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ORIGINAL PAPER

DIGITAL TRANSFORMATION OF SUPPLY CHAINS AND COMPANY'S PERFORMANCE

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ABSTRACT. Background: The aim of the article is to examine the determinants of the digital transformation of the supply chains (DSCs) of companies. The presented research covers the stages of digital supply chain transformation, applied key technologies, and the results of implementation of DSC transformation.
Methods: The research covered 235 randomly selected Polish companies of all sizes, focusing on transport and warehouse management companies (33.6%), industrial processing (15.7%), other services (11.4%) and wholesale and retail trade (11.1%). Data were acquired by the CAWI method in 2022. For statistical calculation, Pearson correlation and factor analysis were used.
Results: The results of this paper indicate that the DSC transformation process is implemented with rather similar and moderate degree of intensity (mean 3.61 on a scale from 1 to 5). The transformation process of DSC is based on several interdependencies, that is, between integration of company's technology base and other entities of the supply chain as well as with scale and improve the solutions for DSC. Moreover, DSC transformation is positive related with all of the performance measures (profit, sales, market share, ROI, and competitive advantage), while the greatest increase is noticed for ROI. Furthermore, the factor analysis confirm that a systematic and comprehensive approach to the transformation of DSC raises company performance.
Conclusions: The presented research allows for a better understanding of analysed variables and the context that determines DSC transformation for both managers and practitioners. Thus, it enable building a strategy and roadmaps for the digital transformation of enterprises and mitigate associated risks.

Keywords: supply chain, digital supply chain, transformation, process, performance

INTRODUCTION

Innovation is one of the key factors that ensures a competitive advantage for enterprises that carry out activities related to introducing changes in their business model [Dymitrowski and Mielcarek 2021]. However, maintaining a high level of innovation in an environment characterised by discontinuity and violent shocks is becoming a growing challenge.

In the face of changes, it becomes increasingly difficult to improve profitability and maintain the effectiveness of supply chains. To put this in a simple formula, supply chain management is about "having the right item in the right quantity at the right time at the right place for the right price in the right condition to the right customer" [Mallik 2010]. As a result, there is increasing requirement for improving sustainable outcomes in the supply chains that based on integrating social, economic and environmental goals of focal company [Carter and Rogers 2008]. Moreover, there are some raising challenges for managing global supply chains concerned with limited visibility and control over scattered between different geographies and multiple business tiers supply chain entities [Choi and Hong 2002, Koberg and Longoni 2019]. One of the directions that can mitigate these threats and meet raising demands of stakeholders is the digital transformation of supply chains [Ageron et al. 2020, Preindl et al. 2020].

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Despite the relatively low advance of the digital transformation of supply chain, forecasts show that this will be one of the key trends in the next five years for many industries, with more than 90% of respondents expecting more process automatization and receiving real-time status updates from the entire supply chain [CapGemini 2016]. Therefore, taking into account frequent and rapid disturbances in the environment and the growth of ICT technology development, interest about digital transformation is increasingly increasing both among theoretical and practical specialists. Digital supply chains (DSCs) are not only more responsive to changes in the business environment than a traditional supply chains, but also they increase transparency for entities across the whole supply chain that support better decision making and communication [Preindl et al. 2020]. The digital supply chain can be defined as 'development of information systems and the adoption of innovative technologies that strengthen the integration and the agility of the supply chain and thus improve customer service and sustainable organisation performance' [Ageron et al. 2020, p. 133]. Another definition of DSC by Kinnett is: 'an intelligent, value driven network that leverages new approaches with technology and analytics to create new forms of revenue and business value, through a centric platform that captures and maximises the utilization of real-time information emerging from a variety of sources.' [2015]. This can be seen as a deep and extensive change in supply chain management and therefore also a challenging project in terms of organisational development process. According to Sabri, Micheli, and Nuur, DSC implementation is a long-term cyclic process with phases that transform interorganisational and cross-functional relations of organisation [2018].

