psychological attempt at the management, being the source of the building confidence among cooperating companies (Wincewicz-Bosy et al. 2017). The need for managing supply chains is forcing the holistic approach managers into seeking solutions in the public and economic environmental aspects. The requirement of the holistic approach is calling a lot of dilemmas of the theoretical nature to the development of the contemporary economy, and especially pragmatic (Wojewódzka-Król et al. 2016).
2. *New regulations.* Regulations are imposing more and more high standards and financial penalties for the harmful impact on the environment. For example, influences limiting the level of the adverse impact of transport to the natural environment are included in the idea of sustainable transport. According to the OECD, environmentally sustainable transport system (environmentally sustainable transport system) is "which isn't threatening the public health or ecosystems and is meeting the transport needs according to principles (a) of using renewable resources below the level of their ability to reconstruct and (b) of nonrenewable

stores below the level of development of their renewable substitutes" (Environmentally Sustainable Transport 2000). Next the White Paper of Transport 2011 clearly shows the modernization the transport to the plan in Europe to the year 2030/2050. European Federation is defining components of the sustainable transport for Transport and Environment. According to that it is possible to regard sustainable only when it is meeting four conditions of the environmental awareness, the economic optimum, social grounds, and the political responsibility the transport (Wojewódzka-Król et al. 2016).

3. *The development of new technologies and the 4.0 industry.* Supply chains are inherently complex and dynamic systems (Surana 2005). In a web-based global business arena witnessing Industry 4.0, collaboration across SC partners has to be smart, innovative, and socially responsible to form value-creating networks. So, one can see a different kind of supply chain emerging. It is possible to envision a supply chain of the future: (1) The supply chain will be incredibly complex and dynamic. Integration of sustainability principles will increase the complexity; (2) Information will increasingly be machine-generated (instrumented); (3) The whole supply chain will be connected. The supply chains take interaction (with customers, suppliers, and IT systems in general). It seems a more holistic view of the supply chain, this extensive interconnectivity will also facilitate collaboration on a massive scale (interconnected).
4. *Growing environmental awareness of the society*. Comprehending the environmental awareness is being considered in two dimensions. In broader meaning, an entirety means acknowledged ideas, the value, or also an opinion on the environment as the place of the life of man, together shared by particular social groups in the given period. In narrower meaning, it is a state of knowledge, views, and conceptions of the role of environment concerning people in the life of man, […], as well as state of the knowledge about ways and tools of managing the use, the protection, and the forming of the environment (Poskrobko 2007a, b). Enterprises which noticed the trend of the change of perceiving the environment by consumers are changing the manner of delivering goods and their production in a more environment-friendly way.
5. *Purchasing and the conversion of the knowledge.* Knowledge is one of the most decisive factors capable of offering competitive advantages for supply chain partners. Some authors (Christopher 1998) recognize the need for cooperation and stress the establishment of closer, long-term relationships as a way to construct increasingly efficient and responsive supply chains. One can maintain that supply chain partners engage in interlinked processes that rich information sharing and building information technology infrastructures to process the information obtained from partners, a scenario that create new knowledge (Capo-Vicedo et al. 2011) with supply chains it is necessary to form a relationship or deal with organizations with very different experiences, languages, and contexts. This implies new organizational ideas, plus an environment of loyalty and trust and collaboration between the enterprises in the supply chain which facilitates knowledge creation and distribution. To obtain advantages from knowledge sharing,

it is strategically important that firms understand the factors affecting partners' knowledge sharing behaviors (Cheng et al. 2008).

6. *Possibility of the cost cutting.* Along with the need of seeking the cost cutting, new concepts are developing of business administration. However according to the J. K. Galbraith (Noble prize winner), action connected with the environmental protection "by their nature are in conflict by force incentive of market economy" (Pietrewicz 2011). And so enterprises and the entire supply chains are implementing concepts of narrow management in order to eliminate the waste of the space, the stores of the production, or the time of producing and delivering for the ultimate customer.
7. *The policy of image.* The sustainable supply chain is a result of combining environmentally friendly management with cost-efficient solutions. It is particularly important in the case of energy-intensive and material-consuming parts of the industry in which a large quantity of waste is occurring (Brdulak 2012). In order to increase the competitiveness, companies are using many different tools influencing their environmentally friendly image. An example of such tools can be tools dedicated to IT. For instance, SEDEX (Supplier Ethical Exchange Date)—platform of the exchange of data associated with managing the sustainable supply chain. It enables an accumulation, publicity, and reporting information coming from suppliers which are divided into four main categories: standards of the work, health and safety, the environment, and business ethics. A further example is SHDB (Social Hotspot Database)—base dedicated to the widest spectrum of recipients, offering transparent information about the social risk and diverse possibilities for cooperation business (Tundys 2017).
8. *The network effect and new models of collaboration.* Along with diverging of enterprises from the traditional model of collaboration functioning in formal and hierarchical structures, new models of collaboration based on changing relations between companies, consumers, and markets are formed. Prahalad and Ramaswamy acknowledged that the new model of collaboration involves the new approach for value creation, based on contributing it by customers' and companies' contribution. Whereas Tapscott researchers and Williams claim that a new model of collaboration of the organization and stakeholders which is leading to the change of the way in which companies and societies are using the knowledge and the ability to the value creation. New opportunities to billion people who are giving access to the Internet were considered, in order to take an active part in innovative processes, to create the common value, and to contribute to the social development. On the other hand, the network effect is about the more knots have a network, the more membership in it is benefitting individual knots. For example, the additional knot in the social network is increasing its value and is encouraging disabled users for joining (Szumniak-Samolej 2013). Supply chains implementing the concept of sustainable development cannot forget about power of Internet, social media, which are encouraging potential prospects. From the other side, using web applications, lets consumers reading environment-friendly and public shares fulfilled by companies.

3 Sharing Economy and Management Based on Cooperation—Genesis and Content

Recently, we can talk about the growing popularity of the emerging new conceptual proposal justifying a new look at economics and management. Jeremy Rifkin identifies this theoretical innovation as a collaborative economy (Rifkin 2016). The cornerstone of this theory is the so-called common good or "collective value achieved by human communities in connection with the development of the natural capabilities of their members, satisfying their individual interests or respecting their individual rights, while taking care to bring the whole community closer to its proper purpose" (Dobro wspólne, Encyklopedia PWN, 18 Oct 2016). The explanations derived from scientific research on the common good turn out to be an effective idea for the organization of the economy and management of its resources (Słodowa-Hepła, 18 Oct 2016). Rifkin points out that the projects of deregulation of economic systems promoted since the early 1980s and the privatization of the best use of all resources, including resources that are common goods, should be interpreted as a renunciation of responsibility by governments for creating welfare and well-being of societies (Rifkin 2016). The effect of many years of efforts turned out to be alarming because "the private sector has caught and devoured, with one huge gulp and in the blink of an eye, most of the profitable riches on the planet, changing into a corporate power that can easily handle any challenge thrown into its power" (Rifkin 2016).

Leading researcher of common goods, Elinor Ostrom presented, as the result of her many years of research, the eight most important assumptions of dealing with these goods by social communities. They are namely (Ostrom 1990)

1. Clear boundaries. Entities entitled to use the common goods are clearly indicated, as well as the collection of these goods;
2. Clear definition of time, amount of resources, and acceptable methods of their use;
3. Ensuring common creation of rules regulating the exploitation of common resources and ways to change these rules;
4. Clear indication of persons controlling compliance with established rules, which should be derived from a community that exploits common goods;
5. The gradual nature of penalties for breaking the established rules, i.e., their transparency and the degree of discomfort that will not prevent the necessary participation of those punished in shaping the success of the community;
6. The existence of procedures and institutions allowing for quick and inexpensive resolution of emerging conflicts;
7. Far-reaching autonomy of the community manifesting its relative independence from the authorities;
8. Nesting the community in the superior system.

The approach proposed by Ostrom allows us to state that "although the common good may contain various material and immaterial resources, it cannot be equated only with resources, as it is unfortunately the case. The paradigm of the common good includes three elements that form an integrated, interdependent whole: resources, community and a set of principles, values, and norms" (Słodowa-Hełpa, 18 Oct 2016). This means that the conceptual category of the common good includes not only specific material resources but also social outlook and attitudes (culture). On this basis, a new way of farming emerges that can be called a model of sharing economy.

Different authors variously define this new economic phenomenon (e.g., Jastrzebska and Legutko-Kobus 2015). Rachel Botsman believes that the sharing economy is "a system of decentralized networks and markets that unlocks the hidden value of underutilized resources by matching those in need who have been bypassing traditional intermediaries." On the other hand, the OuiShare platform indicates that they are "initiatives based on horizontal networks and community involvement, based on energy and community trust, in opposition to centralized institutions, blurring the boundaries between the producer and the consumer, where interactions take place via Internet networks and P2P platforms as well as shared spaces." According to English Oxford Living Dictionaries, sharing economy is "an economic system in which assets or services are shared between private individuals, either for free or for a fee, usually via the Internet" (https://en.oxforddictionaries.com/definition/sharing_economy, 19 Oct 2016). This system consists of starting goods recirculation, increasing the use of assets, exchanging services, and making production potential available. An example of recirculation of goods can be bookcrossing box, that is, public wardrobes or bookshelves that anyone can put books on (sometimes a specific genre for which the bookshelf is dedicated) and take books placed by another person. A copy of the book is not stored in a private library but is read by subsequent users. An example of increasing the use of assets is the joint use of vehicles (car sharing), primarily passenger cars, to move from their place of residence usually to the workplace. It is a kind of a neighborly agreement to use only one vehicle instead of several carrying individual passengers. It is also possible to use group journeys for a distance for a fee. Then, the most common mating of passengers takes place using online social platforms. Mutual exchange of services usually takes the form of the so-called time banks. For example, using a moment's time, someone washes a window at another person, and this one, in a way, repays this service in his free time by giving a child private tuition. Finally, sharing production potential can consist of paid or free permission to use tools or machines for anyone who wants to do some work, usually not necessarily for their own needs. These are, of course, only examples, the list of which could undoubtedly be significantly extended.

Cooperative projects can be both commercial and noncommercial. In the first case, they can rely either on the intermediation of transactions between their parties and the remuneration is than the commission (example of Airbnb) or on direct contracts at a fixed price (Zipcar example). If the sharing economy projects are noncommercial, they rely either on the barter and direct exchange of goods or services (for example, time banks) or on creating opportunities for such exchange (example of a cross-box).

The report prepared by the consulting company Ernst and Young gives the following factors as reasons and benefits of the dynamic development of the sharing economy (The rise of the sharing economy 2015):

1. More use of available resources. The opening of the potential of the various institutions to ideas and use by innovative and motivated people allows for better adjustment of the supply offer to the effectively reported demand. Thanks to this, the unprofitable stock of finished products is also liquidated.
2. Creating new jobs. In particular, enterprises can react much faster to changes in demand, which allows for more intensive use of live work, including more frequent employment of employees. Job opportunities appear even in regions where employment has so far been difficult to find.
3. Increasing social mobility. Opening the possibility of using the existing business potential triggers the entrepreneurship and innovation of many people. In this way, a large group of micro-entrepreneurs is created who start their own business activity on the basis of self-employment.
4. Support for competence development. Professional and economic activation creates opportunities for gathering experience and motivates people to improve their skills through education and professional training.
5. Creation of more favorable conditions for business. It is easier for entrepreneurs to change their ideas for finished products. In turn, customers have the opportunity to find an offer that meets their requirements easier.
6. Building transparency of business activity and financial settlements. Contractual transactions and barter exchanges take place under conditions of full disclosure and none of the parties to the contract is in a privileged position toward the other.

In view of the complexity and multifacetedness of activity models within the sharing economy, diagnosed by Codagnone and Martins (2016), however, slightly modifying their proposition, the characteristics of economic activity in this paradigm can be presented as in Fig. 2.

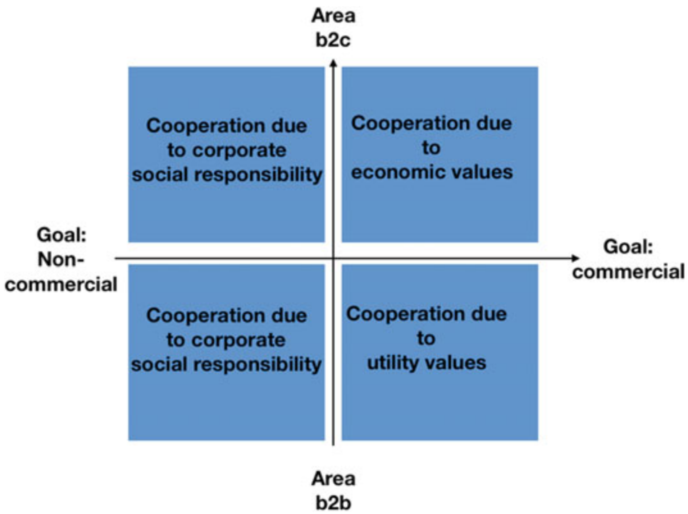

Fig. 2 A map of economic activities in the paradigm of sharing economy. *Source* Own study

Regardless of the logic of economic activity determined by the pursuit of profit or not, in relation to other business partners or to final users, it is necessary to manage this activity in a special way adapted to the conditions of the sharing economy. We can name them—after OuiShare—for horizontal and open management. Horizontal management consists of coordinating and synchronizing a set of actions between two or more organizational units, in which these units have no hierarchical control over themselves and whose goal is to generate results that cannot be achieved if they operate in isolation (Gagnon 2018). In turn, open management consists in increasing the dynamism of an innovative company by creating the possibility of using both own and external resources (Lindergaard 2018).

Relying on the views of Rosabeth Moss-Kanter, it can be said that open management means that companies should be oriented toward three main directions of action (Burnes 2004):

1. Continuous restructuring to create synergy. The basic value for this restructuring should be concentrating all resources on their most effective applications. In other words, this means striving to identify one's core business and outsourcing other activities. In addition to efficiency gains, an important consequence is the leaning of the administrative sphere, the elimination of bureaucratese, and the improvement of the general working atmosphere.
2. Opening organizational boundaries for strategic alliances. This pursuit is a consequence of focusing on the core business. Outsourcing of collateral activities forces the development of cooperation with many business partners who themselves should be very effective in their area of activity. These alliances can have a threefold form: service, opportunist, and interest. The service alliance is concluded between partners who alone could not implement any business projects. This may be due to either a combination of unique competencies, or risk diversification, or the pursuit of dominant market share, etc. The opportunistic alliance is about gaining access to unique competencies, breakthrough technologies, or an attractive market. He points out that, unlike the previous type, this alliance is not mutually beneficial—one partner always gains more. Finally, the essence of a friendly alliance consists of a lasting cooperative relationship with business partners connected by common economic interest. It is usually associated with suppliers, recipients, or distributors.
3. Creation of new ventures from the company's interior thanks to innovation and entrepreneurship. In a classically operating enterprise, the development of new products and new business ventures is the domain of specialized planning and R & D departments. This is a typical silo system. Even important innovations can hardly penetrate the construction silos. Therefore, the inclusion of all employees in the process of creating innovation is encouraged so that their ideas in an emergent way constantly improve the methods of operation and allow for the launching of innovative directions of this activity. This is obviously conditioned by the development of a culture of entrepreneurship strengthened by a pro-innovation system of remunerating employees.

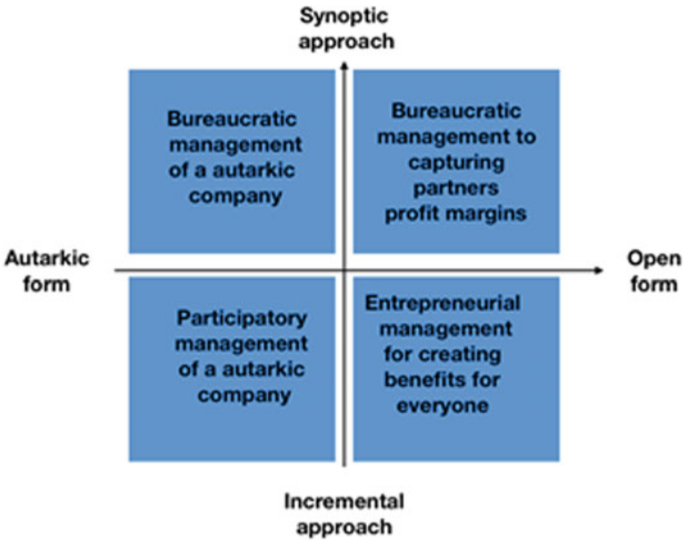

Fig. 3 A map of company management models. *Source* Own study

Having the above in mind and using the idea of Lica Boyer and Noel Equilbey, the relationship between horizontal and open management of the enterprise and the requirements of the sharing economy can be illustrated as in Fig. 3. On the horizontal axis, the closed (autarkic) or open nature of business management is awarded. The first consists of the pursuit of administrative control over the largest possible area of economic activity, and the second—focusing on the core business and the pursuit of forming alliances with external partners. In turn, on the vertical axis, the synoptic or emergent nature of management is awarded. Synoptic consists of a strictly planning approach developed from the top of the organizational hierarchy to its lower levels. The emergent character is expressed through empowering all employees and stimulating them to develop initiative and ingenuity.

The bureaucratic and participative management of an autarkic company assumes that the greatest benefits result from economies of scale and scope. Economies of scale allow to spread fixed costs on an increasing number of products and thus reduce their costs and unit prices, and this leads to strengthening the competitiveness of the company. The economics of the scope consists of enriching the product offer with new product items, which also allows the spreading of fixed costs on a growing number of products. The bureaucratic form of this management assumes the omnipotence of the management and it is the responsibility of the company's current and future financial results. The participation variant recognizes the potential of the total employed and builds remuneration systems that reward employee creativity. Both types of management support neoclassical economic doctrines, only that in the first case, on a more orthodox interpretation of them, and in the second—on a more humanistic interpretation.

Bureaucratic management to capture profit margins of business partners refers to the concept of industry economics and strategic management to a large extent. The key here is the explanation proposed by Michael Porter known as the five forces of competition (Porter 1992). The primary goal of enterprise management is to maximize profit, and one of the possibilities to build a transactional advantage over business partners that allows you to capture the financial surpluses they have developed.

Entrepreneurial management in order to create benefits for all business partners derives precisely from the concept of sharing economy. It assumes a fully autonomous status (independence) of cooperating partners who can derive economic benefits from this cooperation. The condition is a guarantee for a long duration of this cooperation because it allows mutual adjustment (increasing the specificity of resources (Williamson 1994) which results in a reduction of the operating costs. Empowerment should be implemented on two levels. First, for all employees and, second, for companies in mutual cooperation. Of course, other economic benefits are expected by enterprises participating in the supply chain, and others—final consumers. For the company, the exchangeable value that comes to the forefront, which translates into sales revenues and, consequently, profits. For others—the use value satisfies their needs and requirements as to the form of the product, the time and place of its receipt and the cost of acquisition.

4 Premises for Creating a Supply Chain Management Model with Sustainability and Sharing Features

The proposed model assumes that supply chain management is implemented due to three equivalent optimization criteria, closely related to the TBL approach. First of all, it is an economic criterion. Due to the common view in the literature, it is assumed that "the goal of the company's activity in a market economy is to maximize the benefits of ownership. (…) The value of the enterprise is the measure in which maximization is synonymous with maximizing the benefits of its owners." (Czeka et al. 1997) In this interpretation, the market value added (MVA) is the most important factor, i.e., the surplus of the market value of the enterprise over the value of the capital invested in the enterprise. Striving for maximization of MVA requires that in individual periods of economic activity, the aim is to maximize the difference between operating profit after tax and the total cost of capital (own and foreign). While the assumption is understandable in relation to the management of one enterprise, it creates a problem in the case of supply chain management that is the activity of several enterprises. Maximizing the $MVA_{ŁD}$ of the entire chain is not the sum of the MVA maximization of each of its companies. It is necessary to reject the parasitic model in supply chain management and adoption of the symbiotic model. In this model, striving to maximize the market value added of each of the chain-making enterprises requires the development and implementation of a special financial mechanism to compensate the effects of suboptimal decisions in individual enterprises in order to maximize the market value of the chain as a whole. This action undoubtedly requires cooperation and sharing of financial resources.

Second, the ecological criteria should be equivalent to the economic one. Here, the basic premise can be the minimization of the ecological footprint. The ecological footprint is referred to as the land or water area that is required to sustain the human population. It is, therefore, a measure of the size of the planet's natural resources used in the perspective of the process of their reproduction by the forces of nature (Lowellyn 2015). The principle of not creating a deficit in this area requires the application of philosophy and a policy of sustainable development, i.e., striving not to deprive environmental capital and respect the interests of future generations (Domański 1992). However, the operationalization of the ecological criterion (K_e) requires finding a calculation formula that would measure the results and changes in the economic activity of the supply chain as a whole. Referring to the proposal of Kimio Uno, discussed by Parteka (1997) and referring to the specificity of the supply chain, it should, in the reception field of such calculation formula, include the quotients of space (P) and employment (Zt), quotient of economic value added (EWD) and employment (efficiency level), quotient of balance sheet assets (AB) and employment. (load on resources), and the contamination quotient (Zn) and balance assets (creation of negative, economic external effects).

$$K_e = P\big/Zt \times EWD\big/Zt \times AB\big/Zt \times Zn\big/AB$$

These factors are formulated in other units so that a standardization of measurement is necessary.

Finally, in the social criterion, it is essential to meet the needs of people involved in the economic activities of the supply chain as a whole. It is the satisfaction of needs that is the cause of happiness (Poskrobko 2007a, b). The onion theory of happiness of Jan Czapiński can be particularly helpful which (Czapiński 2001) assumes a three-level structure of a sense of happiness: the deepest layer is associated with the will to live, the intermediate layer is related to the so-called subjective well-being, i.e., a positive emotional balance resulting from existence, and finally the most surface layer is partial satisfaction, i.e., everyday joys from current experiences. This allows to propose a criterion related to the shaping of logistics processes and devices in the supply chain in a three-level system. In the first place with the highest significance index, it is a measure of respect for the will to live Wż = Z + W + H + Ś + E + B, where Z is a measure of pollution, W—accidents, H—noise, Ś—ecological footprint, E—ergonomic adjustment, and B—biodegradability. Bringing these quantities to common units of measure also requires standardization. Second, the average significance is the synthetic index of subjective well-being Ds = T, where T is the time of employee participation in company management measured as percentage points in relation to the total time spent at workplaces. Finally, in the third place, that is with the use of the smallest significance index, it is a synthetic indicator of participation in deciding on solutions of processes and logistic devices in the supply chain (Pd) as measured above in percent as above. The three levels of individual indicators can be obtained by assuming weighting factors with values of 0.55, 0.33, and 0.12. Such quantities result from the assumption about the normal distribution of people's feelings and the hierarchical diversity of the determinants of happiness. A comprehensive assessment of solutions in the field of logistics processes and devices in the supply chain (Q_{LM}) can be presented as below:

$$Q_{LM} = 0.55 \times W_{\dot{z}} + 0.33 \times D_s + 0.12 \times P_d$$

Therefore, the optimal shaping of the sustainable supply chain management (SZZŁD) system should fulfill the following function:

$$f_{(SZZŁD)} = \{MVA_{ŁD} + K_e + Q_{LM}\}(SZZŁD)$$

In turn, the sustainable supply chain management system is composed of variable components, as indicated above in the areas proposed by Philip Beske and Stefan Seuring, i.e., strategies, structures, and processes.

Of course, among the set of available supply chain management strategies, those that meet the criteria presented above should be preferred. "Supply chain management strategy is based on synchronization of demand and supply, using assistive technology" (Baraniecka 2008) According to the proposal, Sylwia Konecka, a specific map of potential supply chain management strategies is presented in Fig. 4. The map is three-dimensional and uses three criteria. First of all, the criterion of the uncertainty of demand is determined by the possibilities of predicting market reactions to the product offer. These products can be either functional (standard), for which demand is stable, i.e., predictable, or innovative (innovative), for which demand is difficult to forecast. Second, it is a volume criterion, i.e., the volume of

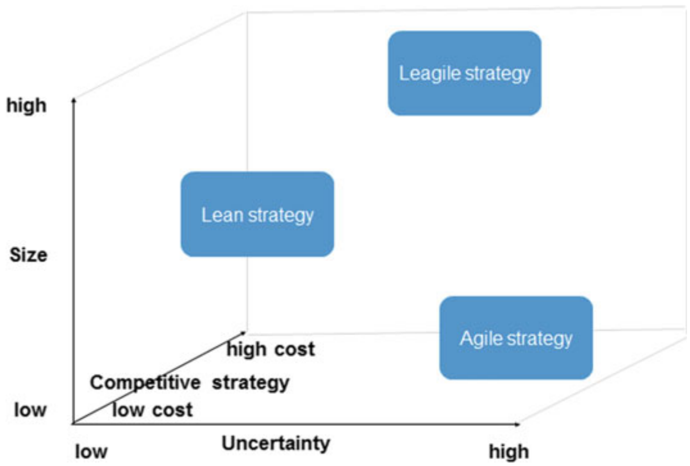

Fig. 4 A map of the potential supply chain management strategies. *Source* Own study based on Konecka (2011, p. 1099)

production and sales. Finally, the third criterion is the preferred competition strategies distinguished according to the taxonomy proposed by Michael Porter, i.e., either a low-cost strategy or a distinction.

Among the potential combinations of management strategies, you can indicate three of their ideal types

1. The lean supply chain management strategy:
   This strategy is suitable in situations of relatively high predictability of demand, which allows to focus on the effect of the scale of production, which results in competition due to low costs. The product offer is therefore standard and it allows to push the manufacturer's offer through distribution channels.
2. The agile supply chain management strategy:
   This strategy is suitable in situations of relatively low predictability of demand, and this requires an individualized approach to clients (customization) and results in competition thanks to distinction. The product offer, therefore, contains innovative products, which forces the attraction of both sales agents and final consumers.
3. The hybrid supply chain management strategy:
   This strategy is suitable in situations of relatively low predictability of demand but the total delivery time is quite long. As products usually have a modular structure, the method of postponing the product to the recipient may be applied until the order appears. Properly locating the decoupling point allows to combine the effects of leaning and variability, as well as competing with low costs.

Considering dependence (SSCM), the hybrid strategy is the most appropriate strategy for sustainable supply chain management. This is because

1. Due to the K_e criterion, this strategy allows for the widest use of the mass production system and thus for very high work productivity and productivity of fixed assets,
2. Due to the MVA criterion, this strategy allows to maximize the profit margin in the long period,
3. Due to the Q_{LM} criterion, this strategy allows the creation of very human-friendly working and living conditions.

Remembering the dependence demonstrated by Alfred Chandler that organizations achieve high efficiency only when they adapt their organizational structure to the implemented strategy (Chandler 1962), the question arises as to the best adapted organizational structure for the hybrid sustainable supply chain management strategy. According to Jean-Pierre Helfer, Michel Kalika, and Jacques Orsoni, it is assumed that this requires answering five fundamental questions about the way of specialization of activities, the way of dividing power, the nature of decentralization of decisions, the method of coordinating activities, and the way of balancing differentiation with integration (Helfer et al. 1998).

The specialization of the activity, in other words, it is called the division of labor between enterprises that makes the supply chain can be of a different nature. However, because the supply chain is by definition created along the technological and operational process of adding value to the manufactured products, it is a division determined by the requirements of this process. Some units of the chain specialize in functions and tasks carried out for other units, others according to established technology of activity, and still others according to implemented projects. In principle, this division of labor is characterized by a relatively high degree of freedom, which is the result of the principle of open management.

The division of power is more important than the division of labor because it creates opportunities to apply the principle of horizontal management. There is a dilemma of seeking a balance between striving to create a chain leader who can form a vision of activity and give the chain development speed. It is an issue closely related to the process of increasing the integration of the supply chain discussed below. It can be assumed that the principle of subsidiarity should be applied, i.e., adopt a policy of service and supporting the activities of the center of power in relation to the federation of enterprises that make the supply chain.

The same is true for the decentralization of decisions between units of the chain. It is not possible to implement a system of total decentralization if the center of power is able to perform its tasks. The best rule is selective decentralization that is concentrating some decision-making powers in the central authority center and leaving the remaining decisions in the chain companies as close as possible to the problems that need solving.

Among the available instruments for coordination of activities, the most effective in regulating the activities of the chain's enterprises is standardization. Different areas of economic activity may be standardized, but the standardization of results is of key importance. These standards are the message of the recipient to the supplier with the required product parameters (items or services). If it is important from a technological point of view, then the procedures implemented in the chain companies can also be standardized.

Another important solution is to find a balance between the diversification of the chain's business profile and the level of its integration. Diversification results from existing specialization, and integration necessitates coordination. The desired strategy is determined by the chain strategy, the industries in which the chain's companies operate and the nature of the competitive environment.

As a result of the above decisions, the organizational structure of the supply chain takes a specific form. According to the proposal of Henry Mintzberg (Bąk-Sokołowska 2015), it should probably reject the extreme forms, which he identifies, i.e., the simple structure (because it characterizes small enterprises) and the adhocratic structure (because it means organizational atrophy). The three others should be considered. First of all, the structure of the industrial bureaucracy in which specialists employed in staff cells play the leading role. First of all, the structure of the industrial bureaucracy in which specialists employed in staff cells play the leading role. This structure works well in a stable and uncomplicated competitive environment and in relation to externally regulated business activity. Second, the structure of a professional bureaucracy in which professionals responsible for production processes play a leading role. This structure works well in a stable but complex competitive environment. Third, the departmental structure, in which mid-level managers play a leading role. This structure works well in a complex competitive environment with strong diversified outlets.

Adapting the structure of the supply chain to hybrid strategies is taking place among others under the influence of changes in the economy according to the TBL concept and the economy of the sharing. These two concepts due to widely comprehended integration are permeating structures and processes occurring in the supply chain. The integration of the supply chain is the base of the contemporary logistic management at present. Issues of the management integration logistic are going beyond the formal bounds of single companies and entire groups of enterprises, operating in the supply chain. Through the interrelation of stores, the ability, processes, and the strategy, initiating the process of the integration of the whole chain is possible. A great significance has a correct evaluation of stores, or abilities being a strategic key in achieving competitive superiority. It means that enterprises forming the supply chain in the given industry should seek the concept and aiming solutions to the full integration (Łupicka 2004).

Developing a conception and the plan of changes in the enterprise being aimed at creating the integrated supply chain is the greatest challenge. Ensuring that the developed plan will be possible to implement requires the comprehensive look at all areas of the process of the supply chain logistic, including purposes, the possibility of all those present and future partners which will be the links integrated about features of balancing and sharing.

In the supply chains, it is possible to divide integration on Table 1:

1. Internal—integration with reference to sustainable development and the sharing economy is obtained due to the strategy and the organizational structure.
2. External—integration concerning the cooperation with stakeholders of the supply chain with reference to the social, economic, and environmental risk shared initiatives of sustainable development and sharing economy.

Table 1 Determinants of the sustainable supply chain with reference to three types of integration

External integration	Internal integration	Operational integration
• Dialogue with stakeholders • Market position • Readiness of the payment for the sustainable development • Public, environmental, and economic risk assessment	• Defining the purposes of the sustainable development • Trainings in the sustainable development • Managing the social, economic, and environmental risk • Knowledge • Availability of human resources	• Audits • Certificates • Sharing information • Market position • Availability of financial resources • Time constraints • Innovations • Public, environmental, and economic risk assessment • Extending the life cycle of products • Innovations

Source Own study with the application: Wolf (2011, pp. 221–235)

3. Operational—integration concerning shared programs with suppliers, the management of the relationships with clients, the manufacturing process, or the process of the recycling in order to take environment-friendly and prosocial action.

For the purpose of the implementation of features of the sustainable development and sharing in supply chains apart from adapting the strategy and the organizational structure, peculiarly managing logistic processes and their integration are playing an important role in the internal and operating levels. Many skeptics certainly will recognize that the minimum price, the maximization of profits, and the minimization of costs aren't harmonizing with environmental-friendly or social slogans. However at present, we are dealing with turning away the value chain, in which the consumer is the most important entity. According to M. Bąk-Sokołowska, in the context of growing, consumer awareness is gaining great importance building the responsible, integrated product, for which at all stages associated with, it's coming into existence and spreading are taken into account (of course apart from economic aspects), public and ethical environmental aspect. It confirms the fact that in 2013, the Unilever company conducted research in 11 countries which demonstrated that three fourth of the consumers more willingly would buy product, knowing that it was produced out of raw materials acquired according to principles of the sustainable development (Bąk-Sokołowska 2015). The supply chain with features of sustainable and sharing is regarding all processes occurring in it whose concept is shown in Table 2.

Table 2 Component parts of supply chains with features of sustainable and sharing

Supply chain with features of sustainable and sharing				
Sustainable and shared orders Proper selection of suppliers often local or neighborly Reducing the number of suppliers Integration of marketing processes, the transport, and the production Purchase of materials and raw materials acquired according to environmental norms	Sustainable and shared production Balanced recruiting of raw materials Frugality of stores Strategic alliances of producers Accustoming suppliers into the manufacturing process	Sustainable and shared distribution Design changes of the product and packages Wider using of renewable materials Reusability of similar packages Limiting intermediaries in delivery channels	Sustainable and shared transport Optimal use of the capacity and the space of vehicles Reducing the exhaust emission More effective managing transport means of transporting The decisions concerning the location of logistic centers Implementing transport strategies	Sustainable and shared opposite logistics Integration of Eco logistic links Maximization of the recovery of waste Rationalizing technical, technological, and logistic new solutions waste disposal Friendly environmentally forms of the recycling
Integration on the internal, external and operating level				

Source Own study

Sustainable and shared orders

Orders are being executed with a smaller number of suppliers to the purpose of the improvement of the quality and the cost cutting, often neighborly and local what is curbing the unnecessary transport. Moreover, integration of marketing processes, the transport, and the production will influence more effective order processing, for example, producing concentrates will cause reducing the importance of the transport and can lead to CO_2 emission reduction. The purchase of materials and raw materials in accordance with environmental norms will influence in reducing their harmfulness for the environment.

Sustainable and shared production

More and more companies apply solutions in the production which are neutral for the environment and are producing less waste. Next strategic alliances in relation to producing some component or the module cause reducing using nonrenewable raw materials and the sharing of costs of research and development. Accustoming suppliers into a production process allows for joint using modern technologies, for example, using big data for the transparency of the supply chain.

Sustainable and shared distribution

Design changes of the product or the package and wider using renewable raw materials are having a positive effect on the corporate image and are encouraging environment-friendly consumers for the purchase of these goods. Moreover applying similar packages by producers and their standardization permit lending and reducing the quantity of waste.

Sustainable and shared transport

Limiting the empty runs to minimum t, applying the respective parameters of the capacity, and using lent containers influences the cost cutting and the optimization of transports. In case of building the logistic canters close to the industrial parks, limits the transport and hence the CO_2 emission reduction takes place. Next implementing transport strategies, e.g., of strategy pooling, whether creating platforms associating carriers with customers allows for getting synergetic effects in the storage, picking orders, and the transport. For example, in pooling, benefits can come out of the reduction in the number of vehicles for relieving and in the process of reduction in the number of employees, the better filling of the surface of cars and the better availability of the fleet.

Sustainable and shared reverse logistics

The sustainable and shared opposite logistics is aimed at the recovery of waste and its recycling. Integration of ecologistic links takes place along the entire supply chain starting from mining companies, through entities collecting waste, organizations of the recycling, being limited to governmental organizations and extra-governmental dealing with issues of environmental protection.

5 Conclusions

The above reasoning proved that it is the sharing economy that is the theoretical basis for shaping sustainable supply chain management. Interpretation of basic assumptions of the concept of sharing economy from the point of view of the management process allowed to recognize the principle of open management and the principle of horizontal management as the most important for the sustainable supply chain management. Subsequently, the problems of decision criteria in sustainable supply chain management as well as structures and processes in this management were developed.

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Simulation Modeling and Analysis for Sustainable Supply Chains

Roman Gumzej and Miroslava Rakovska

Abstract In their decision-making supply chain management, specialists are usually focused on some characteristic performance metrics that mainly influence the construction of their decision support models and partly also the results. Many of the supply chain issues affect the sustainability performance of companies. Since supply chains are complex adaptive systems, appropriate modeling methods are required to tackle their inherent complexity and lead to desired results that contribute to the achievement of sustainable objectives. From the viewpoint of system theory, they should enable the monitoring, analysis, and control of supply chains providing opportunities for system-wide integration. Since multiple views and layers of a supply chain or multiple interconnected supply chains must be considered, different modeling and analysis techniques are used to achieve the desired levels of detail. In this chapter, three simulation modeling and analysis methods are assessed, considering their suitability to support decision-making in diverse supply chain management problems and scenarios. These results are joined in guidelines for the construction of coherent and consistent simulation models that would enable multilayered and multifaceted analysis of common supply chain management problems and lead to making decisions that efficiently utilize supply chain resources, shorten lead times, and eliminate unnecessary waste.

Keywords Behavioral supply management · Decision support · Case studies · Discrete event simulation · System dynamics · Agent-based simulation

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1 Introduction

Decision makers in supply chains (SC) are often faced with strategic decision-making challenges with only partial information on system structure and/or system operation. Hence, adopted decisions may have a negative impact on overall SC performance. These situations should be avoided and can be prevented by utilizing decision support systems (DSS). DSSs enable business and/or organizational decision-making based on rapidly changing data, not known in advance. By applying the holistic modeling approach to capture the extended SC at a strategic, tactical and/or operational level of an enterprise within a DSS the decision-making problem may be efficiently addressed and solved (Rosi and Mulej 2006).

The supply chain is a metastructure (Grzybowska 2012), being an intermediate form between a single enterprise (microstructure) and global economy (macrostructure). Identification of enablers of sustainability in the SC can help in deciding the priorities to take regulatory steps pro-actively aiding in strategic, tactical, and operational decisions for a company wanting to create sustainability in the SC. According to Grzybowska et al. (2014), collaboration planning is vital for achieving sustainable logistics. In the course of these appropriate methods are needed to enable joining all relevant views in a consistent and coherent whole.

As a network of organizations, the SC is obliged to have clearly defined objectives. The main objective of an SC is the maximization of total profits derived across different echelons of the SC. The second most important objective, however, is the maximization of customer's satisfaction, expressed by the service level (Zhang et al. 2011), also referred to as quality of service (QoS). While the majority of DST-based approaches deal with the first objective only, the fulfillment of the second objective, in our opinion, is interrelated with it and as such should be considered in conjunction (Angerhofer and Angelides 2000). On the other hand, sustainability in the SC implies decisions and actions that lead to the highest economic and social benefits while reducing environmental losses (Wang et al. 2017). Achieving all of these objectives and also meeting the requirement for the SC to create customer value in a flexible and agile way pose challenges to companies (Pereira 2009). They have difficulties in managing geographically dispersed supply chains and in establishing the communication and service links between SC entities in a seamless, timely, and cost-efficient manner (Ip et al. 2011). Designing, planning, and operating sustainable supply chains represent an even bigger challenge if companies have to achieve effectiveness considering also economic, environmental, and social objectives (Ramos et al. 2014).

The set goals can only be attained by adequate SC configuration and proper use of management tools. The latter are addressed by supply chain management (SCM), being the process of planning, implementing and controlling the operations of the supply chain in an efficient way. SCM spans all movements and storage of raw materials, work-in-process inventory, and finished goods from the point of origin to the point of consumption (Behdani 2012). Meanwhile, the sustainability issues have become increasingly important for organizations and have been rooted in a number of managerial decisions related to SCM.

