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Digital Technology for Digital Supply Chain – The Clusters Identification

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Abstract:

Purpose: *On the basis of the conducted research global trends that relate to technological support (digital technologies, DT) for the Digital Supply Chain were identified. It resulted in the creation of a set of eight key non-one-directional technological support trends. The goal is of cognitive and conceptual character.*
Design/Methodology/Approach: *The research implemented benefits from the text mining method and cluster analysis using genetic algorithms. Made it possible to identify conceptual clusters by singling out a group of similar objects which coexist intensively.*
Findings: *The use of digital technologies in supply chains will be essential to ensure even and faster global recovery. Over the next three years, we are expected to experience various types of economic turbulence, supply chain disruptions, and unforeseen events. It is clear that neither resilience nor governance will be possible without reliable and advanced digital technologies.*
Practical Implications: *In the near future, digitization will play an even greater role in the operation of supply chains. It will increase the information transparency of supply chains and increase the resilience of supply chains.*
Originality/Value: *The article indicates the directions of research and works on digital technologies and digitization in the coming years in Digital Supply Chains.*

Keywords: *Digital transformation, digitization, digital supply chain technologies, Digital technology assets, Cluster Analysis, text mining method.*

JEL codes: *O31, O32.*

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1. Introduction

A feature of the contemporary complex systems is the continuous expansion of economic impact in space. Not only the structure and the configuration of complex systems undergo constant change, but also their activity and scope of action. Examples of complex systems are organisms, infrastructure such as power grid, transportation or communication systems, social and economic organizations (like supply chain), and ultimately the entire universe. As such systems emerge in many different fields, their similarities have become the subject of their independent area of study.

The system is understood (Nowakowski, 2013): (1) an internally coordinated configuration of elements possessing a specific operational structure => a supply chain consisting of a series of cooperating enterprises, (2) a set of modes of action, the performance of complex activities => procedures of action, (3) a set of organizational rules, a collection of norms, rules, and standards, which are in force in a given field of activity, (4) a comprehensive and structured set of tasks interconnected with one another by specified logical relationships.

Systems theory allows the transfer of research results from one field to another (Relich, 2016; Burduk, 2010; Xing and Dugan, 2002; Majdzik *et al.,* 2016; Jasiulewicz-Kaczmarek, 2015). Complex systems are characterized by, dependencies, competition, relationships, or other types of interactions between their elements or between a given system and its environment. This causes difficulties in modeling the behavior of complex systems.

Digital economy is of highly dynamic technological progress, observable in all economic processes (Szopa and Cyplik, 2020). Digital economy serves as the new paradigm of economic development and reformats business relationship on the basis of the use of information (Vovchenko *et al.*, 2017). Now, the supply chains are in a state of dynamic transformation, digital revolution, pandemic reality, and social changes continue to create new, previously unknown phenomena. Digital supply chains have revolutionised manufacturing enterprises.

Based on the research, global theoretical trends related to modern supply chains were identified. It resulted in developing a set of 14 key supply chain directions (Grzybowska and Stachowiak, 2020). One of them is the Digital Supply Chain.

The publication is focused on the issue of technological support for the Digital Supply Chain (DSC). The article aims at presenting eight key non-one-directional technological support trends. The goal is of cognitive and conceptual character. Digital supply chains have revolutionised manufacturing enterprises.

The structure of the work is as follows: section 2 presents the literature review. The subsequent part of the article discussed the research methods. Section 4 focuses on and comments results of the research – and presents the main trends.

2. Literature Review

Development of the concept of supply chains is proceeding from little differentiation of generality towards increasing transparency and diversity. Of course, the transition from one form to another is spread over time. Such evolution requires energy related to the creative effort of many researchers. This evolution leads to growing unification and differentiation of knowledge, which becomes more complex and precise.

Research shows a nonlinear development of concepts (Grzybowska, 2021) and abrupt changes in thinking (Figure 1). However, it can be observed that subsequent concepts related to the development of the functioning of supply chains use an increasing amount of information exchanged, which allows them to react quickly and accurately to the emerging market changes. For this reason, the subsequent stages of the development of the concept of integrated supply chains report an increasing need for digitization of data exchanged along the supply chain between cooperating entities.