Taking into account the various conditions of DSC transformation, the aim of the article is to examine and describe the determinants of digital transformation of the supply chains of Polish companies. Therefore, it is worth formulating a number of questions that will allow one to broaden the knowledge about this phenomenon in relation to Polish companies:

What is the stage of the digital supply chain transformation process?

Are there any interdependencies between activities of the DSC transformation process?

What are the most relevant elements (technologies) of DSC transformation?

Are there any interdependencies between elements (technologies) of the DSC transformation?

What are the results of the digital transformation of the supply chain for the company's performance?

THEORETICAL BACKGROUND

One of key drivers of digital transformation is the fourth industrial revolution that uses cyber physical systems provided with heterogeneous data and integration of knowledge, which allows to create smart (intelligent) products, apply 3D printing, and use of artificial intelligence, i.e., in autonomous vehicles or smart factories [Hendler 2019]. This change the elements, flows, processes and network structure of the supply chain by pushing towards a new way of management including evolution into merging physical and digital operations within a physical and virtual world [Garay-Rondereo et al. 2020, Cyplik, Zwolak, 2022]. Taking advantage of new technologies within supply chain and the introduced concept of Industry 4.0 will be dependent on establishing full-scale smart infrastructure allowing merge of data, physical objects, products, together with processes [Wu et al. 2016, p. 395-396]. Wu et al. define smart supply chain as the new interconnected business system that extends from isolated, local, and single-company applications to systematic smart implementations [2016, p. 396].

Digital transformation may mean varying degrees of interference in the architecture of the elements that make up the business model and the way it functions. Literature distinguishes three phases of digital transformation [Verhoef et al. 2021]: digitisation (focusing on transforming analogue information into a form of digital recording), digitization (i.e., using ICT to achieve business benefits by modifying the existing processes of the enterprise), and digital transformation (changing the current logic of the functioning of the business model, including

creating added value through digital technology) [Kawalec 2021]. The generalizing first two stages are characterised by a gradual improvement in the way the organisation functions, while the last stage, digital transformation, is aimed at the overall modification and transformation of the enterprise, its supply chain, and business model [Parviainen 2017].

Another approach to digital transformation distinguishes four phases with different strategic goals and a different way to generate added value through the implementation of digital technologies [Subramaniam 2022]. The first stage is to improve operational efficiency by using real-time data to improve business processes. The second step is advanced operational performance based on data generated by customers (e.g., by installing sensors in products that transmit information about how they are used). The third phase covers data generated in the value chain as part of the services provided (an example is engine-mounted sensors that reduce fuel consumption in customers' vehicles, with some of those savings being captured by the manufacturer) [Kawalec 2021]. The fourth phase includes services based on the use of data from digital platforms, thanks to which it is possible to create consumption ecosystems. This, in turn, puts the company in a new role as the entity that creates the technological infrastructure for the development of the supply chain and, in a broader sense, for the entire business ecosystem. Subsequently, it is also necessary to manage the resulting value in such a way as to ensure mutual benefits for the actors involved in the digital supply chain.

In operational perspective transformation of DSC is a long term process that must be embedded in each of the resulting documents such as vision of a whole company, corporate strategy, digital corporate strategy and strategy for development of a supply chain [Preindl et al. 2020 p. 31]. On the basis of the formulated goals and assumptions, you can proceed to the assessment of the current state of supply chain covering such dimensions like: hardware, software, people, processes, and data. As a result several-year road map should be established with pilots and rollouts based on an optimal and most beneficial investments in a technology. It is highly recommended to start from a local pilot and along with confirmation of effectiveness and achievement of the presumed goal, it can be extended in a broader scope of supply chain. To accomplish of this step it is necessary to build strategic partnerships along the DSC [Preindl et al. 2020]. The whole transformation process should be finalised by cyclic revisions and evaluation of a whole system.

Therefore, it is assumed that the goal of the DSC transformation is to change the way digital technologies are used to create new business value for customers and improve performance of the organisation [Ageron et al. 2020]. The above attempts to define the meaning and essence of digital transformation indicate that the acquisition and implementation of modern technologies is not an end in itself, but a means to ensure the achievement of the overarching goal of creating value for the customer and its capture by business. Undoubtedly, harnessing technological opportunities to innovate in DSC requires a longer time horizon, partly because this process is more contextual and dependent on many variables than the implementation of the technology itself.