SCM addresses a wide range of problems, which may be divided into three categories (Georgiadis et al. 2005), considering their aspects:

- supply chain infrastructure (network) design;
- supply chain analysis and policy formulation;
- supply chain operations planning and scheduling.

Within the process of modeling and solving the indicated problems, managers have to make decisions on different hierarchical levels directed toward integration of SC processes within and between organizations and having an impact on sustainability in supply chains. These decisions can be classified as strategic, tactical, and operational, depending on their effects on the overall SC. Due to interdependence among the three levels, SCM remains incapable of satisfactorily addressing many practical real-world problems at a strategic level. Let alone that these levels are difficult to tackle at any individual entity, due to inter-dependencies with other entities and their autonomous behavior they are even more difficult to address. Hence, the majority of modeling approaches in DST provide invalid results (Holland 1995). For obtaining adequate solutions, decision makers need comprehensive models to guide them in the decision-making process.

The purpose of this work is to study and assess the opportunities that simulation modeling approaches, such as system dynamics, agent-based simulation, and discrete event simulation, provide for managers to make decisions on different hierarchical levels to improve the integration and sustainability of SC processes within and between organizations.

System dynamics (SD), being a simulation-based modeling approach, which underpins DST and holistic modeling (Shah 2005), is widely used in logistics and SCM. SD-based models are mainly applicable in situations, where the type of flow elements can be unified (e.g., on transaction level) and the type and behavior of their manipulation entities (SC nodes) does not change over time, and as such imposes no further restrictions to the simulation (e.g., Shah 2005; Tako and Robinson 2012). In situations when the behavior of the modeled systems depends on the decisions and interactions of heterogeneous entities, agent-based simulation (ABS) methods should be used. In both former cases, SC operations are considered on transaction level. Hence, the temporal aspect is mainly determined by the frequency of transactions, rather than real time. To model time-aware operations, discrete event simulation (DES) should be used.

In the sequel, the concept of SC integration with the sustainable perspective is discussed, as well as SC design as a determinant of integration, competitiveness, and sustainability. Also, the mentioned simulation modeling and analysis (SMA) methods' aptitude for solving typical SCM problems is elaborated. Each method's properties and limitations are laid out, followed by an illustrative example to state the case. In our examples, open-source tools are used to emphasize their usefulness for solving real-world problems. In the conclusion, the observations from the presented methods and experiments are summarized in considering the different levels and aspects of SCM with their proposed SMA approach to solving an SCM problem regarding also SC sustainability. In addition, the real-time perspective is emphasized, since SCM decisions need to be performed in real time.

2 Sustainable Supply Chain Management and Supply Chain Design

In the past three decades, there has been a growing interest in both industry and academia in SCM. Coyle et al. (2003) represent SCM as a logical evolutionary extension of the logistics concept. They regard its evolution as a sequential extension of the scope of logistics: from managing the goods flow as a series of independent activities, through their functional integration (procurement, manufacturing, distribution), to SCM extending the scope of integration outside the company to embrace suppliers and customers. Christopher (2011) highlights that SCM is not just an extension of logistics management, but it is also about managing relationships across the complex networks that today's supply chains have become. Based on an extensive literature review of various definitions, Mentzer et al. (2001) have defined SCM as a "systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the SC, for the purposes of improving the long-term performance of the individual companies and the SC as a whole." Integrating sustainability with SCM has led to the important concept of sustainable SCM. Taking the sustainable perspective, the functional coordination should also seek to achieve social, environmental, and economic goals. Thus, the sustainable focus requires companies to develop more comprehensive strategies that go further than the pure goal of SCM to improve the performance/increase the competitiveness of the SC as a whole, as well as of its members, or, in more concrete terms, to maximize the profit/enhance customer satisfaction/achieve high customer service levels at lower costs, etc. When long-term sustainability strategies are integrated throughout, the SC companies can achieve higher economic performance and thus create a competitive advantage (Carter and Rogers 2008).

Judging from the different authors' views, it appears that integration, which passes through several phases of development, is the foundation of the SCM concept. Christopher (2011) underlines that internal integration (within a single organization) by itself is not sufficient for SCM. Thus, he posits four distinct stages of SC integration. The first three stages refer to the sequential internal integration and the final one involves interorganizational integration.

Similarly, Harland et al. (1999) point out four levels of integration: internal level (process integration within the firm); dyadic level (buyer–supplier integration); chain level (integration of a set of dyadic relationships); network level (inter-business network integration). The abovementioned views indicate that two generic levels of integration can be distinguished—internal and external. The coordination of the internal functions needed to achieve the company's goals is often defined as internal SCM (Chopra and Meindl 2007). Sustainable SCM is also often considered as having intra-organizational elements related to company "in-house" processes, and interorganizational elements referring to sustainable initiatives that imply collaboration among SC members (Shi et al. 2012).

Several studies in the field of SCM have shown that there is a relationship between internal and external integration. It has been pointed out that both of them are needed in order to achieve SCM goals and that external integration will not occur until SC members have achieved high levels of internal integration (Stank et al. 2001; Bowersox et al. 2013).

The complex interrelationships in interorganizational systems and within individual firms in the SC are addressed with different approaches. A common way is to regard supply chains concerning their design and their planning and management. SC design defines the topological features of the network and the level of collaboration between partners, while SC planning and management related to the operation of the network (Pero et al. 2010).

SC design critically impacts the competitive position and sustainability of supply chains. According to Harrison (2005) as much as 80% of total product cost may be influenced by decisions related to design issues. When designing sustainable supply chains, increased logistics costs in one SC member may reduce the total SC costs. Thus, the benefits of sustainability may not be perceived due to the lack of immediate returns for the needed efforts (Strandhagen et al. 2017). SC design also greatly determines lead times within the network and SC lead time as a whole as well. SC lead time includes the time for product design, sourcing, production, order processing, and distribution. The lead times for these processes can be further divided into smaller elements for the purposes of management. For example, the elements of the production lead time are queue time before processing, setup time, run time, waiting time after processing, move time (Singh et al. 2013). Many authors agree that it is the run time only that adds values to the products and the other and types of lead times should be continuously shortened if not totally eliminated. Complete cycle time is a function of individual lead times (Samaranayake and Laosirihongthong 2016). Singh et al. (2013) ascertain that by reducing lead times, companies can increase their efficiency, effectiveness, and responsiveness to market thus using it as a competitive weapon.

3 Supply Chain Modeling and Simulation

SC modeling is important to SCM in that it can give a critical input to the SC design. Simulation modeling can be used to graphically visualize time-based "flows" through complex SC "processes" and "resources;" allowing the prediction and quantification of possible outcomes from different scenarios (Rashid and Weston 2012). This helps entities to gain valuable insights and understand the effects of their potential decisions on the SC performance including SC lead time and costs (Ip et al. 2011). Hence, SC modeling can contribute to the SC analysis and to the improvement of the SC design toward achieving higher sustainability.

Various methodologies for SC modeling have been developed. System dynamics (SD) is a methodology for analyzing complex, dynamic and nonlinear interactions in systems and as a result new structures and policies can be designed to improve the system behavior (Kumar 2014). Physical and information flows are addressed with the aim to reduce their delay and ultimately SC inventory.

Discrete event simulation (DES) is one of the most widely used and flexible analytical tools in manufacturing systems. It successfully handles uncertainty and provides possibilities to view in different ways alternatives for lead time reduction and higher machine and resource utilization, to quantify results and compare them to the present performance (Xia and Sun 2013).

Pereira (2009) asserts that the complementary use of SD and DES approach can address data demand issues, since SD helps to understand the interaction between major dynamic partners in the SC and DES can be used where more detailed data are needed as the lead time to make a product. SD successfully deals with complex and strategic problems, allowing the analyst to study different types of flows (material, personnel, money, and information), but it does not address some SC characteristics due to the increased level of uncertainties and risk that are typical for SC activities. That is why SD can be combined with DES which can represent individual events and address the uncertainties (Pereira 2009; Kleijnen 2005).

Agent-based simulation (ABS) is helpful in understanding the behavior of organizations in a market and the behavior of agents within an organization (Gómez-Cruz et al. 2017; Grzybowska and Hoffa-Dabrowska 2018). It supports the analysis of interdependences between consumers, retailers, and producers to aid in decision-making (North et al. 2010; Behdani et al. 2013). Gómez-Cruz et al. (2017) discuss the applications of ABS in logistics, which are some of the earliest used. They assert that ABS could capture the complexities of current logistic markets thus having a great impact in this area.

The above discussion leads to the conclusion that a holistic approach of applying simulation modeling would contribute greatly to complex SC designs where there are many variables interacting with each other. A useful integrated approach could include SD, DES and ABS methodologies which can quantify behaviors of workflows through different supply chain levels.

In general, with the SC simulation model we strive to fulfill the Conant–Ashby theorem (Conant and Ashby 1970) on a *good regulator*, being a model of the system, representing a mapping of the SC to the model or in other words, having as many parts and states as its original.

One can observe an SC on two levels to observe and model different occurring phenomena:

1. Macro-level

   – self-organization
   – co-evolution of entities
   – dependency on connections/transport routes,

2. Microlevel

   – multiple and heterogeneous entities
   – local interactions among entities
   – structured entities
   – adaptive entities.

However, in-between, there are many facets representing different perspectives of the SC. A production manager's view of the SC differs from the marketing manager's view which again differs from supply manager's view. Hence, the models used are different, even for the same company, let alone its SC.

Although they are performed in real time, the temporal aspect of SC operations is somewhat ambiguous. Depending on the level and perspective the durations of operations are measured in days, weeks or even months when considering interorganizational activities, while on the other hand, the intra-organizational operations are measured in hours or even seconds.

Depending on the nature of the modeled problem, the duration of the shortest operation or the maximum frequency of incoming/outgoing requests determines not only the representation of time in an SC model, but also its granularity. The shorter the minimum duration of the shortest operation or the higher the highest frequency of requests is, the finer is the granularity of time or in other words the precision of time keeping in the model. This is important for the modeler, since the model's reaction time cannot be shorter than the predefined time granularity. Hence, one needs to know the durations of processes and inter-arrival times of incoming/outgoing signals in advance to be able to determine the time units of a system model correctly.

On the other hand, in a simulation model, time can either progress by critical events from transaction to transaction or continuously. In the first case, the progression of time in the model is determined by the frequency and durations of transactions. On the other hand, with continuous-time flow, the operations are invoked according to the occurrence times of events and process' durations.

During a simulation, one may speed up the progression of time in the model, so the processes perform faster than in real time, and this way obtain predictions on future situations or trends.

3.1 Discrete Event Simulation

Discrete Event Simulation has the following properties:

- Process orientation;
- Focuses on detailed process modeling;
- Heterogeneous entities;
- Micro-entities are passive objects that are promoted through a system model as defined by the process;
- Events introduce dynamics into the system;

- Formal models are built of events, processes, and service activities;
- Time progresses discretely between critical events or according to a predefined frequency;
- Model flexibility is achieved by changing the structures of processes that are fixed during simulation runs.

DES Example

The following DES usage example comprises a model of variant production, where four different products are being produced (Fig. 1, extracted from the *JaamSim* (King and Harrison 2013) simulation environment). According to the production plan, some 10, 30, 40, 20% of product types 1, 2, 3, and 4, respectively, are being produced. Choosing a product type is induced by the triangular distribution between 1 and 4 with modulo at 3. Each product type has a dedicated production line. The production orders are fulfilled according to the exponential distribution around the 30 s mean time value. The production of every single product takes 100–120 s according to the uniform distribution. After they are finalized, the products are checked for quality at a dedicated test site. The quality check takes 10 s. From the company's experience, on average every 1 out of 10 products doesn't pass inspection. Products of insufficient quality are transported back to the original production line. Their reprocessing takes 120–130 s according to the uniform distribution. The durations of production and quality inspection and reprocessing don't depend on product type. After they have successfully passed their quality control the finished products are transported from

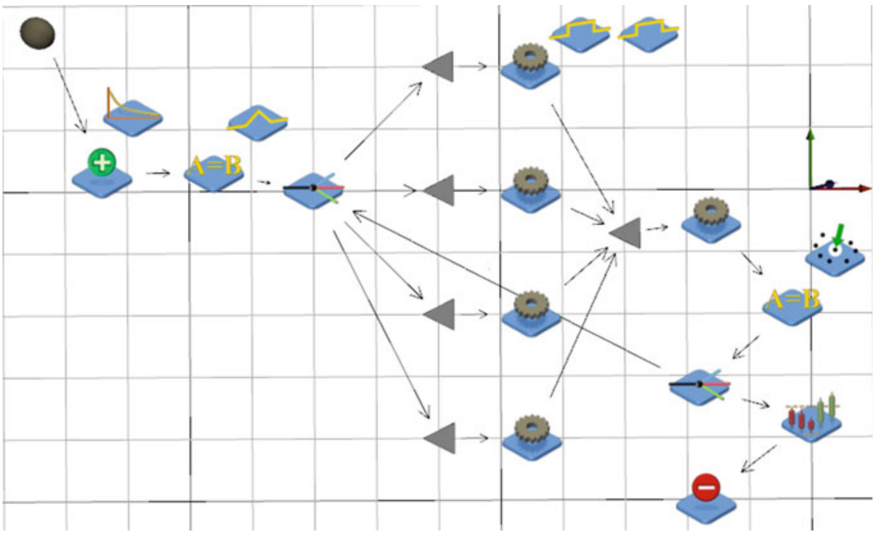

Fig. 1 DES Example: variant production with quality control

the production site to the finished products warehouse. In this way remanufacturing of defective products while still in production facilities appears as an effective way to reduce both environmental impacts and manufacturing costs.

DES Example Analysis
Through the discrete events simulation, the following process parameters can be analyzed and optimized:

- Production cycle length and production quantity;
- Utilization of production cells and spaces;
- Size and placement of storage spaces as well as products' dwell time;
- The utilization of mobile resources (e.g., operators, conveyors, forklifts).

The optimization of all these parameters, especially the utilization of resources, contributes to the sustainability of production. In general, one may say that DES analysis offers the most detailed insight into a logistic (production) process by a consistent and coherent model. The time granularity is closest to the real world. Hence, DES is highly graded as a tool to determine real-time behavior and resource capacities of process industry, including logistics (resource utilization). Moreover, DES could support the establishment of stable production cycles that enable the manufacturer to provide accurate lead time quotes to customers, and more accurate orders to suppliers for materials (Yoho and Rappold 2011). This stability improves the coordination of processes between SC entities and may lower total SC costs.

3.2 System Dynamics

System dynamics has the following properties:

- System centeredness;
- Key performance indicators' oriented modeling of system variables;
- Homogeneous entities;
- Entities on micro-level are disregarded;
- Dynamics is introduced by feedback loop coupling;
- Formal models are built of buffers and flows;
- Time progresses continuously as part of the system variables, being changed through transactions;
- Model flexibility is achieved by changing the structure of the system model that is fixed during simulation runs.

SD Example
Our example (Gumzej and Rosi 2017a) comprises a home appliance company's SC and describes material flows between its subsidiaries (Fig. 2, extracted from the *NetLogo* simulation environment). The company has multiple production sites—main site in Slovenia (SI) as well as affiliate firms in Germany (DE), Poland (PL),

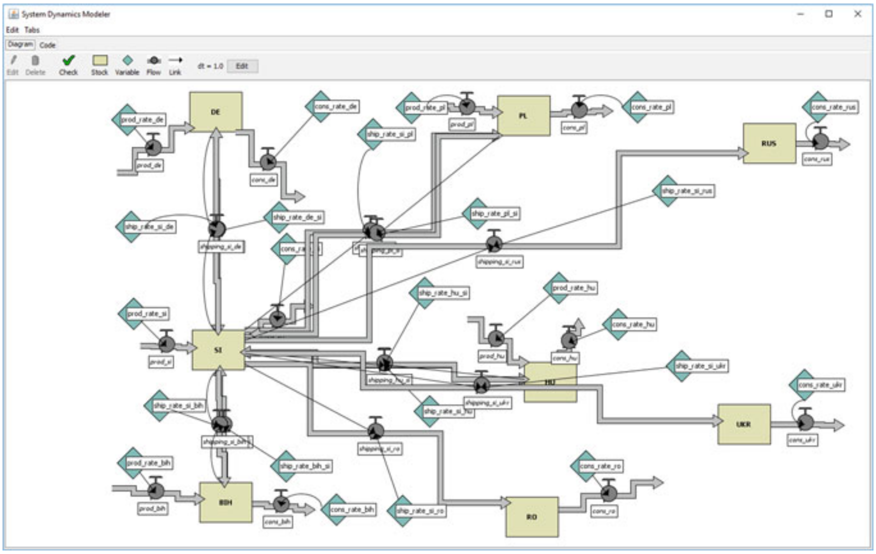

Fig. 2 SD Example: layout

Hungary (H), and Bosnia–Herzegovina (BIH). In addition to production sites, its gross-sales sites are situated in Russia (RUS), Ukraine (UKR), and Romania (RU). The production sites supply their own markets with finished products and each other with product components.

The dashboard serves as an DST (Fig. 3, extracted from the *NetLogo* simulation environment), to covenant the production- and stock quantities with the predispositions and their physical distribution. The time flow is continuous throughout every day's transactions, i.e., every day a certain number of components are shipped between production sites and a certain amount of finished products are consumed on site or shipped to the distribution sites.

Based on an initial stock of 300 units at SI location and 0 stock at other locations and our distribution model the stock quantities at individual locations (Fig. 3) represent the average stock according to given production (pcs), consumption (%) and shipping (%) rates.

SD Example Analysis

Systems dynamics simulation allows for:

- Planning the layout of an SC;
- Optimization of production and distribution quantities;
- Estimation of distribution channels' loads and associated costs.

In general, one may say that SD analysis offers an SC manager's view of a production process by a consistent and coherent model. The time granularity is consistent

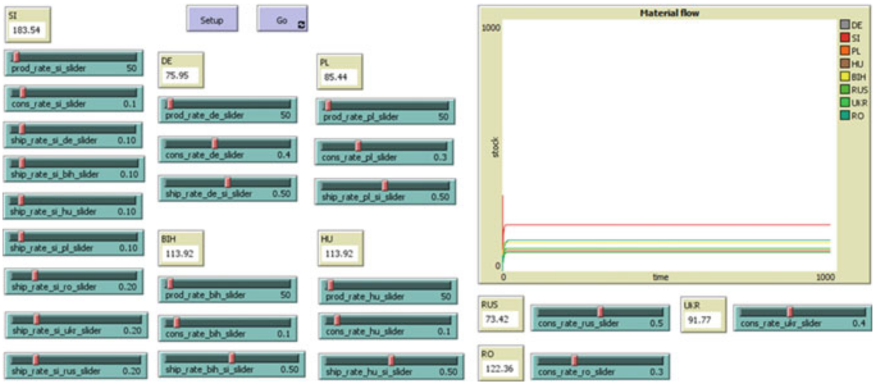

Fig. 3 SD Example: dashboard

with the frequency of SC transactions. Time progresses synchronously for all components of the model. Hence, SD is regarded as a tool best suited to determine the optimal volumes (when and how much) of individual site's inputs, stocks, and outputs. Therefore it allows for the efficient utilization of production and storage facilities.

3.3 Agent-Based Simulation

Agent-based simulation is characterized by

- Entity-centeredness;
- Problem-oriented modeling of entities and their interactions;
- Heterogeneity of entities;
- Micro-entities are active objects that act in their environments, communicate among each other and autonomously make decisions;
- Decisions and interactions between agents introduce dynamics into systems;
- Agents and their environments constitute formal models;
- Time flow is discrete and universal on model-level;
- Model flexibility is achieved by changing the system structure and behavior of agents;
- System structure during simulation is variable.

ABS Example

The presented example (Gumzej and Rosi 2017a) was used to analyze the behavior of the market (Fig. 4, extracted from the *NetLogo* simulation environment) by ABS in a manner similar to (Gumzej and Rosi 2017b). In our example, the introduction of a new product with its effect on a company's SC was investigated. In an environment of an increased rate of product introductions, the SC should be constantly realigned

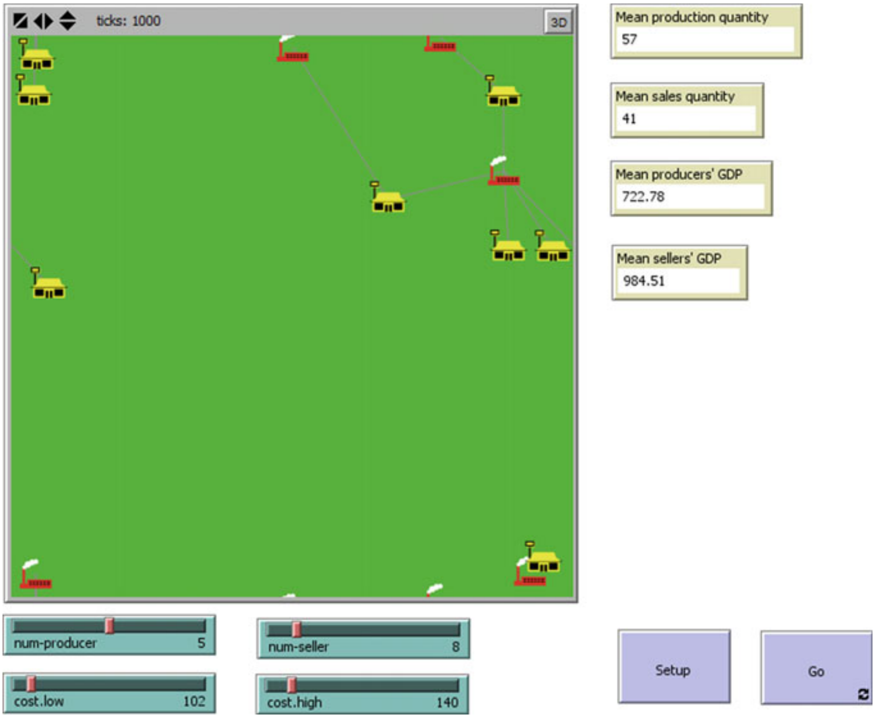

Fig. 4 ABS Example: dashboard with SC layout

to effectively and efficiently deliver the new products to markets. This could prevent failed product launches due to out of stock situations because of insufficient capacities (Pero et al. 2010) as well as avoid overproduction and overstocking which contribute to unnecessary waste.

The model was parameterized to reflect a typical distribution of producers and wholesalers. The answer one was seeking was, how many producers and wholesalers should be involved in the production and dissemination of a product, how many products should they produce per day, and how would this affect the markets—a typical strategic decision.

The model was parameterized based on our previous knowledge about SC entities and their markets in terms of the size (population) of their markets, the average GDP, birth and death rates as well as the foreseen acquisition and return rates of the product. The network was laid out in a way to allow for each seller to be associated with at least one producer from its vicinity. The production sites were parameterized with an initial production size of 100 units, a bay of 1000 potential buyers and their average GDP distributed normally on (500, 600) EUR interval. The sales locations were parameterized with an initial sales quantity of 100 units, a bay of 10,000 potential buyers and their average GDP distributed normally on (400, 500) EUR interval. The birth and death rates were set to 3% and 4–5%, respectively whereas the acquisition and return rates were set to 2–3% and 1–2%, respectively. The simulation time was limited to 1000 days.

Based on the results, the sizing and pricing of the new product and its distribution channels were determined.

ABS Example Analysis
Agent-based simulation allows for:

- Planning the layout of an SC;
- Modeling the dynamic growth of an SC;
- Modeling the behavior of partners within SCs;
- Optimization of global indicators.

In general, one may say that ABS analysis offers a strategic manager's or market regulator's view of one's marketplace by a consistent and coherent model. The time granularity is consistent with the frequency of SC transactions and the life cycles of SC nodes. Hence, ABS is regarded as a tool best suited to determine the optimal structure and layout (where/how many) and assortment (what) of one's market and/or SC by considering their global characteristics (e.g., demography, climate, GDP, quality awareness).

4 Discussion

From the previously stated facts, we can conclude that the selection of a simulation paradigm greatly affects the resulting formal model. Hence, we set the rule of thumb, that one should choose the paradigm that is closer to the nature of the problem being modeled and enables better flexibility, sensibility and maintainability of the models (c.p. Table 1).

Our models show that the results obtained on different levels can be transferred among them without compromising the consistency of the individual models, keeping in mind the temporal aspect. In a usual top-down approach, where first the strategic decisions are made and their effect is then further investigated on tactical and operational levels, the application of methods shall be quite the opposite from the order of presentation in chapter, however, this depends on the problem being solved. If our

Table 1 Suitability of modeling and simulation methods for SC DSS

	Network planning	Strategy formulation	Procedure and time planning
DES	Tactical, operational	Tactical, operational	Tactical, operational
SD	Strategic, tactical	Strategic, tactical	Strategic, tactical
ABS	Strategic, tactical	Strategic, tactical, Operational	Strategic, tactical

problem pertains to only one level/aspect of the domain then it can and should be solved on that level. Otherwise the implications of the solution to other levels should be further investigated prior to taking envisaged actions.

5 Conclusion

When solving the described SC problems, the managers need to make decisions on multiple and diverse hierarchical levels. These can be categorized as strategic, tactical and operational, depending on their effect on the SC as a whole. Due to the interdependences between the three layers, the SC management is often unable to solve their problems on any single level. At the same time, it is also difficult to observe all three levels at any individual SC entity. To find adequate solutions entity- and level-breaching methodologies are necessary like the one presented here.

Simulation Modeling and Analysis methods have proven useful when estimating the effect of introducing changes or new components in a system by enabling system-level insight and performance analysis. By utilizing the methods within the Deming's "plan-do-check-act" cycle of improvements it is easier to foresee the impact of changes and implement only the desired ones. In the course of eco-production, the desired changes are represented by orchestrated changes at SC echelons—the enablers—in order to provide for sustainable cyclic production processes.

While it is possible to foresee the effect of changes at individual SC echelons by simulating and experimenting on their models at individual levels, it is often better to combine simulation paradigms to describe different layers than try to express cross-level dependencies within a single model. Our proposed approach when modeling intra- and inter-logistic problems is the following:

1. Strategic level (where, what): ABS;
2. Tactical level (how, capacity): SD;
3. Operational level (whereby, duration): DES.

When doing so, one should keep in mind the time granularities on different levels. Temporal restrictions can only be expressed by durations of activities on the operational level. The tactical and strategic levels operate with transactions on daily, monthly, or yearly basis, depending on the level, on which our problem is being solved. Time granularities are reduced in the same order, as listed above, from the magnitude of years on the strategic to months on the tactical and days or even hours on the operational level. One should also keep in mind that the time intervals and durations of activities on the operational level need to be reflected by realistic transaction frequencies on higher levels to prevent bottlenecks.

One can combine simulation paradigms at free will, however, one should avoid using methods that would limit the flexibility and maintainability of the produced models on one and the usability of the results on the other hand rather than make them more meaningful and useful to assist decision-making. Every simulation paradigm has some concepts and predispositions that limit the system models in aspect and detail. From the viewpoint of the modeler, it is important to be able to model all relevant entities and processes with their respective properties on each level. By doing so, SC simulation modeling and analysis can fulfill its envisaged purpose.

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Identification of Logistics 4.0 Maturity Levels in Polish Companies—Framework of the Model and Preliminary Research

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Abstract The paper describes maturity model that have been developed in order to assess Logistics 4.0 level. The model is elaborated on the basis of literature review with respect to Logistics 4.0 and maturity models. Its objective is to propose measures that exhibit what solutions are recommended for companies as well as how they can improve their actual state of Logistics 4.0. This paper presents the actual review of literature referred to Logistics 4.0, Internet of Things as well as maturity models. Based on the aforementioned backgrounds, the novelty of proposed model is confirmed. The proposed model distinguishes three main dimensions to be assessed in terms of Logistics 4.0: management, flow of materials, and flow of information. Each dimension comprises particular identified areas such as degree of automation, degree of robotization, integration of value chains, data capturing and usage, the scope of autonomous decisions, and the others. The findings from survey enable classification of companies and assessment of their Logistics 4.0 maturity in each dimension. Furthermore, the authors distinguish five maturity levels: Ignoring, Defining, Adopting, Managing, and Integrated (Oleśków-Szłapka and Stachowiak in Intelligent systems in production engineering and maintenance. Springer, pp 771–781, 2016). The L4MM matrix makes possible a complex overview of the whole processes and finally gives guidelines on how to search for a higher maturity level. The preliminary research has been done within logistics companies and based on the conducted survey, it was possible to assess what is actual knowledge and implementation of Logistics 4.0 tools. The characteristics and areas of the model defined

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enable the assessment of maturity levels within companies providing Logistics services (transport and warehouses) in Poland. Identification of logistics maturity of companies will contribute data for analyzing correlations between the maturity level of a company, and its competitive position, size, development dynamics, number of services offered, structure of capital, and level of internationalization of operations (Oleśków-Szłapka and Stachowiak in Intelligent systems in production engineering and maintenance. Springer, pp 771–781, 2016). The model proposed by the authors will enhance static logistics maturity models adding to them a dynamic aspect.

Keywords Logistics 4.0 · Maturity model · Maturity levels · Logistics services

1 Introduction

In line with the World Economic Forum (Lanng 2017) by 2025, the whole global supply chain will mellow and develop into the network of interconnected companies, processes, and data flows that will support new business designs and models. The industrial Internet will help bring disparate processes from procurement through manufacturing to final delivery, under greater control and visibility, which is crucial for the manufacturing of high-individualized products and services (Oleśków-Szłapka and Lubiński 2016; Oleśków-Szłapka and Stachowiak 2018). The requirements for customized items are growing, thus, the logistics (inbound and outbound) has to adjust to this new dynamic and modifying environment and it cannot be organized by simple planning and control practices (Bowersox et al. 2000; Premm and Kirn 2015; Grzybowska and Lupicka 2017). The solution to enable the shift is called Logistics 4.0 and is inspired and based on the concept of Industry 4.0.

In global economy, in dynamic market environment, meeting customer expectations is, on the one hand, a key aspect of the business, and on the other hand, a constantly increasing challenge. Considering production, the solution that allows companies to cope with the challenge is Industry 4.0—a concept that changes the contemporary manufacturing processes and enterprises. Nevertheless, realization of production processes is impossible without logistics support, which enables efficient and effective implementation of material and information flows. Industry 4.0 elements related to the management of materials and information flow integrating complex global supply networks form a separate solution, referred to as Logistics 4.0, emphasizing the importance of this area. Logistics 4.0 is a set of solutions aimed at improving logistics processes by avoiding errors and disruptions in transport and storage processes, thanks to continuous data exchange between logistic system stakeholders. Hence, Logistics 4.0 is not only about replacing human work with machines and robots, but above all, about effective information exchange across the entire supply network.

Implementation of Logistics 4.0 solutions, so-called "intelligent logistics" seems to be crucial today for the effective and efficient functioning of companies providing logistic services. Hence, the choice of Logistics 4.0 as the subject of the research—on the one hand to recognize the scope of Logistics 4.0 and identify a set of solutions constituting its essence, diagnose the implementation level of these solutions in companies providing logistics services in Poland, defining the condition of the industry, and on the other hand to determine the factors affecting the implementation these solutions and the consequences of this implementation and finally to develop a model showing causal relations of the implementation of solutions in the field of Logistics 4.0 and subsequent levels of maturity (improvement) in this area. The implementation of advanced solutions is, however, a gradual process that requires time and commitment on the road to excellence, hence the research aims to *develop a model covering subsequent levels of logistic maturity of enterprises, showing the determinants, and consequences of implementing solutions in the field of Logistics 4.0 and thus indicating the path of improvement in this matter.*

2 Related Work

In the available literature review, there can be found numerous examples of maturity models for business processes, as well as Industry 4.0 (Borenstein et al. 2011; Bowersox et al. 2000; Bubner et al. 2014; Caloghirou et al. 2004).

A thorough literature review shows that there is a significant research gap in the field of Logistics 4.0 (Camisón and Forés 2010). Logistics 4.0 definitions are imprecise as the concept is not consistent, *hence the need to develop coherent theoretical approach*. Publications on the subject deal with the data flow management and integration of decentralized complex systems (Grzybowska and Kovacs 2014; Barreto et al. 2017; Czaja 2016; Glistau and Machado 2018; Hompel and Kerner 2015; Jeschke 2016; Maslarić et al. 2016; Strandhagen et al. 2017; Szymańska et al. 2017; Timm and Lorig 2015; Wang 2016; Witkowski 2016; Wróbel-Lachowska et al. 2018a, b; Zentgraf 2017).

Logistics 4.0 is described in the reports by research centers and logistics service providers (DHL 2015; Dussmann Group 2016; Fraunhoffer 2016).

Hence, the authors decided to develop their own maturity model to complete the existing gap. The model relies on assumptions that make possible either assessing Logistics 4.0 actual state or define a roadmap for further steps in terms of three key domains: Management, Material Flows, and Information Flows. L4MM is elaborated based on the analysis of current literature items.

The literature search on Logistics 4.0 publications in Scopus and Web of Science databases gave the feedback presented in the diagram (Fig. 1).

The search proves that the number of references for "Logistics 4.0" is small but, on the other hand, it is still increasing. Therefore, this research domain has without doubt big potential. The total number of references comprises press material and professional trade publications.

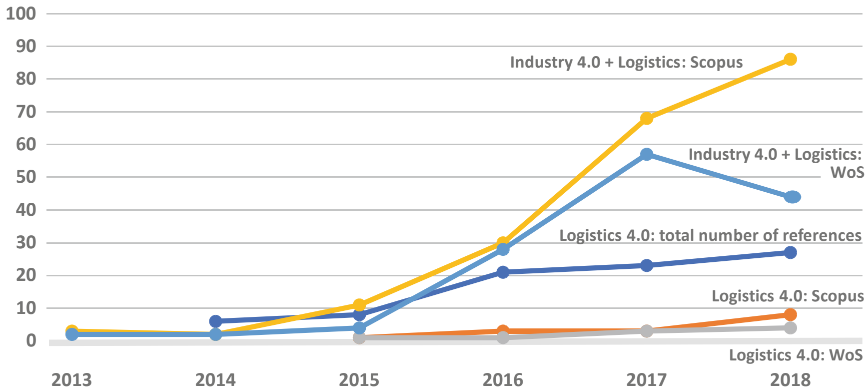

Fig. 1 The number of publications per year referring to Logistics 4.0 and "Industry 4.0 + Logistics". *Source* Own work based on Scopus and WoS

Apart from publications devoted directly to "Logistics 4.0", there are also selected works on the more general subject of "Industry 4.0" where some issues connected with logistics are discussed. The diagram presents scientific papers indexed by Scopus and by WoS. The full list of indexed papers with their brief description is presented in Table 1.

The biggest challenge for companies is to classify, comprehend, and appropriate use of the available knowledge and thus achieving a competitive advantage (Lev et al. 2008; Liao et al. 2007; Lichtenthaler 2009; Grzybowska et al. 2014). Considering the abovementioned issues, the authors of the study decided to research on the *absorptive capacity of companies* striving for implementation of advanced solutions.

Another important term within conducted research by the authors is maturity. Maturity can be defined as "the state of being complete, perfect or ready" (Karkkainen et al. 2014; Mettler 2009). Maturity is referred to growth, as in Maier et al. (2012), which defines maturity as a state of growth and development.

The subject of maturity is in the field of interest of scientists for a long time. One of the first scientists dealing with this subject was Crosby who in 1979 developed a quality management model with five levels of maturity (Kwak and Ibss 2002; Maslaric et al. 2016; Timm and Lorig 2015).

Maturity models are actually distributed and applied in Project Management (PM), Knowledge Management, Information Systems, and Supply Chain Management (Banyani and Then 2010; Vaidyanathan and Howell 2007).

Plenty of researchers also have defined Industry 4.0 maturity models (Cooke-Davies 2004; Fraser et al. 2002; Lahrmann et al. 2011; Rosenthal 1978; Schumacher et al. 2016; Wang et al. 2016), but the authors did not recognize any maturity models referring specifically to Logistics 4.0.

Thus, the authors proposed their own model of maturity believing that it would bring added value to existing literature and research in the field of logistics maturity of companies.

Table 1 Literature on Logistics 4.0 review

Authors	Title, Year, Journal	The scope of interest
Glistau, E., Machado, N.I.C. (2018)	Industry 4.0, logistics 4.0 and materials—Chances and solutions (2018), Materials Science Forum, 919, pp. 307–314	The paper defines the terms of Industry 4.0 and Logistics 4.0. It also outlines the big opportunities of this development. The paper provides an overview of important solutions and tools in this domain
Wrobel-Lachowska, M., Wisniewski, Z., Polak-Sopinska, A. (2018a)	The role of the lifelong learning in logistics 4.0 (2018), Advances in Intelligent Systems and Computing, 596, pp. 402–409	This paper describes the role of the lifelong learning in the Logistics 4.0. The paper shows the key competences needed by all groups of employees
Wrobel-Lachowska, M., Wisniewski, Z., Polak-Sopinska, A., Lachowski, R. (2018b)	ICT in logistics as a challenge for mature workers. Knowledge management role in information society (2018), Advances in Intelligent Systems and Computing, 605, pp. 171–178	This paper analyses the scope of ICT competencies required by employees—logisticians Conclusions of the study are the result of multi-faceted research conducted in 2012–2016 using grounded theory methodology
Strandhagen, J.O., Vallandingham, L.R., Fragapane, G., Strandhagen, J.W., Stangeland, A.B.H., Sharma, N. (2017)	Logistics 4.0 and emerging sustainable business models (2017), Advances in Manufacturing, 5 (4), pp. 359–369	This paper addresses challenges such as data flow, automated solutions, and real-time big data analysis. It proposes a model to understand and relate the different elements of business operations. The paper links the elements of sustainability, business models, Industry 4.0 and Logistics 4.0
Barreto, L., Amaral, A., Pereira, T. (2017)	Industry 4.0 implications in logistics: an overview (2017), Proceedia Manufacturing, 13, pp. 1245–1252	This paper presents some considerations on how to enable organizations to be efficient, and fully operational in Logistics 4.0 context
Hompel, M., Kerner, S. (2015)	Logistics 4.0: The vision of the Internet of Autonomous things [Logistik 4.0: Die Vision vom Internet der autonomen Dinge] (2015), Informatik-Spektrum, 38(3), pp. 176–182	This article attempts to elucidate some key aspects of ongoing development and convey a view of “Logistics 4.0”

(continued)

Table 1 (continued)

Authors	Title, Year, Journal	The scope of interest
Wang K. (2016)	Logistics 4.0—New challenges and opportunities (2016), Conference: 6th International Workshop of Advanced Manufacturing and Automation	This paper identifies the term "Logistics 4.0", tries to define it as well as make a list of its fundamental technical elements. It also deals with the question—how to address proactively challenges of Industry 4.0 revolution
Maslarić M., Nikoličić S., Mirčetić D. (2016)	Logistics Response to the Industry 4.0: the Physical Internet (2016), Open Eng. 2016; 6:511–517	This paper provides an overview of the different views in the field of Physical Internet trying to identify the biggest challenges (technological, societal, business paradigm) of proposed new logistics paradigm as a practical solution in supporting Industry 4.0
Timm I., Lorig F. (2015)	Logistics 4.0—a challenge for simulation (2015) Yilmaz L., Chan W.K.V., Moon I., Roeder T.M.K., Macal C. & Rossetti D. (Eds.), Proceedings of the 2015 Winter Simulation Conference, IEEE Press Piscataway, NJ, USA, pp. 3118–3119	The value of this paper can be summarized as follows: Integrating autonomous decision makers into conventional material flow simulation, as required for addressing the requirements of Logistics 4.0, results in increasing complexity

Source Own work based on Scopus and WoS

3 Proposed Work

The authors start from *literature analysis* in order to identify the elements of the Logistics 4.0 concept, its specific solutions, and tools. This stage will allow to develop a framework model of the logistics maturity of enterprises.