Increasing global uncertainty and constantly changing customer requirements mean that traditional interactions between partners are no longer sufficient to manage supply chains (Rasool *et al.*, 2022). Traditional cooperation lacks the speed, transparency, flexibility, and timely actionable information needed to remain competitive in the current business environment (Büyüközkan and Göçer, 2018).

This challenge is met by digital technologies that solve enterprises' most critical problems currently reported. They enable the direct connection of business partners throughout the supply chain, which helps reduce complexity, and cost and increases volume and flexibility, leading to higher service levels (Agrawal and Narain, 2018). For this reason, the implementation of digitization in supply chain management can be considered a revolutionary change.

Digital technologies that are currently developing or developed over the next few years will substantially alter the business environment. Digital Supply Chains can have the capabilities to process an extensive amount of information and to empower supply chain partners to move together to collaborate and communicate.

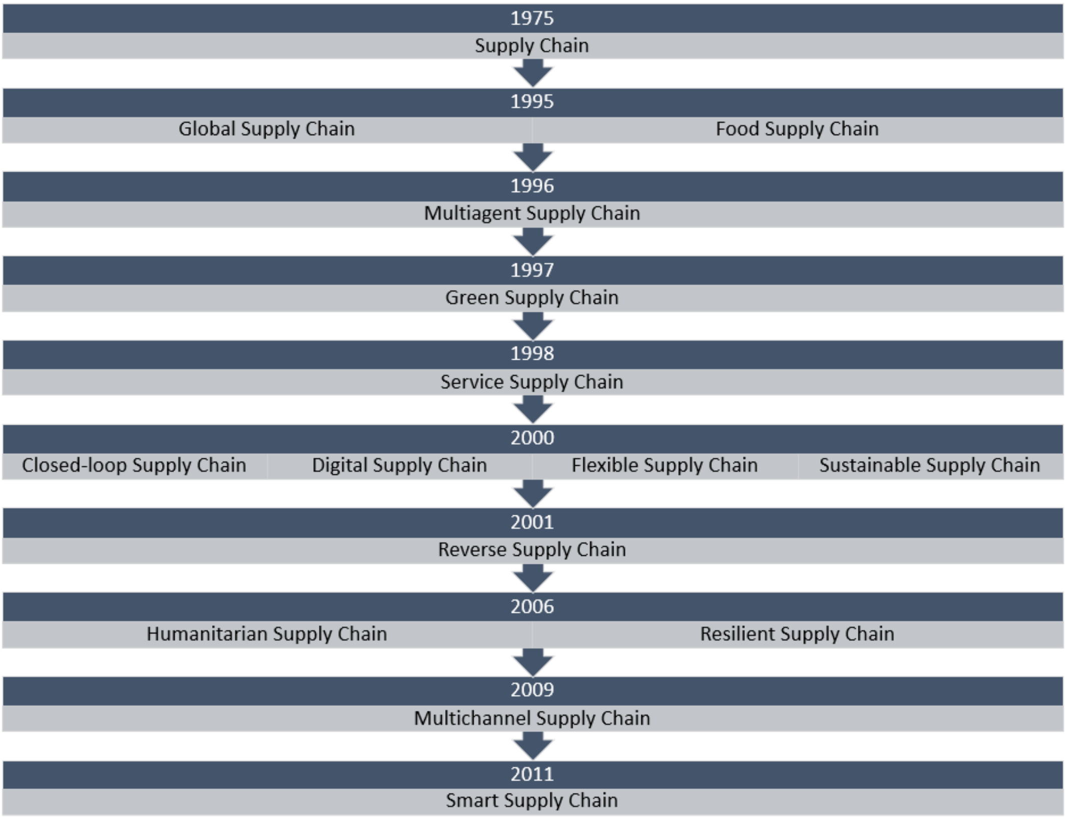
Digital Supply Chain management can be defined as powerful innovative technologies that are capable of changing the traditional way of doing various processes of the supply chain like supply chain planning, task execution, interacting with all the participants of the supply chain, achieving integration among the members of supply chain and enabling new business model (Agrawal and

Narain, 2018). In a traditional supply chain, organizational structures are bound by their geography/function, act in silos, and are reluctant to share information openly.

The IT systems used are limited to exchanging information within individual enterprises, and their functionality is often not fully exploited. Contrary to traditional supply chains, Digital Supply Chain uses available systems (e.g., software, hardware, and communication networks) that support activities performed by globally distributed partners to buy, make, store, move and sell a product (Bhargava *et al.*, 2013).