DATA AND RESEARCH SAMPLE

A total of 278 responses from Polish companies were selected at random. Of this group, 235 entities transformed towards business model innovation and therefore were included for further analysis. The structure of the surveyed entities (employment, ownership, and period of operation) is presented in Table 1. The most numerous in the sample are: large companies (41.2%), in terms of activity scope there is transport and warehouse management (33.6%), in case of time of operation are companies functioning more than 20 years and in terms of ownership dominates national owned companies (42.1%).

The quantitative research presented in the article was based on a questionnaire that contained 22 questions. Data were collected using the CAWI (Computer-Assisted Web Interview) method. A five-point scale was used to evaluate responses, where 1 – is not important and 5 – is very important. The research covers the period 2021-2022. The respondents to the study were employees of companies, especially

middle-level managers dealing with innovation and strategic management, and specialists in this field. The collected data was coded and analysed. The Pearson correlation coefficient as well as factor analysis were used for the calculations with the use of MiniTab statistical software.

Table 1. Characteristics of the research sample, n=235

Employment size	1-9 employees – 12.8%	10-49 employees – 22.6%	50-249 employees – 23.4%	250 employees and more – 41.2%
Dominant scope of activity	Transport and warehouse management – 33.6%	Industrial processing – 15.7%	Other service activities - 11.4%	Wholesale and retail trade – 11.1%
Period of operation	1-3 years– 15.7%	4-9 years – 17.5%	10-19 years – 25.5%	20 years and more – 41.3%
Company's ownership	National – 42.1%	International under foreign control – 35.3%	International under Polish control – 22.6%	

Source: Self-developed materials.

RESEARCH RESULTS

The first of the aspects analysed is the degree of transformation process of the supply chain (Table 2). Altogether, there are 11 different steps of this process, which in general are implemented with rather a similar and moderate degree of intensity (average of a whole process is 3.61 in a scale from 1 to 5, where 1 is a minimal level of digital transformation and 5 is maximum level). In general, a higher degree of the implantation of DSC transformation process was observed for the building competences and the modelling phase (3.69) that indicate concentration on the operational aspect of the whole process. The most completed of all the activities of the process is training and developing skills (3.83) and the least implemented are tests and simulations of changes related to the transformation of DSC (3.41). But still the gap between them is not very significant.

Therefore, the next analysis that can give some spotlight is correlation between individual activities of the DSC transformation process (see Table 3). All of the activities examined in the DSC transformation process are shown to be positive correlated and those relationships are statistically significant.

Table 2. Implementation of the supply chain digital transformation process of companies, n=235

Process phase	Mean of the phase	Activities of digital transformation of the supply chain	Result	Standard deviation
Planning and preparation for the change	3.590	Initiating activities related to the digital transformation of the supply chain.	3.47	1.03
		Planning and integration of procurement. production and distribution processes.	3.74	1.00
		Tests and simulations of changes related to the digital transformation of the supply chain.	3.41	1.08
		Change management and project management.	3.74	0.97
Building competences	3.690	Training. Developing competences.	3.83	1.02
		Development of a digital supply chain operational model. Integration of inputs. transformation processes into outputs.	3.55	1.01
Implementation	3.593	Introducing new technologies in the enterprise.	3.68	0.98
		Integration of technologies existing in the enterprise.	3.58	0.98
		Integration of the company's technology with the technology of entities in the supply chain.	3.52	1.00
Evaluation and impro	3.585	Development of a measurement system: measures and indicators as well as expected values. Control process.	3.68	1.00
		Scale and improve solutions for digital transformation of the supply chain	3.49	1.02

Source: Self-developed materials.

There is a moderate strong correlation between introducing new technologies in the enterprise and integration of technologies within the enterprise (0.587), as well as with entities in the supply chain (0.526) and between both

activities related to integration of technologies (0.556).