The next stage of the research will include *research on enterprises* carried out with the use of questionnaires (CAWI, CATI) addressed to enterprises providing logistics services in Poland, i.e., assigned to the H section of the Polish Business Activity Classification. The questionnaire will include questions about the knowledge of the solutions and scope of their application, as well as about the intentions to implement solutions and tools from the scope of Logistics 4.0. The results of the survey will allow to determine the degree of absorption of solutions from the scope of Logistics 4.0 and to determine the level of logistic maturity in the context of Logistics

4.0 in the population interview. The results of the research will be compared with the published research results on the implementation of contemporary solutions in companies providing logistic services around the world.

The third stage of the research will include the *analysis of correlations between* the identified absorptive capacity and the level of logistic maturity of companies providing logistic services, and their competitive position, size, development dynamics, offer range, internationalization of capital, and the degree of internationalization of business activity. This stage of the research will include enterprises included in industry rankings (TSL Ranking).

On the basis of the research conducted, conclusions will be drawn regarding the condition of the industry and the relationship between the abovementioned characteristics of individual companies, leading to identification of *causal relations* showing the dynamics of the system, which undoubtedly the company providing logistic services is, functioning, and the relationship between the enterprise's characteristics, implemented elements of the Logistics 4.0 concept and its competitive position. The feedback model that illustrates the behavior of the company providing logistic services will complement the static concept of logistic maturity levels in the field of Logistics 4.0, leading to the research goal realization.

The theoretical stage of the research based on review and analysis of publications on Logistics 4.0 will allow to develop an original maturity model, showing the evolution of logistic solutions and the scope of their application, as well as defining the reference level of logistic excellence. The Logistics 4.0 Maturity Model will contribute to the development of the discipline.

The research carried out among companies providing logistics services will help to gain knowledge about the level and scope of implementation of solutions of the Logistics 4.0 concept in Polish enterprises. It will also deal with the issue of absorbing knowledge in the field of Logistics 4.0 and will allow to determine absorptive capacity level, showing the ability to absorb knowledge and the potential of enterprises in the area of acquiring and implementing contemporary, intelligent and autonomous solutions and technologies. The diagnosis of the industry will complement the knowledge about the condition of enterprises providing logistics services in Poland with aspects related to the digitization and application of modern technologies. The results will help to validate the model and if necessary correct it based on the feedback from industry. Moreover, the data obtained and the conclusions drawn from them will be compared with the available materials describing solutions implemented other countries in this respect. The analysis will contribute to civilization development as it reflects the shift of paradigms, from traditional taylorism to contemporary, information-based industries, and societies (Zawadzka et al. 2010).

The analysis of the relations between the Logistics 4.0 maturity level and company's market position, its size, development dynamics, range of services offered, structure of capital, and level of internationalization of operations will lead the authors of the proposal to develop a cause-and-effect model in the form of a causal loop showing the relationships between the determinants of the decision to implement solutions in the field of Logistics 4.0 and the consequences of these decisions. Presenting the dynamics of system behavior, the model will be a complement to the static model of logistic maturity, contributing to development of logistics as a discipline.

The research process planned includes the following actions:

A.1 Developing framework *Logistics 4.0 Maturity Model (L4MM)* based on literature review (objectives 1, 2, and 3).
A.2 Research on *absorptive capacity* of companies providing logistics services in Poland (objective 4).
A.3 *Assessment of Logistics 4.0 maturity* of companies providing logistics services in Poland (objective 5).
A.4 Analysis of *correlations* between the level of Logistics 4.0 maturity and company's competitive position, its size, development dynamics, range of services offered, internationalization of capital, and level of internationalization of operations (objective 6).
A.5 Developing dynamic model of behavior of a company providing logistic services based on relations between the identified level of maturity and company's competitive position, its size, development dynamics, range of services offered, internationalization of capital, and level of internationalization of operations (objectives 7 and 8).

And dissemination of project results in scientific papers (A.6) and a monograph entitled: *Logistics 4.0: challenge and opportunity* (A.7). The actions listed above will be continuously adding value to the project and the discipline, as presented in Fig. 2.

In order to define Logistics 4.0 Maturity Model based on the level of absorption of Logistics 4.0 solutions in companies providing logistics services, the authors have carried aforementioned literature survey in the scope of Logistics 4.0 domain. The next step was a pilot study on Logistics 4.0 among companies providing logistics services. Based on these research stages, it was possible to develop Logistics 4.0 Maturity Model. The Logistics 4.0 Model was used to select classification criteria.

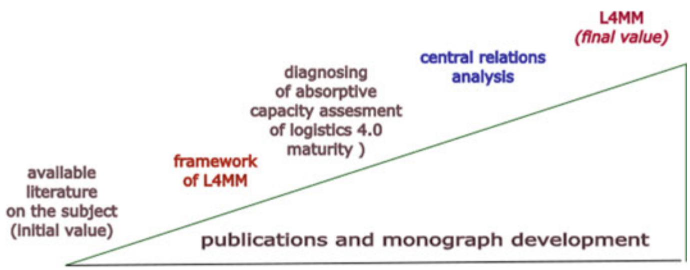

Fig. 2 The increase in value of the project. *Source* Own work

Table 2 Logistics 4.0 dimensions and areas of evaluation

Logistics 4.0 dimensions	Areas of evaluation
Management	Ongoing and planned investments, innovations management, integration of value chains
Material flow	Automation and robotization implemented in warehouse and inbound logistics, implementation of solutions such as Internet of Things, 3D printing, 3D scanning, advanced materials, augmented reality
Information flow	Implementation of solutions such as data-driven services, Big data (data capturing and usage), RFID, RTLS (real-time locating systems), IT systems (ERP, WMS, cloud systems)

Source Own work

The classification is based on the three aspects of logistics[1] including: (1) management (2) material flow, (3) information flow, which becomes naturally three dimensions for Logistics 4.0 solutions, as presented in Table 2.

The three dimensions of the model can be used to assess the maturity and awareness of managers concerning solutions within Logistics 4.0 implemented in a company. Based on the number and scope of solutions implemented, the conclusion on present Logistics 4.0 status can be drawn. Moreover, based on the gaps identified, recommendation concerning the Logistics 4.0 status improvement, and maturity increase, can be defined, making the model useful not only in terms of diagnosis, but also in terms of management.

According to the authors, the term "Logistics 4.0 maturity" reflects the level of Logistics 4.0 solutions implementation, the less solutions implemented, the lower Logistics 4.0 maturity level. The authors defined five maturity levels: Ignoring, Defining, Adopting, Managing, and Integrated. In Fig. 3 maturity levels are confronted with Logistics 4.0 dimensions.

The assessment of maturity level is based on analysis of solutions implemented within Logistics 4.0 dimensions. The authors decided that the most important determinant of maturity and dimension of logistics is management, and if integration level is coherent with at least one form of the flow (either material or information) the maturity level the two represent is the one that characterizes the company best, assuming in the same time that the latter dimension is soon to be upgraded. The gap identified and the steps to be taken to fill it in should be presented to the company, representing the general guidelines for reaching the next level of maturity.

[1]According to Council of Supply Chain Management Professionals (previously the Council of Logistics Management) logistics is the process of planning, implementing and controlling (altogether referred to as **management)** procedures for the efficient and effective transportation and storage of goods (**material flows**) including services and related information (**information flows**) from the point of origin to the point of consumption for the purpose of conforming to customer requirements and includes inbound, outbound, internal and external movements.

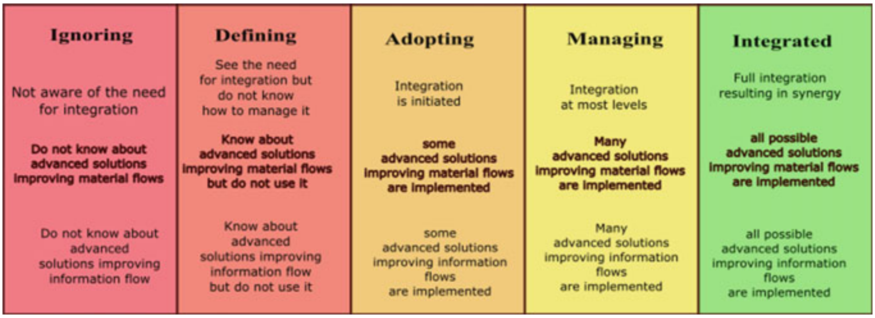

Fig. 3 Logistics 4.0 maturity levels. *Source* Authors' own work

4 Results

The first action taken was the search for the literature on Logistics 4.0 and its results are presented in the application form in the Sect. 2. The search showed a cognitive gap, as the term and the issue of Logistics 4.0 was referred to eight times only. According to the authors' opinion, it is the rationale for realization of there searches recognizing new term in logistics management is interesting and promising field of research.

The second step was the survey among Polish companies providing logistic services. The survey aimed to find out whether the companies know the term Logistics 4.0 and/or use solutions usually referred to as Logistics 4.0 solutions (identified based on the preliminary literature review).

The survey was a direct interview (CAWI—Computer-Assisted Web Interview) distributed among 17 companies. The sample included 17 enterprises (11 enterprises employing more than 250 people, 2 companies employing between 100 and 249 people, 2 2018 companies employing 50–99 people, and 2 companies employing 10–49 people) operating both, in Poland and internationally.

The survey research was being conducted for six weeks, from April, 1 to May 15, 2018. To identify the level of knowledge on Logistics 4.0 and the solutions within it, the respondents were asked whether:

1. they know the terms Logistics 4.0 and Industry 4.0?
2. their warehouse is automated?
3. their handling processes are automated?
4. their data flow and access to information is integrated in real time?
5. they analyze, store and process data with contemporary technologies (i.e., Big Data, Cloud Computing)?
6. they use RTLS in their logistics processes?
7. they know the term Internet of Things and/or Services?

The answers to the questions are presented in Table 3.

Table 3 Results of preliminary survey on Logistics 4.0 solutions

<table>
<tr><td colspan="12">Question 1</td></tr>
<tr><td colspan="3">53% responses: never heard of Logistics 4.0 nor Industry 4.0</td><td colspan="3">0% responses: know the concept of Industry 4.0 only</td><td colspan="3">29% responses: know the concept of Logistics 4.0 only</td><td colspan="3">17.5% responses: know the terms Logistics 4.0 and Industry 4.0</td></tr>
<tr><td colspan="12">Question 2</td></tr>
<tr><td colspan="4">70.6% responses: warehouse partially automated</td><td colspan="4">17.6% responses: warehouse not automated</td><td colspan="4">11.8% responses: warehouse fully automated</td></tr>
<tr><td colspan="12">Question 3</td></tr>
<tr><td colspan="4">82.4% responses: handling operations partially automated</td><td colspan="4">11.8% responses: handling operations not automated</td><td colspan="4">5.9% responses: handling operations fully automated</td></tr>
<tr><td colspan="12">Question 4</td></tr>
<tr><td colspan="4">88.2% responses: benefit from integrated data flow and access to data in real time</td><td colspan="4">5.9% responses: do not use integrated data flow and access to data in real time</td><td colspan="4">5.9% responses: have no information on integrated data flow and access to data in real time</td></tr>
<tr><td colspan="12">Question 5</td></tr>
<tr><td colspan="4">52.9% responses: analyze. store and process data with contemporary technologies</td><td colspan="4">23.6% responses: do not analyze. store or process data with contemporary technologies</td><td colspan="4">23.6% responses: have no information on analyzing. storing or processing data with contemporary technologies</td></tr>
<tr><td colspan="12">Question 6</td></tr>
<tr><td colspan="3">17.6% of responses: use RTLS in their logistics processes</td><td colspan="3">29.4% of responses: plans to use RTLS in their logistics processes</td><td colspan="3">47.1% of responses: do not use RTLS in their logistics processes</td><td colspan="3">5.9% of responses: have no information of using RTLS in their logistics processes</td></tr>
<tr><td colspan="9">Question 7</td><td colspan="3"></td></tr>
<tr><td colspan="4">41.2% of responses: know the term IoT/IoS</td><td colspan="4">47.1% of responses: do not know the term IoT/IoS</td><td colspan="4">11.8% of responses: have no information whether they know the term IoT/IoS</td></tr>
</table>

The highlighted boxes represent positive answers, meaning that the respondents know and implement the tools and methods within Logistics 4.0, disregarding whether they know the term itself. Nevertheless, the awareness of the Industry 4.0 (including some of the tools and methods within Logistics 4.0 range) and Logistics 4.0 is quite high (47% of respondents), proving that companies providing logistics services see the potential of contemporary solutions and are willing to benefit from them. The trend is even more visible among USA companies, where the potential of contemporary solutions such as IoT is recognized by 84% of companies (HP Report 2018). Referring the conclusion to the limited number of valuable literature sources proves that there is a significant gap and the need for dissemination of knowledge and research on the field, and that achieving the objectives of the research could contribute to both, science and economy development.

5 Conclusion

The goal and the requirement of contemporary economy are both agility and ability to learn—thanks to the connected digitization and solutions broadly referred to as Industry 4.0 and Logistics 4.0. The research carried out by the Ministry of Development and Siemens in the years 2016–2017 collected as part of the Smart Industry Polska Report (2018) prove that many enterprises have little knowledge about the characteristics of these concepts, the solutions they propose, as well as the benefits of using the latest methods of process digitization. The pilot research conducted by the author among polish logistics companies confirms the conclusion presented in the Smart Industry Polska Report.

The diagnosis is important and valuable when it becomes the basis for improving actions—thanks to knowing where companies are today, they can define their future goals and steps required to reach it. Thus, assessing Logistics 4.0 maturity will help visualize companies' path forward and set priorities for process improvement. Based on preliminary results from survey conducted by the authors in logistics and manufacturing companies from among the surveyed companies, only 33% know the term Logistics 4.0, 50% of companies know the concept of big data, and 83% companies want to apply automated data exchange systems and are willing to automate their processes as well as introduce partial robotization of the processes. The diagnosis shows that there is a need for education and space for improvement.

Consequently, the diagnosis of logistics maturity of companies will enable assessment of the logistics sector condition in Poland and will provide data for analyzing correlation between the maturity level of a company, and its competitive position, size, development dynamics, range of services offered, structure of capital, and level of internationalization of operations. The analysis is expected to be on the basis of general conclusion and development of original system dynamics model presenting behavior of a company providing logistics services in the form of causal loop. The model will add dynamic layer to the static concept of logistics maturity levels and contribute to the development of management science.

6 Future Work

The objective of the research will be the diagnosis of absorptive capacity of Polish companies providing logistic services. Based on the developed survey questionnaire, it will be possible to identify absorptive capacity of companies providing logistics services in Poland and define their Logistics 4.0 Maturity level. Furthermore, mapping the survey results on the developed Logistics 4.0 Maturity Model makes possible to assess logistics maturity of companies (individual, average, minimum, maximum, and dominant). Then, Logistics 4.0 maturity of Polish companies providing logistics services will be compared with the correspondent data on companies representing the same industry but operating on different markets. At this stage, the authors plan to apply statistical analysis: multidimensional comparative analysis using basics statistics and Multiple Correspondence Analysis (MCA) to detect and represent similarity and diversity across countries.

The next stage will be statistical analysis: (1) chi-square independence test to verify the relation between the level of maturity and factors indicated (competitive position, size, development dynamics, range of services offered, internationalization of capital, and level of internationalization of operations) and assumption of selected measures of association adjusted to nominal and ordinal data (Pearson's contingency coefficient C, Cramér's V, Gamma, Somers' d, Kendall's tau-b, and nonparametric Spearman's rank-order correlation coefficient) with testing correlation significance using the data from published reports ranking the companies providing logistics services; (2) Multi-criteria Decision Analysis (MCDA) to analyze the importance and the relations among the main determinants of Logistic 4.0 solutions and rank data; using the technique based on the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method to build the structural model with position and relations among the determinants showed at the Impact-Digraph-Map. Finally, the authors want to develop the causal loop with feedbacks between the determinants and consequences of Logistics 4.0 solutions implementation and combine Logistics 4.0 Maturity Model with dynamic model of behavior of a company providing logistic services based on feedbacks between the level of maturity and company's competitive position, size, development dynamics, range of services offered, internationalization of capital, and level of internationalization of operations.

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Dynamic Organisation of Traffic Flows in the Transport Network in Terms of Sustainable Mobility and the Development of Industry 4.0

Grzegorz Sierpiński and Ireneusz Celiński

Abstract The chapter presents a concept for the method of traffic flow organisation in the transport network by dynamic changes to various components of the infrastructure. Proposed improvements include continuous (dynamic) changes of traffic flow organisation based on collected and processed data that describe the road network as regards its instantaneous use. The data in this approach are acquired with respect to specific profiles of the road network. Road network components in question enable to change dynamically and improve the traffic flow organisation based on data collected and processed in Big Data sets. Those sets are associated with the entire urban socio-economic system rather than a specific transport network. For their legitimate use, data acquired from multiple sources, examples of which are presented in the chapter, undergo complex processing and modification according to the Industry 4.0 concept (in this sense, transport network user is integrated into network-based IT systems). At the same time, the idea of dynamic traffic improvement, regarding nearly all components of the transport infrastructure, should lead to reduced cost and better traffic flow distribution in the transport network from the point of view of the entire system. The above means that the traffic distribution should be typically implemented in transport systems with controlled traffic. The introduction of a large number of reasonable changes to a number of road network cross sections reduces the stochastic nature of the road traffic. At the same time, the aim is to promote sustainable mobility not only in designated sections of the transport network, but also in the entire area.

Keywords Sustainable mobility · Traffic flow organisation · Transportation network design and planning · Big data sets · Road network

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1 Introduction

The observed continuous increase in the number of vehicles on the road network, combined with a reduced financial and technical capacity to develop transport infrastructure, leads to urban congestion, which apart from lost time translates into an adverse impact on the environment (Clean Power for Transport 2013; Stanley 2014). This phenomenon is particularly vivid during rush hours, which become increasingly long each day. Only a major change in traffic flow organisation in the road network can rectify the situation. Such comprehensive, holistic changes, which take into account the various data, modes of travelling in the network, and recognises events outside the transport network (entire socio-economic environment), should be applied at the same time to a large number of road network sections.

Use of Intelligent Transport Systems (ITS) enables to increase the use of existing transport infrastructure within a certain area (restricted control zone) (White Paper: Roadmap to a Single European Transport Area 2011). It is possible, among others, by improving the distribution of traffic in time and space in the network by dynamic traffic distribution. This same applies to locations away from congested streets in the road network, the capacity of which has not been utilised. The organisational method enables to reduce the number of bottlenecks in the transport network. The problem is, however, that these systems use information originating mainly from urban areas connected through developed transport infrastructure, its direct environment, whereas the control system disregards information from a wider surrounding of the transport network.

In this context, changes in the modal split by increasing the role of public transport are also important. Activities supporting the development are based on the dedicated and long-term development of modal split, as manifested by a balanced transport (Our Common Future Report 1987; Banister 2008; Verma and Ramanayya 2014). This entails the influence on people travelling to change their transportation behaviour. In many instances, integrated traffic control in the road network is not sufficient in this respect. Thus, it is necessary to promote synergy through a wide range of different actions. It requires not only a bidirectional flow of information between individuals travelling and broad understanding of the 'city' with particular emphasis on its transport infrastructure, but also sources of information outside the transport network, especially that undoubtedly, a number of such sources are available. In this context, it is important to develop information technology that allows us to determine transport needs and, at the same time, predict and better plan future solutions for the organisation of the traffic flows in the transport network.

The implementation of the idea of Industry 4.0 involves the use of automation, processing and exchange of data in combination with the relevant production techniques (Zezulka et al. 2016; Gunasekaran et al. 2019). The implementation of Industry 4.0 for the development of transport networks to enhance integration between people and the transport system provides a wide range of possibilities to develop smart mobility. It should be noted in this context that, in traffic control systems, a group of vehicles rather than an individual traveller is integrated with the system. Information, originating from a variety of sources, can be processed between the transport system and its users on an ongoing basis. Then, it is possible to use information dedicated to specific groups of users by disseminating dynamic information in the urban space (Sierpiński and Staniek 2016).

The chapter presents the possibility of combining Industry 4.0 with smart mobility to promote sustainable transport development. The proposed method points to existing data sources, including trip planners. The chapter presents other available sources of data that may be relevant. It also discusses the expected effects of broad integration between Industry 4.0 information technology and the urban transport system.

Moreover, the publication discusses various ways of information processing and data exchange that facilitate traffic flow organisation adjustment to the needs of citizens following the principles of sustainable development. Considering the above, transport infrastructure can be considered as a collection of objects which enable continuous traffic flow organisation improvements. As regards the subjects of transport, traffic flow organisation focuses on trips themselves rather than vehicles, which is particularly important for the optimization of the public transport. This, however, necessitates to collect data (in large quantities, Big Data sets), and modify and adjust them for the purpose of designing and producing modern traffic flow organisation elements in the form of the vertical signs with a variable content.

2 Dynamic Organisation of Traffic in the Transport Network

In the transport network, the organisation of traffic flow involves the distribution of road traffic (including node and line infrastructure). The distribution needs to take into account of technical and technological limitations on particular connections in the transport network, such as capacity of road sections, load bearing, limited road gauge. Traffic flow organisation is constant in the long-term perspective. In such an approach, traffic flow organisation is considered in statistical terms (in fixed intervals) for known demand ZP for transport on specific routes between points a and b (Jacyna 2008):

$$ZP = \left\{x^{ab} : (a, b) \in R\right\} \tag{1}$$

where

a, b pair of vertices, source and exit in transport network
x^{ab} demand for transport between a pair of vertices in the network: a and b
A, B sets: traffic flow sources and exits
R origin–destination relationships in the transport network $R \subset \mathrm{A} \times \mathrm{B} = \{(\mathrm{a}, \mathrm{b}) : \mathrm{a} \in \mathrm{A}, \mathrm{b} \in \mathrm{B}\}$.

Additionally, static traffic flow organisation is determined with the known set of all routes P used in the transport network in the form of (3)

$$P = \bigcup_{(a,b)\in R} P^{ab} \tag{2}$$

where

P^{ab} set of roads on routes: (a, b).

Thus, we define traffic flow organisation in the transport network as follows (3):

$$o : P^{ab} \times ZP \to R^{+} \tag{3}$$

where

o traffic flow organisation:
$O = \{o : o\left(p, x^{ab}\right) \in R^{+}, p \in P^{ab}, x^{ab} \in ZP, (a, b) \in R\}$.

At this point, we should distinguish between the traffic flow organisation described by functions (1)–(3) and the organisation based on using road signs. The distribution of traffic on roads is associated with a specific demand for transport and it is determined considering specific traffic flow organisation in the transport network as a set of horizontal and vertical road signs. The authors have drawn attention to the fact that such an organisation can be dynamically adjusted by relevant changes of the content displayed in vertical road signs. The same is true for horizontal signs, although it is a separate topic not discussed in the chapter.

It should be noted that today, apart from a few cases, the demand for transport is not constant both in relation to the transport of goods and the public transport of people (as well as individual transport). It is not constant both over time and in transport network space, since there are daily, weekly, periodic and seasonal fluctuations. Changes that have taken place in the life of contemporary societies in recent decades cause that demand for transport changes each year. Not only does the volume of demand on individual routes change, but also routes themselves. This is due to the partial relocation of traffic generators and absorbents within the settlement network.

The organisation of traffic flow, taking into account changes observed in time and space in the transport network, should be treated as follows:

$$\langle O_1, O_2, .., O_i, \ldots, O_n \rangle = \left\langle \left\{ o_i : o_i\left(p, x^{ab}\right) \right\} \right\rangle \tag{4}$$

where

O_i organisation variant i.

In this sense, we define n variations of traffic flow organisation in the transport network depending on the status of the network, and the proposed dynamic changes of the organisation using vertical signs should facilitate these changes. For various periods of a day, due to uneven daily traffic, we may adopt one and the same variation.

Hence, it is a collection of certain variations. However, due to such fluctuation in the transport network, we should define a number of traffic flow organisation variations.

The key to implement this type of projection is the dynamic shaping of routes in the transport network and examining the flow of goods and/or people on those routes. This approach to traffic flow organisation should be supported by an appropriate modal split in order to balance the development of transport. In this sense, the organisation of traffic flow in the transport network following principles of sustainable transport development is consistent with the projection:

$$O_i^M \propto (SM_1 : SM_2 : \ldots : SM_i : \ldots SM_n) \quad (5)$$

where

O_i^M variation taking into account the modal split in the network
SM_i share of a specific mode of transport i in total traffic flow in the network.

The function is generated from the point of view of the modal split in the entire transport network. Therefore, instantaneous organisation of traffic flow (4) is adjusted to the modal split. Apart from this form of traffic flow organisation, interpreted as the distribution of traffic flows (existing) on roads in transport network, there are also restrictions on traffic flow organisation on specific road sections implemented through traffic control systems, and vertical and horizontal road signs. Although in the case of traffic control, we can refer to certain dynamics of changes as regards the parameters and algorithms of traffic control system (Małecki et al. 2017), in the case of horizontal and vertical signs these elements remain static in a longer period. Is it possible to improve the traffic flow organisation on these sections in relation to dynamic changes in demand for transport, including the shaping of the modal split? In the case of traffic control systems, it is possible to adapt traffic light programs to the changing traffic (Celiński and Sierpiński 2013b). Thus, traffic parameters can change. The same is also possible in the case of vertical and horizontal road signs. The use of variable content signs and their possible influence on travelling persons was discussed by several publications, including (Erke et al. 2007; Arbaiza and Lucas-Alba 2012; Er-hui et al. 2013; Celiński et al. 2015; Li et al. 2016; NCHRP SYNTHESIS 383 Report 2008). While this type of display technology to provide information about traffic using vertical signs, it is possible to improve traffic flow organisation on specific sections of the road network. The criterion for these changes should depend on the actual demand for transport on specific routes, including from the point of view of a relevant modal split (Celiński and Sierpiński 2013a).

At present, traffic flow organisation based on vertical and horizontal signs is archaic in the majority of transport networks. It is often justified on the grounds of safety, whereas financial considerations in this respect are believed to be objective. Fixed vertical signs prevail in road networks when the production cost of an LCD display of comparable surface area is close to the cost of a fixed sign. The development of solar photovoltaic systems enables to supply power to this type of road and street signs with no major difficulties. It is more relevant the closer the road network is to the equator. The development of electromobility supports the above solution since more powerful rechargeable batteries are developed as well. Although current legal regulations permit the use of VMS signs, it is done by replicating fixed signs (the same road signs designs). According to the authors, there are no obstacles preventing variable content signs to be actually used as such. For example, a sign may require individual vehicles to change lanes, which will eventually lead to changing their routes in the transport network or to change their speed. Such an approach enables to adjust traffic flow organisation to the actual traffic in a similar manner to what is currently achieved by traffic lights (but in the proposed approach it is larger information capacity). Nevertheless, the number of contents may be much larger than in the case of classical light signalling. This in turn allows for dynamic traffic flow organisation in the road network adapted to the actual traffic.

The proposed dynamic traffic flow organisation in specific transport network profiles provides better conditions for public transport. At the moment, the limiting factor is the lack of specialised control systems and physical space to designate separate lanes for public transport vehicles. According to the proposed method, while organising traffic in the road network, the system should know what priority needs to be applied for public transport vehicles. The means of transport will be matched with the number of events in the network as described in the further part of the chapter. Traffic control system is capable of separating traffic in time and space and the traffic flow organisation is capable of separating different modes of transport, provided it is based on variable content and operates according to data acquired in a manner described in the chapter.

Changes of traffic flow organisation implemented using the proposed method can be transferred as feedback to users in information displays and, according to the technological advancement of Industry 4.0, in the form of direct messages sent to their mobile equipment, navigation devices, etc. Those communication channels are crucial since they help users to adjust to the new configuration of the road network. This will consequently reduce the number of hazardous situations. The rate of changes depends on actual needs and intelligent traffic flow organisation should reduce congestion.

3 Source of Data and Industry 4.0

So far, various methods have been applied to determining of demand for transport in the transport network. *The discussion presented is limited to passenger transport only*. Surveys of transport behaviour among citizens are an important source of information. Such surveys enable to establish traffic flows between regions and/or within the transport network (Ortúzar and Willumsen 2011). Survey data enable to adjust public transport offer and to a certain degree influence traffic flow organisation in the transport network. However, due to limited frequency of such surveys, they have a limited influence on traffic flow organisation, and hardly any influence on traffic control. The above surveys are supplemented by those which examine traffic flows from the point of view of traffic control systems. In the case of road traffic, the surveys may help to optimise algorithms used in the traffic control system usually on a microscale. In the case of rail traffic, the surveys help examine utilisation of capacity on specific sections of the rail network and lead to better adjustment of the transport offer to actual needs in the transport network (as regards development of desired capacity matched with rolling stock available).

Surveys focus on the following terms: ‘actual’ and ‘transport network’. On the one hand, all those surveys are implemented in considerable intervals that make it impossible to react to actual changes of processes concerned (i.e. statistical traffic flow organisation). On the other hand, the surveys cover the transport network or its immediate vicinity. Thus, they are always partial, since the distribution of traffic depends on a number of factors that are disregarded by the survey (Szarata 2013).

Industry 4.0 involves automated collection, processing and exchange of information (with emphasis on the latter) (Faheem et al. 2018; Grzybowska and Łupicka 2019). It is also done with the aim of traffic flow organisation in the transport network (Kijewska et al. 2016). In this context, it is worth noting that every socio-economic event, apparently not related directly to the transport system, may potentially influence traffic flow organisation in the transport network. We witness such an influence when an event can be registered by available technology, especially mobile devices supported with functionalities provided by GPS and GSM. Another requirement is the possibility of defining the relationship between the event and traffic flow organisation in the transport system while determining its time and place, as well as various categories of the event (various databases describing event). The problem, in this case, is mainly the reference of the relation of this activity to the future load of the transport system. This translates into a specific function of influence of specific activities generated in the socio-economic system on the transport system. Below the article lists some examples related to the utilisation of the transport network.

A client buying a product in the point of sales not only identifies the route in the chain of manufacturer–supplier–vendor–recipient, but also does it with the connection to external databases (e.g. national identification numbers, banking systems), determines locations (or potential locations) for the consumption of the product, as well as a number of additional parameters. At the same time, the client defines parameters for several related activities (means of transport, time of day, accompanying people, profession, etc.). Thus, while using modern technologies, used for the registration of the event in time and space, the influence of the event can be measured with the precision on the level of one/several roads in the transport network. While quantifying activities in time and/or space (in relation to other activities), we may attempt to determine the influence on traffic flow organisation in the road network (function of influence), and match demand and supply in the transport network through feedback channels. Such balancing can be secured by traffic flow organisation referred to in the title of the article (both traffic flow-based and road sign-based traffic flow organisation). For this purpose, it is necessary to create variable traffic flow organisation for transport infrastructure in specific sections of the road network.

An example of the above is a system based on information acquired from mobile phone operators (e.g. call detail record—CDR) (Valerio 2009). Such data directly define actual traffic in the transport network and daily changes in the traffic. Such

Fig. 1 Trip planner—main GT planner window (*Source* Own research)

data are provided by subscriber's calls, as well as procedures related to changes in the location area code (LAC). Traffic flows between areas of the network controlled by base transceiver stations (BTS) are reflected in data collected by operators (Sierpiński and Celiński 2012). Improvements in traffic flow organisation in specific components of transport infrastructure can be linked with such data. The precision depends on the size of network units within the area of a given mobile phone operator. The more advanced technology, the smaller those units are.

Another example of using such data for traffic flow organisation in the transport network is a trip planner. Trip planners enable fast and intuitive search for a route between two points defined by the user in the transport network (Jaunzems and Lektauers 2013; Borkowski 2017; Sierpiński 2017). Between the origin and destination. Frequently, the used also defines intermediate locations (i.e. POI—Points of Interest), if certain matters need to be dealt with in locations before the destination is reached. Figure 1 presents GT Planner which is one of the outputs of the international project of Green Travelling under the ERANET programme funded by the National Research and Development Centre. The trip planner application can be used (usually thorough website) to obtain data describing transport behaviour among citizens and their travelling needs within a given area. Trip planners can be integrated with meta search engines. The program (website, service) based on a meta search engine searches simultaneously through several search services (planners). Archived data usually cover origins, destinations and means of transport selected by the planner user. Spatial information is usually linked with trip commencement and completion time. In the case of public transport, travelling time information is precise since it is based on actual timetables often defined in their digital format, e.g. General Transit Feed Specification (GTFS) (https://developers.google.com/transit/gtfs/). Such data are reliable and they describe transport behaviour from the point of view of time and space. In the case of individual transport, such data apply to the beginning and end of the trip. Frequently, during the interaction between the user and the planner, it is possible to acquire information about user transport preferences. An example of the

Fig. 2 Trip origins and optimised routes in selected area and example of input data (*Source* Sierpiński et al. 2016)

above is information about preferred modes of travelling in the transport network, e.g. green, fast, safe. The first option means that the user prefers ecological means of transport. The second one, shows that the user is interested solely in terms of reaching a desired destination. The third one means that the user focuses on trip safety. In such a mode of operation, it is possible to define precise parameters of user transport behaviour. Data from session registration (service user session) help to improve the organisation of the transport network (Sierpiński et al. 2016) (Fig. 2).

Another example is Internet-based timetables for public transport. Transport behaviour profiles are determined as in the case of trip planners. Increasingly often, the configuration of the web-based route finder enables to determine transport behaviour not only in terms of distance covered but also travelling time. For example, rail operators search engines request users to define the travelling time in narrow period.

The same is true for such activities as searching maps in other cities using a mobile device and the Internet (location search), finding fuel stations, ticket purchase/inspection, change of base location to actual position of mobile phone, any electronic payment especially when related to goods consumption in specific location (facility), use of info kiosks, etc. All those activities enable to determine transport behaviour profiles. To a large probability, we may assume that the list of such activities is going to expand in the global and mobile society. The above activities determine the potential for improving traffic flow organisation in specific components of the road network by identifying the locations of certain activities.

It is worth considering some basic questions related to the transport system. Does the socio-economic system generate a specific event and what major parameters does the event implies from the point of view of the transport network? Those basic questions are as follows:

Where?—information directly linked with the location.
When?—information regarding time.
Who?—information related to the subject involved.

What?—information concerning parameters of the event detected by modern equipment and technologies (purchase of goods or services, change of means of transport, phone call, payment, etc.).

By linking such information with other data in various databases and owners (banking systems, GPS, GSM, city information systems, timetables, national identification numbers, system of Central Registry of Vehicles and Drivers, System of Registering of Accidents and Collisions, other GIS systems, etc.), those questions (who, where, when and why) can be further extended:

Where from? (origin), i.e. place of domicile/work of the user,
Where to? (destination), i.e. place of domicile/work of the user and what are his/her usual destinations,
How often? (Historical data about travelling and activities of the user),
For what? (Banking system information about transactions),
Facilities applicable? (Mobile phone network, BTS on the route),
With whom? (Correlation of data in space and time with other users within the same information systems).

Facilities related to travelling can be determined using popular spatial databases. Open access databases include, for instance, popular Open Street Map (OSM) (http://wiki.openstreetmap.org). An example of commercial databases is Google Maps (http://maps.google.pl). One may also use the Geographical Information System (GIS) in a given city or metropolis (Hu et al. 2016). An example of object location based on OSM is presented in Fig. 3.

Provided relevant data are acquired from existing databases (aggregation and acquisition of data is a challenge), a precise question (where, when, who…etc.) enables us to define parameters for complete transport chains in the transport network. In those transport chains, the variation of trips can still occur, e.g. due to imprecise measurement. One of the telemetric systems is the mobile phone network. In the case of large GSM cells (in GSM networks show tendency to reduce the size of basic cells), the precision with which a trip is recorded may lead to variations for a given transport chain. Another positive fact is that the size mobile phone network cells correspond to transport network density indices. In the case of large GSM cells, usually, the transport network is usually less dense.

Figure 4 presents a method for defining parameters of activities in the socio-economic system, which can be used to define transport chain parameters by asking relevant questions. Thus, it is possible to adjust to those data to traffic flow organisation on specific sections of transport infrastructure as regards transport chains. This requires data mining, exchange and processing according to the principles of Industry 4.0 (Grzybowska 2012; Dalenogare et al. 2018; Zezulka et al. 2018). We can achieve a full integration of the subject with surrounding IT systems, which in this particular case, become in fact telemetric systems.

Figure 5 presents links between databases that can be used for the identification of trips in the transport network. The figure lists major IT systems which may contain information necessary to define parameters of trips. However, all of them can hardly be listed, since their number is still growing.

Fig. 3 Example of OSM data presented in the map (key/amenity = fast_food) (*Source* https://overpass-turbo.eu/# © Open Street Map)

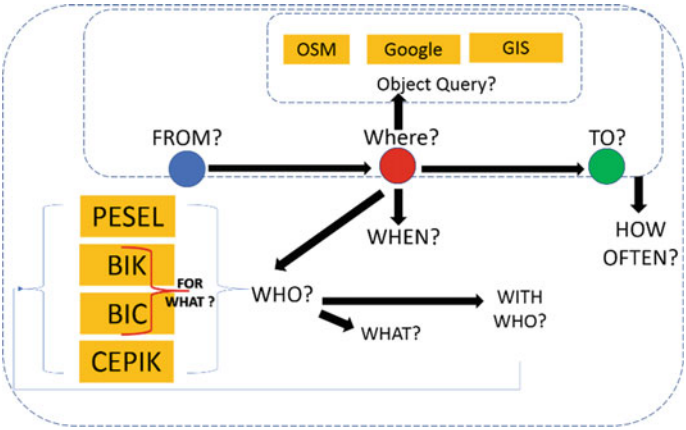

Fig. 4 Identification of trips by linking databases (PESEL—Universal electronic system for registration of the population, BIK—Credit Information Office, BIC—Business Identifier Code, CEPIK—Central Register of Vehicles and Drivers, OSM—Open Street Map, GIS—Geographic information system) (*Source* Own research)

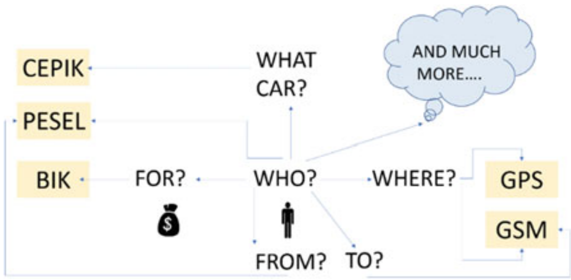

Fig. 5 Data exchange (*Source* Own research)

As presented in Fig. 5, there can be many patterns of acquiring information about an event in the transport network. It depends on available databases, majority of which are or should be public.

4 Section Function of Event Influence on Traffic Flow Organisation

In the opinion of the authors, in the transport network and in its socio-economic environment, each event that can be recorded and influence future traffic in that network should be taken into consideration while organising such a network. In practical terms, it is possible to determine parameters for traffic flow organisation at any section transport network from the point of view of events that may influence the traffic at a given section. Improvements to the efficiency of the transport network cannot be made at all points simultaneously since iterations are necessary for the process. Discrete profiles are selected for consecutive improvements, profiles which are situated at a certain distance to each other. An event that may influence the transport network can be determined using modern telemetric techniques with the accuracy level up to:

– place of event,
– time of event,
– subject generating event and
– object related to origin of event.

After exchanging such data with external databases, an event can be further described by a number of additional parameters, such as

– origin of subject (e.g. place of registration, domicile),
– destination, determined in the transport system or forecasting based on additional parameters,
– objects relevant for event and
– economic parameters describing event, etc.