Information distribution in DSC is adapted to the changing needs of enterprises, thanks to which material flow systems are reliable, agile, and effective, and at the same time, facilitate collaboration and communications across digital platforms (Raab and Griffin-Cryan, 2011). In their research, Weit et al. also emphasize that in the traditional supply chain, technology is used to collect, store, and present data, while in Digital Supply Chain, technology is used to make strategic decisions (Wei *et al.*, 2019).

Figure 1. *Supply chain trends recognized in own research*



Source: *Own study.*

We are currently observing an increasingly intensive development of technologies and concepts that support Digital Supply Chain management. Among the most frequently described innovations in the literature, the following are indicated (Büyüközkan and Göçer, 2018): Augmented Reality (AR), Big Data (BD), Cloud Computing (CC), Robotics (R), Sensor Technology (ST), Omni Channel (OC), Internet of Things (IoT), Self-Driving Vehicles (SDV), Unmanned Aerial Vehicle (UAV), Nanotechnology (N) and 3D Printing (3DP).

Determining all potential benefits of different Digital Supply Chain implementations is a tedious task, as most of the benefit is not derived from the DSC itself but from the numerous solutions that arise from DSC implementations (Büyüközkan and Göçer, 2018). Integration of Digital Supply Chain can provide various benefits to supply chains and logistics. The DSC provides more visibility of the material flows along the value chain. It reduces any bullwhip effects by making available real-time information for making accurate and timely decisions that will support the organizational performance objectives such as revenue, profit, market share, quality, responsiveness, cost, dependability, and sustainability (Ageron *et al.*, 2020).

The advantages of the Digital Supply Chain are (Ageron *et al.*, 2020): (1) agility, (2) integration activities, (3) effective optimization, (4) transparency, and (5) holistic decision making. The results of the literature research conducted by Büyüközkan and Göçer. Based on a literature review, these authors have identified the advantages of DSC, which are the result of combining eleven main functions that should be achieved through the supply chain through digitization. These are (Büyüközkan and Göçer, 2018): (1) speed; (2)flexibility; (3) global connectivity; (4) real-time inventory; (5) intelligent; (6) transparency; (7) scalability; (8) innovative; (9) proactive; (10) eco-friendly; (11) cost-effective.

Digital technologies make supply chains faster, more efficient, and more reliable. But on the other hand, they introduce a higher level of complexity and variables into the system that require more sophisticated metrics to measure its performance (Cho *et al.*, 2012; Ralston *et al.*, 2015). Formulating metrics adequate to the needs of managing such complex organizations is a challenge for modern supply chains. At the same time, it is worth noting that many benefits of digitalization in supply chains are still untapped because crucial organizational transformations and their management are often neglected or postponed (Büyüközkan and Göçer, 2018).

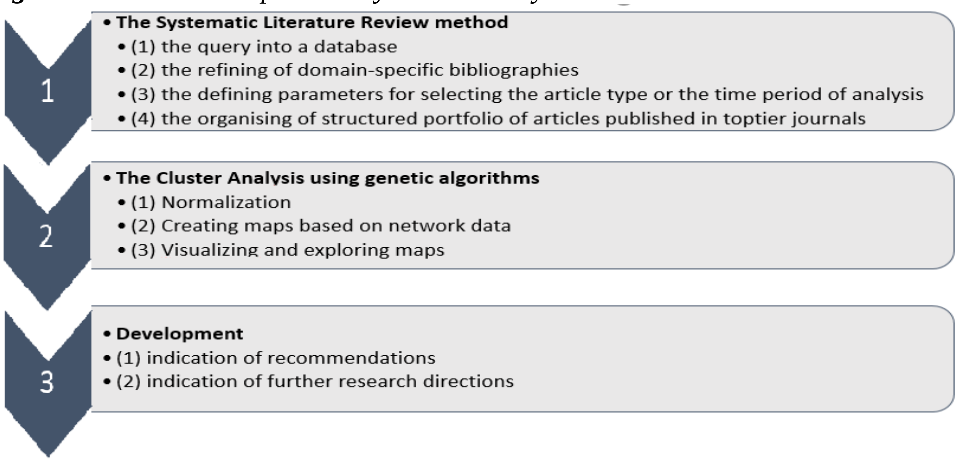
Despite extensive knowledge of the digital supply chain, the potential of the Digital Supply Chain is still relatively unknown.