Another set of relations is between: scale and improve solutions for transformation of DSC and integration of technologies within enterprise (0.587) and entities of supply chain (0.571), and development of measurement system (0.508).

This can be interpreted that to achieve better performance of DSC there is not only a need to integrate company's technology and also to match with other entities' of supply chain technology base of other entities, but it is also very important to implement sufficient and comprehensive control system over the activities carried out and engaged assets.

The next main point of analysis concerns technologies used for the DSC transformation process (see Table 4.). The most important is synchronised scheduling (4.08) (in scale 1-5), flexible and dynamic order processing (4.07), and smart delivery (3.96). Less common solutions used in DSC transformation process are the most sophisticated and advanced technologies like Intelligent product factory and smart factory. However, all of the technologies used received above average note, that means they all are crucial for DSC transformation process. Moreover, some insight can be show by analysing correlation coefficient for the applied technologies (see Table 5).

Table 3. Correlation of activities of supply chain digital transformation process of companies, n=235

Process of supply chain digital transformation	1	2	3	4	5	6	7	8	9	10	11
1. Initiating activities related to the digital transformation of the supply chain.	-										
2. Planning and integration of procurement processes. Production and distribution.	0.456*	-									
3. Tests. simulations of changes related to the digital transformation of the supply chain.	0.333*	0.188**	-								
4. Change management and project management.	0.204**	0.294*	0.317*	-							
5. Training. Developing competences.	0.236*	0.266*	0.272*	0.409*	-						
6. Development of a digital supply chain operational model. Integration of inputs. Transformation processes into outputs.	0.442*	0.320*	0.411*	0.369*	0.324*	-					
7. Introducing new technologies in the enterprise.	0.273*	0.337*	0.340*	0.345*	0.335*	0.378*	-				
8. Integration of technologies existing in the enterprise.	0.337*	0.354*	0.283*	0.351*	0.338*	0.440*	0.587*	-			
9. Integration of the company's technology with the technology of entities in the supply chain.	0.498*	0.398*	0.422*	0.277*	0.319*	0.453*	0.526*	0.556*	-		
10. Development of a measurement system: measures and indicators as well as expected values. Control process.	0.277*	0.321*	0.245*	0.309*	0.308*	0.456*	0.352*	0.343*	0.485*	-	
11. Scale and improve solutions for digital transformation of the supply chain	0.373*	0.265*	0.328*	0.355*	0.389*	0.487*	0.378*	0.516*	0.571*	0.508*	-

Note: *p-value<0.001;**p-value<0.05.

Source: Self-developed materials.

Table 4. Relevance of elements (technologies) of digital supply chains of companies, n=235

Elements of digital supply chains	Result	Standard deviation
Synchronized scheduling	4.08	0.93
Flexible and dynamic order processing	4.07	1.03
Smart delivery	3.96	1.05
Digital platform of information exchange	3.84	1.04
Digitization of customer and consumer experience	3.76	0.95
Digital development - Intelligent product factory	3.58	1.02
Smart factory	3.49	1.07

Source: Self-developed materials.

The analysis of the interdependencies between implemented technologies shows several observations. First, there is moderately strong correlation of intelligent product factory with smart factory (0.617) and smart delivery (0.507). The smart factory is related to smart delivery (0.532). Finally, the digital platform for information exchange is correlated with flexible and dynamic order processing (0.507).

Table 5. Correlation of individual elements (technologies) of digital supply chains, n=235

Elements of digital supply chains	1	2	3	4	5	6	7
1. Synchronized scheduling	-						
2. Digitization of customer and consumer experience	0.426*	-					
3. Smart factory	0.290*	0.393*	-				
4. Smart delivery	0.285*	0.359*	0.532*	-			
5. Digital development - Intelligent product factory	0.296*	0.350*	0.617*	0.507*	-		
6. Flexible and dynamic order processing	0.469*	0.450*	0.341*	0.490*	0.322*	-	
7. Digital platform of information exchange	0.337*	0.444*	0.391*	0.407*	0.439*	0.507*	-

Note: *p-value<0.001.

Source: Self-developed materials.