Once we define the transport network in a geocentric system, we may determine distance j of the profile, for which traffic flow organisation is provided in a dynamic setting, from place e of the event, both in space and to specific elements of the network infrastructure:

$$e : \{s_g^j, s_n^j\}, s_g^j \neq s_n^j \tag{6}$$

where

e event number [−]
j profile number [−]
s_g^j distance in geocentric system [m]
s_n^j distance by network elements [m].

The event impact area is not limited to a single profile, but can actually influence future traffic flow organisation in several different profiles of the network. Based on travelling time at specific sections, we can determine the expected arrival time of an object that generates an event to profile j of the network from the point of its identification:

$$t_p^j = (t_p^1 - \Delta t_p^j) + t_p^2 +, \ldots, t_p^i, + \cdots + (t_p^m - \Delta t_p^m) \tag{7}$$

where

t_p^j expected arrival time to profile where traffic is organised [s]
t_p^i i travelling times [s] from the place of event to the profile
Δt_p^j travelling time based on distance to the location of the profile on section [s]
Δt_p^m travelling time based on distance to the location of the place of event on section [s].

In the context of (7), the issue is to determine travelling times on sections of the road network. The parameter shows major fluctuations during a day. Nevertheless, such information is available in telemetric systems. Similar data can be accessed in Google Maps. The accuracy is sufficient to estimate the arrival time from the place of event to the measurement profile.

Based on notifications of consecutive events by the same subjects, generated in other locations in space, we can determine a route on which the subject reaches a specific profile in that road network.

In practice, due to several options in the transport network, a subject initiating an event may appear at one of a set of possible profiles. The number of variations exceeds 2 or 3 only in very dense and inhomogeneous transport networks. Whether a user appears in a given profile of the transport network depends on additional parameters that describe trips (e.g. motivation, history). It should be emphasised that an average is to be drawn from parameters of registered notifications in particular profiles, since the goal is to reduce the cost of traffic flow organisation from the point of view of the entire system rather than individual trips. Additionally, traffic flow organisation should ensure a relevant modal split. Therefore, once we know time, place and routes of a given subject, we can implement a relevant traffic flow organisation using elements of transport infrastructure. It is described by the section function of event influence on traffic flow organisation in a given profile as follows:

$$F_w^j = f(s_n^j, t_p^j, SM, x_e, y_e, t_e, x_d, y_d, x_s, y_s, FF, HD) \quad (8)$$

where

x_e, y_e Coordinates of place of event (WGS 84)
t_e time of event
x_d, y_d coordinates of destinations taken from databases
x_s, y_s coordinates of origin
FF financial attributes of event taken from relevant databases
HD historical information about trips.

In a certain area of the network, each element involved in dynamic traffic flow organisation has a set of influence function values available (for all major events for given profile, average is calculated for events registered):

$$SF_w^j = \left\{F_e^j\right\} \quad (9)$$

where

SF_w^j set of events in transport network of certain influence function value higher than zero for profile j
F_e^j events e influencing profile j.

In (9), the set of function parameters can be supplemented in various ways with information about the manner of travelling by a party generating an event in the transport network. For this purpose, average speed of the subject can be determined for a given moment (based on various systems and databases). It is also possible to use historical information or information from client sessions in the trip planner or any other similar device in which the subject declared his/her preferred means of transport. It should be emphasised that in rush hours on a single lane and given profile under dynamic traffic flow organisation, we may have from 1000 to 1800 vehicles, movement of which can be linked to dozens of thousand events in the socio-economic environment of the transport network (Big Data sets).

In each of profiles, we may define the expected modal split which results from the characteristics of subjects generating events significant for a given profile:

$$EMS^j = SM_1^{j,zn} : SM_2^{j,zn} : \ldots : SM_i^{j,zn} : \ldots SM_n^{j,zn} \quad (10)$$

where

zn number of events identified as significant for profile j.

Thus, the modal split is determined by using artificial intelligence (AI) while analysing data from registered events. The description of the use of AI methods while processing events to obtain information about the modal split extends beyond the framework of this article and it is going to be discussed in a separate publication.

If in a given profile of the transport network, we have more than one lane and it is a profile before a node with possibility to change directional and type structure, the profile can be used for shaping the justified modal split by using vertical signs (VMS).

Passenger cars or cars with conventional engines (not electric or hybrid) can be directed to other profiles in the transport network. For this purpose, it is possible to place a dynamic turn sign for vehicles of certain type (it is assumed that according to Industry 4.0, such signs are to be designed). The process can be implemented not only from the point of view of a given road cross section, but also from the point of view of the modal split on certain sections of the network and its entire space:

$$EMS^{net} = SM_1^{zt} : SM_2^{zt} : \ldots : SM_i^{zt} : \ldots SM_n^{zt} \tag{11}$$

where

zt number of events in entire transport network.

In the case of (11), the dynamic traffic flow organisation in terms of selecting a modal split applies to the entire transport network simultaneously.

5 Discussion

In the road network, vehicles move in an unregulated manner and it is a typical stochastic process. Junctions fitted with traffic lights are locations where traffic can be controlled on limited distances. After leaving a junction with traffic lights, after leaving the intersection with the traffic lights, there is a dispersion of the traffic flow. The further from the junction, the more random traffic becomes and equal access to traffic for vehicles is no longer possible. We also lose the influence on the characteristics of the traffic flow. Such a network can be described by the Nash equilibrium (Bressan and Han 2011). The distribution of traffic flows in the transport network is developed in such a way that for each route the average cost of transport is minimum and equal to the one used by that traffic flow. Since there is no global traffic flow organiser, the cost of the system is not optimised. A change in the route does not increase benefits for the user. Such situation is true assuming that the traffic is not controlled, characteristics of transport network infrastructure elements are defined and the traffic flow is homogenous. According to the Nash equilibrium, the distribution of traffic *w* the transport network can be described as follows (Jacyna 2008):

$$\forall(a, b) \in R\ \forall p, q \in P^{ab}_{x>0} c^{p,ab}(X) = c^{q,ab}(X) = \alpha^{ab}\alpha^{ab} \rightarrow \min \tag{12}$$

where

q alternative route.

As long as the method presented in the chapter enables to introduce dynamic changes of traffic flow organisation on specific sections of the transport infrastructure and sections can 'self-improve' based on information about trips, we are close to minimising cost of traffic flow distribution from the point of view of the entire network (its organiser). It depends on the possible function of traffic flow organisation for each user. When very large number of elements of infrastructure can adjust to dynamic changes in the transport network, no user who fails to follow those changes can increase their benefits. It is similar to the situation describing the Stackelberg equilibrium (Jacyna 2008; Groot et al. 2012):

$$f(X) = \sum_{(a,b)\in R} \sum_{p\in P^{ab}} c^{p,ab}\left(x^{p,ab}\right) * x^{p,ab} \rightarrow\sim \min \tag{13}$$

where

$f(X)$ function describing minimum cost of transport on all routes (for all events).

It is related to the fact that the entire space of the network under such organisation enables to increase benefits while deviating from a specific form of traffic flow organisation (imposed by organiser who has information about all (or almost all) associated events in transport network) in the transport network (apart from possible legal consequences of failure to respect laws). At least in the case of the modal split, we become close to minimising cost for the system. In the case of individual transport, the stochastic nature of the process is going to be more strictly limited. However, we should remember that in the case of breaking traffic regulations, road events and accidents will make major difference between minimum and actual costs.

Therefore, it is possible to conclude that dynamic changes in traffic flow organisation, which is an important element of transport network, can produce benefits for the entire city. The city and its efficient transport network is a function of the goal of changing traffic flow organisation in specific elements of infrastructure. Needs of users, which are identified by various elements of the Industry 4.0 system, is the basis for general improvement of cost in the transport network and the quality of its operation. Of course, in a number of instances, the transformation of the network in the global scale brings benefits for individual users as well.

6 Conclusions and Final Comments

A major advantage of the method is its holistic approach, in which information important for traffic flow organisation in specific profiles of the transport network originates from a large number of sources, including those located beyond the transport network. Such information not only provides new data, but also integrates those data using new or modified vertical signs in the transport network. A major role is played there by the concept of Industry 4.0 which, sooner or later, will be adopted in the road network.

Another advantage of the method is the fact that while organising the network, the managing body will no longer use a narrow range of information about the network (geometric parameters) and traffic events. The latter comprises a narrow group of examples of various occurrences in the network. The method presented in the article enables to analyse traffic flow organisation in a much broader sense, and since it is holistic, the network is treated as a whole by extending the analysis beyond the transport network and taking into account various events (including those not related directly to transport, variable sections of network).

Yet another advantage of the method is created by the possibility of using it (data obtained) when designing and planning of the transport network. There, data can be used at a very basic level while developing the transport network, and taking into account principles of sustainable mobility (Jacyna et al. 2013).

A major downside of the solution is that data analysed originate from commercial databases managed by private institutions, such as banks, mobile phone operators. In general, such data are not made available, including their anonymous form. However, considering the development of Industry 4.0 and information technologies, it should be noted that the exchange of data is going to be an indispensable component of each process. Therefore, the problem is limited to accessing relevant data sources and appropriate data processing.

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Attractiveness of the Region in Connection with Intermodal Transport Development

Lilla Knop and Marzena Kramarz

Abstract Intermodal transport, as exemplified by numerous studies, is very important for sustainability development of the industry. Individual regions should strive to develop these transport technologies, which use physical resources of the region, geographic shape, communication routes, etc. This matches the concept of sustainable development of the region, particularly through the impact on the reduction of external transport costs. Thus, the purpose of the chapter is to identify and evaluate the criteria shaping the attractiveness of the near-border region from the intermodal transport development point of view. Modified Emerald model was used to study the region attractiveness and the evaluation was based on statistic indicators, description data and estimates of experts. The chapter is an attempt and introduction to wider studies concerning the regions' attractiveness in the context of development of intermodal transport and determination of its maturity level in cross-border region TRITIA. Future plans involve performing studies within different near-border regions within the scope of TRITIA cooperation and verifying indicators subjected to evaluation.

Keywords Sustainability transport · Ecosystem · Cooperation in regional network · Cross-border transport · Transport development

1 Introduction

Theories of regional development mean almost 150 years of history, starting with neoclassical theories of growth, through conservative theories of local and regional convergence, theories of structural changes, institutional and socio-economic theories, theories of innovation and knowledge, up to neoclassical theories of endogenous growth and competitiveness and clusters (Pike et al. 2011). At the moment, regions develop smart specializations, i.e. a concept according to which region development

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is affected by its potential, assets, so-called region specializations. The basis for specialization identification is the identification of own resources, cooperation network, human potential as well as R&D&I. The concept of smart specialization puts greater emphasis on innovations and concentrates the limited human and financial resources within a few areas competitive to global scale in order to excite the economic growth and wealth (Olko and Brzóska 2017). Polish regions have not only identified smart specializations but also constantly developed them. In this case, it was important not only to identify the strengths of the region but also to evaluate its attractiveness from the standpoint of new specializations development. Śląskie Province develops three key smart specializations: medicine, energy and ICT as well as new ones, focused around new material technologies and environment protection as well as development of the TSL sector. The TSL sector becomes more important from the intermodal transport development perspective, which in fact, besides smart specializations, is underlined in the European developmental policy. The intermodal transport means transport of cargo within a single cargo unit or vehicle, using successively different branches of transport without reloading the cargo itself in the changing transport branches, based on a single transport contract for which one entity is held responsible—intermodal transport operator (Crainic and Kap 2007).

Intermodal transport, as exemplified by numerous studies, is very important for sustainability development of the industry (Grzybowska et al. 2014). Individual regions should strive to develop these transport technologies, which use physical resources of the region, geographic shape, communication routes, etc. This matches the concept of sustainable development of the region, particularly through the impact on the reduction of external transport costs (Awasthi et al. 2014). Moreover, regions located within cross-border areas are predisposed but also have needs in order to become leading regions in the sector of intermodal transport development. Thus, the purpose of the chapter is to identify and evaluate the criteria shaping the attractiveness of the near-border region from the intermodal transport development point of view. Modified Emerald model was used to study the region attractiveness and the evaluation was based on statistic indicators, description data and estimates of experts. The chapter is an attempt and introduction to wider studies concerning the regions' attractiveness in the context of the development of intermodal transport and determination of its maturity level in cross-border region TRITIA. TRITIA aims to use the significant cooperation potential, which all cooperating regions, i.e. Moravian-Silesian Region, Silesian and Opole and Žilina self-governing regions dispose of, through the creation of functional cross-border governance structures and making use of the cooperation projects identified in the course of the creation of the strategy as well as the three bilateral strategies. In order to fulfil the objectives formulated in the strategy, the cross-border cooperation involves all potentially relevant actors. In the chapter, we tried to answer two research questions: 1. Which factors decide about attractiveness of a region from the standpoint of intermodal transport? Is the Silesian Province, as a near-border region, attractive from the intermodal transport development point of view? Creation and development of the cross-border territory rely on cooperation in the following four areas: transport and infrastructure, economic cooperation, tourism, energy and environment. The article consists of three key parts: theoretical, research and synthesis. The first theoretical part presents key definitions and relations between the attractiveness of the region and the development of intermodal transport in the cross-border area. In this part, the methods of assessing the attractiveness of the region were discussed. Part of the research includes the identification of indicators evaluating the region's attractiveness for the development of intermodal transport and their expert evaluation for the Silesian Province. The synthesis part presents research results and final conclusions.

2 Attractiveness of Regions Versus the Essence of Intermodal Transport

Attractiveness of a region can be generally defined as the ability of the territorial system of being perceived as competitive (e.g. for potential investors). You may say that regions compete with each other with the degree of their attractiveness for potential investors or the development of new sectors. Regional attractiveness is a complex concept and covers many factors important from the standpoint of the analysed problem, e.g. potential investments, regional specializations or performed economic operations (Godlewska-Majewska 2011). On the other hand the growing concern about sustainable development has an increasingly greater impact upon the Supply Chains and TSL sector (Grzybowska 2011).

The chapter is focused on the development of intermodal transport, which both by practitioners and theoreticians of the logistics management is identified as a chance to reduce external costs of transport, thus as a chance to improve regions' attractiveness. Council Directive 92/106/EEC (directive on combined transport) is the sole legal instrument at the Union level that directly encourages to transfer from road transport to different types of transport of lower level of emission, such as inland navigation, maritime and railway transport. It is to increase the competitiveness of the cross-border intermodal transport, comparing to only road cargo transport. Intermodal transport is interpreted as transport of cargo within a single shipment unit using different types of transport branches (UN/ECE 2001), however, the main part of the transport should be performed using railway transport, inland and maritime navigation, air transport and the beginning and/or end section using road transport, within the shortest time possible (Finger and Holvad 2013; Feder 2018). Narrowed share of road transport for supply and return operations is justified in the concept of sustainable transport, more ecological and competitive economy, such as this implemented within the scope of the strategy Europe 2020 (Hyard 2013; Kozłowski et al. 2018; Golińska and Kawa 2015).

The market of intermodal carriage is young in Poland and characterizes with minor, but constant development. At the moment, Poland is ranked 11 among the Union countries in terms of the weight of cargo transported using intermodal transport. Development potential of this transport in Poland is considerable all the more that the European Union drives at gradual replacement of road transport with maritime and railway transport. The results of using intermodal transport are usually divided into three groups: economic, ecological and social. Economic results consist mostly in reducing operational expenditures (fuel, time of drivers work, etc.), longer life of trucks, limiting road tolls (motorways, tunnels, etc.), less wearing of the roads. Ecological results are especially related to reduced pollution of the environment through the reduction of exhaust gases and noise emission and diminished external costs of transport. Social results are related to traffic safety improvement.

In order to understand the methods of region attractiveness, it is necessary to mention a few models related to studying competitiveness and attractiveness of a given area. One of the most common ones is the Porter Diamond Model or R. Florida concept of creative class; moreover, there are many reports being published on competitiveness. In the studies, the Extended Emerald model was used, developed by Sasson and Reve (2012). The diamond model (Porter 1990) has been used widely in studying the competitive advantage of regions. In this model, a region has a competitive advantage based on its factor conditions, demand conditions, existence of strong related and supporting industries, and firm strategy, structure and rivalry. The underlying argument in the creative class thesis is that as talents and creative people become a crucial resource for knowledge-intensive production (technology), the quest for talent and creative people increases. Contrary to traditional resources, talents and creative people are mobile, that is why we should be tolerant (Hansen 2007). The Emerald model has six dimensions and one moderator. The dimensions in the model are educational attractiveness, talent attractiveness, R&D and innovation attractiveness, ownership attractiveness, environmental attractiveness and cluster attractiveness. The model has been originally developed to evaluate the attractiveness of a location to attract foreign direct investments (FDI) and was previously used in the assessment of health industry (Sasson 2011a), oil and gas industry (Sasson and Blomgren 2011), metals and materials industry (Sasson 2011b) and telecom industry (Vinje and Nordkvelde 2011).

3 Indicators of the Region's Attractiveness: Assumptions of Research

Studies of attractiveness of the region in the context of intermodal transport development are based on the Emerald model, presented by Sasson and Reve. It is preferred and used as frames diagnosing and describing a given state of affairs because it is based mostly on chronological data and facts. Moreover, it allows for illustrating general development or change of situation. This way, the authors have evaluated the potential of the cluster (Sasson and Reve 2012), but also development of the sector in a specified area. Based on such assumptions, the modified Emerald model was used in the paper to evaluate attractiveness of the region in the context of intermodal transport development. The proposal concerning adaptation of the Emerald model to evaluate attractiveness of the region is not a new solution because such studies have been performed earlier.

The proposal to change the model and process of studies is based on two key discriminants which are not present in the classical evaluation of region attractiveness. First, you evaluate a region from the perspective of developmental opportunities of not one but a few sectors (according to Polish Classification of Activities—intermodal transport consists of a few sectors); and second, you take its near-border geographic location into consideration. Based on these assumptions, the studies also included six planes of region attractiveness evaluation in the context of intermodal transport development: infrastructure attractiveness, human capital attractiveness, R&D&I attractiveness, ownership attractiveness, environment attractiveness, cooperation and network attractiveness. Modification of the Emerald model consisted of merging the attractiveness of education and talents in the plane of the attractiveness of human potential. The attractiveness of infrastructure and physical resources has been added as a new platform. Instead of attractiveness of a cluster, attractiveness of cooperation and network relationships was detailed.

In the plane of the attractiveness of infrastructure, as it results from studies related to development of intermodal transport, the basic indicator of evaluation is reloading terminals. In this case, one mentions not only the number of available terminals in the region but also their capacity, location and level of satisfying technical and technological requirements. Within the nodal infrastructure, it is important to indicate storage areas, including number, capacity and degree of concentration. From the demand point of view, storage areas are nodes in the logistic network, which generate cargo streams (and among other things decide about their frequency and utilized branches of transport). The infrastructure of container terminals is mostly located within the regions of concentration of storage and industrial infrastructure. Another set of indicators included in the plane of the infrastructure attractiveness are factors describing linear infrastructure. The availability of different transport branches as well as density and quality of roads is important for intermodal transport development. Characteristic of evaluated indicators is presented in Table 1.

The second plane of the region attractiveness evaluation is the attractiveness of human capital. Among the key factors describing this area, based on a classic approach, you differentiate the number of employed persons in the sectors related to intermodal transport and average remuneration. The supply of specialists, managers and sector experts is also an important factor. Moreover, from the standpoint of building future human capital, the number of persons studying and learning in post-secondary schools on logistic, transport and similar faculties are separated. Table 2 presents results and criteria of this plane evaluation.

As mentioned before, evaluation within the R&D&I plane emphasizes the potential of competitiveness and innovation of the region. Basic data that may be identified and evaluated for the purposes of the development of intermodal transport is the number of patents within this scope and number of universities and research centres. An important factor describing the scope of innovation implementation is the number and level of implemented new technologies, number of innovations and innovative

Table 1 Indicators of infrastructure attractiveness

Indicator	Evaluation index
Infrastructure attractiveness	
Number of intermodal terminals	Insufficient (1), average (2), sufficient (3)
Linear infrastructure—road transport	Insufficient (1), average (2), sufficient (3)
Linear infrastructure—railway transport	Insufficient (1), average (2), sufficient (3)
Linear infrastructure—inland navigation	Insufficient (1), average (2), sufficient (3)
Air infrastructure (cargo transport)	Insufficient (1), average (2), sufficient (3)
Storage areas	Insufficient (1), average (2), sufficient (3)
Level of satisfying the technological requirements	Low (1), average (2), high (3)
Sources of information Statistical data, reports about region attractiveness	

Source Own studies

Table 2 Indicators of human capital attractiveness

Indicator	Evaluation index
Human capital attractiveness	
Number of employed persons	Decline (1), stabilization (2), increase (3)
Average remuneration	Below the national average (1), the national average (2), above the national average (3)
Supply of qualified personnel	Insufficient (1), average (2), sufficient (3)
Availability of managerial personnel	Insufficient (1), average (2), sufficient (3)
Availability of experts	Insufficient (1), average (2), sufficient (3)
Number of students on logistics, transport and similar faculties	Insufficient (1), average (2), sufficient (3)
Number of secondary school students on the mentioned faculties	Insufficient (1), average (2), sufficient (3)
Sources of information Statistical data, reports about region attractiveness	

Source Own studies

companies within section H (transport and storage economy) of the Polish Classification of Activities. Moreover, evaluation of region developmental policy continuity and coherence with politicians of the near-border regions seems to be essential. In the process of creating and implementing innovations, business environment institutions play an important role thus, the indicator of entrepreneurial and technological incubators number and technology transfer centres. Table 3 presents results and criteria concerning evaluation of the R&D&I plane attractiveness.

In the plane of ownership attractiveness, indicators pointing to the development of the TSL sector within a given region were combined with indicators of the region investment attractiveness. Evaluation of the TSL sector development requires considering both the number and dynamics of companies performing transport and storage services. The third separate category is the level of the logistic centre maturity.

Table 3 Indicators of R&D&I attractiveness

Indicator	Evaluation index
R&D&I attractiveness	
Number of patents	Low (1), average (2), high (3)
Number of universities and research centres	Insufficient (1), average (2), sufficient (3)
Number of entrepreneurship incubators, centres of technology transfer, etc.	Insufficient (1), average (2), sufficient (3)
Number of innovations	Low (1), average (2), high (3)
Number of innovative companies	Low (1), average (2), high (3)
Implementation of new technologies	Insufficient (1), average (2), sufficient (3)
Continuity of development-favouring policy	Lack of continuity (1), jumping (2), continuous (3)
Integrity of policy with adjacent cross-border regions	Low (1), average (2), high (3)
Sources of information Statistical data, reports about region attractiveness	

Source Own studies

Of course, logistic centre can be included among organizations performing transport and storage services. However, due to comprehensiveness of the performed services, container terminal and availability of three transport branches (road, railway and inland navigation), it is found that the organization is of key importance for the logistic development of the region. Factors pointing to investment attractiveness include also the level of sector maturity, level and offer for new investments as well as industrial risk. Maturity of the sector is a factor which on the one hand shows the general maturity of the TSL sector (that is the dynamics of companies, innovativeness, dynamics of prices and labour costs, etc.) and on the other, such maturity must consider detailed component—maturity of the TSL sector within intermodal transport. The level of investment is a factor affecting the industrial development of the region, thus it does not have to be considered exclusively through the prism of investment in the area of transport and logistics. Industrial risk, however, is analysed by future investors and represents one of the key factors affecting the decision about investing in a given region. Table 4 presents indicators evaluating the attractiveness of ownership.

The environment attractiveness plane is a set of factors describing the first and foremost macroeconomic and demand conditions. With reference to the original model, the set of indicators in this plane is much greater. Within this area, macroeconomic conditions (political, social, economic, international and geographic) and the level of strategic program implementation are evaluated. The latter is of a special meaning because it refers not to the essence of the programs but to the level of their implementation. Intermodal transport is frequently mentioned as a developmental multi-sector; however, the number of successfully implemented projects is small. From the demand standpoint, two indicators are distinguished, one local—showing the number of industrial and service companies in the region, which may use the offer

Table 4 Indicators of ownership attractiveness

Indicator	Evaluation index
Ownership attractiveness	
Number of transport companies	Low (1), average (2), high (3)
Level of logistic centre maturity	Low (1), average (2), high (3)
Dynamics of number of the companies providing storage services	Low (1), average (2), high (3)
Dynamics of income from transport and storage services	Low (1), average (2), high (3)
Sector maturity	Initiative (1), development (2), maturity (3)
Level of investment (scale)	Low (1), average (2), high (3)
Functioning and updated complex offer for investors	Insufficient (1), average (2), sufficient (3)
Industrial risk	Low (1), average (2), high (3)
Sources of information Statistical data, reports about region attractiveness	

Source Own studies

of intermodal transport, the other describes the dynamics of demand for intermodal transport. In the first case, one tries to evaluate regional and cross-border demand, and in the second, one point to the character of the trend. The set of indicators and method of their evaluation are presented in Table 5.

The sixth plane of region attractiveness evaluation is cooperation and network relationships. This group combines factors related to the TSL sector networking both to the country and international scale with factors related to the cooperation of companies with institutions at the national and regional levels. A decision has

Table 5 Indicators of environment attractiveness

Indicator	Evaluation index
Environment attractiveness	
Political considerations	Inappropriate (1), moderate (2), favourable (3)
Social considerations	Inappropriate (1), moderate (2), favourable (3)
International considerations	Inappropriate (1), moderate (2), favourable (3)
Geographical considerations	Inappropriate (1), moderate (2), favourable (3)
Level of strategic programs implementation	Low (1), average (2), high (3)
Number of production and trade companies	Decrease (1), stabilization (2), increase (3)
Level of market saturation/demand for transport and logistics services	Low (1), average (2), high (3)
Brand of the region at the national and international field	Poor (1), moderate (2), recognizable (3)
Sources of information Statistical data, reports about region attractiveness	

Source Own studies

been made to separately treat clusters and the remaining business networks. In clusters created through combining companies, scientific and research institutions and business environments, entities benefit mostly from intensive transfer of knowledge. They also allow for developing common development strategy. Because of geographical closeness, companies help to create solid bonds and strengthen the feeling of responsibility for the region. This, in turn, facilitates building the cluster brand and recognizability of the cluster in the world enhances attractiveness of a region and favours foreign investments. Another form of cooperation is creation of more or less formalized relationships between the TSL sector companies. Motives related to creating logistic networks are different, starting from the exchange of information, e.g. about 'empty runs' through mutual investment in logistic infrastructure, implementation of logistic projects or even common implementation of the whole processes. So-called virtual networks are best developed, as manifested by the increasing meaning of freight exchanges. Growth of network relationships within the TSL sector favours the transition to intermodal technologies. The cooperation of companies with regional institutions is a key factor in the development of intermodal transport in a region and country. Organizations of the TSL sector, as mentioned before, are key beneficiaries on the intermodal transport map. Development of common rules, listening to the needs, application of different types of incentives and specification of regulations within the scope of intermodal transport are key premises showing the importance of this factor in the evaluation of attractiveness of the region in terms of development of intermodal transport.

4 Evaluation of Śląskie Province Attractiveness in the Context of Intermodal Transport Development—Studies' Results

Within the past few years, Śląskie Province has been one of the most attractive provinces in Poland from the investment attractiveness standpoint. This is confirmed with a high GDP generated by the region. This affects a series of factors mostly related to natural resources of the province, which have dominated the economic development of the region. Main assets of the province are as follows (investment attractiveness of regions 2013—2017):

- The largest urban complex in Poland, creating a unique investment potential.
- The largest communication node in Poland, favouring industrial development, and
- numerous cooperation relationships. Good communication is ensured by International Airport 'Katowice', A4 motorway, E40 road (European route), E75 road (European route) and direct railway connections with the following cities: Berlin, Vienna, Budapest, Bratislava, Prague, Moscow and Hamburg.
- The most industrialized region of Poland of traditional specializations, however, subjected to effective restructuring.
- Numerous economic sub-zones, offering attractive investment terrains.

- Major fields of studies within the province are oriented at exact sciences and technical faculties (Częstochowa University of Technology and Silesian University of Technology) which fact results mostly from the features of the regional economy.
- The province shows significant investment potential as confirmed byvery
- Highrates of potential and actual investment attractiveness for national economy, capital-intensive and labour-intensive industry, trade, tourism, financial agency, services for business and education.
- High work ethos.

The objective of Śląskie Province is to become a region of differentiated, modern economic structure oriented not only at production solutions but also first and foremost at the wide spectrum of services. Creativity and innovativeness of companies operating within Śląskie Province are therefore emphasized in the strategic documents for Śląskie Province (Regional Innovation Strategy 2014–2020) and the policy for economic development for Śląskie Province. Strengthening the role of Śląskie Province economy within international values chains), three basic smart specializations have been differentiated: medicine, energy and ICT and through the entrepreneurial discovering—(Smart Specialization Platform) modern materials, environment protection, and transport and logistics. Current geopolitical situation and Internet technologies have changed the TSL sector development paths. This underlines the necessity to observe, evaluate and design the TSL sector development in Śląskie Province. Moreover, considering the meaning of geographical location, Śląskie Province plays a significant role in the TSL development within the cross-border system. Taking this into consideration, the region attractiveness, based on the modified Emerald model, has been evaluated. Table 6 presents the evaluation of the region attractiveness indicators within individual planes, considering the adopted scale. The evaluation is of expert character and results from the analysis of the source data assigned to the analysis of individual indicators (Table 7).

Table 6 Indicators of cooperation and network attractiveness

Indicator	Evaluation index
Cooperation and network attractiveness	
Number and activity of clusters	Low (1), average (2), high (3)
Level of TSL sector networking	Low (1), average (2), high (3)
Freight exchange	Low (1), average (2), high (3)
Activity of self-government institutions in winning investors	Low (1), average (2), high (3)
Activity of government institutions within the scope of intermodal transport development	Low (1), average (2), high (3)
Cooperation of regional institutions at the national and international level	Low (1), average (2), high (3)
International cooperation of companies	Low (1), average (2), high (3)
Sources of information Statistical data, reports about clusters, attractiveness, investments,	

Source Own studies

Table 7 Attractiveness evaluation of Śląskie Province

Indicators	Evaluation
1. Infrastructure attractiveness	
Number of intermodal terminals	2
Linear infrastructure—road transport	3
Linear infrastructure—railway transport	2
Linear infrastructure—inland navigation	1
Air infrastructure (cargo transport)	2
Storage areas	3
Level of satisfying the technological requirements	2
Average	2, 1
2. Human capital attractiveness	
Number of employed persons	2
Average remuneration	1
Supply of qualified personnel	1
Availability of managerial personnel	2
Availability of experts	2
Number of students on logistics, transport and similar faculties	3
Number of secondary school students on the mentioned faculties	2
Average	1, 86
3. R&D&I attractiveness	
Number of patents	1
Number of universities and research centres	3
Number of entrepreneurship incubators, centres of technology transfer, etc.	2
Number of innovations	1
Number of innovative companies	1
Implementation of new technologies	1
Continuity of development-favouring policy	2
Integrity of policy with adjacent cross-border regions	1
Average	1, 37
4. Ownership attractiveness	
Number of transport companies	3
Level of logistic centre maturity	2
Dynamics of number of the companies providing storage services	3
Dynamics of income from transport and storage services	3
Sector maturity	2
Level of investment (scale)	2
Functioning and updated complex offer for investors	2, 5

(continued)

Table 7 (continued)

Indicators	Evaluation
Industrial risk	2
Average	2, 44
5. Environment attractiveness	
Political considerations	2
Social considerations	2
International considerations	2
Geographical considerations	2
Level of strategic programs implementation	2
Number of production and trade companies	2, 5
Level of market saturation/demand for transport and logistic services	2
Brand of the region at the national and international field	2, 5
Average	2, 12
6. Cooperation and network attractiveness	
Number and activity of clusters	1
Level of TSL sector networking	2, 5
Freight exchange	3
Activity of self-government institutions in winning investors	2
Activity of government institutions within the scope of intermodal transport development	2
Cooperation of regional institutions at the national and international level	2
International cooperation of companies	3
Average	2, 2

Source Own studies based on Atrakcyjność inwestycyjna regionów (Investment attractiveness of regions). Warszawa (2014, 2015, 2016, 2017)

4.1 Infrastructure Attractiveness

The average value of the expert evaluation of infrastructure and physical resources attractiveness is 2.1. Individual factors were evaluated according to principles given in the above section. Linear infrastructure and storage areas obtained the highest rates. Śląskie Province belongs to regions of the highest provincial road density indicators per 100 km^2. Dolnośląskie Province is the only region with higher density. According to the Provincial Roads Development Plan in presenting the diagnosis of linear infrastructure concerning road transport, sections of roads in good condition—52.3%, sections of roads in unsatisfactory conditions—34.3% and sections of roads in poor condition—13.1% (Intermodal transports in 2017). This means that significant investments that have been performed within recent years do not solve the problem of road capacity, especially within highly-urbanized areas. Moreover, good transport availability of the region is affected not only by routes but also by very high density of road infrastructure (Śląskie Province came sixth in the transport availability ranking). This region is one of the best-communicated regions in Poland. Silesian agglomeration, wherein A1 and A4 motorways cross, plays a very important role in the communication system. The dominating direction in the agglomeration is the east–west direction along which A4 motorway and Drogowa Trasa Średnicowa (DTŚ) route run, wherein the total traffic may reach within close future, in Katowice, ca. 150 thousand vehicles per day. One must also notice the transit location of the region, where the Paneuropean transport corridors run, guaranteeing expressway network development: corridor III (Berlin–Wrocław–Katowice–Cracow–Lviv); corridor VI (Gdańsk–Katowice–Zilina).

Another highest rated indicator is the storage area availability. Śląskie Province is the leader in the storage areas in Poland. The supply and demand for storage areas in Śląskie Province increase annually by 11% on average with simultaneous reduction of vacant premise indicators.

The next factors have been evaluated at the level of two points. This concerned the number of among other things intermodal terminals. Śląskie Province considers itself well developed from the standpoint of available intersectional reloading terminals (6 out of 37 terminals located in Poland are located in Śląskie Province). This mostly covers four reloading railway terminals of intermodal character. These are Cargosped Terminal Kontenerowy (Gliwice), Euroterminal Sławków Sp. z o.o., PCC Intermodal—Terminal PCC Gliwice and Polzug Terminal Dąbrowa Górnicza. Moreover, it is necessary to mention the port in Gliwice, operating within the scope of the Śląskie Logistics Centre and International Airport Pyrzowice, which develops cargo services. Intersectional reloading terminals are focused in the central belt of Śląskie Province. According to annual reloading capacity, marine terminals are included in the highest group (over 500 thousand TEU), including DCT Gdańsk, BCT Gdynia, GCT Gdynia; the second group (200–500 thousand TEU) includes two terminals from Śląskie Province: Euroterminal Sławków and PCC Intermodal Gliwice. The next Silesian terminals are included among the lowest groups in respect of reloading capacity. It can be said that the reloading capacities of the container terminals in Śląskie Provice are high against the background of the whole country, but still not enough in order to ensure efficient intermodal transport, as clearly seen by comparing this data with different countries.

The linear infrastructure of the railway transport, also rated 2, shows not the improper density but poor technical condition of the infrastructure. The number of cargo wagons, including platforms, has increased within recent years. This is a positive fact that shows increasing meaning and utilization of railway transport, including intermodal. In Śląskie Province, where the network density is 2.5 times greater than average (Śląskie Province—15.9 km per 100 m^2; country—6.1 km per 100 m^2), there is ca. 50% of the national railway transport services performed. The share of electrical lines in Śląskie Province is 85% and this is one of the highest indicators in the country within the scope of railway network electrification. However, there are many speed limits in the railway network of the Silesian Province, which are caused by the general poor technical condition of tracks, inadequate geometrical arrangement of tracks and poor condition of junctions. Lines of unsatisfactory technical condition represent 54.5% of all railway lines in Śląskie Province, and lines of poor technical condition 0.8% (according to PKP PLK S.A. data).

Cargo air transport, despite a good position in Poland, has a relatively low position in the global market. The international airport Katowice–Pyrzowice, Śląskie Province, plays an important role in cargo transport because it ranks first in the country among regional airports—the volume of cargo traffic in 2015 exceeded 16 thousand ton. Pyrzowice handles six cargo forwarders (all-cargo and courier) and is the element of the transport corridor BAC–Baltic–Adriatic.

The condition of inland navigation infrastructure is the bottleneck for the dynamic development of intermodal transport. The problem of the inland navigation fleet in Poland is its age. The major part is from the 50s through the 80s of the last century. Arrangement and length of inland watercourses in Poland remained on a similar level for years. The specificity of this infrastructure and navigation conditions affect the indicators of demand for inland navigation transport, including relatively low capacity of barges as well as low number of carriage services.

The presented characteristics aspire to evaluate the level of technical requirements satisfaction. The infrastructure, first and foremost linear, is partially obsolete and requires additional significant outlays.

4.2 Human Capital Attractiveness

The second plane of region attractiveness involves the evaluation of human capital, in case of which the average rate is 1.85. Employment in Śląskie Province in 2016 was almost 1.8 million persons, whereas 6% was employed hired in section H (over 112,000). This is the fourth section in the region in respect of employment, behind mining and winning (ca. 60%), trade (14%) and construction (6.9%). Employment in this sector constantly grows in relation to 2015, i.e. 5.7% which is the highest in the region. As a result, despite the low number of the employed in relation to all employed persons in the region, it is worth to underline the systematic increase in employment, resulting from the growth of demand on the TSL market. Compared to the whole country, employment in Śląskie Province in the logistic sector is rated very high—the second location in the scale of the country after Mazowieckie Province, which fact strongly emphasizes development of the sector.

In turn, average remuneration in Śląskie Province amounts 6600 PLN; in the sector of transport and logistic service, the average is only 3,740 PLN and is one of the lowest remunerations against the background of the remaining sectors of Śląskie Province economy. This is definitely a weakness, which despite systematic growth of remuneration, causes increased fluctuation of employees within this sector and transfer to other branches of the economy or leaving the country, where the employees of this sector are offered much better conditions. Moreover, in Śląskie Province, 20% of transport companies suffers from lack of steady drivers, and over 60% struggles with periodical problems concerning assembling full personnel for transport operations which fact poses a major threat to the sector of transport, both road, railway and inland. The demand not only for drivers but also traders and storeroom managers increases.

The availability of managerial personnel is much better, however, intensive development of logistics and growing demand for experienced specialists with suitable competences cause that within some areas of the logistics where the employee market term is used more and more often. The availability of experts is enough. This results not only from the number of experts working within the region but also from the wide cooperation of experts from the whole country and abroad. The number of students is a very positive factor. Demand for this faculty is constantly growing; ca. 1000 students graduate every year the transport and logistics faculty in the province. The logistics faculty in the Silesian University of Technology has won the 'Perspektywy' award 2 years in a row. However, the situation is completely different in relation to the post-secondary school graduates. Lack of proper sector-oriented schools causes shortages in specialized employees of low and medium level on the TSL market.

4.3 R&D&I Attractiveness

The Polish TSL sector does not characterize with a high level of innovativeness. The average rate in this sector is 1.375. It has been noticed that among the existing innovations, most of them are transferred from the industry and not generated by the logistics sector. The TSL sector, against the background of service operations, cannot be perceived as distinguishing. This is evidenced by insignificant number of patents, innovations and number of innovative companies. In Śląskie Province, in relation to all innovations within the region, only 1% of product and 1% of process innovations have been implemented. The situation is better in case marketing (3.6%) and organizational (5%) innovations. Compared to other sectors, the innovative activity of companies is much weaker in favour of the existing adaptations of sometimes obsolete solutions proposed by investors. At the same time, one must notice the lack of complex studies showing the complete innovativeness of the TSL sector against the whole region, thus the missing information on the continuity of developmental policy. However, you may observe that the meaning of the TSL sector within regional strategies grows, and transport and logistics are among the group of new regional specializations. Unfortunately, in this context, you cannot see the cohesion policy with neighbouring cross-border regions—Opolskie Province, Moravia-Silesia regions and Zilina region in Slovakia. Even though they cooperate within the European Grouping of Territorial Cooperation (EGTC) under the name TRITIA and a few projects have been started, the effects are still negligible.