3. Methodology

The conducted study considers research methodology based on the systematic literature review and knowledge visualization. The overall research plan was divided into three stages (Figure 2):

- Step 1 – the bibliometric analysis conducted employing the systematic literature review method,
- Step 2 – the identification and classification of global trends technological support for the Digital Supply Chain, performed by cluster analysis using genetic algorithms,
- Step 3 – development of recommendations and indication of further research directions.

***Figure 2**. Research steps to carry out the study*



***Source:** Own study.*

The bibliometric analysis conducted employing the systematic literature review method (Strozzi *et al*., 2017) made it possible to evaluate the research results and comprehensively present the global scientific output. It provided essential information about the worldwide structure of science and showed its dynamics. The analysis was performed in three stages: (1) the scope of the analysis was determined; (2) specified keywords, document types, and types, and language; (3) activities consisting of: selection, evaluation, and synthesis of the existing set of reviewed and registered scientific articles in the analyzed databases were carried out.

The result of this approach is a collection of scientific publications, identified in a systematic, open, comprehensive, and repeatable manner and yielding the same results (Fink, 2010). The identified set of selected scientific publications was used to move to the second stage and conduct further research.

The four-stage genesis of a bibliometric review as a methodological procedure focusing on (Bartolacci *et al.*, 2020; Kipper *et al.*, 2020; Goyal and Kumar, 2021; Deepa, 2018):

- Stage 1 – the query into a database,
- Stage 2 – the refining of domain-specific bibliographies,

- Stage 3 – the defining parameters for selecting the article type or the time period of analysis,
- Stage 4 – the organizing of a structured portfolio of articles published in top-tier journals,

is adopted in the current study. The search query string used in each stage and the search results of each stage is shown in Table 1.

The first stage is defining the appropriate keywords for bibliographic search in the WoS and SCOPUS databases. The keywords used for bibliographic search include 'Supply Chain' AND 'Digital' OR 'Technological support', which resulted in a total of 11,099 documents. The second stage is defining the focus of the subject area of bibliographic search to 'Engineering' AND 'Business Economics', which resulted in a total of 4,317 documents. The third stage was restricted to 'journal articles' (excluding conference papers, book chapters, reviews, conference reviews, books, editorials, and notes), resulting in 2,309 research articles published in the journal.

The fourth refinement stage is based on the bibliographic attribute of 'Source Title'. This stage was restricted to 'publication years', resulting in 2,232 research articles published from 01.2000-12.2021. The fourth stage refinement was limited to Source Journals categorized as A* and A-rated journals in the Australian Business Deans Council recommended list of Quality Journals 2019 (6 December 2019), resulting in 567 research articles from 39 source titles.

The identification and classification of global trends in Digital Technology for Digital Supply Chain, performed by Cluster Analysis using genetic algorithms (step 2, Figure 2), made it possible to identify conceptual clusters by singling out a group of similar objects which coexist intensively. The study was conducted using the VOSviewer free software. For the purpose of the work, VOSviewer version 1.6.9 was used, which was made available on 29 August 2018.

The main advantage of VOSviewer, which decided to choose this and not another IT tool, is the continuous process of updating the software functions and a relatively easy way to use it. A particular positive feature is that the program completely focuses on visualizing bibliometric networks.

Table 1. *Four-stage bibliographic search and results*

Search refinement stage	Search query string	Search results (no. of document)
Stage 1	‘Supply chain’ AND (Digital OR ‘Technological support’)	11,099
Stage 2	‘Supply chain’ AND (Digital OR ‘Technological support’ AND (LIMIT-TO (SUBJAREA, ‘BUSI.ECON.’ AND ‘ENGIN.))	4,317
Stage 3	‘Supply chain’ AND (Digital OR ‘Technological support’)	2,309

	AND (LIMIT-TO (SUBJAREA, ‘BUSI.ECON.’ AND ‘ENGIN.) AND (LIMIT-TO (DOCTYPE, ‘ART.’ AND ‘PROC.PAP.’))	
	‘Supply chain’ AND (Digital OR ‘Technological support’) AND (LIMIT-TO (SUBJAREA, ‘BUSI.ECON.’ AND ‘ENGIN.) AND (LIMIT-TO (DOCTYPE, ‘ART.’ AND ‘PROC.PAP.’)) and (PUBLIC.YEARS, ’01.2000-12.2021)	2,232
Stage 4	Search refinement by ABDC – A*/A categorized journals (39)	567