The next analysis issue is the performance result of the DSC transformation process of companies (see Table 6). All of the observe indicators (profit, sales, market share, ROI and achieving competitive advantage) improve after implementation of DSC. The most significant raise concerns ROI (18.13%), market share (12.92%) and profit (11.83%). However, in case of ROI there is also the highest standard deviation (2.51), which indicates significant dispersion of results around the mean and can disturb the final reading of the indicator.

Table 6. Digital transformation of supply chain and results of companies, n=235

Phase of implementation	Metrics	Profit	Sales	Market share	ROI (return on investment)	Competitive advantage
Before introducing digital transformation	Mean	3.72	3.70	3.56	3.31	3.51
	Standard deviation	0.98	0.97	1.00	0.94	1.01
After introducing digital transformation	Mean	4.16	4.02	4.02	3.91	3.98
	Standard deviation	0.88	0.92	0.85	2.51	0.90
Percentage change		11.83%	8.65%	12.92%	18.13%	13.39%

Source: Self-developed materials.

Another analysis covers correlation coefficients for elements of digital supply chains (see tab. 5) and performance metrics (see tab. 6). All the interactions of the acquired variables were found to be positively correlated and statistically significant (p-value<0.05). The highest correlation coefficient is for smart deliveries and competitive advantage (0.344), synchronised scheduling and sales (0.338), digitisation of customer and consumer experience and competitive advantage (0.335) and flexible and dynamic order processing and sales (0.334). However, to give some more insight a multidimensional analysis more specifically factor analysis was applied (see tab. 7).

Altogether, there were 12 variables that indicate the designation of 12 factors, of which five will be analysed in detail. These four first factors explain 75.3% of the total variance of the variables investigated. Factor 1 (second column in tab. 7) indicates that almost 40% of the analysed companies analysed can be called "comprehensive" digital supply chain transformation because they achieve high positive correlation of all elements of digital transformation and also high positive results of performance metrics.

Factor 2 can be called the "laggards" of digital supply chain transformation with 13.6% of the companies investigated. These businesses can ensure relatively good performance results, but still significantly lower than in factor 1, without investing in digital supply chain transformation. In other words, those companies have a negative correlation between applied digital technologies of supply chain and business performance.

Factor 3 can be called 'operational excellence' of digital supply chain transformation with more than 8% of companies focus on synchronised scheduling, flexible and dynamic order processing, and digital platform of information exchange that can accelerate sales but with very significant cost of other performance metrics such as: ROI and competitive advantage.

Factor 4 represents 6.2% of the companies surveyed and can be called "market conquerors" of digital supply chain transformation. Those businesses focus on synchronised scheduling, smart factory, and smart delivery with results in rise of market share and sales.

Factor 5 covers 5.6% of the variance and can be called "logistic excellence" of the transformation of the digital supply chain. These companies focus on smart delivery as well as flexible and dynamic order processing that results in rise of ROI and competitive advantage.

The graphical result of the factor analysis is presented in a figure below (figure 1) consisting of three elements: 1) the vertical axis represents the number of applied technologies, 2) the horizontal axis represents the scope of company performance improvements calculated as a sum of correlation coefficients, 3) the size of a circle represents % of variance.

DISCUSSION AND CONCLUSIONS

The purpose of this article is to examine and describe the determinants of digital transformation of Polish company supply chains. The presented research results enabled the formulation of the following conclusions and points for discussion with the literature on the subject:

1) The transformation process of the DSC of Polish companies is implemented with rather similar and moderate degree of intensity (the average of a whole process is 3.61 out of a 5 point scale). This observation can be supported by the high rate of applied digital technologies like synchronised scheduling (4.08) (in scale 1-5), flexible and dynamic order processing (4.07) with relatively lower results for intelligent product factory (3.58) and smart factory (3.49). That result shows that there is focus on the operational efficiency with supplication and use of digital data. Altogether, this indicates relatively initial phase (the first or second stage of supply chain digital transformation) according to M. Subramaniam concept [2022].