4.4 Ownership Attractiveness

The group of factors within the ownership attractiveness plane has been rated 2.4. This high-rank results mostly from the number of TSL sector companies located in the province and the level of income they generate. The number of companies operating within the H section Transport and Storage Economy in Śląskie Province amounted 25,595 in 2017 (2016—25,496, 2015—25,314). This means annual increase of 1% in the region, the same as at the country-wide level. The number of entities within section H in Śląskie Province represents 11% of employment within this section in Poland (second place, behind Mazowieckie Province) and means 6% of all companies registered within the province. This value was very similar within the previous years. This is reflected by poor dynamics of companies' number growth, however, it is still significant compared to the rest of the country. The reports show that Śląskie Province is very well developed from the standpoint of logistics operators active in its area. The region distinguishes by this fact against the country. The largest global logistics operators operate in this region, e.g. DB Schenker, DPD Polska, Rohlig Suus Logistics SA, JAS-FBG SA, Grupa Raben, Kuehne + Nagel, DHL, Dachser and many more. Forwarders with the largest share in the intermodal transport also operate in the region: PKP Cargo, Lotos Kolej, DB Cargo Polska. There are many distribution centres in Śląskie Province (e.g. distribution centres of many chain companies such as Biedronka, Lidl, Rossmann and Decathlon). However, the available reports do not provide the difference between storage objects and distribution centres, thus it is not possible to specify the accurate number of distribution centres. Śląskie Province is showed as a region with very well developed storage areas. The following cities can be mentioned—Katowice, Mysłowice, Gliwice, Chorzów and Sosnowiec. Śląskie Province is now the second in the country in respect of demand for and supply of storage areas. The number of storage areas and the distribution centres themselves has a growing tendency and the region is constantly showed as one of the most competitive ones from the standpoint of new logistic investments.

The total income of all companies quoted in 2017 in the country ranking was close to 22 billion PLN, however, the total income within the H section of the Polish Classification of Activities is ca. 10 times higher. The pace of growth of companies that were included in the ranking, as measured by TSL operations income, was twice as high in 2017 compared to GDP growth and amounted 13% (11% in 2016). The average income in Śląskie Province is at the level of 10–13% of the country average and represents significant share in the TSL market. Dynamics of income growth concerned both the sector of industry and services which fact is a good forecast for the sector. This enforces continuous developmental activities. New investments constantly appear in the region. At the same time, Śląskie Province is mentioned as one of the most attractive regions from the investment attractiveness point of view. It came first in terms of investment attractiveness in the country, the highest level of attractiveness—TSL. The climate for foreign investment is stable in Poland (Poland with stable climate for foreign investors). Performed studies showed that 92% of foreign investors are glad to have invested in Poland and would do that again.

The investment climate in Poland is rated by foreign investors to 3.7 points (in 1–5 scale), which is one of the best rates in the history of ranking. Economic stability and large internal market are the main assets of Poland as the location for foreign investments. The areas that need to be improved are changing legislation, prolonged court proceedings and complicated tax system.

At the moment and in the past, there are no complex studies over the TSL market maturity. One must consider in this case partial data concerning transport, TSL market and intermodal transport in Poland. This is especially difficult to transfer this knowledge to a single province. Experts underline that the Polish market of distribution, logistic, transport and forwarding services are, according to analysts, completely balanced and mature This is affected by a few key factors, first and foremost the relatively stable political and economic situation. Experts convince that geopolitical matters, such as membership in the European Union, contributed to the fact that Poland is called a logistic operator in the region (Entropoland, Ranking of TSL companies). Industrial risk in Śląskie Province is determined as relatively low (in relation to other regions in Poland), however, against the background of its neighbours, such as Czech Republic and Slovakia, Poland is somewhat worse. This is mostly related to the level of VAT and income taxes or more liberal principles of determining tax-deductible expenses.

4.5 Environment Attractiveness

The average attractiveness of the environment for the development of intermodal transport is quite high (2.1). Political conditions are favourable—both at the European Union, country and regional level, and there are coordinated programs being developed in favour of limitation of harmful impact of transport through integration of transport policy with ecological polity. Regulations given in the White Book on Transport (2011) and Green Book (2013), provide for striving to attain a competitive and energy-efficient transport system. In Poland, in the Responsible Development Strategy (2017) or Program for Silesia (2017), sustainable development of transport is underlined. The disturbing fact is the scope of the proposed activities which are called unreal by some of the experts. On the other hand, part of the projects does not find investors, funds or cooperation and is postponed to the following years. Within the international environment, wide-ranging policy concerning development of transport corridors is pending. Śląskie and Opolskie Province, as well as Moravia-Silesia regions and Zilina region in Slovakia, have been cooperating for over 4 years within the scope of the European Grouping of Territorial Cooperation (EGTC) under the name TRITIA. The level of this cooperation concerns determination of opportunities, assumptions related to cargo transport development within all forms—both using the road and railway network as well as air and water transport. Analyses are to assist in preparing large infrastructural projects within the whole area of near-border regions. However, cross-border approach to the development of the transport system is poorly underlined and implemented. The issues related to integration of transport within the near-border areas are not widely discussed. It seems that it is a result of building a hierarchic strategy which fact leads to polarization of regional strategy towards national direction, and marginalization of local and regional transport initiatives. Social conditions favour development of intermodal transport within the studied region. Considering the external costs (congestion, noise, accident rate, environment pollution and area occupancy), pressure towards modification of cargo haulage increases, not only in Śląskie Province. Geographical conditions are also conducive. The linear infrastructure mentioned above and general land shape allows for stable development of intermodal transport. Mountain areas in the south part of the province, mining damage and climate, which can reduce the utilization of water courses, can be a limiting factor.

The number of companies in the region increased by 1% and amounted 425,693 entities in 2017 (which is 11% in the country—two locations after Mazowieckie Province). This represents the grounds for TSL services development, including intermodal services. The demand for transport and logistics services is at a very high level. This is a result of the largest urban complex in Poland, very high level of population, high degree of urbanization and well-developed industry reporting a demand for complex and specialized services. The region is very well developed from the standpoint of the number and type of economic entities offering a wide spectrum of services on the market. In this context, one may expect high level of income attained in the region on the sale of TSL services. In spite of significant level of the TSL service development in Śląskie Province, it still has major developmental potential in this region in the future. In many papers (P), it is underlined that the market will continuously show significant needs within the scope of developed logistics activity. This proves high absorption of the market and incomplete saturation of the market with TSL services.

Śląskie Province is a recognizable region on the map of Poland and Europe. Due to geographic location, investment attractiveness, infrastructure, level of human capital, physical and material resources, it is an important region in intermodal transport development.

4.6 Cooperation and Network Attractiveness

The last group of factors—the attractiveness of cooperation and network relationships have been rated 2.2. In Śląskie Province, both transport clusters (Knop 2015) and logistic clusters have been established, however, they are of no significance for the development of intermodal transport. Nevertheless, logistics companies use different forms of networking. They create both formal and informal relationships with other players of the logistic network. They are also participants of virtual networks and freight exchange. The rate is reduced by the level of cooperation between self-government institutions and logistic companies.

One may notice the increased activity of government institutions within the scope of supporting the intermodal transport development, including the intermodal relief, which has been paid to cargo forwarders since 2014. This is given in the regulations of the 'Contract concerning financial support of railway infrastructure management and its protection within 1 January 2014–31 December 2017 from the state budget' concluded between the Minister of Infrastructure and Development (now Minister of Infrastructure and Construction) and PKP PLK.

The international cooperation of companies is very highly rated. Major operators are organizations of global outreach, who must cooperate with other members of the logistic network around the world in order to implement their basic goals. Less important actors cooperate in order to increase comprehensiveness of the provided services and widen the geographic outreach.

5 Discussion

Evaluation of individual platforms of the attractiveness of the Śląskie Province in the area of intermodal transport development allowed for drawing synthetic conclusions resulting from the performed studies—Fig. 1.

Expert's opinion showed that planes describing the attractiveness of ownership, infrastructure and cooperation are valued the most in the region. Surrounding is a set of factors that positively affect development of intermodal transport in Śląskie Province. This, however, does not mean that there are no improvement needs within this scope (infrastructure, especially railway and inland); however, the plane of human potential and R&D&I have the lowest rate. Unfortunately, as the forecasts show, companies in the region, especially the TSL sector, will struggle with shortage of employees for a few more years. The situation related to remuneration is quite different. Its level is unsatisfactory compared to the national or regional average in

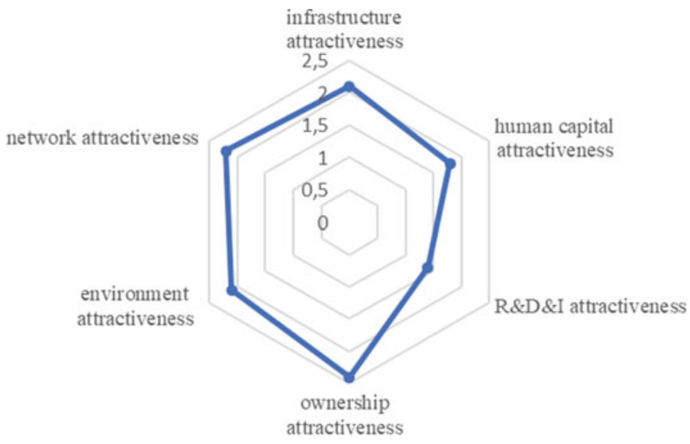

Fig. 1 Śląskie Province attractiveness in area of intermodal transport development. *Source* Own studies

the sector. The improvement within the R&D&I sector is crucial for coherent development of intermodal transport. Innovative operation within this scope seems to be most important. With current demand for the TSL services, the pressure is negligible, however, the future of the sector development requires innovations, e.g. innovative distribution and storage centres, implementation of digitization and autonomous trucks.

6 Final Conclusions

At the moment, under market relationship conditions, the meaning of the regional economy has increased and the near-border regions play an important role in the development and intensification of integration processes between different countries. The chapter did not answer the given question, however, it initiates a discussion on a system-based development of intermodal transport. Therefore, it is not enough to use the limited set of data in order to obtain reliable image of both short-term and long-term forecasts. The proposed methodological approach to the evaluation of region attractiveness allowed for evaluating the near-border region condition through implementation of systematic and complex approach. One must remember that transport companies are direct beneficiaries of intermodal transport as their operators. Alike in case of available storage areas or distribution companies, they may but do not have to be participants of intermodal transport. These are the groups of beneficiaries where the direct incentives concerning participation in intermodal transport should be directed to.

In the future, the authors intend to focus their studies around the following:

- Evaluation of the remaining near-border regions within the TRITIA cooperation in the context of intermodal transport development.
- Verification of the adopted methodological approach, including indicators of cross-border regions' attractiveness evaluation and moderate dimension.
- Evaluation of intermodal transport maturity from the regulation change perspective.

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Smart Glasses in Sustainable Manual Order Picking Systems

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Abstract The concept of sustainable development is gaining attention in all spheres of our life. Especially in production environments, it is important to reduce environmental impact and improve working conditions while still increasing economic value. This comprehensive effort roughly describes sustainability that we address on the example of manual order picking system, which is a part of many production systems. These systems have the potential to introduce new technologies, which require a judgment on the sustainability of the action, through the perspective of sustainability. One of the technologies with a great potential for use in order picking process are smart glasses, which integrates the core functionality of a smartphone in a pair of glasses. They are classified as a head-mounted device. As such, they are among the modern technical widgets with great expectations about their usable value in framework of Industry 4.0. Until now, only some practical examples in industry are described in literature. Order picking "man-to-goods" workplaces are an example of working environments where humans are still central actors and determine their effectiveness and efficiency (Gajšek et al., Proceedings of MOTSP international conference, Zagreb. Croatian Association for PLM, 2017a; Gajšek et al., Organizacja i Zarządzanie 72:45–61, 2017b). Full automation still will not be rational in the near future. Order picking activities are labor-intensive and time consuming. Smart glasses could be one of the means to improve working conditions and human-friendly rise in productivity. When working in a warehouse as order picker, having both free hands and information displayed in natural vision field is a progress in ergonomics and can help increase picking performance. In parallel, order pickers can be easily supported by any distant expert from any wired location, alerted to environmental hazards, acquainted with the achievement of a personal plan and more. Smart glasses could completely take over a function of a central personal information source. New questions arise with inflating expectations and expansion of their use in practice, such

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as the impact of long-term use on employee's vision characteristics, the impact of different user interfaces, the employee's perception of the long-term use of the device, and other. In the chapter, we review scientific literature on use of smart glasses in manual order picking system and contribute to finding answers to the above questions by performing an experiment in a laboratory environment with realistic equipment.

Keywords Sustainable logistics · Smart glasses · Manual order picking · Productivity · Ergonomics

1 Introduction

Digitalization, digital transformation, and evolving technologies trigger the fourth industrial revolution or Industry 4.0 that is characterized by the extensive networking of products, devices, machinery, vehicles, workplaces, ICT systems, enterprises, and human resources. Everything is becoming smarter. The data collected is growing. For the first time, production can use a variety of (evolving) technologies. The technological upgrade is interesting because of its ability to bring the information to the worker in an immediately applicable form, to the workplace where he/she is located and exactly at the time of need. The effect must be double, namely increased productivity and preserved or improved well-being of workers. An example of such technological achievement are smart glasses, a kind of head-mounted display. They have their own processor and are powered by on the frame-attached battery. A display is placed in the visible area of left or right eye. The data is collected from a wireless network and projected onto a tiny screen. Users do not use hands to access computer-generated data while moving, routing to storage locations, receiving/giving voice/video messages, rapidly receiving data in the form of symbols or images and last but not the least fine-routing with help of augmented reality. All these most likely influence on economic, environmental and social aspects. Smart glasses are a research-interesting technology with noticeable increase in number of publications per year (based on WoS; 43 publications in 2014 and 465 publications in 2017). Smart glasses as an enabler of augmented reality are also included in the Gartner Hype Cycle for Emerging Technologies 2018 (Panetta 2018). Augmented reality is in phase of "Trough of Disillusionment". This means that surviving providers are trying to improve their model of smart glasses to the satisfaction of early adopters.

In addition to Industry 4.0, the concept of sustainability now has an influence on a wide variety of global debates. Like the rest, the production is also scrutinized itself for the degree of sustainability. One of the many challenges of moving toward sustainable production is finding out which options are sustainable and balancing a plethora of disparate economic, environmental, and social aspects (Azapagic et al. 2016). Web of Science database search returned none result for combine set "smart glasses" and "sustainability". The question, therefore, arises as to how the systems where smart glasses are used can contribute to sustainability.

Our research took place in a logistics production environment, more precisely in manual order picking. The introduction of smart glasses is being tested through the perspective of sustainability instead of a picking list that requires the use of hands during the work. Modern logistics operators are under increased pressure and administrative regulations in order to fulfill environmental objectives and reduce congestion (Grzybowska et al. 2014).

In practice, among a multitude of different order picking systems, prevail manual "picker to part" systems. Despite the available automation, it remains that more than 80% of all orders processed by warehouses are picked manually (De Koster et al. 2007; Burinskiene 2015). Traditionally workers are routed by paper or electronic picking lists to locations in warehouse racks with stored items where they retrieve items for orders. This process requires a large amount of manual work and is recognized as the most costly in most warehouses. Its activities amounts up to 55% of the warehouse total operating costs (Tompkins et al. 1996; Sternad 2018). Picking uses a large amount of resources, and can reflect around 60% or more of warehouse staff (Walker 2018). Since traveling between storage locations is up to one-half of the time spent for preparing a customer order (Tompkins et al. 1996; Đukić and Oluić 2004), warehouse managers try to reduce or eliminate movements between storage locations, set up time, and search time. Solutions can be purely mathematical, in terms of routing and controlled disposal, or technological ones such as the introduction of forklifts, conveyor belts, and lately smart glasses. Despite the first pilot projects, smart glasses are still evolving technology. Theory (Peli 1996) and practice (Ames 2017) share opinion that new and advanced models should be tested before wider use in the warehouses. The question is how we contribute to sustainability by introducing smart glasses.

2 Theoretical Background

2.1 Sustainable System Framework

According to Wichaisri and Sopadang (2013), the framework for a sustainable system combines sustainable development with the elements typically included in a traditional system. By focusing on sustainable development and implementing sustainable sub-systems, for example, logistics system (Wichaisri and Sopadang 2013), a company can positively influence its long-term performance objectives. A sustainable logistics system will enable a company to take steps to insure that its long-term performance objectives have a positive effect on maximizing its profitability, minimizing its environmental impact, and improving the community's quality of life or minimizing social impacts (Wang and Zhang 2007; Croom et al. 2009). When introducing new technology, it makes sense to determine how the technology, for example, smart glasses, will help achieve these goals. In doing so, it is possible to rely on the findings of Wichaisri and Sopadang (2013) who deduced from literature review that sustainable logistics has three perspectives and 15 criteria (Table 1).

Table 1 Sustainable logistics perspectives as proposed by Wichaisri and Sopadang (2013)

Perspectives	Criteria	Sub-criteria
Economics	Quality	Quality of product
		Lead time
	Responsiveness	Demand responsiveness
	Cost	Manufacturing cost
		Logistics cost
	Profit	Return on investments (ROI)
		Market share
		Profit margin on sale
	Mobility	Intensity of goods transport
Environment	Resource usage	Energy usage
		Water usage
		Land use
		Raw material use
	Pollution	Air pollution
		Water pollution
	Emission	CO_2 emission
	Waste	Waste disposal
	Eco-efficiency	Product/Service value
		Environment influence
Social	Health and safety	Employee safety
		Health care benefits
	Quality of life	Accident
		Education and training
		Working condition

2.2 Smart Glasses

Smart glasses or data glasses are an example of head-mounted device that integrates the core functionality of a smartphone in a pair of glasses. Order picking systems using this kind of devices are Pick-by-vision systems. Smart glasses enable augmented reality by displaying additional information on top of it. In this way, the user has free hands. Pick-by-vision systems are further subdivided according to the making use of tracking technologies on 2D systems that do not track user's position and AR systems that use tracking and make explicit use of augmented reality (Schwerdtfeger et al. 2009). 2D pick-by-vision systems are enabled to inform the user with sound and textual information in a form of a list of items or images. AR pick-by-vision systems enrich worker's view with the necessary information

(Mazuryk and Gervautz 1996). Due to the great potential of this technology, it became a focus of many research and development projects at the end of previous century, also in the area of order picking.

One of the pioneers, Peli (1990), could not prove any potential harmful effects because of use of head-mounted device with short, 20 min tests in laboratory environment. The only limitation was that he did not recommend use of such devices while driving. From his Peli (1996) point of view, the concerns about possible harmful effects must be present and researched at introduction phase of almost any new technology. Effects of use of new technology/device on human should be tested separately for each emerging system.

Already before 2009, Schwerdtfeger et al. (2009) researched the use of head-mounted devices in the order picking process. They compared the pick-by-vision system to established methods, namely paper document, pick-by-light, and pick-by-voice. Comparison of different technologies is also a common practice today in the academic sphere to motivate its capabilities, and check the user strain besides the general performance. They were satisfied with results, which we present in Table 2, although they were not statistically significant. Results largely depend on pick-by-vision system and not just on the model of head-mounted device (Schwerdtfeger et al. 2009; Weaver et al. 2010b; Pickl 2014). There is always a way to improve method's shortcomings. Pick speed and accuracy with pick-by-vision systems can be improved by associating colors with shelves and shapes with bins (Iben et al. 2009).

After two decades of research work in 2010, smart glasses have been recognized as a safe enough technology. Their use spread from laboratory environments to the first pilot projects in companies. The number of studies that research different technical designs of head-mounted designs has increased. We are witnessing searching for synergies between technologies and to the first tries to combine different technologies to achieve optimum work results. We begin to encounter more studies that explore. Rammelmeier et al. (2011) reasoned about active prevention of picking errors by employing pick-by-vision systems. The authors confirmed with laboratory test, that the provision of information via head-mounted device facilitates an accurate information reception. Head-mounted device enables permanent visibility of the instructions to the order picker and not just for a short period, as it is in a case of pick-by-voice.

Most authors of research papers have a positive attitude to pick-by-vision systems with head-mounted devices. They recognized and proved several cases and system design specific advantages compared to paper, pick-by-voice and pick-by-light. They agree that pick-by-vision is promising technology and the effect of long-term use of smart glasses on worker is still unexplored (Josefsson and Lingegard 2017).

Unlike the current ones, early research works on smart glasses were more specialized in a specific sustainable logistics perspective. Peli (1990, 1996) was primarily focused on health and safety as social sustainable logistics perspective. In this respect, the user is set to the foreground. Only when it turned out that short-term use of smart glasses probably does not harm the user, the number of research work researching

Table 2 Scientific literature on smart glasses classified on sustainable logistics perspectives

Authors	Perspectives			Findings
	Ec	En	So	
Schwerdtfeger et al. (2009)	*	*	*	• Head-mounted systems support the worker with the right information at the right time • Pick-by-vision (AR) could have lover error rate than pick-by-vision (2D) • Pick-by-vision systems could have about 10% better picking time performance than that of the paper list • After about 1/2 h with the system, subjects did not feel uncomfortable or constrained • It was not indicated that working with pick-by-vision (AR) system caused a higher strain than use of paper list • The errors for the pick-by-vision (AR) system decreased during runtime and increased for the paper list • One group of head-mounted device users can make user input while walking while the other cannot • Possible problems are headaches, pressure in eyes, problems focusing on the head-mounted device, difficulties with text reading
Peli (1990)			*	• Extended use of the monocular display may result in changes in the phoria posture and cause asthenopic symptoms • Changes in phoria and fixation disparity are more likely in people who are already symptomatic or who have various uncorrected visual deficits • Appearance of asthenopic visual discomfort symptoms in a user may be regarded a protective-screening effect, since it appears to uncover existing latent problems • Long-term effects are small, since the visual system tends to recover quickly when the monocular occlusion is removed • Although awareness of the environment is maintained when using the display, it is obviously unsafe to attempt to use some types of monocular display while driving • At work with researched head-mounted device, there were no evidence of motion sickness or loss of postural stability in any of the users, standing or sitting • The image motion noted during saccades is small • Eye dominance can potentially affect performance

(continued)

Table 2 (continued)

Authors	Perspectives			Findings
	Ec	En	So	
Weaver et al. (2010a)	*		*	• Head-mounted device (MicroOptical SV-6), as a part of pick-by-vision (AR) system performed better than the traditional method of text-based paper. The work was faster than with graphical paper/text-based/audio version • Time is saved because both hands are free • It is important to adjust that the part bins and the display are at the same focal distance to maintain constant focus • Head-mounted device was not significantly harder to learn than other methods. Text-based version was harder to learn
Rammelmeier et al. (2011)	*	*		• Head-mounted device enables permanent visibility of the instructions to the order picker, which can results in a reduction in error rates • Confirmation of an item by voice or a button in combination with checking numbers on the item can positively influence the reduction of errors • Wrong picking can be prevented by additional control mechanism, for example: picking with RFID glove; a picking trolley with additional sensors, which identify the collected items during the order picking process; adding weight or volume sensors into the trolley
Pickl (2014)	*	*	*	• Results of comparison of different order picking methods strongly depend on the use-case • For specific use-case projection method was the best one, in regard to overall errors, task completion time and overall usability • Errors can be divided on cart, pick, filling, part and amount errors. At head-mounted device method, the amount of amount errors and part errors is very low in comparison to paper/projection/voice method. Contrary the amount of filling and pick errors is high • Use of head-mounted device method resulted in a higher task completion time • According to NASA Task load Index, head-mounted device method was the most demanding method for users. They would not want to use it for a whole workday

(continued)

Table 2 (continued)

Authors	Perspectives			Findings
	Ec	En	So	
Guo et al. (2014)	*	*	*	• Head-mounted device is faster than CMD, pick-by-light and pick-by-paper • Head-mounted device is not harder to learn and no less comfortable than any other methods • Wrong order bin errors happen more frequently for pick-by-paper. Missing part errors are frequent at pick-by-light. No substitution errors happened on head-mounted device but they happened on CMD
Josefsson and Lingegard (2017)	*	*	*	• Compared to alternative methods, smart glasses enable higher quality • Smart glasses had great potential to reduce the cognitive load for the operators • Transmitted information that operators upload to the system is not an applicable information type for smart glasses. A complementary solution is needed • Displaying experience-based information was identified as the main potential for smart glasses • Adding too much or irrelevant information will have a negative performance impact • Displaying additional information during picking could help operator to pick with both better quality and better ergonomics • Flexibility could be achieved if operators or managers can do changes without consulting programmers, as long as the system supports that

Eco (economic)—productivity/time consumption/flexibility
En (environment)—number of wrong picks
So (social)—ergonomics

productivity has increased. Lead time, responsiveness, time consumption, and flexibility sub-criteria from economic sustainable logistics perspective. Use of smart glasses has proved to be competitive to paper-based order picking. Smart glasses can contribute to reduced paper consumption and energy usage. We can say that authors like Josefsson and Lingegard (2017), Guo et al. (2014), and Pickl (2014) contributed to clarification of environmental sustainable logistics perspective.

2.3 Manual Order Picking System "Man-to-Goods"

Man-to-goods manual order picking (MOP) systems are systems where the picking units of different shapes, weights, dimensions and colors are placed in fixed storage locations and the order picker walks to individual products according to the order list (De Koster 2004). Compared to automated systems, they prevail and are cheaper at the implementation phase but more onerous for the employee and management. Our research focus is on the use of smart glasses in low-level manual picking systems (Gajšek et al. 2017a, b) in which the order picker picks requested items from storage racks or bins while traveling along the storage aisle. There is no need for vertical movements on the higher levels of the warehouse racks. Low-level, man-to-goods systems employing humans are increasingly labor intensive with up to 1000 picks per person-hour (Gajšek et al. 2017a, b) and form the very large majority of picking systems in warehouses worldwide (De Koster et al. 2007). The human enters the MOP system with his/her unique anatomical, physiological and psychomotor characteristics, which relate to the worker's physical activity and to a certain degree his adaptation to the current situation. Work in such flexible systems requires continuous mental processes whose efficiency, through interactions between humans and other elements of the work system, influences productivity, quality and worker well-being. In the MOP system and its roughly predefined organizational structures, policies, and loose processes employees are faced with a low level of optimization (as compared to smart automated systems), therefore they are largely left to their own ingenuity and experimentation. This situation is typical for leftover allocation strategy in which all functions that can be easily automated should be relegated to machines, and the remaining functions should be left to the workers (Butlewski 2017).

More than 90% of the literature on MOP planning models in connection to "outcomes" focuses on minimizing travel distance, total costs and throughput time, while less than 10% focuses on minimizing the risk of injury, maximizing occupational safety and improving working conditions (Grosse et al. 2015). According to the same source, 16.4% of the literature focuses on read/picklist and only 6.9% on other techniques like pick-by-light/vision/voice. Research emphasizes on economic sustainable logistics perspective, less on social and minimal on environmental.

3 Method

A laboratory experiment (Fig. 1) was used for studying the effects of using smart glasses Vuzix M300 on specific sustainable logistics perspectives sub-criteria during order picking activities.

Four shelves at different heights (900, 1170, 1440, and 1710 mm) were among the 3000 mm long storage rack divided into 60 storage spaces identified with QR codes in three different sizes (34 mm × 34 mm, 29 mm × 29 mm, and 24 mm × 24 mm).

Four men and ten women participated in the experiment. Twelve were students with mean age of 24 years (SD = 1.7) and two women were employed with mean age of 45 years (SD = 1.41). Each person performed for four hours order picking activities without a break in the same order for all participants with smart glasses.

Each participant twice passed four ophthalmologic tests, first time before and the second time after the use of smart glasses. Professional ophthalmologist performed 28 measurements for each ophthalmologic test. He tested visual field, visual acuity, color test, and contrast sensitivity. Statistical analyses were conducted using SPSS 21.0. Owing to the small sample size and non-normally distributed data

Fig. 1 Laboratory environment

(Kolmogorov–Smirnov test of normality), we used nonparametric tests (Wilcoxon-Paired samples test).

Each participant also filled in a questionnaire on the experience of working with smart glasses. The questionnaire consisted of 15 questions, one of them with 11 sub-questions asking about possible health problems during the experiment. Responses were provided in the form of a 1–5 scale.

3.1 Performed Tests

Visual acuity, as the first test in our experiment, according to Levenson and Kozarsky (1990) refers to "the ability of the visual system to discern fine distinctions in the environment as measured with printed or projected visual stimuli. The presence of excellent visual acuity tells the examiner that the ocular media are clear, the image is clearly focused on the retina, the afferent visual pathway is functioning, and the visual cortex has appropriately interpreted signals received. Measurement of visual acuity is the most sensitive test of the integrity of the visual system and fulfills all standard criteria of a good screening test." In our research, the visual acuity was measured separately for each eye (right and left) using the Snellen table.

The second test was checking contrast sensitivity. Contrast sensitivity is the capacity to discriminate between similar shades (Katz 2018). In daily life, good contrast sensitivity is necessary to see a gray car on a cloudy day, to detect unmarked curbs and steps, and to distinguish subtle contours on people's faces to recognize them. In our research, the contrast sensitivity was measured using the Pelli–Robson table. According to Katz (2018) the normal result of contrast sensitivity is a value of 1.95 or 2.0. Values less than 1.8 could indicate improper contrast vision in bad visual conditions.

A visual field test was used according to Boyd (2019) to determine if there are blind spots (called scotoma) in participants' vision and where they are. A scotoma's size and shape can show how eye disease or a brain disorder is affecting someone's vision. The testing was performed with a computer static perimeter using an OCTOPUS machine at standardized illumination parameters. All measurements were performed with the program Treshold 30-2 and only on the right eye in front of which the smart glasses' display was set. To examine changes in the visual field Mean Deviation (MD) and Pattern Standard Deviation (PSD) were used.

The last was Ishihara test. The participants were tested with help of 15 color plates. The procedure is used for testing color vision that can indicate the presence of color vision defects.

4 Results

4.1 Visual Acuity Results

Normal visual acuity for a healthy human is 1.0. Results of visual acuity testing for all 14 participants before and after order picking activities are presented in Table 3. At 11 participants measured visual acuity was more than 0.7. 3 participants had visual

Table 3 Results of visual acuity testing (Vujica Herzog et al. 2018)

Test	rVAb	lVAb	rVAa	lVAa
1	0.8	0.8	0.8	0.8
2	1.0	1.0	1.0	1.0
3	1.0	1.0	1.0	1.0
4	0.25	0.4	0.25	0.4
5	0.63	0.4	0.5	0.32
6	1.0	1.0	0.8	0.8
7	1.0	1.0	1.0	1.0
8	1.0	1.0	0.8	1.0
9	0.8	0.8	0.63	0.63
10	1.0	1.0	1.0	1.0
11	1.0	1.0	1.0	1.0
12	0.4	0.4	0.8	0.63
13	0.8	0.8	0.8	0.8
14	0.8	0.63	0.8	0.63

rVAb—right eye, visual acuity, before; rVAa—right eye, visual acuity, after; lVAb—left eye, visual acuity, before; lALa—left eye, visual acuity, after

Table 4 Results of contrast sensitivity testing (Vujica Herzog et al. 2018)

Test	rCSb	lCSb	bothCSb	bothCSa	rCSa	lCSa
1	1.65	1.65	1.80	1.80	1.65	1.65
2	1.65	1.65	1.80	1.80	1.65	1.65
3	1.65	1.65	1.80	1.80	1.65	1.65
4	1.50	1.50	1.65	1.65	1.50	1.50
5	1.65	1.50	1.65	1.65	1.65	1.50
6	1.65	1.65	1.65	1.65	1.65	1.50
7	1.65	1.65	1.80	1.80	1.65	1.65
8	1.65	1.65	1.80	1.80	1.65	1.65
9	1.65	1.65	1.80	1.65	1.35	1.35
10	1.65	1.65	1.95	1.95	1.65	1.50
11	1.65	1.65	1.80	1.80	1.65	1.65
12	1.65	1.65	1.80	1.50	1.50	1.50
13	1.65	1.65	1.80	1.80	1.65	1.65
14	1.50	1.50	1.80	1.80	1.50	1.50

rCSb—right eye, contrast sensitivity, before; rCSa—right eye, contrast sensitivity, after; lCSb—left eye, contrast sensitivity, before; lCSa—left eye, contrast sensitivity, after; bothCSb—left and right eye, contrast sensitivity, before; bothCSa—left and right eye, contrast sensitivity, after

acuity less than 0.7. Most of the participants have good eyesight before and after order picking activity.

4.2 Pelli–Robson Contrast Sensitivity Results

The measured value 2.0 shows normal contrast sensitivity, or 100%. If measured contrast sensitivity is less than 1.5 that points on visual handicap. Further on, if measured contrast sensitivity is less than 1.0 that points on greater visual impairment. Results of Pelli–Robson contrast sensitivity testing for all 14 participants before and after order picking activities are presented in Table 4. All 14 participants had contrast sensitivity equal to or greater than 1.5. All of them have normal contrast sensitivity.

4.3 Visual Field Testing Results

Visual field testing was used to determine if differences of MD and PSD before and after order picking activities are significant. Results of testing for all 14 participants before and after order picking activities are presented in Table 5. They show the dif-

Table 5 Results for visual field (Vujica Herzog et al. 2018)

Test	rMDb	rPSDb	rMDa	rPSDa
1	−2.25	3.71	−2.16	2.47
2	−0.71	2.01	−1.05	2.99
3	−4.80	3.24	−3.09	2.54
4	−5.21	2.42	−3.55	2.32
5	0.29	3.10	−2.87	3.19
6	−5.27	3.45	−4.48	3.02
7	−1.68	2.37	−2.77	2.33
8	−1.45	1.97	−3.99	2.18
9	−0.69	1.79	−2.63	2.61
10	−1.39	2.09	−1.07	2.37
11	−3.32	2.15	−3.79	3.15
12	−1.8	2.34	−2.29	1.99
13	−1.99	2.09	−3.15	3.21
14	−5.64	3.62	−0.49	2.34

rMDb—right eye, mean deviation, before
rMDa—right eye, mean deviation, after
rPSDb—right eye, pattern standard deviation, before
rPSDa—right eye, pattern standard deviation, after

ference in MD mean value before (−2.54) and after (−2.67) order picking activities. The mean value before four hours of order picking activity was 5% higher than the mean value after four hours of order picking activity.

With Threshold 30-2 and Driver's licence procedures we also studied the possible scotomas in the area of the visual field where was a projection of data from smart glasses. The results can be found in Table 6. Testing recorded for some participants the presence of scotomas after the use of smart glasses. The presence of scotoma is recorded with value 1. If the scotoma was not present that is recorded with value 0. The presence of scotoma indicates that smart glasses can cause some vision impairment during the use.

4.4 Ishihara Color Test Results

Results of Ishihara color tests for all 14 participants before and after order picking activities are presented in Table 6. twelve participants had normal color vision. For two additional participants, impairments in color vision were indicated.

Table 6 Results for Ishihara color test and scotoma presence (Vujica Herzog et al. 2018)

Test	CTb	CTa	Treshold 30-2		Driver's licence	
			SCOb	SCOa	SCOb	SCOa
1	15	15	0	0	0	0
2	3	3	0	0	0	0
3	15	15	0	0	0	0
4	15	15	0	1	0	0
5	15	15	0	0	0	0
6	1	1	0	1	0	1
7	15	15	0	0	0	0
8	15	15	0	1	0	0
9	15	15	0	0	0	0
10	15	15	0	1	0	0
11	15	15	0	1	0	0
12	15	15	0	0	0	0
13	15	15	0	1	0	1
14	15	15	0	0	0	0

CTb—Ishihara color test, before; CTa—Ishihara color test, after; SCOb—scotoma, before; SCOa—scotoma, after

4.5 Statistical Analysis Results

The results from statistical analysis for all four performed tests can be seen in Table 7. Statistically significant differences appear when value for $p \leq 0.05$. Significant correlations are presented with bold records.

The participants' sight was tested with measurement of visual acuity among other tests. Their sight was weaker after the use of smart glasses than before. The results of *t* test and Wilcoxon test show that this correlation is significant for left and right eye.

Comparison between right and left eye shows that visual acuity of the right eye was reduced more than in the case of left eye. Because the display on smart glasses was placed in front of participants' right eye, we assume that weaker sight on the right eye could be caused by use of smart glasses.

The mean values of contrast sensitivity for both eyes were lower after using smart glasses, but analyze did not prove the significance of this correlation. Measured values were not lower than 1.5, consequently, we can not argue that the use of smart glasses is harmful to eye contrast sensitivity (Karatepe et al. 2017).

High values of PSD represent the scotomas (Karatepe et al. 2017). The Threshold 30-2 Program and the Driver's license test confirmed the increased level of scotoma in the right eye. We can conclude that the presence of scotoma in the right eye can be the result of load caused by using smart glasses but further research is needed.

Table 7 Results from statistical analysis (Vujica Herzog et al. 2018)

	Before order picking activity		After order picking activity		*p* (*t* test)	*P* (Wilcoxon test)	Effect size
	Mean	SD	Mean	SD			
VAR	0.820	0.242	0.757	0.245	**0.020**	**0.041**	**−0.38**
VAL	0.842	0.210	0.786	0.234	**0.024**	**0.039**	**−0.39**
CSR	1.628	0.054	1.596	0.095	0.189	0.18	–
CSL	1.617	0.063	1.564	0.096	0.055	0.059	–
CS	1.778	0.080	1.746	0.111	0.189	0.18	–
CT	13.143	4.737	13.143	4.737	–	1.00	–
MD	−2.542	1.950	−2.670	1.171	0.822	0.470	–
PSD	2.596	0.675	2.622	0.409	0.904	0.975	–
ST	0	0	0.428	0.513	**0.008**	**0.014**	**0.45**

VAR—visual acuity, right eye; VAL—visual acuity, left eye; CSR—contrast sensitivity, right eye; CSL—contrast sensitivity, left eye; CS—contrast sensitivity, both eyes; CT—colour test; MD—mean deviation; PSD—pattern standard deviation; ST—scotoma, Threshold 30-2

We noticed some changes in sight characteristics after 4 h use of smart glasses, some of them are even significant. Although we can not claim that use of smart glasses negatively influences on human well-being. Used test are rather subjective, with results that depend on the willingness of test subjects to collaborate.

4.6 User Experience

Each participant filled in a questionnaire on the experience of working with smart glasses. Learning to use smart glasses was quick. Six participants (42.9%) gained the necessary skills in less than 15 min and the remaining eight in less than an hour.

The adjustable display on smart glasses was for all participants set in front of the right eye. None of the respondents had a feeling of unbearable problems with the left or right eye. 35% of the respondents did not report problems with left eye during the work, 29.3% had slight problems, and 35.7% reported bearable problems. Left eye problems occurred mainly due to the need to close the left eye while reading the text on the display in front of the right eye. Three (21%) of 14 respondents stated that the closing of the left eye was necessary to sharpen the image on the display. The experience for the right eye was slightly worse. 78% of all respondents reported problems with the right eye during the work. Three of them marked problems as minimal, for one person problems were almost unbearable, 7 (50%) reported bearable problems. Six respondents mentioned problem with blurred image on the display, in addition, individually they further mentioned fatigue of the eye, dryness, burning sensation in the eye and the appearance of double vision.