Source: *Own study.*

This research stage created (generating) a knowledge map as a semantic map. Semantic maps are generated from various text sources based on individual words extracted from scientific titles, descriptive entries, or descriptors assigned by the publisher provided by the database provider (e.g., ISI keywords) (Börner *et al.*, 2005). Then the so-called clusters are configured on the created knowledge and science maps. Cluster Analysis (CA) is used to create clusters. The result of cluster analysis is the division of a finite set of objects into clusters (subsets). The finite set X consists of n objects, and the finite set A contains m attributes that describe the properties of the object $x \epsilon X$. A grouping of clusters is created during the group (Jain *et al.*, 2009):

Grouping is the primary activity that the researchers perform for cognitive purposes. As a result of the cluster analysis, it is possible to divide a heterogeneous set or set of elements into homogeneous, "similar" subsets. As a result, the objects are grouped into set A and the second set, not A. Each object belongs to exactly one cluster – this assumption concerns "hard" grouping. The conceptual clusters are created using the similarity or distance function (Jain *et al.*, 2009). In this case, the goal is to divide the set of objects into the number of subsets.

This research stage provided important information about the structure of science and showed the dynamics of changes in the directions of scientific research. As a result of cluster analysis, critical global trends in Digital Technology for Digital Supply Chain were identified, and the third stage was initiated.

A cluster is a set of closely related nodes. Each node in a network is assigned to exactly one cluster. A resolution parameter determines the number of clusters. The higher the value of this parameter, the larger the number of clusters (van Eck and Waltman, 2014). Each keyword as an object on the semantic map has a different color. The colors allow you to group keywords that result from the similarity and relationship of concepts and the compatibility of the research topic. Keywords with the same color belong to the same cluster.

The analysis focused on scientific documents published in the period 01.2000–12.2021 in different journals. The authors considered the following two bibliographic data sources: Scopus and WoS. Scopus is a data source produced by

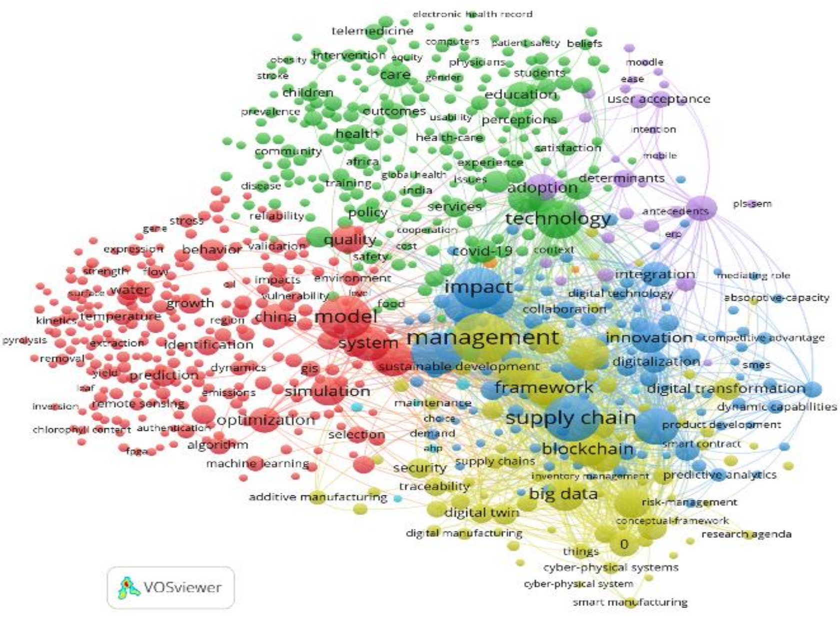
Elsevier. WoS is a data source produced by Clarivate Analytics. The different data sources have other content selection policies. WoS has an internal editorial team for content selection (Visser *et al.*, 2021). Scopus collaborates with an international group of researchers to perform content selection (Baas *et al.*, 2020).