Table 7. Factor analysis for digital transformation of supply chain and results of companies – correlation coefficients, n=235

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12
1. Synchronized scheduling	0.632	-0.082	0.438	0.227	0.019	-0.417	-0.283	0.120	-0.178	0.202	-0.033	0.088
2. Digitization of customer experience	0.660	-0.165	0.167	-0.318	-0.421	-0.067	-0.060	-0.432	-0.048	-0.131	-0.131	0.003
3. Smart factory	0.619	-0.436	-0.306	0.208	-0.348	-0.047	0.106	0.053	-0.009	0.032	0.388	0.007
4. Smart delivery	0.589	-0.476	-0.112	0.161	0.344	-0.025	0.376	-0.250	0.035	0.136	-0.148	0.154
5. Intelligent product factory	0.610	-0.419	-0.423	0.123	-0.051	0.050	-0.199	0.278	-0.008	-0.162	-0.311	-0.111
6. Flexible and dynamic order processing	0.658	-0.239	0.481	-0.042	0.284	-0.021	0.112	0.087	0.100	-0.327	0.140	-0.196
7. Digital platform of information exchange	0.644	-0.239	0.238	-0.315	-0.007	0.492	-0.106	0.172	0.075	0.284	0.023	0.050
8. Profit	0.623	0.513	0.005	-0.029	-0.200	-0.184	0.326	0.133	0.201	0.208	-0.118	-0.228
9. Sales	0.640	0.530	0.118	0.195	-0.146	0.163	0.126	0.158	0.034	-0.234	-0.045	0.333
10. Market share	0.615	0.430	-0.043	0.357	0.099	0.326	-0.097	-0.253	-0.273	0.044	0.032	-0.199
11. ROI	0.604	0.259	-0.329	-0.479	0.218	-0.156	0.088	0.122	-0.354	-0.031	0.082	0.045
12. Competitive advantage	0.657	0.301	-0.298	-0.058	0.231	-0.119	-0.350	-0.176	0.387	0.006	0.107	0.055
Variance	4.7588	1.6282	1.0063	0.7381	0.6720	0.6312	0.5621	0.5334	0.4420	0.3924	0.3428	0.2927
% Variance	39.7%	13.6%	8.4%	6.2%	5.6%	5.3%	4.7%	4.4%	3.7%	3.3%	2.9%	2.4%

Source: Self-developed materials.

2) However, DSC transformation, even at this stage of implementation, gives positive results for all of the assessed measures (see Table 6.), i.e. profit, sales, market share, ROI and competitive advantage were improved after implantation of digital technology into supply chain. The greatest increase was noticed in terms of ROI (by 18%), which can be the result of better access and utilisation of digital data and adjustment and integration of the technological base within DSC.