Due to the intensity of the work, it was necessary to power smart glasses with an additional external battery, which each user together with power cable installed to the most suitable place, for example in the back pocket of trousers. In this way, the drop of energy under the operational requirement did not disturb the work. For 64.3% of the respondents wearing extra battery was not a problem. During the work, they forgot that they are carrying it. 14.3% of respondents had a feeling of slight interference, while the remaining 21.4% rated the carrying of the battery as disturbing. While wearing smart glasses, power cable between the main unit and additional external battery causing slight problems. Some users had got caught up in close-up objects from time to time, like shelves or cart. Cable caused additional concern for the participants, who had to be careful not to get caught, stumble, or unintentionally unplugged it. Such and similar concerns distract the order picker's attention and reduce concentration.

Users were disturbed by the weight of the external battery attached to the platform of smart glasses. At 9 (64%) of respondents pain occurred on the spot where glasses rest on the ear. Pain was increasing with the time of use and in some cases (five persons or 35% of all) it has been intensified into a slight headache.

A user interface showed on the display of the smart glasses was not specially designed for this specific testing, it was much similar to the one displayed on hand terminal. User interface in our case is not in the domain of smart glasses producer. Users were not able to adjust it to their own wishes. The background color, text color, and font size were pre-configured. 4 (28.6%) of respondents describe the font size as very suitable, 4 (28.6%) of respondents as suitable with small opportunities for improvements, 4 (28.6%) of respondents as partially suitable, 1 (7.1%) respondent as less suitable with large potential for improvements, and 1 (7.1%) respondent as completely inappropriate.

3 (21.4%) of the participants believe that all the information displayed was necessary for work. Opposite, 1 (7.1%) participant noted that most of the information was redundant. 7 (50%), of the participants reported that they got more information that they need but not to many. The average of all responses is 2.79 (SD = 1.188) on 1–5 scale.

On the question to what extent was wearing glasses physically strenuous none of the respondents answered that it was not physically strenuous. 1 (7.1%) respondent had the feeling of very small disturbance. 4 (28.6%) experienced moderate disturbance. The average of all ratings was 3.8 (SD = 0.89) on 1–5 scale. 3 (21.4%) of respondents rated wearing glasses as very physically strenuous. If they could, they would take them off before the task was completed. Respondents reported pain on the spot where glasses rest on the ear. Other problems include nose pain, burning sensation in the eyes, headache, pain in the legs and hands. In some cases, glasses were gliding off the nose and, consequently, there was a need for constant lifting.

5 (35.7%) of respondents always stopped and closed their left eye while reading information from the display. They never managed to read during the movement. Described the type of user prevail over those who never closed their left eye while reading information (14.3%) and are able to walk and read in parallel. The average rating was 3.43 (SD = 1.5) on the scale from 1 to 5.

Three identifications using a QR code scan were required to move the item in the storage rack. We assumed the impact of the QR code size on the scanning speed. Users performed two scans per minute on average or 480 in 4 h. During this time, approximately, 160 items were moved. 8 (57.1%) of respondents rated QR code scan speed as fast and 4 (28.6%) as neither fast nor slow. The average rate was 3.42 (SD = 0.9) on the scale from 1 (very slow) to 5 (very fast). From the respondents' comments, it is clear that opinions on QR code scan speed and, in particular, about the causes for that differ. Some have experienced slower performance at the beginning, which has improved in parallel with enhancing skills. Several respondents highlighted the importance of capturing the QR code at an angle that approaches the right one. However, there is also a belief that difference in the QR code scan speed depends on the size of the QR codes. Two respondents pointed out that the intervals of quick and slow QR code scans were cyclic exchanging along the process. Slower performance was also detected toward the end of the test, probably because the battery on the smart glasses had already been slightly discharged.

The users of the smart glasses did not notice the emergence of major problems during the 4-hour work. Based on literature review (Table 2), 11 possible problems were proposed for rating on the scale from 1 (mildly present) to 5 (strongly present), namely neck pain, pains in arms, pains in legs, back pain, headache, pressure in eyes, double vision, blurred vision, dizziness, balance disorder, difficult sharpening text on the display, and difficultyin walking and reading in parallel. Additionally, they could also chose 0 (did not appear).

Only blurred vision, difficult sharpening text on the display and difficulty in walking and reading in parallel slightly stand out (Table 8), observed by around 80% of users. Due to the small size of the sample, these problems can not be generalized to a wider population.

Neck pain and pains in legs, noticed by 57% of the respondents, could be correlated with the highly fixed upper shelve. In particular, people with lower growth had to stretch their necks upward so that they could position the camera on smart glasses at an appropriate angle according to the position of the QR code identifying storage location.

Pains in arms, noticed by 71% of the respondents, could probably not be correlated with the weight of loads, weighing from a few grams to a maximum of 0.5 kg. The displaced mass did not exceed 40 kg within 4 h.

For problems like back pain and headache, users did not give any reason or possible cause.

5 Discussion

Wichaisri and Sopadang (2013) deduced from literature review that sustainable logistics has three perspectives and 15 criteria (Table 1). We used their framework to describe sustainable use of smart glasses in the case of order picking. Needed data was provided from literature review and own laboratory experimental work.

Table 8 Problems at 4 h use of smart glasses

Type of problem	0—Did not appear	1—Mildly present	2	3	4	5—Strongly present
Neck pain	**6 (43%)**	*4 (28.6%)*	1 (7.1%)	1 (7.1%)	1 (7.1%)	1 (7.1%)
Pains in arms	**4 (28.6%)**	**4 (28.6%)**	1 (7.1%)	1 (7.1%)	*2 (14.3%)*	1 (7.1%)
Pains in legs	**6 (43%)**	*3 (21.4%)*	1 (7.1%)	*3 (21.4%)*	1 (7.1%)	0
Back pain	**4 (28.6%)**	*3 (21.4%)*	2 (14.3%)	*3 (21.4%)*	2 (14.3%)	0
Headache	**8 (57.1%)**	*4 (28.6%)*	0	1 (7.1%)	1 (7.1%)	0
Pressure in eyes	**6 (43%)**	1 (7.1%)	1 (7.1%)	*5 (35.7%)*	1 (7.1%)	0
Double vision	**5 (35.7%)**	*2 (14.3%)*	*3 (21.4%)*	1 (7.1%)	1 (7.1%)	1 (7.1%)
Blurred vision	2 (14.3%)	1 (7.1%)	*3 (21.4%)*	**5 (35.7%)**	*3 (21.4%)*	0
Dizziness, balance disorder	**12 (85.8%)**	1 (7.1%)	1 (7.1%)	0	0	0
Difficult sharpening text on the display	2 (14.3%)	*3 (21.4%)*	1 (7.1%)	**4 (28.6%)**	2 (14.3%)	2 (14.3%)
Difficult walking and reading in parallel	*3 (21.4%)*	1 (7.1%)	1 (7.1%)	**5 (35.7%)**	2 (14.3%)	2 (14.3%)

5.1 Economics Perspective of Sustainability

The first criteria is quality. The output of order picking process is a service. Its quality is measured by the capacity to accomplish the clients' orders expressed in the form of a pick list. To compare the use of smart glasses with other technologies (paper, hand terminal, voice picking) on quality criteria scientists usually measures the number of wrongly picked items. Their results are rarely statistically significant, but they often notice that in their specific case the use of smart glasses can reduce the number of wrongly picked items, mainly because of the ability to supply the order picker with information directly at the workplace and track position of the order picker in the warehouse. However, the contribution depends on a system as a whole and not solely on smart glasses as a piece of hardware or system widget.

Theoretically, lead time can be shortened due to free hands and reduced need for walking around to get information. However, shortening lead time is not a logical consequence when introducing smart glasses. It largely depends on order picking protocol and the combination with other technologies. In our case the lead time for order picking by smart glasses was approximately 50% longer than in case of using paper or hand terminal. The activity that significantly prolonged the process was scanning QR codes identifying storage locations on the shelves. This activity is acceptable only if the QR codes are placed at eye level of a straightened person.

Smart glasses are conceptually the ideal tool to achieve the highest demand responsiveness if the corresponding software and enabled real-time connectivity permit this. Smart glasses together with appropriate software can guide the order picker along the shortest way between the piking sites. By projecting graphical symbols onto display order picker is routed on micro location or precisely on item itself. The need for searching locations and items is minimal. Productivity is not a logical consequence when introducing smart glasses but it can be easily increased if the whole order picking system is appropriately designed.

5.2 Social Perspective of Sustainability

Social perspective include two criteria, health and safety, and quality of life. Smart glasses themselves and systems using smart glasses are still developing. Literature review revealed research gap concerning human health, safety, and comfort during eight hours workday when using smart glasses. The basic unanswered question is whether the use of smart glasses could negatively affect the human eye during prolonged use. In fact, it is necessary to answer this question for each model separately. This may prolong the time of entering the new product on the market and even introduce confusion between customers and users.

The ophthalmologic tests in our laboratory environment revealed some statistically significant differences between results measured before and after 4 h use of smart glasses for order picking activities. As we reported (Vujica Herzog et al. 2018), in case of visual acuity, differences between results for left and right eyes are small, but, for both eyes, the visual acuity is lower after the use of smart glasses. The contrast sensitivity and color test did not show any statistically significant differences between results of tests before and after use of smart glasses. The results of the visual field test before the use of smart glasses did not reveal scotomas in the right eye's inferior quadrant, where the projection of smart glasses was performed. Second test after use of smart glasses in the same quadrant revealed scotomas in 43% of cases. This might indicate that use of some models of smart glasses for four hours and more can cause scotomas and subsequently impairment in the visual field and vision.

The results confirm the need for further research, especially since the existence of other influence parameters. One of them is the test itself. The perimetry is a subjective testing, affected mainly by the psychological state of the individuals and by their willingness to cooperate and concentrate. Second, the tested group was relatively small.

However, the procedure of using smart glasses can affect beside user vision also the musculoskeletal system in positive and negative manner. For example, in case of scanning different identification codes, codes should be placed at the eye level of a straightened person. In this case, the code lies ideally aligned with the position of the camera fixed on the frame of the smart glasses, the body of the user is in the neutral position and there is no risk of injury. Codes placed above the eye level require lifting the view with stretching the body, bending the neck and lifting to the toes to achieve the appropriate alignment of the camera according to the code. Long-term strain in the neck and legs can have a negative effect on the neck vertebrae and the muscles in the neck and legs. Placing codes to lower locations has a long-term negative impact on the lower part of the spine. Identification of codes placed below or above the eye level is also more time consuming. We can conclude that negatively affects the productivity and the user's well-being.

64% of users in our test evaluated specific model of smart glasses as physically disturbing. From their comments, we can summarize some recommendations for the establishment of a sustainable system, which includes smart glasses. Used model should ensure a comfortable fit to the user's head, with the ability to adapt to the specific anatomy of the individual. The device should not slide on the user's head when he/she performs workplace-specific movements. The mass of the device should be kept to a minimum. Otherwise, pain can occur during long-term use on the spot where glasses rest on the ears. Long cables and protruding parts should be fixed to the dress or body to prevent accidents at work and damages on device. Producer should ensure the ease of disassembly and assembly of the device, exotic and unusual designs increase the likelihood of damage to device due to the use of force instead of logic.

64% of users in our test did not have any special problems with the left eye, and 43% of all confirmed this for the right eye. In the case of frequent changing of the view between real and virtual, a short-term incapacity of focusing on the content on glasses' displayed can occasionally occur. Only rare users detected mild pain in the right eye, slight headache, double vision, blurred vision.

78.6% of users in our test failed to perform the movement simultaneously with reading the information on the display of smart glasses. Maximum productivity requires the ability of simultaneous reading and movement. It is very likely that there is a correlation between the user's inclination to new technologies and productivity.

The main advantage of using smart glasses is the ability to deliver information directly to the eyes and ears of the user. The device should allow to the user the adjustment of the position of the display in desirable position. Device can be damaged easily and quickly if its design does not allow display's rotation, shift to the left, right, up, and down.

The software and design of user interface are just as important for productivity and well-being as the device itself. Reading the text is more time consuming than communicating with symbols and colors. Pressing the buttons on the smart glasses frame is a time consuming and ergonomically inappropriate method of validation. The fastest way is voice authentication and machine vision. The software solution should include navigation and graphically supported pointing on the target location.

In traditional systems, the order picker uses about 50% of the time to move between picking locations, and another 20% for searching. The implementation of information management system requires consideration of both human factor and technical solutions (Wyrwicka et al. 2018).

5.3 Environmental Perspective of Sustainability

Environmental perspective includes five criteria, resource usage, pollution, emission, waste, and eco-efficiency. In our experiment, this aspect of sustainability was not at the forefront. The most obvious contribution to sustainability is definitely eliminated need for paper. The use of navigation and route optimization reduces energy consumption and the need for workforce.

6 Conclusion

The findings of the literature review, results from ophthalmologic tests and conducted survey motivate us to believe that smart glasses have a place in a sustainable order picking systems. They can gain on higher productivity, safety, and well-being for employees, decreased resource usage and other. We have indicated potential contributions to individual sustainability perspectives. Opportunities for further research work are indisputable. Sustainable characteristics does not depends only on the introduction and use of smart glasses as a piece of device. It is important to carefully combine all the system's components, including software, user interface, order picking strategy, storage location labeling, and others.

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Solutions Dedicated to Internal Logistics 4.0

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Abstract The contribution presents methodological arrangement of internal logistics in the context of Industry 4.0. In addition, it discusses the innovativeness level of solutions suggested as belonging to the area of internal logistics interests in the context of Industry 4.0. Numerous concepts related to Industry 4.0 in the area of internal logistics were treated with attention in the contribution in order to take care of subjectively identified advantages and disadvantages of all the presented solutions. One of the research questions of this contribution is as follows. The chapter's authors attempt to answer the research question to what extent the current considerations regarding Industry 4.0 are applied to date in internal logistics, warehouses, logistics centres and other facilities of such kind. Some researchers tend to consider that the observed and announced transformation of industry is not so much a revolution rather than the evolution of existing solutions. Therefore, another research question is stated in the contribution: is Industry 4.0 truly a revolution? In order to acquire sufficient information, a considerable significant number of foreign literature sources and a few Polish, Slovak and German publications were considered. In other words, desk–research methodology was used for this contribution. In the contribution, the authors decided to use the qualitative approach, aiming at full resource of information available in Polish, Slovak and English sources, both scientific (scientific papers, monographs) and popular ones (in particular, press reports about the so-called technological novelties applied in facilities of internal logistics and subjected to the fourth industrial revolution as Industry 4.0 is being called informally).

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1 Introduction

The first reference to the Industry 4.0 was introduced at the Hannover Fair of Industrial Technologies in 2011, according to Barreto et al. (2017), Bartevyan (2015). The main purpose of the Industry 4.0 is the emergence of digital manufacturing which gained its own term of 'smart' factory (sometimes recall as Factory 4.0), which is connected to smart networking, mobility, flexibility of industrial operations (in logistics, production and other domains) and their interoperability, integration with customers and suppliers and certainly in adoption of innovative business models (Nasser 2014). The important feature associated with the so-called fourth industrial revolution are the intelligent networks based on cyber-physical systems, Barreto et al. (2017). Cyber-physical systems (CPS) are physical and engineered systems, whose operations can be monitored, coordinated, controlled and integrated by a computing and communication system of telematics. Dynamic development of Industry 4.0 concept is a result of several worldwide social and technological processes, for example, internationalization, information technology development and also hyper global competition, according to Grzybowska and Łupicka (2017), Olesków-Szlapka and Stachowiak (2019). Most of all, it is connected to all variety of technologies which were developed recently, e.g. Radio-Frequency IDentification (RFID), Narrow Band IoT (NB-IoT), Wireless Fidelity (Wi-Fi), Near-Field Communication (NFC), Fifth-Generation mobile networks (5G), Global Positioning System (GPS), Wireless Sensor Network (WSN), robotics (Liu et al. 2018). No one needs to be convinced anymore that Industry 4.0 is the future of entrepreneurship. From the study indicated in Fig. 1, it can be observed that the elements which make up the idea of Industry 4.0 and Logistics 4.0 are relevant for the next couple of years.

Logistics 4.0 would be considered as strictly connected to the idea of Industry 4.0, meeting its objectives, assumptions and conditions. The aforementioned statement can be confirmed by quoting Jeschke (2015, 2016) who defined Logistics 4.0 as an integral part of Industry 4.0. Jeschke claimed that Logistics 4.0 might refer to various terms, practices, initiatives, new applications around existing solutions in broadly understood logistics world. These include terms such as: smart logistics, digitalisation of the supply chain (or any essential part of it), Internet of Things (IoT) alias physical internet, virtual reality (VR), artificial intelligence (AI), machine learning (ML), blockchain, autonomous vehicles or simply Industry 4.0. Logistics 4.0 as an integral part of Industry 4.0 is understood as a kind of global trend due to the broad interest in the subject matter and the increasing frequency of implementations. It shall apply equally to management aspects of logistics alike engineering research connected to logistics and transportation matters (Kostrzewski 2017). In the paper Barreto et al. (2017), its authors indicate in turn that Logistics 4.0 is a

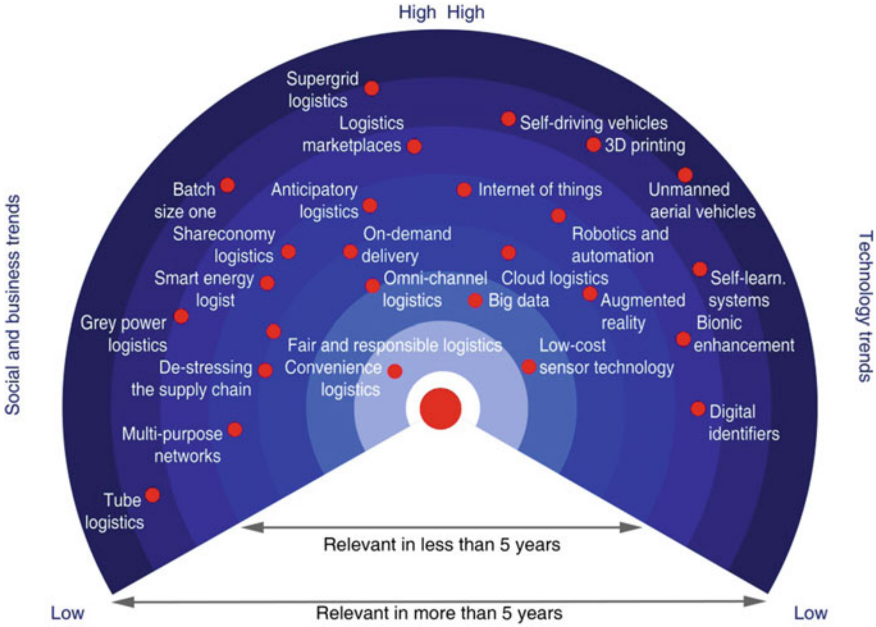

Fig. 1 Trend research. *Source* Logistics Trend Radar (2016), redesigned and rewritten after http://www.dhl.com/content/dam/Local_Images/g0/New_aboutus/logistics_insights/header_720x180/trend_2016_2_full.jpg. Accessed 11 Dec 2018

combination of using logistics with the innovations and applications added by cyber-physical systems (CPS). According to mentioned authors Logistics 4.0 is related to the same conditions as smart services and smart products. Therefore it can be stated, they defined term of smart logistics which might be treated as synonym to Logistics 4.0. Smart products and services are the ones that can execute activities in logistics processes, that normally are realized by employees, in order to employees' concentration on processes that are more sophisticated, more focused on intelligence than automatic and repetitive processes (authors of the paper Grzybowska and Łupicka 2019 researched the key competencies of managers in that kind of purposes). The authors of Barreto et al. (2017) stated that Logistics 4.0 rely on the following compounds: resource planning, warehouse management systems, transportation management systems, intelligent transportation systems and information security. The authors of this paper could add systems of telematics as well. Nonetheless, these are not key aspects since such systems and application are broadly used currently. Logistics 4.0 is more connected to correspondence between the mentioned compounds with less direct human involvement in the processes, it is 'evolvement of the cyber technologies and their integration into digital ecosystems of all industry value chain' (Barreto et al. 2017), as Industry 4.0 is sometimes understood. This correspondence is realized with use of so-called agents which include: sensors, actuators, control processing units, and communication devices.

At the current stage of implementation of Industry 4.0 solutions, it is not possible to clearly identify and estimate the scale of benefits and risks, which may occur as a result of the application of technologies focused around this concept. In the paper Götz and Gracel (2017), authors mentioned endangered due to the inability to maintain the pace of transformation of domestic entities—unsuccessful catching up in the area of Industry 4.0. Another author adheres to threats to data security, privacy or even the problem of industrial espionage (Godlewski 2016). Another authors' concern is the loss of jobs. According to OECD studies, due to automation in Germany—the homeland of Industry 4.0—about 12% of jobs are threatened, and in the case of Poland, this quantity is circa about 7% (Brandt 2016). Such levels of threatened jobs are considered to be positions where 70% of the work can be replaced by machines. In the United Kingdom this rate reaches 10%, in the USA—9% and in Japan—7%, (Götz and Gracel 2017). The industrial revolution would certainly change the structure of employment in the labour market, and although some studies even speak of the disappearance of more than 200 occupations, new ones will certainly emerge (Both 2015). On the other hand, in the last 60 years, automation has only eliminated one occupation: elevator operator (Mahdawi 2017) and a lot of currently major operations in logistics are still made manually, with no automated techniques (Guide and van Wassenhove 2001; Kosacka 2018).

The authors of the chapter, referring to this concept of Logistics 4.0, wish to present several implementations and solutions equipped and enriched with the mentioned agents. Based on the analysis of described implementations and solutions, an attempt was made to obtain answers to two research questions. These are as follows:

- RQ1: What is the innovativeness level of solutions suggested as belonging to Logistics 4.0 in the context of Industry 4.0?
- RQ2: Is Industry 4.0 truly a revolution?

In the first section of this chapter the research methodology is described. In the next sections research questions are analysed and attempt to obtain answers is undertaken. In the case of first research question RQ1, in the proper section, the following groups of solutions are discussed: autonomous mobile robots, automatic guided vehicles and civil drones in autonomous warehouses. In the penultimate section, the answer to research question RQ2 is analysed. And at the last section of the chapter, some conclusions can be found.

2 Methodology

This chapter analyses solutions connected to internal logistics, therefore it is mainly connected to autonomous warehouses, especially that with world economic globalization, warehouses have become increasingly essential (Zając 2015). It is an important topic in the era of Industry 4.0 and Logistics 4.0 as far as it is strongly connected to the mentioned pair of terms. Meanwhile, analysis of Science Direct database sources on April 2018, from the view point of term 'autonomous warehouse' has shown a remarkable rarity in taking up this topic. Only two papers were found: Vasiljević et al. (2016), Rascon and Meza (2017). In the month of this chapter's writing one more paper occurred: Subrin et al. (2018). In order to acquire sufficient information, a considerable significant number of foreign literature sources and a few Polish, Slovak and German publications were considered in this chapter. Desk–research methodology was used for this contribution. In the contribution, the authors decided to use the qualitative approach, aiming at full resource of information available in Polish, Slovak, German and most of all English sources, both scientific and popular ones (in particular websites, press reports about the so-called technological novelties applied in facilities of internal logistics and subjected to the Fourth Industrial Revolution as Industry 4.0 is being called informally). The research strives to develop evaluation methodology to assess whether the current status of a subject matter corresponds in any way with Logistics 4.0 and Industry 4.0 assumptions.

In the case of the first research question, primarily solutions were divided into fields of interest and their components were discussed (chosen technical aspects, processes they perform, information systems they benefit from and management approach they use). And then the innovativeness of solutions based on the proposed simple mathematical structure of formula was assessed. It can be said that insights on the future directions towards building smart warehouses were given.

In the case of second research questions, pros and cons are given for and against the statement that Industry 4.0 is a kind of revolution. All of them are referenced to proper literature sources and chapter's authors opinions.

3 Innovativeness Level of Solutions Suggested as Belonging to Logistics 4.0 in the Context of Industry 4.0

First of all, it should be mentioned that innovativeness level is understood here as ratio between the number of solutions released after Hannover Fair of Industrial Technologies event, that are considered as innovative, and the total number of post-trade fair solutions presented in this chapter. This ratio is expressed as a percentage and is a subjective value determined as a result of the application of the expert method. The innovativeness level is presented at the end of this section. Meanwhile, innovativeness per se is understood as a tendency to innovate, or introduce something new or different, characterized by innovation (Harper 2010).

In the paper (Götz and Gracel 2017) certain groups of main application examples of the Fourth Industrial Revolution were mentioned. These are as follows: autonomous vehicles (e.g. cars, drones), advanced robots (working together with people in factories, caring for the elderly, cleaning), 3D printing and the use of new materials, e.g. self-cleaning fabrics, ceramics exchanging pressure into energy, or graphene. It is worth taking a look at the currently proposed solutions' application in internal logistics, some of which also belong to the abovementioned groups.

Most companies are not ready to apply Logistics 4.0 concepts and technologies. However, in some industries, progress, development and rapid deployment of applications cannot be avoided in order to stay competitive. This mostly pertains to the automotive industry and electronics ones. Certainly, those two can be considered as leading industries in Logistics 4.0 implementation (this might be concluded from paper Nagy et al. 2018). Automatic supply of parts to assembly lines using autonomous guided vehicles and robotic workstations, and fully automatic welding lines can be observed today for example in Volkswagen Slovakia Bratislava or Škoda Czech Republic Prague. These and other kinds of solutions connected to Logistics 4.0 are discussed below.

3.1 Autonomous Mobile Robots (AMR) and Similar Solutions

One of wide spectrum of autonomous mobile robots (AMR) designed for different tasks in logistics processes is the example of Vecna robots. They produce robots which are specialized in order-picking processes, putting or picking of a case, pallet moves, and tuggers for a warehouse areas, Banker (2018). According to Banker (2018), for example Amazon's Kiva robots are designed to be operated in a section of a warehouse off-limits to humans, in the restricted area of automatic warehouse. On the contrary, Vecna's robots have vision systems that allow them to navigate safely around humans and share common transit paths by application of machine learning technologies (these robots are apt to discover things, and their reactions are not predefined—in case of a situation when a robot does not know how to react, it can call human for help). They also correspond and collaborate with each other which is one of the assumptions of Industry 4.0 (machine-to-machine communication). As example, part of order-picking process may be given—picking robot might place a case on an automated guided vehicle style robot that would then transport a case to a pallet build station.

The term of automated guided vehicle was in use before application of different sensors to such a vehicle which might assure new perspective of using this kind of vehicle. Nowadays, these are autonomous automated guided vehicle (AAGV; other authors call them as mobile robot fulfilment systems—MRFS, Boysen et al. 2018; according to Azadeh et al. (2018), Boysen et al. (2018), and Jünemann (1989) was the first author who conceptualized MRFS). Automated Guided Vehicle System (AGVS), which elements are Automated Guided Vehicles (AGVs) was used as a material handling system for several decades (Bocewicz and Banaszak 2013) from 1950s (Wurman et al. 2008), however from several years this system may be used in more efficient way. AGVS is a computer-controlled material handling system which parts are AGVs—driverless vehicles that are controlled with microprocessors and which can automatically perform loading, route selection and unloading (Awasthi et al. 2009; Vishwanadham and Narhari 1992). Nowadays, AGVs become more independent than before, especially that they become cheaper, smaller, and more capable because of using inexpensive wireless communications, computational power, and robotic components (Wurman et al. 2008).

Some researchers mentioned that this is a new group of vehicles which acronym is AAGV as autonomous automated guided vehicles which are characterized by the fact of using integrated ceiling-mounted camera for tracking and dynamic control purposes (Culler and Long 2016). This camera works in order to detect the presence of a vehicle robot in a warehouse, track its movement, and identify pathways and obstacles on a floor. Special controllers, sensors and devices were added to the basic robot platforms (vehicles) in order to their adaptation to different situations by receiving commands from a main computer and for interacting with their surroundings. This solution was prototyped before 2016 (Culler and Long 2016). In more general, it can be said that these are solutions under the term multivehicle system (MVS) to refer to multi-agent systems with autonomous, robotic vehicles, where multi-agent system (MAS) refers to the general class of systems in which autonomous agents carry out actions and communicate with each other through procedures and sensors (Wurman et al. 2008).

Kiva robots, mentioned a couple of paragraphs before, started this revolution of autonomous AGV with its first implementation in 2006 (Wurman et al. 2008)—by the way, the patent is mentioned for 2008 (Mountz et al. 2008; Boysen et al. 2018). The Kiva system consists of small storage shelves structures (inventory pods) which are lifted and transported by small autonomous mobile robots (AMR)—drive units. These shelves, with products on them, can be transported to any predefined area of a warehouse including employees, work area where employee can pick items off inventory pod and put them into shipping load unit. Such a process increases productivity twice or even more and in the same time improves accountability and flexibility (Wurman et al. 2008). Kiva robots are not depended on each other, however all the system is designed in such a way to accomplish a certain task connected to customer's order. This system is highly influenced by artificial intelligence techniques (Wurman et al. 2008). In 2012, Amazon fulfilled its centre in California with more than 3000 AGVs/AMRs of Kiva to redistribute goods for delivery—as the effect the productivity was reported to increase by 20% (CNET 2018).

Similarly to Vecna's and Kiva robots mentioned several paragraphs before, also CEIT robots allow to navigate safely around humans.

Central European Institute of Technology (CEIT) specializes in automation for internal logistics. The company has implemented its own smart logistics system to Volkswagen Slovakia—largest automotive company in Slovakia and also into Škoda in the Czech Republic. The system uses CEIT smart mobile robots (with artificial intelligence implementation, Hercko and Botka 2017). These robots transfer material to production lines. The material can be individually loaded and unloaded exactly in time and in the right place. This kind of robots respond flexibly to the current production situation. At the same time, they collect a huge amount of data about the flow and development of internal logistics processes. The data are monitored and evaluated in online mode. Based on the collected data, a virtual real-world logistics mirror of a logistics facility is implemented and thanks to such simulation tool all of internal logistics processes can be managed, analysed, evaluated and optimized.

The solution were appreciated as a successful connection of automatic vehicles (AGV) and extended reality and was awarded during Automotive Logistics Europe in 2018 (CEIT Group 2018). This device was released in 2007 (CEIT 2007).

The innovative solution offers great potential for various types of optimization as well as verifiable improvements for a customer. In case of Volkswagen Slovakia, CEIT has also developed Overall Equipment Effectiveness (OEE). OEE is a comprehensive production benchmark designed to assess the effectiveness of production. This indicator can be implemented in AGV MCS (AGV Monitor and Control System). Using OEE tool, enriched with different types of sensors unique data on logistics and system's productivity are collected and visualized in online mode. The result of the analysis is all-in indicator (calculation and display). It ensures overall efficiency of a robotic device.

These and other elements of smart logistics can be found in other companies as well. In most cases, they represent suppliers for the automotive segment.

The basic of the autonomous solutions of the CEIT is the connection of automated guided vehicles equipped with co-working robot installed on AGV (cobot). The modular connection provides the option of picking goods from shelves in a warehouse in fully automatic mode (Hercko and Botka 2017).

The whole system with robots and automated guided vehicles (AGV) is called as CEIT line feeding system (Automatic Guided Vehicles are a class of autonomous mobile robots according to Culler and Long (2016). Currently, it consists of two AGV types—'run under' version and 'towing' version. Some characteristics of these solutions are as follows: speed of vehicle is up to 2 m/s, weight capacity (tensile strength) is up to 3000 kg, they are equipped in brake energy regeneration, automatic localization and positioning, wireless monitoring and control system, safety scanners and automatic charging during exploitation (Hercko and Botka 2017; Gregor et al. 2009). This solution is conducted via cloud, whereas the cloud-based solution is also accessing information from other factory data sources, such as production planning and control systems, external logistics.

Run under AGV device can be used as a movable mounting table and may be used in particular for the transport of parts which are sensitive to handling, respectively, during manipulation threaten to damage. On the contrary, towing AGV might be more productive since this device is able to take more load/products at once. This system is equipped with tough 'c-frame' movable pallets, which are used as wagons. This feature is supported with automatic system of connecting and disconnecting wagons by automatic system, therefore this solution works as AVG milk–run (Hercko and Botka 2017). During a transport process a set of c-frame pallets is pulled by a guiding vehicle (automated logistics tractor). Tractors are moving along predefined routes delineated by magnetic tape fixed to floor in an aisle.

Solution connected to AAGV or MRFS might be used also as connecting a quay with the container storages in sea terminals since AGVs do it already (Schönemann and Plattner 2012).

3.2 Civil Drones in Autonomous Warehouses

Robots that are mentioned in the previous section have one main limitation. They are restricted to be used in the case of ground (one level) motion. Therefore, it is worth mentioning about solution which allows to realize some logistics processes in multiple dimensions. One of proposal providing a solution to this issue is usage of drones.

Civil drones started to be used in warehouses. Two companies (Geodis and Delta Drone) in cooperation developed fully automatic drone warehouse inventory solution. According to Whittaker (2018), it combines a robot on the ground, with a battery that provides the energy needed to navigate a drone (in the same time assuring overcome the constraints of autonomy), and a quadcopter drone equipped with four high-definition cameras (Geodes 2018). The set, equipped with indoor geolocation technology, might work in total autonomy inside a warehouse. There are several reasons this solution might arouse interest of warehouse managers in the nearest future. One of them is the fact that productivity of a warehouse enriched with such drones may generate certain logistics processes also beyond hours of activities of a warehouse (which means a warehouse may work even without human supervision). Drones can monitor autonomous warehouses especially in its areas where employees are not allowed to enter (e.g. in the restricted area of automatic warehouses) for reasons of potential danger to health and life. By the way, there are research human comfortable and safety in an environment with heavy mobile robots passing in vicinity, for example, in these kinds of restricted warehouse areas, in order to make some repairs and inspections of robots involved to work in such an environment. The authors of Puljiz et al. (2018) proposed using live cameras feed and communication options enabled by augmented reality devices for quick interventions or even preventions which could be made by the workers inside of mentioned warehouses with support of remote specialists (navigate and support human workers in such automated environments). This project is under simulation mode.

Initiators of this technology claim that it might be easily transferred from one warehouse to another without any prior modification of warehouse regular processes (Whittaker 2018). They also claim that this solution might be adapted to either warehouse management system (WMS). They have tested this solution under real conditions in order to respond to certain specific constraints of warehouses. Whereby, it seems to be not complicated since a typical warehouse consist of many similar semi-structures (the infrastructure is more or less similar in every logistics facilities of such kind).

Industrial production of such a technology has been announced at the end of 2018, Whittaker (2018).

This kind of research are conducted also by other implementations' makers, e.g. in Deepak (2015). A drone in this system navigates inside a warehouse using an image that it obtains from the primary camera, it has and similarly to the previous solution, it does not depend on any of the fixed markers. This solution consists of four subsystems: map creation for navigation, autonomous flying based on object detection, creating steering commands, performing inventory (Deepak 2015).

Inspections of a warehouse might be also realized by Micro-air Vehicle (MAV) with no prior knowledge of the environment which is described in the report on field tests of autonomous inspection in an industrial indoor facility. Nevertheless, this is not a device which would take part in the logistics processes of operation independently (Eudes et al. 2018).

3.3 Management Assistantship

Solutions connected to Logistics 4.0 are also connected to office work–balance management. Digital HR Assistant, called also as Chatbot, is a kind of independent employees' self-service platform which might be fully integrated with company's employees' systems in order to arrange paid or unpaid time off, cancel or postpone meetings and automatically inform colleagues or customers aforementioned (Lockett 2018). Therefore not only warehouse or production employees could concentrate on processes that are more sophisticated, more focused on intelligence than automatic and repetitive processes—also managers could be released from routine tasks and free to concentrate on value-adding aspects of their work. According to Lawler and Boudreau (2015), Lockett (2018), HR managers—as in the 90s of previous century—spend 25% of their time on record keeping and auditing employment practices and 50% on providing and developing HR programmes and services.

In addition to the growth of data that will be generated by different machines and devices, the least important step on the way to Logistics 4.0 is Electronic Data Interchange between subscriber and supplier (EDI). EDI is computer-to-computer exchange of business documents in a standard electronic format between business partners (Narayanan et al. 2009). Some companies often mistakenly believe that EDI also involves writing emails and sending orders via e-mail. According to the data of the Czech Statistical Office, only 10% of small businesses, 15% of small and medium-sized enterprises and about 30% of large enterprises are currently using EDI to exchange data with their suppliers, Sidora (2017).

3.4 More Solutions

Different other solutions are also connected to internal logistics and at the same time meet the assumptions and objectives on Industry 4.0. Several of them are worth mentioning:

- Butlers—pallet delivery robots that handles palette load units of up to 1600 kg and has been designed to deal with bulk inventory in factory warehouses, omnichannel fulfilment centres and large distribution hubs (Post & Parcel 2018),
- CarryPick KMP600 AGV robots (since 2012, Boysen et al. 2018) similar to mentioned Kiva robots and as well as Kiva also based on AGV idea (Swisslog 2018),

- BinGo—novel transportation concept (Kerner 2016),
- Multiple Autonomous forklifts for Loading and Transportation Applications (MALTA)—a modified forklift truck with an AGV controller and a reflector-based localization laser for guidance purposes. Two front lasers are used for real detection and safe navigation. The 1000 autonomous forklifts of such kind are tested at the testing facility in Schio (Astrand et al. 2009; Malta Project 2018),
- e-Palette—autonomous movable distribution warehouse designed by Toyota (Banks 2018)—authors of the paper (Grzybowska and Kostrzewski 2016) realized research on movable distribute warehouses,
- KUKA mobile platform (KMP) 1500 (KUKA 2017),
- Other.

3.5 Solutions Assessment

This section presents the proposal of the tool for assessing the innovativeness of the discussed solutions in relation to Industry 4.0. Industry 4.0 was introduced at the Hannover Fair of Industrial Technologies in 2011, according to Barreto et al. (2017), Bartevyan (2015). And this date is useful in the proposed formula (tool by Kostrzewski).

At the first stage of assessment, the following datasets should be given:

- $\boldsymbol{A}$—a set of presented solutions, $\boldsymbol{A} = \{1, \ldots, a, \ldots, A\}$,
- $\boldsymbol{S}$—a binary set explained by its elements, $\boldsymbol{S} = \{0, 1\}$, $s = 0$ if the solution in question existed before 2011, $s = 1$ if the solution in question existed after 2011.

The Cartesian product shall then be designated as in Formula (1), the elements of which are transferred to set $\boldsymbol{I}$ as it is given in Formulas (2) and (3).

$$\boldsymbol{A} \times \boldsymbol{S} \rightarrow \boldsymbol{I} \tag{1}$$

$$\boldsymbol{I} = \{i(1,0), i(1,1), \ldots, i(a,s), \ldots i(A,S)\} \tag{2}$$

$$i(a,s) = \begin{cases} 0: & \exists s = 0 \\ 1: & \exists s = 1 \end{cases} \tag{3}$$

In the next stage, the parameter $\bar{i}$ should be computed (4). This parameter quantifies solutions which determines the number of solutions that can be considered as potentially innovative.

$$\bar{i} = \sum_{a \in \boldsymbol{A}} \sum_{s \in \boldsymbol{S}} i(a,s) \tag{4}$$

Table 1 Application of Kostrzewski's formula

Device/solution	Year of release	a	s	$i(a, s)$
Vecna	2017	1	1	1
Kiva	2006/2008	2	0	0
CEIT	2007	3	0	0
Geodis and Delta Drone	2018	4	1	1
Micro-air vehicle	2018	5	1	1
Digital HR assistant	2018	6	1	1
EDI	XX century	7	0	0
Butlers	2018	8	1	1
CarryPick KMP600	2012	9	1	1
BinGo	2016	10	1	1
Multiple autonomous forklifts for loading and transportation applications	2009	11	0	0
e-Palette	2018	12	1	1
KUKA mobile platform (KMP) 1500	2017	13	1	1

The prerequisite for innovative solutions are as follows:

- $\exists \frac{\bar{i}}{card(\boldsymbol{A})} \leq 0.50$—solutions from set $\boldsymbol{A}$ (taken together) are not considered to be innovative,
- $\exists \frac{\bar{i}}{card(\boldsymbol{A})} > 0.50$—solutions from set $\boldsymbol{A}$ (taken together) can be considered as innovative,

where: $card(\boldsymbol{A})$—cardinality of a set $\boldsymbol{A}$.