In order to carry out the analysis of knowledge visualization with the help of keyword co-occurrence maps, a set of keywords was separated, which concerns the created local database with a total of 567 scientific papers. A separate set of concepts was subject to the process of "normalization". This means that the specified keywords have been standardized as to form (lowercase/uppercase), and the letter 's' at the end of the keywords have been removed. Noun expressions have been transformed from plural to singular, e.g., "systems" into "system" or "chains" into "chain". This way, many plural, and singular keywords have been unified.

4. Research Results

As a result, a network was created based on keywords. As a result, 3569 keywords were listed that describe the scientific papers identified in the local database over the years 01.2000–12.2021. Among them was a set of keywords that considered the minimum occurrence of keywords. Their total number is 743 expressions. On their basis, a semantic map was developed. The collection of scientific publications from the analyzed period can be divided into seven clusters (Figure 3).

Figure 3. *Visualization of the semantic network*



Source: *Own study.*

Semantic maps are two-dimensional maps in which the keywords are positioned so that the distance between the two keywords reflects their relationship as accurately as possible. This means that the greater the number of co-occurrences of two keywords in scientific work, the shorter the distance between them.

In this way, semantic maps present a visual image of the keywords used to describe identified scientific papers and show their mutual relationship. There is a rule in the construction of semantic maps which says that the greater the number of scientific publications in which a given keyword appears, both in the title, abstract or specified set of keywords, the more clearly the given keyword is presented on the map (van Eck and Waltman, 2014). This means that the more frequently appearing keyword is presented using a larger font or has a larger node – a graphic element on the semantic map (Figure 4).

Table 2. *Clusters with the identified Digital Technology for Digital Supply Chain*

Clusters	Items	Digital Technology
Cluster 1	267	-
Cluster 2	233	Assistive technology Communication technology Information technology Educational technology
Cluster 3	118	Digital technology
Cluster 4	82	Blockchain technology Distributed ledger technology
Cluster 5	31	
Cluster 6	8	Emerging technology

Source: *Own study.*

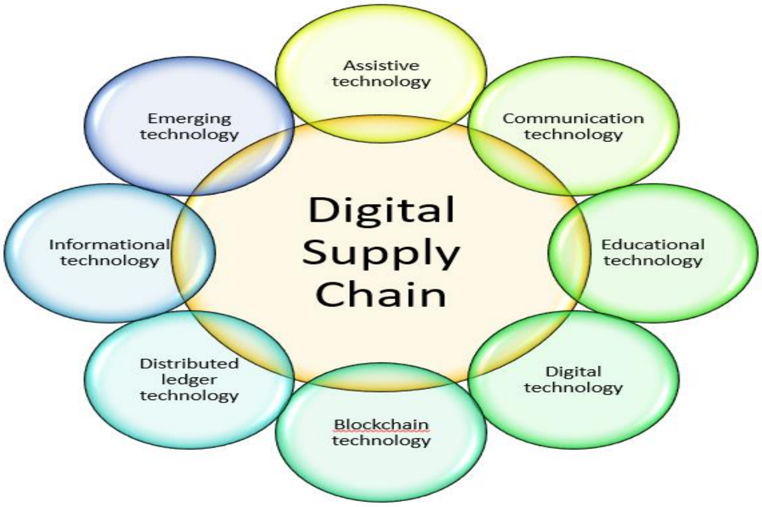
Table 2 presents the concept clusters identified based on the semantic map with the identified Digital Technology. Figure 4 shows the identified digital technologies for the Digital Supply Chain.

5. Conclusion

The digital revolution, pandemic reality, and social changes create new, previously unknown phenomena that shape new economies and their new entities and services. The digital complex systems; the Digital Supply Chain to support Industry 4.0 can shift from a traditional supply chain to a Digital Supply Chain appears as a necessity. New technologies can strengthen the resilience of supply chain; can adapt to incremental change and sudden disruptions to survive and prosper. At last, Digital Technology for Digital Supply Chain can reduce operational costs and improve sustainability monitoring.

The Digital Supply Chain is not only the trend recognized in research but also the practical approach promoted by organizations and authorities. The follow-up direction of research will concern the development of an integrated digital, resilient, sustainable (DRS) supply chain model in the form of a triple helix. The digital, resilient, sustainable structural model of the supply chain aims to increase the effectiveness of the DRS transformation of supply chains to global changes.

Figure 4. *Digital technologies for the Digital Supply Chain*



Source: *Own study.*

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