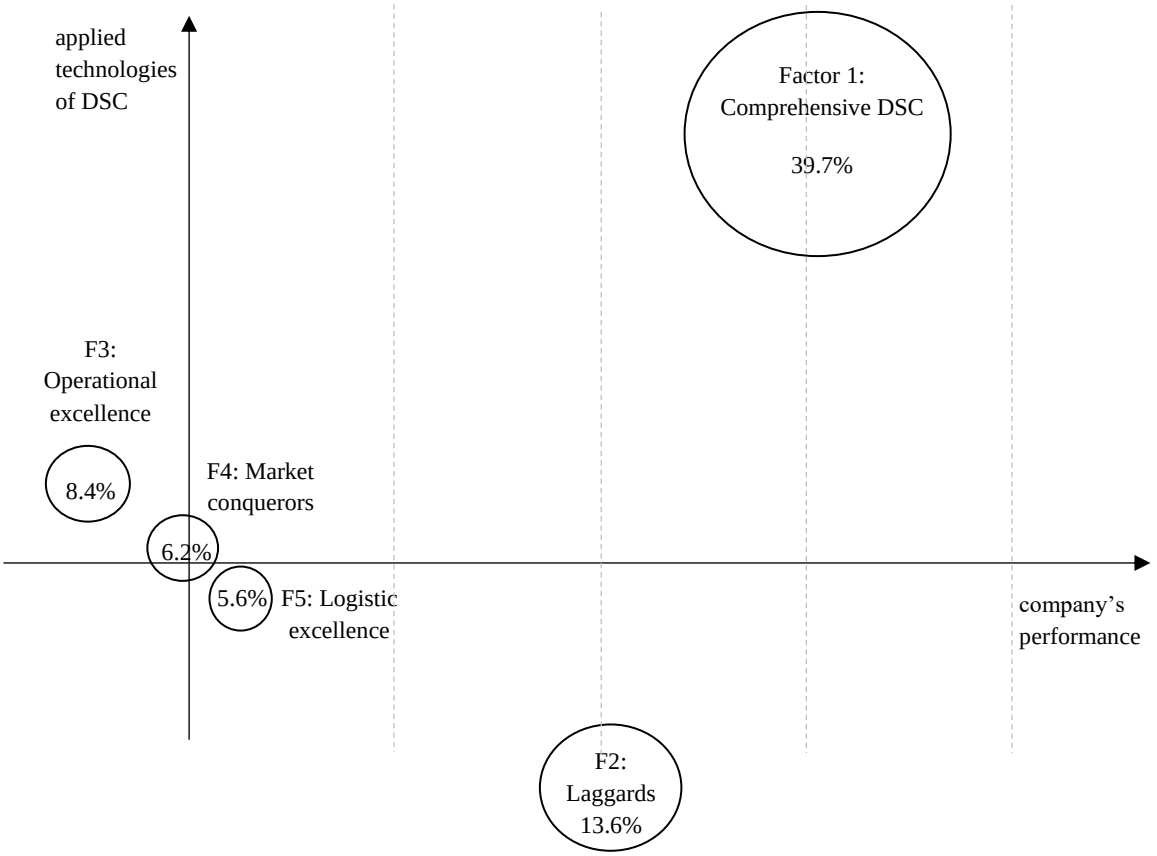

Fig. 1. Applied technologies of digital supply chain and company's performance – graphical presentation of factor analysis
Source: self-developed materials.

3) The factor analysis confirmed that the systematic and comprehensive approach to the DSC transformation process gives positive results for all performance metrics (Factor 1: 'Comprehensive DSC'). What is interesting is that skipping investment in DSC transformation (Factor 2: 'Laggards') gives better results than focusing only on a specific area of technology (ie, Factor 3: "Operational excellence" or Factor 4: 'Market conquerors').

4) In terms of practical implications considering applications for implementation projects, there is relatively strong correlation between introducing new technology and its integration, both within company and other entities of supply chain. This relation, which is also conditions Scaling and improving of supply chain digital transformation. However, to achieve technology integration, the company must mitigate "difficulty of visualizing the digital and physical flows and the determination of the appropriate level of interconnectivity between the physical and digital world" [Garay-Rondereo et al. 2020].

5) In summary, DSC transformation should be treated as a strategic renewal project and therefore need to be embedded in a broader strategic context, by concluding its assumptions within a vision of a whole company, corporate

strategy, digital corporate strategy and strategy for development of a supply chain [Preindl et al. 2020]. To provide broader context and help in the digital transformation process company can use the innovation concept of the business model [Wang et al. 2018]. By applying of this framework, it is possible to analyse the interdependencies between the resources, activities, and needs of the involved entities and the financial result achieved.

LIMITATIONS OF RESEARCH

The presented research procedure is not free from some limitations. The first is the size of the surveyed sample, which could be expanded in the future, including foreign entities and specific division between types of company activities (i.e. industries, services, mining and energy production, agriculture, and so on) and type of production model (Make-to-stock, Make-to-order, Assemble-to-order, Engineer-to-order) [Cyplik, Zwolak, 2022 p. 162].

The second limitation are performance metrics applied in the research, while proposed to use a more complex measurement system combined of real-time control on strategic, tactical and operational level based on engaged technology like IoT, Big Data, blockcahin technology, online communication channels [Ageron et al. 2020 p. 135, Bal, Pawlicka 2021 p. 73]. This could help to close the gap between the existing theoretical approach and the real needs of companies in terms of the control of DSC transformation process.

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