Table 1 presents the application of presented formula. It can be stayed that almost 70% of presented devices/solutions were released after the Hannover Fair of Industrial Technologies which took place in 2011. This might mean that the idea of Industry 4.0 significantly contributes to the innovation of products in the sphere of Logistics 4.0. With regard to RQ1, it can be said that the innovativeness level of solutions suggested as belonging to Logistics 4.0 in the context of Industry 4.0 is circa about 70%, therefore it is highly satisfactory. The described solutions might be considered as best practices in logistics (Chaberek and Mańkowski 2017).

4 Is Industry 4.0 Truly a Revolution?

A lot of authors defined Industry 4.0. On the one hand, it is understood as a collective term for technologies and concepts of value chain organization (Hermann et al. 2016). On the other hand, it is comprehended as a complex solution created at the junction of engineering, computer science and management knowledge (Götz and Gracel 2017).

The buzz word is that it is another 'revolution'. Taking into account the fact that many of the solutions driving the fourth revolution are already working (cloud computing, Big Data), some researchers tend to believe that the observed and announced transformation is not so much a revolution rather than an evolution of existing solutions (Götz and Gracel 2017; Maślanek 2014; Alcácer et al. 2016). The authors of this paper are also inclined to define Industry 4.0 as the issues focused on the progress of the mentioned areas of evolutionary character. In the paper of Götz and Gracel (2017), referring to Schwab (2016), the authors highlighted the differences between the third and fourth industrial revolutions: global access to the Internet, dramatic reduction in data storage costs, mobility of devices, intelligent sensors, renewable energy sources and artificial intelligence (including machine learning). Further concepts have been traced in order to verify the thesis that Industry 4.0 is revolutionary or evolutionary in fact and whether it is a new conception or not. Industry 4.0 is connected to the disappearance of the barrier between human and machines or devices. The beginning of its era is considered to be at the beginning of the current decade. The term Industry 4.0 comes from the German government's high-tech strategy which is promoted in order to the computerization of manufacturing processes and it was recalled for the first time at the Hanover trade fair in 2011 (Kagermann et al. 2011). With regard to this date, the mentioned differences between the third and fourth industrial revolution will be traced and on this basis an attempt will be made in order to answer RQ2. Differential factors will now be traced in this section of the paper.

As the first one, worldwide access to the Internet is analysed. It has undoubtedly been growing over the last decades, albeit not evenly distributed across the globe. According to Internet World Stats (2018) only 55.1% of worldwide population have access to the internet. And this percentage value is average for worldwide human population. It is least for African countries amounting to 36.1%, and the most abundant in case of North America's countries: 95% (Internet World Stats 2018). In view of the presented data (see also Fig. 2), it is quite risky to state the Internet access is common and widespread.

As the second one difference between the Third and Fourth Industrial Revolutions drastically reduction of storage data costs was mentioned. As indicated in the research in (Götz and Gracel 2017), storing 1 GB of data in 1995 cost about 10 000 USD/year, meanwhile in 2016, this cost was equal to 3 cents. And in 2017, cost of 1 GB data storing was equal 2 cents (Mearian 2017). Data storage technology has transformed completely since the initial models of magnetic tape from the 1920s (Kimizuka 2012) to currently used cloud computing. It is undeniably true that there has been drastically reduction of data storage costs, however, quantity of stored data increased even more drastically. Therefore, relative cost of storage would be considered as much bigger.

Another difference between the Third and Fourth Industrial Revolutions is mobility of devices. Let us assume that we will limit ourselves here to considering the issue of smartphones. The historically first smartphone was created in 1992, designed and developed by International Business Machines Corporation (Woyke 2014). It was a prototype device called Simon with a touch screen and Personal Digital Assistant (PDA), therefore it was considered as combining the functions of a mobile phone

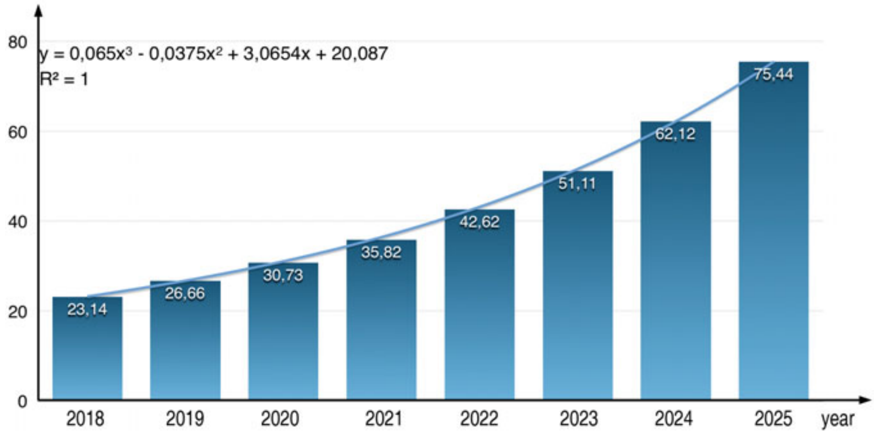

Fig. 2 Internet World penetration rates by geographical regions for June 30, 2018. *Source* Own elaboration based on Internet World Stats (2018)

and a portable computer (PDA). And thus, it was much before Hanover trade fair and many other smart devices were based on smartphone conception.

This was also the case with intelligent sensors (including those responsive to the presence of people in the vicinity) which are believed as one more difference between the third and fourth industrial revolutions. Intelligent or rather smart sensors was probably created in the middle of the 70s of previous century (Corsi 2014). It is difficult to give an unambiguous date since smart sensors technology was kept restricted within a close military environment. This technology started to be used in the world of civilians in applications and performances in the 90s of previous century (Corsi 2014). Smart sensors, however, use Internet of Things, the term of which is also much older than idea of Industry 4.0. The term Internet of Things is 18 years old. But the actual idea of connected devices had been around longer, at least since the 70s of the previous century. Back then, the idea was often called ‘embedded internet’ or ‘pervasive computing’. But the actual term ‘Internet of Things’ was coined by Kevin Ashton in 1999 during his work on promoting RFID technology (Lueth 2014). Despite of such a long existence of the concept, the popularity of the term Internet of Things accelerated at the turn of years 2010 and 2011 and reached mass market in early 2014 (Lueth 2014). Both these dates are important for Industry 4.0 as the first is when the term Industry 4.0 was used for the first time and around 2014 probably Jeschke started to define and use the term Logistics 4.0 for the first time. Certainly, the definitions of Internet of Things varies and changes. Herein, it is understood as ‘sensors and actuators embedded in physical objects are linked through wired and wireless networks, often using the same Internet Protocol (IP) that connects the Internet’ (Das et al. 2018 after Uckelmann et al. 2011). Application of Internet of Things in industry and logistics became much easier task with 26.16 billion connected devices expected to be in use worldwide in 2019, up to 75.44 in 2025, thus prognoses with polynomial trend (Fig. 3), Statista (2018).

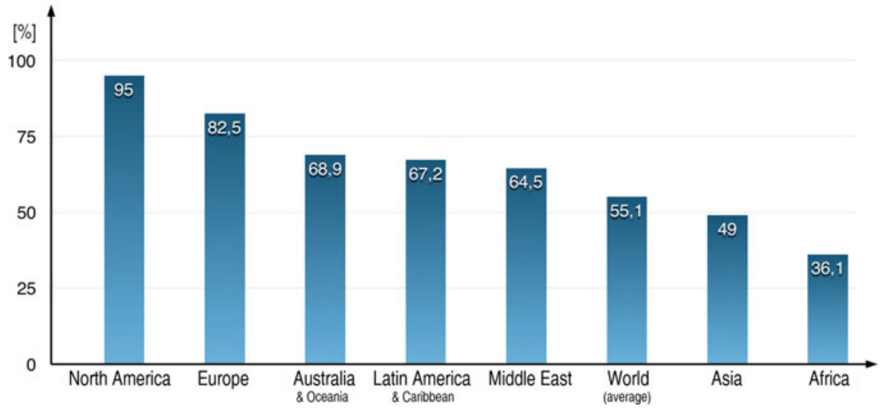

Fig. 3 Expected quantities of devices used in the world, in billions. *Source* Own elaboration based on Statista (2018)

It would now be appropriate to respond to RQ2. As a result of the above statements, it can be concluded, on the one hand, that the Industry 4.0 concept consists of a conglomerate of concepts and applications used much earlier. On the other hand, it can be concluded that Industry 4.0 is a complicated net of dependencies, therefore it is not obvious whether it is innovative conception. However, it changes rather in evolutionary than revolutionary way. As if it were not, the idea is noteworthy because while it continues to evolve, the four key pillars within Industry 4.0 that impact the supply chain are smart factories, Internet of Things, advanced analytics and more knowledgeable workers.

5 Summary

Due to the demographic development, it is not possible to cope with the growth associated with the development and shopping via the internet. Smart technology and robots with the ability to learn can improve efficiency. In economically advanced countries, they can help with a lack of workforce in logistics. However, this is a long-term process. Developments to a high degree of warehouse automation can be expected over a 10–20-year horizon. Applying a high degree of automation is most likely due to a reasonable return on investment. The availability of automation solutions is important not only for newly built but also for already built warehouses (Polák 2018).

From the financial point of present view, collaborative robots and other solutions connected to Logistics 4.0 appear to be the optimal solution for logistics processes. Collaborating robots (cobots) are complemented by artificial intelligence. These are able to learn directly from warehouse employees without the need for a lengthy and costly software change (it is human–robot collaboration). Their properties are close to humans. They perceive their surroundings, move and accurately carry out their actions with people. This should not endanger work safety.

At selected distribution centres and warehouses, rotary robots have been tested for pilot projects for several years. In case of robots increasing of workflow efficiency is the fact that instead of five employees, only two employees and one robot could do the same work (Polák 2018). What is more, unmanned carriage in a warehouse would follow a worker. This way of ordering items is more efficient and ergonomic. Similar benefits are expected from the rapid scanning of the size and weight of shipments that allow optimization and automation of loading and unloading of shipments. Warehouses with the use of autonomous means of transport and equipment require an efficient operation. It would be risky to check and test processes taking place in real facilities of such kind due to potentially high costs of the used technologies, therefore it is advisable to use modelling with the use of simulation methods. Just as in the case of CEIT robots, it was mentioned that based on the collected data a virtual real-world logistics mirror of a logistics facility might be implemented in order to use it as simulation field test. What-if simulation analysis could help to research on the innovativeness level of certain solutions suggested as belonging to Logistics 4.0 in the context of Industry 4.0 in any company. In proportion, on the basis of the data set out in the chapter it can be stated that mentioned innovativeness level is circa about 70%, therefore it is highly satisfactory. And in general, all the aspects of Industry 4.0 change rather in evolutionary than revolutionary way.

It is obvious that the development of Industry 4.0 based on digitization and automation represents for Logistics 4.0 not only huge challenges but also opportunities for increasing efficiency, no matter whether it is revolution or evolution. It is also worth mentioning that the similarity of logistics and production processes blur the differences between Logistics 4.0 and Factory 4.0 and consequently also Industry 4.0.

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Manager’s Maturity as a Derivative of Competencies and Dynamic Capabilities—Vivisection in the Context of Industry 4.0

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Abstract The role and importance of management staff is very important in the era of the Fourth Industrial Revolution. A high-quality production environment will require mature management staff with experience in working with new technologies, machines, and, especially, data and information. The undertaken research indicates that both in terms of theory and practice of management, there are many unresolved issues concerning the measurement of maturity of a manager. Given the above, it was recognized as justified in this chapter to contrive and implement an assessment method in practice. The fundamental purpose of the chapter is attempted assessment of maturity of managers in manufacturing companies operating in the agricultural machinery sector being an answer to the upcoming Fourth Industrial Revolution identified as a concept regarding the use of automation and processing and exchange of data as well as implementation of various new technologies enabling to create the so-called cyber-physical systems and change of the methods of manufacturing.

Keywords Manager’s maturity · Industry 4.0 · Dynamic competences · Cyber-physical systems · Management staff

1 Introduction

The extensive approach to organization, functioning at the beginning of the twentieth century, has been strongly devalued in the recent few dozen years. Routine behaviours and consolidation of rigid, hierarchical action structures are more and more often rejected, and simply undesirable. The innovative model becomes a standard in the development of contemporary businesses, consisting of delivery of

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an increasingly more attractive offer to the market using qualitative development factors. A necessary and basic factor in increasing the innovation of Polish enterprises and, in consequence, their competitiveness based on high value-added products and services, is a human who is able to create innovative solutions. Therefore, it is necessary to take action focused on the formation of innovators, without whom the transition to the stage of innovation-based economic growth will be difficult.

In connection with the above, it should be emphasized that dynamic economic growth related to future macro trends will require human capital quality growth. The Fourth Industrial Revolution, involving a deep, digital industry transformation will be one of the most important technological macro trends in the coming years. The properly prepared management staff, mainly using knowledge, applying, in their work, new techniques of obtaining information and processing data, are the necessary precondition for the assumed 'civilizational leap'. The demand for management capabilities, skills, and competencies will be determined by trends emerging on European and world markets, which are also present in the Polish market.

It is, therefore, necessary to take actions focused on strengthening competencies necessary for the development of innovation in enterprises. Apart from resources needed to create and develop innovation such as good ideas, breakthrough inventions, cash capital and a team of outstanding specialists also a well prepared and mindful manager is necessary. In the first place, he or she is able to stimulate, see, assess and sell innovative ideas and solutions adapted to consumer needs.

Therefore, particular attention will be focused on the competencies of managers, who help form the innovative culture and manage the whole innovative cycle. Due to the empirical evidence proving the presence of a strong connection between a well-managed innovative process and the company's market success, improvement in innovation management skills by dedicated management programs should significantly contribute to the development of innovative businesses.

The prevailing dynamic changes will require the development of new competencies and capabilities related to the use of technologies such as cyber-physical systems, advanced production management systems, advanced robotization, complex production data analysis systems, and artificial intelligence. The need to operate databases and to have algorithmic thinking skills, allowing new programming languages to be learned fast, will become common. The most important competencies, both general and specialist ones, will include: data assessment and analysis, data safety, data documentation and reading skill, work in a cloud, ability to take relevant decisions in the IT environment, programming, software development, artificial intelligence algorithms, software cooperation, 3D print, digital tool-based applications, user-focused IT design and IT diagnostics.

Numerous attempts to distinguish competencies from capabilities include those that point to the superiority of competencies over capabilities. In the chapter, competencies have been separated from capabilities, with the clear differences present between them being emphasized. Competencies are considered in comparison to the achieved results, on the other hand, capabilities are identified with possibilities or skills. In addition, the authors question the fact, whether the identification of competencies with capabilities is adequate for an organization operating in the present business reality, an organization that looks to the future, gains new knowledge, arouses intellectual curiosity and encourages discussion.

The following direction aggregates competencies and capabilities focused on the maturity of managers. As a result, the decision was made to focus the research on operations related to the key challenges for the development of managerial capital from the point of view of productivity growth and quality of their work.

Given the above, it has been deemed justified in this chapter to contrive and implement an assessment method of maturity of managers in practice. The fundamental purpose of the chapter is attempted assessment of maturity of managers in manufacturing companies operating in the agricultural machinery sector being an answer to the upcoming Fourth Industrial Revolution identified as a concept regarding the use of automation and processing and exchange of data as well as implementation of various new technologies allowing creation of the so-called cyber-physical systems and change of the methods of manufacturing (Lee et al. 2015; Kagermann 2014). In order to limit the amount of text maturity of a manager aspiring to function in the era of Industry 4.0 will be shortly referred to in the chapter as Industry 4.0 manager's maturity or manager 4.0's maturity.

In connection with the so outlined aim, the following have been recommended as necessary actions:

- in the theoretical perspective—by reconstructing and interpreting Polish and foreign subject matter literature, supported by experts' knowledge, nominate the definition of a manager's maturity—as adequate to the research;
- in the project perspective—compile a research tool in the form of an assessment sheet being a result of the literature study and a discussion among intentionally selected experts; recommend questions assessing the level of maturity of a manager aspiring to function in the era of Industry 4.0;
- in the empirical perspective—practical use of the method; maturity assessment of managers operating in the agricultural machinery sector.

It seems that the complexity of the problems and the so far limited scientific recognition justify the treatment of the mentioned matters as the subject matter of the research. Additional confirmation for the need to undertake research also results from the following facts:

- on the editorial market there is an absence of studies concerning the assessment of the maturity of managers, especially in terms of their functioning in the context of Industry 4.0;
- the subject literature usually applies to general definitions in this area; there are scarce studies representing specific definitions and suggestions which can be translated into the practice of management.

According to the intent of the authors, the work is to show a broader perspective for defining the competencies and capabilities in the context of a manager's maturity.

The presented research does not exhaust the problem area of maturity of a manager, however, the authors do hope that it will become a guideline at least to a minimum extent for those who want to make changes in their company.

2 Starting Point

2.1 From a Manufacture to the Era of Industry 4.0

The embryonic form of a capitalist enterprise was manufacture. Numerous production inventions and improvements resulted in business growth—from small workshops, manufactures to industrial plants. The transformations in the industry started at the end of the eighteenth century, referred to as the Great Industrial Revolution was a breakthrough period in the history of humanity (Adamiecki 1985). Thanks to the technical development of work tools and manufacturing organizations (exchangeability of parts, manufacturing in production batches), the volume of the manufactured goods increased, and they were produced in series (Niewiadomski 2016). In the 1950s, the concept of production started to change. A new economy emerged, with three basic attributes—it is global, favors intangible goods (ideas, information, linkages and knowledge) and is internally highly interconnected. While the Third Industrial Revolution consisted in the automation of individual machines and processes, the next one brings along a comprehensive digital transformation of all assets and deepened integration with partners contributing jointly to creating the value chain within digital ecosystems.

The idea of Industry 4.0 is a very young concept (Magruk 2017). In many aspects, particularly in the system perspective, it involves a high degree of uncertainty. Despite a high level of complexity—in the opinion of the authors—it is necessary to run research implying assimilation of the primary and practical knowledge in this scope.

Although the term ‘Industry 4.0’ has already been used for nearly 7 years, it was coined for the first time during Hannover Messe in 2011 (Lee 2013; Qin et al. 2016). The term ‘Industry 4.0’ is often referred to as the Fourth Industrial Revolution (Kagermann et al. 2013). On the European level, the term ‘Factory of the future’ was proposed, in the United States ‘Industrial Internet’, while in China ‘Internet +’ (Mrugalska and Wyrwicka 2017).

among others InternetIndustry 4.0 cannot be assigned to one technology or a single change in management methods (Kagermann et al. 2013; Lasi et al. 2014; Schmidt et al. 2015). The Fourth Industrial Revolution is a concept related to use of automation and data processing and exchange as well as the implementation of various new technologies allowing the creation of the so-called cyber-physical systems and change of the methods of manufacturing (Lee et al. 2015; Kagermann 2014). It also applies to production digitization, where technological devices and systems are linked, also over the Internet, and where large production data volumes are analysed (Łupicka and Grzybowska 2017). Here, Industry 4.0 is a conceptual aggregate incorporating a number of new technologies (Dmowski et al. 2016)—among others Internet of Things (Atzori et al. 2010; Zuehlkea 2010), computational clouds (Xu 2012; Subashini and Kavitha 2011; Valilai and Houshmand 2013; Wang and Xu 2013), Big Data analysis (Lee et al. 2014) artificial intelligence as well as incremental print (Sęp and Budzik 2015) augmented reality (Stadnicka and Antonelli 2014; Szulewski 2016) or cooperating robots (Stadnicka and Antonelli 2016).

The second dimension of Industry 4.0 is related to production management, organization's operations, and value chain. Here, what changes, in particular, is the architecture of production management systems and transition from line processes and the traditional production management systems pyramid to a network of connections and nonlinear manufacturing. A combination of the previously mentioned innovations with new capabilities concerning artificial intelligence can consequently lead to a revolutionary change in manufacturing management methods, where systems would operate in a highly autonomous way, dynamically changing their structure and functions within the organization.

Due to the continuous and sudden variability in conditions, enterprises must create new characteristics, behaviours and attitudes, which will be an adequate and effective answer to the globally transforming reality. In the era of the Fourth Industrial Revolution very important is the role and significance of qualified management staff, who should stand out with their unique competencies and dynamic capabilities as well as substantive preparation to work in a specific environment. This means that a typical characteristic of the present era is recognition of competencies and dynamic capabilities as a critical factor determining survival or development of the organization, and skillful management of the attribute being dynamic competencies becomes (in the conditions of uncertainty and dynamical changes) a factor that determines the manager's maturity.

Contemporary managers are expected to create effective enterprises that will demonstrate systematic, excellent performance in the long run while preserving the highest level of customer satisfaction and employee commitment. The new managerial competencies paradigm is evolving towards more aspiring leader's competencies, which are the leverage for the organization's competitiveness. In fact, a high production environment will require qualified management staff and production employees with experience in working with new materials, technologies, machines, and especially data and information.

2.2 Manager's Maturity in the Opinion of Experts [PS_1]

To speak about the reality, phenomena and processes related to the generally understood management, the scope of the terms resulting from the research should be clearly specified. Since the term '*manager's maturity*' is rarely present both in colloquial thought and in scientific studies, the authors have regarded as justified to nominate a definition significantly corresponding to the subject matter of the present research (Irizar and Wynn 2019; Al Aboodi 2006; Elmaallam and Kriouile 2011;

Skrzypek 2014). It is important to develop, adopt and consistently apply and understand the term, the more so that there is no precisely determined meaning of it. Attempts taken in this study to order terms have only had the cognitive advantage, allowing the authors to conduct the basic research.

How is the notion '*manager's maturity*' understood by representatives of manufacturing enterprises from the Polish agricultural machines sector? The above question and the conviction about the presence of business demand for results being applicable in nature were the main inspiration to undertake the research. It seems that the complexity of the problems and the so far limited scientific recognition justify the treatment of the mentioned issues as the subject matter of the research.

According to the intent of the authors, the research is to show a broader perspective for defining the '*manager's maturity*'. The presented research findings have given direction for the authors' further works. Performing the initial research [PS_1], the authors used the method of literature studies and discussion among intentionally selected experts. For this purpose, a team composed of 23 persons was created, including representatives of small (5 persons), medium (14 persons) and large (1 person) manufacturing enterprises functioning in the agricultural machinery sector and representatives of: the Industrial Institute of Agricultural Engineering (1 person), a higher education school (1 person), Department of Regional Policy, Marshal's Office of the Wielkopolska Voivodeship—Deputy Director (1 person). When selecting the experts, their knowledge, broad, holistic perspective, independence and practical experience in organization and management were taken into account. In each case, those were professionally active persons, dynamically participating in the management of the enterprise they come from and work for. In relation to the presented principles and literature concepts, and based on the experience from their companies, the task of the experts was to present their own views in the discussed scope.

In the authors' view, research conducted based on a large number of variables would strongly complicate implementation—prevent the formulation of essential conclusions—it was important to determine a short list of definitions—resulting from observations of the management practitioners. In 15 min, each person had a possibility to write down, on a piece of paper, the catalogue of desiderata constituting a manager's maturity. The research authors wrote down all the mentioned characteristics, grouped similar ideas together, which later made it possible to determine the final list of 23 definitions (Table 1).

A preliminary study was a precondition for conducting the proper research; the main intent of the authors was to determine the dimensions which would best reflect the sense of the notion: manager's maturity. The purpose of the discussion was only the right selection of the definitions without ranking them. The point was to create a collection from which it could be possible to choose the terms most corresponding to the problem raised in the study. The list was built so as to ensure that it can be modified and supplemented as required, in fact, it was assumed that the specified characteristics are not fixed categories.

The presented definitions provide the context of different approaches. The essence of the manager's maturity presented by the particular expert is relatively scattered;

Table 1 Manager's maturity—insights among the experts

No.	Definitions
1	Ability to learn quickly adapting the manager to changes realizing different optional actions at the same time
2	Being in readiness for intensive development—by pursuing properly designed and adjusted—according to the goals adopted by the organization—personal competences (knowledge, skills, personal characteristics, experience, motivations, attitudes and behaviours)
3	Manager's creativity; thinking leading to original and relevant solutions being obtained; capacity of creating something new
4	Knowledge in the field of organization and management, knowledge of technologies, designs, machine operation and design; ability to practically use data and information; experience being resultant of tasks being performed and implementation projects
5	Knowledge, skill, experience and motivations to implement evolutionary and revolutionary change
6	Knowledge, skills, characteristics and experience implying the manager's capacity of provoking and using opportunities
7	Ability to dynamically adapt the company's goals to the conditions in which the manager is forced to act
8	Knowledge, experience and skill in using the resources being at the disposal of the enterprise; machines, tools and devices for processing and manufacturing
9	Collections of knowledge and skills underlying the enterprise's sustainable competitive advantage. These are substantially intellectual in nature and are related to the management systems
10	Ability to practically apply knowledge determining the ability to immediately respond to change, what, by a properly harmonized reconfiguration of the resources, implies the possibility to use the opportunities emerging in the environment
11	Key managerial competencies being a bundle of knowledge, skills, experience and capabilities underlying the enterprise's competitive advantage
12	Knowledge implying the skill of adaptation to changes taking place within the company and in its environment
13	Knowledge, experience, attitudes and behaviours which will result in the pursuit of developing new technologies, and later, having the dynamic capabilities, with their proper reconfiguration, will imply a sustainable leading business position
14	Ability to solve management (managerial) and technological problems based on the acquired knowledge, characteristics and experience
15	Knowledge, experience, capabilities and predispositions for teamwork used at the workplace, specific skills required at work and personal culture
16	Predispositions, knowledge, experience, attitudes, motives and behaviours (intangible resources) allowing efficient, effective and productive management aimed at the ability to use and provoke opportunities emerging in the environment
17	Dispositions concerning knowledge, skills, attitudes and behaviours making it possible to undertake production and managerial tasks on a properly high (mature) level

(continued)

Table 1 (continued)

No.	Definitions
18	Knowledge, capabilities, predispositions, experience, (routine) and motivations that, with the manager's personal culture, get the enterprise closer to the achievement of the adopted objectives and principles
19	Manager's strategic potential, which, through knowledge, skills, personal characteristics, attitude and experience, contributes to achieving specific (desired) results
20	Visible characteristics, in the form of knowledge, skills, experiences and behaviours, allowing successful management, including use of any opportunities emerging in the direct and further environment
21	Art of effective, responsible, energetic, economic and skilful management of the whole of matters, material, capital, human and information resources, intended to pursue the assumed goals and tasks
22	Integrated use of capabilities, personality traits as well as the acquired knowledge and skills, for successful management
23	Manager's strategic capabilities giving them a possibility to undertake operations that are difficult to imitate. They are to be developed in order to take advantage of the new opportunities. Competencies and capabilities are indicated, which are treated in the company as unique resources

Source Own development based on research

some of the proposals are limited to reaction, others only to the adaptation to the changing conditions, still others restrict the scope of maturity to knowledge, skills, characteristics or attitudes.

Manager's maturity assumes a certain combination of knowledge, skills, personal characteristics, experiences, attitudes and behaviours which help the manager undertake what the other employees are not able to. Adoption of the assumption that the manager's maturity is illustrated by both individual skills and experience and discriminative ways of action within the company, allows for deriving the conclusion that the essence of maturity consists in the ability to create, transform, collect, integrate and use thereby assimilated competencies and dynamic capabilities.

3 Research Method

3.1 Preliminary Study [PS_2]

Performing the preliminary study [PS_2] aimed at developing the research form, the authors used the method of literature studies and creative discussion among intentionally selected persons. The inspiration for preparing the assessment tool were the works of Polish (Bieniok 2016; Bratnicki 2000; Grzybowska 2012; Grzybowska and Łupicka 2016, 2017; Rakowska 2005, 2017; Szczepańska-Woszczyna 2014; Łupicka and Grzybowska 2017), and foreign (Katz 1974; Ortega 2010; Quinn and

Hilmer 1996; Spencer et al. 1990; Antti and Greenhalgh 2012; Boytazis 1982; Cappellen and Janssens 2008; Ena and Sahoo 2014; Woodruffe 1991; Quintana et al. 2014; Rothwell and Lindholm 1999; Trivellas and Drimoussis 2013; Teece et al. 1997; Teece 2007, 2012) researchers. Preliminary study—being a precondition for conducting the proper research [MS0]—was intended to develop the research form as a list of key factors confirming Industry 4.0 manager's maturity level.

At the stage of formulating the list—in order to adapt the research tool to the examined sector and limit the amounts of the generated desiderata—the technique of open discussion in a group of 15 persons directly related to the agricultural machinery sector was used. The characteristics of the experts are presented in Table 2.

In the discussion, two stages were distinguished: in the first one, the theoretical model of factors formulating the manager's maturity level was presented, while in the second one individual experts put new suggestions forward, trying to indicate practical solutions in the scope concerned. Taking under consideration the ease of assembling a proper group of competent interlocutors, the possibility to animate the group to stimulate creative thinking, low cost of performing the research and the possibility to generate a high number of ideas in a short time, it was recognized as justified to nominate the proprietary method 335. Over 5 min, each expert—by

Table 2 Characteristics of the experts

Group/Institution/Position	Number	Specialization	Share (%)
Owners and co-owners of manufacturing enterprises in the agricultural machines sector	8	Organization and Management, owner's supervision	53.33
Managers of manufacturing enterprises in the agricultural machines sector	4	Organization and Management; managerial supervision	26.66
Industrial Institute of Agricultural Engineering Research Laboratory Manager	1	Modelling machine safety and assessment of conformity with requirements of EU directives and standards harmonized at the stage of concept and product designing	6.67
Business Centre Club expert	1	Management strategies, SME innovation, science-knowledge-business cooperation	6.67
Consultant/Expert/Practitioner	1	For over 12 years linked with manufacturing companies; directly coordinates lean projects; has ISO 31000 Certified Risk Manager qualifications; a representative for Integrated Management System (ISO 9001, ISO 14001, PN-EN 18001)	6.67
Sum (%)			100

Source Own work based on research

Table 3 Characteristics of spaces oriented on maturity assessment

No.	Space	Acronyms	Number of assessing indicators
1	Knowledge management	ZW	13
2	Skills/Capabilities	UZ	15
3	Personal characteristics/Predispositions	CO	14
4	Experience	DO	1
5	Motivations/Attitudes/Behaviours	MPZ	10
Sum			53

Source Authors' own study

writing down on a piece of paper—had the possibility to nominate 3 components proving Industry 4.0 manager's maturity. Then, after 5 min he or she gave the card to the subsequent person who added their observations. After the next 5 min, the card went to the hands of the subsequent expert. In this way, after 3 rounds the group of 15 experts generated 135 desiderata. After the end of the session, the assessment of the obtained results was summed up. The authors wrote down all the mentioned characteristics, grouped similar ideas together, which later made it possible to determine the final list of 53 indicators consistent with the five spaces oriented on Industry 4.0 manager's maturity (Table 3).

Assessing the manager's maturity, the authors focused on persons having appropriate experience in the industry. Attention was paid to ensuring whether knowledge and skills gained in one field can be used in new circumstances in a new and creative way. Given the above, the assessment is unambiguously positive.

In order to conduct the research, a five-grade scale was adopted to describe the Industry 4.0 manager's maturity level corresponding to the separated assessment spaces. The respondents were asked to assess the particular 4.0 manager's maturity indicator in the scale 1–5, where 1 means very low maturity within the examined indicator, while 5—very high.

3.2 Proper Research [BR—Basic Research]

The basic stage of the research [BR] was performed in the period November–December 2018. For this purpose, direct meetings were used as well as—in order to obtain a higher level of representation of the examined target group and collect answers as quick as possible—additionally the surveys were provided to selected partners cooperating with the Spare Parts and Agricultural Machinery Production Company 'Fortschritt' and Industrial Institute of Agricultural Engineering as parties of the research.

83 managers of micro—11 persons (13.25%), small—24 persons (28.92%), medium—42 persons (50.60%) and large—6 persons (7.23%) manufacturing enterprises in the agricultural machinery sector took part in the study. For the needs of the preliminary study, it was assumed that a manager is a managing person, and the one who appoints him or her to this role is the owner of equity contributed to the company, sometimes its founder and originator. Managers are all the employees of the company who were given superiors' functions—starting from a master, to the president of the board or owner.

29 owners (34.94%), 24 managers (28.92%), 7 presidents of the board (8.43%), 3 members of the Management Board (3.61%), 2 proxies (2.41%) and 18 directors (21.69%) took part in the study. Such positions as the following were identified among the participants: Purchasing Department Manager, Distribution and Logistics Manager, Area Manager, Cost Optimization Project Leader, Logistics Manager, Senior Project Buyer, Global Category Manager, Purchasing Manager, Strategic Clients Manager, Individual Clients Manager, Production Director, Sales and Marketing Manager, etc.

Structure analysis of characteristics of 83 enterprises the managers of which attended the study shows that companies based only on Polish capital (81.93%) dominate among them, present on the market for over 10 years (77.11%). Less than half (45.78%) of the enterprises participating in the study are organized as a company; 80.72% declare operations on the domestic and foreign markets.

The age of those surveyed was between 24 and 73 years (including: 2.41% managers were below 30 years; 24.10% were persons 31–40 years old, 38.55% were 41–50 years old, 25.30% were 51–60 years old, while 9.64% were manager less than 60 years old). Detailed characteristics are depicted in Table 4.

Among the surveyed, the group of persons with high school and higher education was the biggest: (96.38%), 68.67% of which had higher education, 27.71%—medium, 3.61%—professional education. Detailed characteristics are depicted in Table 5.

One of the most important stages in the research process is the analysis and interpretation of the research results. That is why further in the paper an attempt has been made to interpret the results and perform a deeper study based on respondents' declarations. It was necessary to describe the obtained data.

4 Manager's Maturity—Research Findings

Manager's maturity 4.0 is a result of the accumulation of impacts of many factors, which include the ability to function within a market partnership. Modern managers must be open to new trends in the functioning of enterprises, first of all resulting from globalization challenges, work online, technological innovations implying the opportunity to build competitive advantage and continuous pursuit of new knowledge. The existing competition results in new problems being formed, and, first of all, increases requirements for the management staff.

Table 4 Characteristics of surveyed managers—age distribution

Manager/Position		Age					Σ
		<30	31–40	41–50	51–60	>60	
Owner	N	$N = 1$	$N = 8$	$N = 11$	$N = 7$	$N = 2$	29
	%	1.20	9.64	13.25	8.43	2.41	34.94%
Manager	N	$N = 1$	$N = 10$	$N = 9$	$N = 4$	$N = 0$	24
	%	1.20	12.05	10.84	4.82	0	28.92%
President of the Board	N	$N = 0$	$N = 0$	$N = 3$	$N = 3$	$N = 1$	7
	%	0	0	3.61	3.61	1.20	8.44%
Board Member	N	$N = 0$	$N = 0$	$N = 1$	$N = 2$	$N = 0$	3
	%	0	0	1.20	2.41	0	3.61%
Proxy	N	$N = 0$	$N = 0$	$N = 1$	$N = 0$	$N = 1$	2
	%	0	0	1.20	0	1.20	2.40%
Director	N	$N = 0$	$N = 2$	$N = 7$	$N = 5$	$N = 4$	18
	%	0	2.41	8.43	6.02	4.82	21.69%
Σ	N	2	20	32	21	8	83
	%	2.41	24.10	38.55	25.30	9.64	100%

Source Own work based on research

Table 5 Characteristics of surveyed managers—distribution according to education

Manager/Position		Education			Σ
		Professional	High school	Higher	
Owner	N	$N = 3$	$N = 11$	$N = 15$	29
	%	3.61	13.25	18.07	34.94
Manager	N	$N = 0$	$N = 7$	$N = 17$	24
	%	0	8.43	20.48	28.92
President of the Board	N	$N = 0$	$N = 1$	$N = 6$	7
	%	0	1.20	7.23	8.43
Board Member	N	$N = 0$	$N = 0$	$N = 3$	3
	%	0	0	3.61	3.61
Proxy	N	$N = 0$	$N = 0$	$N = 2$	2
	%	0	0	2.41	2.41
Director	N	$N = 0$	$N = 4$	$N = 14$	18
	%	0	4.82	16.87	21.69
Σ	N	3	23	57	83
	%	3.61	27.71	68.67	100%

Source Own work based on research

The problem of maturity of persons who manage enterprises—although is not a new problem—is presently the current topic and the subject of interest of many researchers. Literature analysis shows that characteristics of a mature manager 4.0 have been described by a few researchers; among others, attempts were made to find skills that managers 4.0 demonstrate to a bigger extent than modern managers.

The subject literature most commonly presents model sets of competencies of mature managers employed in miscellaneous organizations. On the other hand, the literature definitely misses a scientific examination of profiles of managers who manage enterprises from the agricultural machines sector. The found and above described knowledge gaps have created a problem situation and have become the motive for the authors to undertake research the results of which are depicted in the following Table 6.

The surveyed managers declare a high level of assimilated comprehensive concerning knowledge in organization and management (average score 4.47; 57.8% of the indications for 5-point score). They are prepared for performing different management tasks and organizational roles related to running a business. They have competencies allowing correct decisions to be made concerning both the business strategy as a whole as well as functional strategies.

In response to large market saturation and the rapidly changing environment, managers demonstrate a high level of knowledge regarding what to produce (average score 4.46; 55.4% of the indications for 5 point score) how to produce (average score 4.31; 47.0% of the indications for 5 point score) and whom to sell the product to (average score 4.43; 55.4% of the indications for 5 point score) and what marketing actions they should take for this purpose (average score 4.41; 54.2% of the indications for 5 point score). As, for contemporary companies, creating new products is the essence of innovative operations and gives the direction for their development, the knowledge—assimilated by managers—regarding new technologies and innovations becomes key for achieving and maintaining their companies' competitive advantage (average score 4.40; 53.0% of the indications for 5-point score). Such knowledge should be protected and—though it seems controversial in the context of the omnipresent orientation on the vision of unrestricted knowledge sharing—made available to a minimum extent only to selected employees for whom it is necessary for work. In this regard, managers declare significant moderation (average score 4.00; 32.5% of the indications for 5 point score).

The need to operate databases and the algorithmic thinking ability will become common in the face of Industry 4.0, allowing new programming languages to be learned fast. Manager's maturity in this area was authenticated by knowledge of cybernetic technologies and analytical systems (average score 3.99; 38.6% of the indications for 5-point score), general practical knowledge on project implementation in IT (average score 4.11; 32.5% of the indications for 5 point score) and automation and robotics (average score 4.02; 27.7% of the indications for 5-point score).

The need to smoothly and timely perform complex and largely unique projects have made projects and project approach become a permanent element of current business operations. The special nature of project implementation and the characteristics distinguishing them from among 1–6 other operations of an enterprise create

Table 6 Knowledge management—assessment of manager 4.0's maturity

	Descriptors	1	2	3	4	5	ŚR.
		%					
Management knowledge	Knowledge sharing and knowledge base creation	–	–	27.0	29.0	27.0	4.00
		–	–	32.5	34.9	32.5	
	Production knowledge	–	1.0	11.0	32.0	39.0	4.31
		–	1.2	13.3	38.6	47.0	
	General practical knowledge concerning implementation in IT	–	1.0	16.0	39.0	27.0	4.11
		–	1.2	19.3	47.0	32.5	
	General knowledge concerning automation and robotics	–	2.0	17.0	41.0	23.0	4.02
		–	2.4	20.5	49.4	27.7	
	Project knowledge	–	1.0	8.0	33.0	41.0	4.37
		–	1.2	9.6	39.8	49.4	
	Knowledge concerning organization and management	–	1.0	7.0	27.0	48.0	4.47
		–	1.2	8.4	32.5	57.8	
	Marketing knowledge	–	2.0	7.0	29.0	45.0	4.41
		–	2.4	8.4	34.9	54.2	
	Knowledge of clients and market	–	1.0	8.0	28.0	46.0	4.43
		–	1.2	9.6	33.7	55.4	
	Economic knowledge	–	4.0	13.0	29.0	37.0	4.19
		–	4.8	15.7	34.9	44.6	
	Knowledge of cybernetic technologies and analytical systems	2.0	7.0	13.0	29.0	32.0	3.99
		2.4	8.4	15.7	34.9	38.6	
	Knowledge regarding new technologies and innovations	–	1.0	9.0	29.0	44.0	4.40
		–	1.2	10.8	34.9	53.0	
	Knowledge about products	–	1.0	6.0	30.0	46.0	4.46
		–	1.2	7.2	36.1	55.4	
	Command of foreign languages	1.0	3.0	11.0	35.0	33.0	4.16
		1.2	3.6	13.3	42.2	39.8	

Source Own work based on research

specific requirements regarding project knowledge, namely knowledge related to project implementation. Therefore, in the context of Industry 4.0 challenges, new knowledge becomes essential, gathered or created throughout the project implementation time, which, for the surveyed managers, is also used after its completion; the managers are characterized by a high maturity level in this area (average assessment 4.37; 49.4% of the indications for 5-point score). Attention is paid to a high level of the managers in terms of economic knowledge assimilation (average score 4.19; 44.6% of the indications for 5-point score). The gained economic knowledge allows opportunities and threats related to the operation of the market to be recognized, giving managers 4.0 an opportunity to make informed decisions, especially financial ones.

As a result of the conducted research, the achievement of the goal of the study has been made easier. The made analysis of the knowledge level among the managers, which was codified in the form of 13 questions, allowed the hypothesis formulated at the beginning to be verified and confirmed. Based on the research in the scope of knowledge management, it may be stated that managers demonstrate a significant maturity level, what makes them able to function in the era of Industry 4.0.

In order to perform the next stage of manager 4.0's maturity assessment, a set of assessing research questions was prepared (Table 7).

A typical operation that drives the development of businesses and each manager's results is decision-making. The conviction as to whether managers are aware of their own decision-making process, method or are not aware of which models, thinking schemes they use, proves their maturity (average score 4.47; 51.8% of the indications for 5-point score). It is sure that better quality decisions improve business performance.

Due to competitive pressure, many businesses begin cooperation with other companies without proper preparation, not understanding the partner's needs, objectives and expectations. Such cooperation often ends with failure (Duysters et al. 1999), as the absence of conformity of the objectives and compatibility among the partners leads to conflicts and opportunistic behaviours (Moeller 2010). That is why so essential is—in the context of manager 4.0's maturity—the ability to select the business partner, which is something more than just a well-considered process based on quite a rigid set of criteria and, for the surveyed managers, it is realized on a very high level (average score 4.43; 50.6% of the indications for 5-point score).

A mature manager 4.0 is a person affecting behaviour of the employees and focused on improvement of their performance, which is later to contribute to growth in organizational effectiveness (average score 4.41; 49.4% of the indications for 5-point score), having the ability to break the problem down into pieces and rediscover the sense and the logical structure in it (average score 4.36; 44.6% of the indications for 5-point score), and a high level of permanent memory, intelligence of words, items, facts and relations, the manager faces while performing their job (average score 4.36; 47.0% of the indications for 5-point score).

The high maturity level of the surveyed managers is proven by the ability to learn quickly—as declared by themselves (average score 4.33; 47.0% of the indications for 5-point score), and the ability to delegate decision-making authorities to other

Table 7 Skills and capabilities—assessment of maturity of manager 4.0

	Descriptors	1	2	3	4	5	ŚR.
		%					
Skills capabilities	Ability to build, standardize dictionaries of the terms related to modern technologies present between supplier–company–client	2.0	4.0	23.0	36.0	18.0	3.77
		2.4	4.8	27.7	43.4	21.7	
	Ability to define objectives	–	1.0	14.0	33.0	35.0	4.23
		–	1.2	16.9	39.8	42.2	
	Ability to select partners	–	–	6.0	35.0	42.0	4.43
		–	–	7.2	42.2	50.6	
	Conciliatory capabilities; ability to solve conflicts	1.0	2.0	8.0	35.0	37.0	4.27
		1.2	2.4	9.6	42.2	44.6	
	Perceptive capabilities	1.0	3.0	7.0	38.0	34.0	4.22
		1.2	3.6	8.4	45.8	41.0	
	Ability to learn quickly	1.0	1.0	7.0	35.0	39.0	4.33
		1.2	1.2	8.4	42.2	47.0	
	Organizational-planning capabilities	1.0	1.0	7.0	38.0	36.0	4.29
		1.2	1.2	8.4	45.8	43.4	
	Analytical skills	–	1.0	5.0	40.0	37.0	4.36
		–	1.2	6.0	48.2	44.6	
	Decision-making abilities	–	–	4.0	36.0	43.0	4.47
		–	–	4.8	43.4	51.8	
	Intellectual capabilities	–	1.0	7.0	36.0	39.0	4.36
		–	1.2	8.4	43.4	47.0	
	Research skills	2.0	4.0	21.0	39.0	17.0	3.78
		2.4	4.8	25.3	47.0	20.5	
	Motivational abilities	–	1.0	5.0	36.0	41.0	4.41
		–	1.2	6.0	43.4	49.4	
	Ability to delegate rights	–	2.0	5.0	40.0	36.0	4.33
		–	2.4	6.0	48.2	43.4	
	Ability to design target organiza-tional-human structures required for operation of highly automated produc-tion parks	1.0	3.0	17.0	39.0	23.0	3.96
		1.2	3.6	20.5	47.0	27.7	
	Prognostic abilities	1.0	2.0	7.0	39.0	34.0	4.24
		1.2	2.4	8.4	47.0	41.0	

Source Own development based on research employees in the enterprise (average score 4.36; 43.4% of the indications for 5-point score).

Monitoring the inventory level of raw materials, materials, products or other means of production used in work, supervision over production plans and implementation of the enterprise's budget principles—are sample tasks that, in the context of Industry 4.0, are faced by a contemporary manager. Individuals employed in this position will be responsible for supervision over the orders schedule or performance of the work plan as well as preparation of studies on the basis of which the efficiency of the production process is specified. The managers responsible for the continuity of operations in an enterprise are therefore expected to have planning abilities, which, for the surveyed managers, foreshadow a high level of performance of the mentioned activities (average score 4.29; 43.4% of the indications for 5-point score). In the context of the above, attention is paid to prognostic abilities (average score 4.24; 41.0% of the indications for 5 point score) implying strategy formulation and planning based on the respective methods, as necessary to create the future of the company. It is a basic task of the executives. Managers 4.0 must have the ability to forecast the future position of the company and take account of different options of its development, see the opportunities and identify the risk.

Conflicts are unavoidable and certainly inherent in professional life. They are a frequent and natural phenomenon, resulting from the dynamics of the processes taking place between people. However, it is certain that it can be learned how to prevent conflicts, neutralize their effects and solve them for the benefit of both parties involved—which is proven by declarations of the surveyed managers; they declare a high level of empathy and self-control, which proves their emotional maturity (average score 4.27; 44.6% of the indications for 5-point score).

In its job, a manager is responsible, on the one hand, for good management of the entrusted management area, and, on the other hand, for improvements and new solutions permanently raising the company's goodwill, namely for their objectives. Therefore, the ability to imagine what the company is to achieve, what is the desired condition as well as the ability to define indexes allowing to identify that it is already the target condition—assimilated by the surveyed managers on a very high level (average score 4.23; 42.2% of the indications for 5 point score)—proves a high level of their maturity.

A mature manager, in order to effectively perform management functions and efficiently perform their tasks, should do all their best to ensure that communication in the organization is constructive. Development of correct relations with subordinates and partners, organizing teamwork and group-based making of the most important decisions require the manager to have perceptive skills (average score 4.22; 41.0% of the indications for 5 point score).

With the high self-esteem of the mentioned desiderata (average above 4.00) it is necessary to mention a slightly lower level of assimilated skills of designing target organizational-human structures related to the operation of highly automated production parks (average score 3.96; 27.7% of the indications for 5-point score) and the ability to build, standardize dictionaries of the terms related to modern technologies present between supplier–company–client (average score 3.77; 21.7% of the indications for 5 point score). While the level of assimilation of these two competencies does not raise any greater anxiety among the authors, attention must be paid to the need to immediately improve research skills (average score 3.78; 20.5% of the indications for 5 point score), especially that a mature manager 4.0 seems like a person who independently plans and performs research tasks or expert's studies using advanced technologies and research tools as well as documents and interprets the obtained results.

The made analysis of the level of managers' abilities and skills, which was codified in the form of 15 questions, authorizes the authors to determine that managers demonstrate a significant maturity level, what makes them able to function in Industry 4.0.

In order to perform the next stage of manager 4.0's maturity assessment, a set of 14 assessing indicators was prepared (Table 8).

Efficient management is also the art of clear and concise formulation of objectives and skilful communication with people. A mature manager, in order to effectively perform management functions and efficiently perform their tasks, should do all their best to ensure that communication in the organization is constructive. Communication skills—a characteristic highly assimilated among the surveyed managers (average score 4.57; 66.3% of the indications for 5-point score) allows proper relations to be established and maintained as well as organization of cooperation and common work with subordinates, customers and other partners of the organization, facilitating and improving performance of one's own tasks.

Building personal authority and image are important personal traits of each manager, significantly affecting his or her maturity. Apart from formal authority, giving the right to command (issue commands), but not always imposing obedience, a manager should have personal authority. It is gained by skilfully leading and being a leader, which is a specialty of the surveyed managers (average score 4.40; 53.0% of the indications for 5 point score) whose management is based to a certain extent on sense and intuition (average score 4.29; 50.6% of the indications for 5 point score).

A mature manager 4.0 is a person open to building value added, responsible, resistant to stress, operating without complexes, self-confident and having high self-regard. He or she is characterized by creativity, a sense of strategy and courage in making decisions. A high-class manager with extensive knowledge will not create a productive team of employees, pursuing the company's objectives and strategy, unless he or she has a high level of emotional intelligence. Some have such abilities in a way naturally, others must learn correct ways of conduct. One is certain: a manager 4.0 should have a high level of EQ. It is a person focused on action, likes risk and often faces difficult situations. The made analysis of the level of personal characteristics, codified in the form of 14 questions, authorizes the authors to determine that the managers subjected to the study demonstrate a significant maturity level, which makes them able to function in Industry 4.0 (Table 9).

A mature manager 4.0 is a person focused on cooperation, success and development. He or she is characterized by tactful behaviour, truthfulness, justice, honesty, kindness, high personal culture as well as ambition and professional passion. Has a sense of self-fulfilment, doing what he or she actually wants to do.

Table 8 Characteristics and predispositions—assessment of maturity of manager 4.0

	Descriptors	1	2	3	4	5	ŚR.
		%					
Characteristics predispositions	Communication skills	–	1.0	6.0	21.0	55.0	4.57
		–	1.2	7.2	25.3	66.3	
	Sense of strategy	–	2.0	8.0	29.0	44.0	4.39
		–	2.4	9.6	34.9	53.0	
	Leadership; being a leader	–	1.0	9.0	29.0	44.0	4.40
		–	1.2	10.8	34.9	53.0	
	Focus on risk	1.0	3.0	13.0	29.0	37.0	4.18
		1.2	3.6	15.7	34.9	44.6	
	Emotional intelligence	1.0	2.0	8.0	29.0	43.0	4.34
		1.2	2.4	9.6	34.9	51.8	
	Sense and intuition	1.0	2.0	11.0	27.0	42.0	4.29
		1.2	2.4	13.3	32.5	50.6	
	Openness to building value added	1.0	4.0	16.0	35.0	27.0	4.00
		1.2	4.8	19.3	42.2	32.5	
	Creativity	–	2.0	10.0	35.0	36.0	4.27
		–	2.4	12.0	42.2	43.4	
	Courage in making decisions	1.0	3.0	8.0	38.0	33.0	4.19
		1.2	3.6	9.6	45.8	39.8	
	Self-confidence; confidence; self-esteem	1.0	3.0	9.0	28.0	42.0	4.29
		1.2	3.6	10.8	33.7	50.6	
	Responsibility	–	2.0	7.0	28.0	46.0	4.42
		–	2.4	8.4	33.7	55.4	
	Vision	–	3.0	8.0	31.0	41.0	4.33
		–	3.6	9.6	37.3	49.4	
	Resistance to stress	2.0	5.0	12.0	35.0	29.0	4.01
		2.4	6.0	14.5	42.2	34.9	
	Absence of complexes	2.0	4.0	9.0	35.0	33.0	4.12
		2.4	4.8	10.8	42.2	39.8	

Source Own work based on research

A mature manager 4.0 needs not only vision, authority, energy, imagination and strategy formulation ability, but also the skills of activating the so-called soft factors, as kind atmosphere at work or entrepreneurial thinking. And thus, he or she must show courage, sincerity as well as strong will and a high level of aspiration and ethical–moral attitude. The study of the level of attitudes, motivations and behaviours, codified in the form of 10 descriptors, allows to conclude that the surveyed managers

Table 9 Attitudes, motivations and behaviours—assessment of maturity of manager 4.0

	Descriptors	1	2	3	4	5	ŚR.
		%					
Attitudes, motivations behaviours	Focus on cooperation	–	2.0	10.0	35.0	36.0	4.27
		–	2.4	12.0	42.2	43.4	
	Focus on success	–	2.0	11.0	32.0	38.0	4.28
		–	2.4	13.3	38.6	45.8	
	Focus on development	–	2.0	11.0	37.0	33.0	4.22
		–	2.4	13.3	44.6	39.8	
	Personal culture	–	–	8.0	24.0	51.0	4.52
		–	–	9.6	28.9	61.4	
	Keeping word	–	–	4.0	24.0	55.0	4.61
		–	–	4.8	28.9	66.3	
	Ethical standards	–	–	6.0	24.0	53.0	4.57
		–	–	7.2	28.9	63.9	
	Ambition; professional passion	–	–	7.0	31.0	45.0	4.46
		–	–	8.4	37.3	54.2	
	Self-fulfilment	–	1.0	8.0	34.0	40.0	4.36
		–	1.2	9.6	41.0	48.2	
	Moral standards; sincerity	–	1.0	7.0	23.0	52.0	4.52
		–	1.2	8.4	27.7	62.7	
	Entrepreneurial thinking	–	2.0	8.0	45.0	28.0	4.19
		–	2.4	9.6	54.2	33.7	

Source Own work based on research

are characterized by a substantial maturity level, what in the opinion of the authors makes them able to function in Industry 4.0.

5 Summary

By the concept of a 'mature manager', the authors understand a person professionally involved in management whose competences can be considered mature from a qualitative point of view. Maturity assessment can be different in each organization, but in each case, for a manager to be mature, he or she must be efficient, predictable and provide high-quality results. Manager's maturity is the ability to achieve the objectives and tasks focused on the systematic delivery of better and better operational results. Manager's maturity is the degree to which his or her competences allow the implementation of the organization's strategic goals. Maturity defines 'the state of being complete, excellent or ready'. It is indicated that maturity develops gradually as a result of a process in which desirable competencies are formed, allowing certain tasks to be performed.

One of the basic research needs is the development of a universal model, to enable assessment of the level of Industry 4.0 manager’s maturity. The need for such an assessment tool is reported from the business environment. To authenticate the existing research gaps, the authors of this research conducted a number of interviews with managers representing the agricultural machinery sector. The obligatory nature of the undertaken research also resulted from their daily observations of the ‘practice’ within the performed professional duties.

The research described in the publication aimed to examine the actual level of maturity of a manager aspiring to function in the era of Industry 4.0. The adopted research methodology allowed the authors to recognize the quantitative and qualitative resource among selected managers of enterprises operating on the Polish agricultural machinery market. The collected research material allowed conclusions to be formulated, these being general and cognitive in nature. In the chapter, a procedure and a tool were proposed, allowing identification of key maturity designata, which, as the authors believe, will contribute to completing, in a fragmentary way, the absence of knowledge in this area.

The maturity assessment method presented in the chapter is part of a comprehensive approach to self-assessment of managerial competencies. It is used to indicate strengths and weaknesses and to identify areas requiring improvement.

The surveyed managers declare a high maturity level in particular areas, which, as the authors believe, proves their transformation according to the concept of the new generation era. A contemporary manager is required to constantly improve his or her knowledge and improve managerial skills. His or her tasks involve, first of all, the analysis of the market and other components of the environment, improvement of the information system, especially IT systems, planning and organization. A manager is ‘mature’ and successful in managerial work, if, apart from knowledge, skills, personal characteristics, attitudes, motivations and behaviours, he or she has vast experience.

Assuming rigid experience requirements, it is assumed that knowledge and skills gained in one field can be used in new circumstances in a new and creative way.

The presented research exhausts the problem area of maturity of a manager aspiring to function in Industry 4.0, however, it is important that, at least to a minimum extent, it becomes a guideline for persons wanting to improve their competencies.

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Partner Sales Networks as Determinants of Road Maps for the Development of the Telecommunications Industry in Poland

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Abstract In the economy, there have always been cooperative agreements resulting from the adopted tactics of enterprises or operational needs. Networking of the implicators of changes and the development of the telecommunications industry in Poland is related to partner sales networks. The creation of network structures results from the search for new forms of task implementation. The text presents a study based on data from 2017 (and earlier years) of the road map of the telecommunications industry in Poland until 2022. System analysis method (network visualization) was used. Individualized development scenarios for four companies forming the telecommunications industry in Poland were developed. In the analysis and visualization of large networks, the "Pajek" program was used. A total of 10,694 network elements and 258,099 relations between them were examined. Among the main tendencies which, in the authors' opinion, will be revealed by 2022 in the telecommunications industry in Poland are reduction of the number of employees, stores and dealers, reduction of sales commission, the need to conduct costly tenders for telecommunications frequencies, actions for increasing the attractiveness of the offer, and partnership with other entity with the objective of combining the offer or selling products.

Keywords Network analysis · Road map of the telecommunications industry · Telecommunications industry in Poland · Relationships · Profitability of the operation

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1 Introduction

Planning at the company's strategic level is one of the fundamental elements considered not only in the context of the system or management phases but also as an opportunity to imply organizational development or in terms of survival on the market. Therefore, one may point to the important role of forecasting future market events and attempts to use both the opportunities associated with the broadly understood diversification of operations and preparation for threats and adverse conditions occurring in the environment and resulting in disruptions.

Contemporary strategic activity should take into account, in addition to economic issues, also environmental protection and the need of the local community. In this context, it should be noted on the idea of sustainable logistics. According to this approach, the basic assumption of logistic activities (including sustainable development) is to effectively use the potential of technology to meet ecological challenges, while maintaining economic growth and improving the competitiveness of the entity on the telecommunications market.

Forecasting and developing alternative scenarios in conjunction with planning is even more important if the market or sector is already mature and shows a slight increase in demand, even if it is in decline and revenues of competitors in the sector are decreasing. This is the situation in the telecommunications industry, which is the subject of the analysis contained in the chapter. Both the subsector of Internet access services and mobile telephony (of key importance for the telecommunications industry) recorded a decline in value in 2015–2017 (revenues of telecommunications operators).

A telecommunications company is an economic entity authorized to carry out economic activity consisting of the provision of telecommunications networks, associated facilities, or the provision of telecommunications services, while a telecommunications entrepreneur entitled to (Raport…, 2018, pp. 5–30)

- provide telecommunications services is called a "service provider";
- provide public telecommunications networks or associated facilities is called an "operator".

The service provider and operator may be the same entity—in this study, all enterprises are both a service provider and an operator.

One may become a telecommunications entrepreneur after the entry into the register of telecommunications undertakings kept by the President of the Office of Electronic Communications (UKE). The telecommunications industry in Poland in the context of functioning and organizational and capital links is an advanced and complex network system (in particular, in the area of sales network).

A network is an organizationally related structure occurring inside and/or outside the enterprise with its own resources and tasks. This structure is also a link between the market and the company, by means of which, for example, the sale of goods takes place.

There are three types of sales networks in telecommunications companies. These are own sales network and partner sales network—also called external or dealership network and mixed networks—where both previously mentioned solutions operate simultaneously. The functioning of own sales network depends entirely on the resources of the enterprise: employees are employed on employment contracts. On the other hand, partner sales networks are usually based on trade agreements, and most of the operating costs are passed on to entities operating in this type of network.

Entities forming a partner sales network are enterprises. Therefore, the lead entity—parent company (forming the network) establishes cooperation on the basis of trade agreements (cooperation agreements) with partners who are to implement the sales processes of products and services for the parent company. In turn, the partners further shape their own sales structures.

The concept of network, in the aspect of economic sciences, describes the structural conditions through which separate nodes (people, computers and enterprises) are connected with each other, through connections (bonds) and flows (Hakansson and Snehota 1995; Child and Faulkner 1998; Ford et al. 2003; Reid et al. 2008; Agndal and Nilsson 2009; Pfohl and Müller 2015).

The network's functioning methods emphasize the appearance of new relationships. The development of network organizations is a part of a wider process of changes taking place as a result of contemporary developmental and competitive challenges (Etzkowitz 2002; von Tunzelman 2004; Luoma-aho and Vos 2010; Metcalfe 2010; Wachnik 2016). A dynamic network becomes a symbol of science, as the only organization capable of attitude-free development or free learning, which can accommodate a multitude of truly divergent elements. In this view, the web is a possible solution, a model of diversity problem (Wasserman and Faust 1994; Kelly 1995, p. 25; Scott 2000; Symon 2000; Dolan et al. 2003; Inkpen and Tang 2005; Kagami 2006).

The study consists of an analytical part containing the results of research on the current state of the telecommunications market in Poland and a utilitarian one, in which the methodology of own research and the road map of the telecommunications industry in Poland until 2022 were included. The purpose of the text presented hereinafter is the presentation of the potential development path.

2 Telecommunications Industry in Poland—Current Status

Telecommunications activity in Poland is connected with several market areas, such as Internet access, mobile telephony, landline telephony and related services (e.g., mobile telephony and mobile Internet, mobile Internet and television, etc.). However, the analyses included in the research part concerned mobile telephony and mobile Internet. The functioning of the telecommunications market in Poland is governed by the telecommunications law (Dz. U. of 2018, item 1954).

The number of users of mobile telephony has been systematically declining for several years. At the end of 2017, active SIM cards totaled 53.3 million, which meant a 4% decrease compared to 2016. Thus, the saturation of mobile telephony services was lower and amounted to less than 139% compared to 144% in 2016 (Raport…, 2018, pp. 5–30).

According to Analysys Mason data, the average penetration of mobile telephony services decreased slightly compared to 2016 in selected European countries as well. According to the company, the saturation of mobile telephony services in Poland, which amounted to 134.1%, was still higher than average, at 129. 9%, on the European market. The declining trend in revenues from mobile telephony services started in 2012. In 2017, the total revenues of operators amounted to PLN 15 billion and were almost 11% lower than in 2016. However, despite the decline in the value of the mobile telephony market, it still continued to be the key area of telecommunications activity, which accounted for 38% of total revenues from this sector (Raport…, 2018, pp. 5–30).

Saturation of broadband Internet (landline and mobile) in Poland in 2017 was at the level of 103% per household. In turn, penetration in relation to citizens amounted to 38% in 2017. The value of the Internet access services market in 2017 was at the level of PLN 4.7 billion. It was a drop of about PLN 0.2 billion compared to 2016. Along with revenues, the average monthly revenue per subscriber also decreases. In 2016, it amounted to PLN 28.2, a year later, it was lower by PLN 1 and reached PLN 27.2 (Raport…, 2018, pp. 5–30).

The revenue structure in 2017 was very similar to the one from 2016. The operators gained the greatest revenue from the Internet access service using dedicated mobile devices (about 35% of revenues). The second place was taken by xDSL technology (22%) and the third by TVK cable modem (20%) (Raport…, 2018, pp. 5–30).

The number of subscribers to the network access service remained at a similar level when compared to 2016. In 2017, there were approximately 7.1 million users of fixed-line Internet. 7.4 million people used mobile access. In total, approximately 14.5 million users had access to the Internet service (Raport…, 2018, pp. 5–30).

It should be noted that in the following years, the situation on the telecommunications market due to the intensity of competitive struggles, strong focus on reducing prices of services by operators, as well as the decreasing number of customers may be even worse. The telecommunications operator is under legal and administrative pressure, especially in the context of new areas of activity (Grzybowska et al. 2014, pp. 1311–1319). Therefore, it seems reasonable to create forecasts and identify determinants of changes that may occur both in the environment and within telecommunications entities.

3 Methodology of Own Research

In the research process, the entire statistical population was inferred from the information collected during the statistical (representative) sample survey (Neyman 1938, pp. 101–116).

The research sample consisted of all (four) enterprises which at the same time constituted the entire telecommunications market in Poland in accordance with the adopted base criteria. Based on the data of the Office of Electronic Communications, it can be concluded that there were 23 business entities in 2015 in the telecommunications market in Poland. However, only four entities meet the following criteria:

- enterprises operate on the territory of the Republic of Poland,
- enterprises operate, in particular, in the mobile telephony segment,
- enterprises covered by the study use partner networks,
- partner networks, operating at the request of enterprises in the telecommunications industry in Poland, carry out sales both on the business market and on the individual customer market (sales to other natural persons),
- enterprises offer postpaid services, i.e., subscription services.

The aim of the research was to develop a road map of the telecommunications industry in Poland until 2022. The leading method in this study was network analysis, which is used to detect, describe, and identify relationships among groups of people or organizations (Reid et al. 2008, pp. 345–352), as well as broadly understood business operations (Kijkuit and van den Ende 2010, pp. 451–479).

The following network analysis indicators were used:

- node betweenness, the ratio of the number of shortest paths between any two nodes going through a given node to the total number of all shortest paths, sometimes betweenness is normalized in such a way that the maximum betweenness in the network is 1, betweenness indicates which nodes are the most important ones, i.e., the probability with which a given factor (element) is crucial for all flows in the network;
- the closeness of a given node is the average length of the shortest paths between this node and all other nodes (it is the expected distance between a given node and any other node), it is also a measure of the reach of a given node;
- cumulative value of a vector, the summed values of all connections from a given network node, it parameterizes the scope of impact of a given factor on flows in the network.

The discussed method is supported by various IT applications such as the "Pajek" program (used in this study), developed by Vladimir Batagejl and Andrej Mrvar, Brzeziński and Wyrwicka (2015), Brzeziński et al. (2016), Program for Large Network Analysis (2015), Brzeziński and Wyrwicka (2018), thanks to which it is possible to show the relationship and interaction between the elements forming the partner sales networks and individual factors.

Network analysis is a combination of graph theory, statistics, computer science, and matrix algebra and is applied in economics (Wasserman and Faust 1994). Such an approach can be classified as a quantitative and qualitative combination in which quantitative data are subjected to qualitative analysis and interpretation (Scott 2000).

4 Road Map of the Telecommunications Industry in Poland Until 2022

The road map, including projections of possible changes, trends, and directions in the future, were prepared on the basis of analysis and network visualizations of partner sales networks of four telecommunications companies (marked as A, B, C, and D), which are the development implicatures of the entire industry. The forecast is medium-term and covers the period of the next 5 years (i.e., until 2022).

To identify the impact force, the scale commonly used in scenario methods was adopted. During the research process, unique factors were selected for each of the entities whose impact is stimulating (positive impact force) from 1 to 5 (where 1 is a very weak impact and 5 a very strong impact) or destimulating (negative impact force) –1 to –5 (where –1 is a very weak impact and –5 a very strong impact). For each company, an individual set of factors has been defined (which may be stimulating or destimulating). The factors were selected on the basis of the in-depth interview conducted in connection with the case study method with the person managing the partner sales network in the company. This is due to the specificity of each entity's operation and other conditions of the partner sales networks.

The factors and the strength of their impact on partner networks of the surveyed enterprises are presented in Table 1.

In order to identify the factors that will have the greatest impact on the partner sales network of the companies covered by the research, three indicators from the field of network analysis will be applied: betweenness value, closeness value, and cumulative vector value.

For each company, the values of betweenness, closeness, and cumulative vector were determined, and a visualization of the partner sales network was created—which, in addition to the employees' structure, also included the impact (stimulating or destimulating) of individual factors.

It should be noted that extremely complex dependence networks were created during the analyses.

In **enterprise A**, the number of elements making up the network was **2673**, while the total number of connections (relations) was **83,243**. Such a number of relationships is difficult to illustrate in the figure. In **enterprise B**, the number of elements forming the network was **2428**, and the number of connections (relations) was **61,004**. In **enterprise C**, the number of elements making up the network was **3777**, and the number of connections (relations) was **71,825**. **In enterprise D**, the number of elements making up the network was **1816**, and the number of connections (relations) was **42,027**.

In enterprise A, in terms of the value of betweenness, the highest values applied to work organization, workload, meetings and meetings with management, work experience, lowering sales commission, current work, stress, enterprise values, sales standards, partnership with another telecommunications entity, price competition, tenders for telecommunications frequencies and company image (all at 0.45026).

Table 1 Identified factors affecting partner sales networks of enterprises A, B, C, and D

Entity	Factors
A	Absences, errors during work, lack of documentation for the contract, shortages of expected products in the warehouse, manager's decisions, additional tasks, form of placing orders, number of clients, the amount of current work, completeness of documents, workload, lowering sales commission, responsibility for the level of service, responsibility for achieving goals, organization of work, partnership with other telecommunications entity, creation of new stores, customer contact preferences, promotions, telecommunications frequency tenders, reduction of partner network, advertising with well-known people, complaints, meetings, sales standards, work experience, stress, price competition, enterprise values, employment size, company image, cooperation with other departments, business trips, communication guidelines for employees, team management, reporting complaints by customers, customer knowledge
B	Absences, attractiveness of the offer, customer base, mistakes at work, cost reduction, manager's decisions, additional tasks, amount of current work, completeness of documents, consolidation of telecommunications and energy services, number of employees, methods of work, customer expectations, responsibility for service level, planned reduction of stores and dealers, dismissals program, tenders for telecommunications frequencies, complaints, way of placing orders, sales standards, work experience, stress, company values, implementation of a new strategy, business trips, team management, management meetings, customer knowledge
C	Absences, attractiveness of the offer, manager's decisions, additional tasks, investing in fast wireless Internet technologies, amount of current work, number of employees, company brand, lowering sales commission, responsibility for service level, responsibility for achieving goals, planned reduction of stores and dealers, tenders for telecommunications frequencies, advertising with well-known people, work experience, application of ISO 9001:2008 standard in customer service, stress, business trips, team management, management meetings, customer knowledge
D	Absences, attractiveness of the offer, manager's decisions, additional tasks, development philosophy, amount of current work, number of employees, company brand, network modernization, lowering sales commission, responsibility for service level, responsibility for achieving goals, planned reduction of stores and dealers, possession of an environmental management certificate ISO 14001:2004, tenders for telecommunications frequencies, complaints, meetings, work experience, stress, launch of fast Internet networks covering the majority of the country, launch of banking services, price competition, business trips, team management, customer knowledge

In terms of closeness, these were promotions, work organization, workload, number of clients, lowering sales commission, current work, stress, mistakes at work, enterprise values, partnership with other telecommunications entity, price competition, and company image (all at 0.986706). The highest destimulating (negative) cumulative value of the vector had such factors as lowering the commission for sales (–13180.000000) and reduction of the partner network (–9400.000000). The highest positive (stimulating) value was the number of clients (10540.000000), partnership with other telecommunications entities (10544.000000) and tenders for telecommunications frequencies (13180.00000).

In company B, the factors of the highest betweenness value include additional tasks, amount of current work, responsibility for achieving goals, work methods, participation in management meetings, work experience, stress, enterprise values, tenders for telecommunications frequencies, attempts at cost reduction, and consolidation of telecommunications and energy services (all at 0.57100). Factors with the highest value of closeness indicator are additional tasks, the amount of current work, responsibility for achieving goals, methods of work, work experience, stress, enterprise values, tenders for telecommunications frequencies, pursuit of cost reduction, and consolidation of telecommunications and energy services (all at 0.98595). Referring to the value of the cumulative vector, it is worth distinguishing factors such as the attractiveness of the offer, enterprise values, consolidation of telecommunications and energy services, work methods, pursuit of cost reduction, and the amount of current work. In turn, destimulating factors include dismissals program, stress, planned reduction of stores and dealers, mistakes during work, additional tasks, and absences.

On the other hand, in enterprise C, factors of the highest betweenness value include investing in fast wireless Internet technologies, additional tasks, amount of current work, attractiveness of the offer, meetings with management, work experience, stress, and tendering for telecommunications frequencies (all at 0.88078). The highest value of closeness was recorded in the following factors: investing in fast wireless Internet technologies, additional tasks, amount of current work, attractiveness of the offer, management meetings, work experience, stress, and tenders for telecommunications frequencies (all at 0.994731). In terms of a summed vector with positive force, the highest value had investing in fast wireless Internet technologies, attractiveness of the offer, and tenders for telecommunications frequencies (18780.000000). The largest destimulating impact had the planned reduction of stores and dealers and reduction of sales commission (both at –13250.000000).

In enterprise D, however, the factors of the highest betweenness value included the development philosophy, network modernization, possession of ISO 14001:2004 environmental management certificate, additional tasks, amount of current work, attractiveness of the offer, work experience, stress, the company's brand, tenders for telecommunications frequencies, and price competition (all at 0.059049). The factors of the highest closeness value include the development philosophy (70/20/10), network modernization, possession of ISO 14001:2004 environmental management certificate, additional tasks, amount of current work, attractiveness of the offer, work experience, stress, company's brand and price competition (all at 0.986949). The highest value of the accumulated vector with a positive impact on the functioning of the network was observed in the range of tenders for telecommunications frequencies (8955,000000), development philosophy (70/20/10) (8955,000000), and possession of environmental management certificate ISO 14001:2004 (8955,000000). The factor of the highest destimulating influence has been the lowering of the sales commission (–6500.000000).

Selected factors and the strength of their influence on individual elements of the network were used to develop a road map of the telecommunications market in Poland (Table 2).

Table 2 Road map of the telecommunications market in Poland

Entity	Road map
A	Synthesis of the road map until 2022: in the partner sales network, there will be a reduction in the number of employees and lowering of the sales commission. This is mainly due to lower sales profitability and growth dynamics of active SIM cards in Poland. Winning tenders for telecommunications frequencies and entering into partnerships with another telecommunications entity may give the enterprise access to the provision of new services, which may slow down the process of lowering the sales margin
B	Synthesis of the road map until 2022: the most important factors are reductions in the number of stores and dealers, attractiveness of the offer, tendering for telecommunications frequencies, attempts at cost reduction, and the consolidation of telecommunications and energy services. Such a combination of variables suggests, on the one hand, a quantitative reduction in the number of employees and, at the same time, an intention to maintain at least their current market share
C	The synthesis of the road map until 2022: the management of company C, until 2022, will strive to reduce the structure of the partner sales network, there will also be a reduction in commission payments for the sale of products and services. Actions will also be taken to create a wireless mobile Internet infrastructure. Final decisions regarding tenders for telecommunications frequencies will be crucial
D	Synthesis of the road map until 2022: company D management board will take actions related to reducing the number of employees of the partner sales network and the commission for the sale of products and services. There will be a price fight with competitive enterprises, combined with building the attractiveness of the offer, conducted with the objective of obtaining or improving the position on the market—but with considerably smaller sales forces. The results of telecommunications tenders and investments in infrastructure modernization will also be important
Total market	The next 5 years will be determined by factors such as telecommunications tenders, building the attractiveness of the offer, and investing in telecommunications infrastructure. It can be assumed that the commission for the sale of products and services will be further reduced, the competitive struggle between market participants will increase, the number of stores and dealers will be reduced together with the profitability of sales

The most important indication for the roadmap is the fact that in the next 5 years, there will be a reduction in the number of people involved in the activities of the partner sales network. This is related to the decreasing growth rate of the telecommunications market and the deterioration of sales profitability.

5 Conclusions

The main factors that will shape the scope of activity and the structure of the researched telecommunications companies in the period up to 2022 include

- reductions in the number of employees, stores, and dealers,
- lowering the sales commission,
- tenders for telecommunications frequencies,
- attractiveness of the offer,
- partnership with other entities with the objective of combining the offer and sale of services and products.

In addition to the factors discussed above. The analysis also included promotions. They constitute an extremely important determinant of the activity of the entire sales network (not only partner network). Having an offer with unique features that distinguish a given service or product among competitors is an asset that cannot be overestimated. The price competition, related to the promotions, will grow in the coming years (Brzeziński and Wyrwicka 2018).

Therefore, it can be concluded that there will be a reduction in the number of sales representatives and a reduction in their sales commission. This is mainly due to lower sales profitability and growth dynamics of active SIM cards in Poland. Thanks to winning tenders for telecommunications frequencies and entering into partnerships with other entities, the companies from the telecommunications industry in Poland will be able to gain access to the provision of new services. The attractiveness of the offer is a key aspect in maintaining the desired sales dynamics despite the reduction of resources involved in sales.

Telecommunications enterprises generally implement two types of strategies: immediate and long-term. The first concerns new customers and taking over customers from competitors, the second concerns staying on the market. The solutions regarding telecommunications frequencies are crucial. The first one was for 1800 MHz, for which two companies are going to pay PLN 500 million. The most important, however, will be the fight for the frequency of fast mobile Internet, 800 MHz. Practically every company is focused on supplementing the offer with such services.

There is a price competition in the industry that is beneficial to customers, but it is definitely negative for individual telecommunications entities. It led to the introduction of unlimited services and subsequent reduction of unit prices. This results in a deterioration in the profitability of the operation. The concentration on the current competition for the client stopped the investments in modern infrastructure. In the near future, tenders for telecommunications frequencies will be finalized, which require significant financial outlays. The result is that the market environment will be extremely demanding. In such conditions, building a competitive advantage can be based on specialist knowledge and unique skills of employees (Lupicka et al. 2018; Grzybowska and Lupicka 2017).

As an additional element shaping the telecommunications industry in Poland, the concept of industry 4.0 should be indicated. The Fourth Industrial Revolution is associated mainly with factories; however, it is a far broader notion, referring also to other areas of organization activities, e.g., global supply chain management and telecommunications. This concept goes beyond a single company and is carried over to a network of links between organizations where data are integrated into a cloud and processes are organized along a supply chain in virtual space (Szozda 2017). Industry 4.0 technologies is an accelerator or catalyst that enables individualized solutions, flexibility, and cost savings in industrial processes (Saturno et al. 2018).

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