



ORIGINAL ARTICLE

Citation: Krykavskyy, Y., Pokhylchenko, O., & Hayvanovych, N. (2019). Supply chain development drivers in industry 4.0 in Ukrainian enterprises. *Oeconomia Copernicana*, 10(2), 273–290. doi: 10.24136/oc.2019.014

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Received: 3.11.2018; Revised: 4.04.2019; Accepted: 28.04.2019; Published online: 2.06.2019

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**Supply chain development drivers in industry 4.0
in Ukrainian enterprises**

JEL Classification: *M11; O33; L81; L86*

Keywords: *industry 4.0; digital technologies (DT); supply chain development drivers*

Abstract

Research background: Industry 4.0 is a response to rapid technical progress, caused by the dominant role of information technology, which covers and penetrates virtually into all the aspects of people's economic and social activities. At present, the terms “Digital Supply Chain”, “Supply Chain 4.0”, “Digital logistics”, and “Smart logistics” are widely used in business, and in particular, in the theory and practice of supply chain management (SCM). This demonstrates the relevance of the implementation of Industry 4.0 innovations into the practical activities of manufacturing, trading, and logistics companies, interconnected by networking in the process of delivering products or services to final consumers. In turn, this causes fundamental changes in the structure of supply chains, their business processes and behaviours, making existing approaches to management obsolete.

Purpose of the article: The article aims at identifying supply chain development drivers under the conditions of ‘Industry 4.0’; determining the effect of DT in the cross-section of strategic and

operational changes of supply chain; clarifying the readiness and capacity for DT implementation in the enterprises activity as exemplified by the enterprises operating in Ukraine in various fields of activity.

Methods: Stratified proportional sampling was applied as the research method. Ukrainian enterprises of different size, involved in different supply chains, were considered as an object of research. The attitude of the Ukrainian enterprises to the DT implementation is presented, and the results are compared to the relevant research data in other countries.

Findings & Value: This study will be valuable to both scientists and practitioners. Scientists will be able to understand the conceptual transformation of SC under the influence of DT. Practitioners will become aware of the following issues: current SCM trends and requirements; DT effects on the strategic and operational levels of the classical model of management; the level of readiness and ability of the Ukrainian enterprises to implement DT in their activities as compared to the enterprises in other countries.

Introduction

A global tendency in the global industry development is its movement towards the ‘Industry 4.0’ level and penetration of information technologies into all the fields and aspects of human activity. It causes numerous consequences for the whole society, and digital technologies (DTs) are the leaders in such changes. In particular, at the macro level, they act as a technological platform for such concepts as ‘digital economy’, ‘digitalisation’, ‘network economy’, and draw the attention of the national governments throughout the world. Currently, we may observe the appearance and the use of the terms ‘Digital Supply chain’, ‘Supply Chain 4.0’, ‘Digital logistics’, ‘Smart logistics’ in the field of business, and, in particular, in the theory and practice of supply chain management (SCM).

Hence, on the one hand, modern companies and their supply chains (SC) must get ready for such changes through their conscious selection and adjustment of their logistic systems to the digital environment, regardless of the country of origin. On the other hand, the more complicated the economic conditions for the enterprise activities are, the more uncertain and incomprehensible their digitalisation potential is.

The purpose of the article is to identify supply chain development drivers under the conditions of ‘Industry 4.0’; determine the effect of DTs in the cross-section of strategic and operational changes of SC; clarify the readiness and capacity for DT implementation in the enterprises activity as exemplified by the enterprises operating in Ukraine in various fields of activity.

Hence, the literature review provides an overview of available publications and researches dedicated to the modern interpretation of the ‘Industry 4.0’ notion, the role of DTs, their potential and difficulties of implementation.

Stratified proportional sampling was applied as the research method. The survey was conducted over a period of February-March, 2019, at the Ukrainian enterprises, with enterprise size taken as the classification characteristics, while the number of strata was 4 (large, medium-size, small and micro-enterprises).

The research also provides a specific description of the research methodology based on 4 consistent steps, the implementation of which will make it possible to verify two scientific hypotheses.

The results include a detailed elaboration of each step, envisaged by the research methodology, with final verification of the hypotheses made. The attitude of Ukrainian enterprises to the DT implementation is presented, and the results are compared to the relevant research data in other countries.

The discussion provides an assessment and critical analysis of the research results as compared to the results of other authors.

Conclusions include the results of the study in accordance with the proposed research methodology, implications, practical recommendations, and suggestions for further research.

Literature review

8 years have passed since Industry 4.0 was first mentioned in public at the 2011 Hanover Fair in Germany. Over that period, the term has acquired a clear meaning, a deep sense, and has ‘developed its roots’ in the consciousness of a wide range of scientists, researchers, consultants and businessmen throughout the world.

Now “Industry 4.0” stands for the comprehensive digitisation of industrial production (Buhr & Stehnen, 2018). According to Kolberg and Zühlke (2015), it fundamentally transforms modern production, thanks to new technological achievements, including digitalisation and robotisation, artificial intelligence and the Internet of things (IoT), new materials and biotechnology (Vasin *et al.*, 2018, pp. 63–76).

According to the final report of the Industry 4.0 Working Group (Final report of the Industrie 4.0, 2013), both academic and industry professionals have been trying to fully comprehend its consequences for manufacturing. However, this report could also be used for identifying the potential of Industry 4.0 in the field of SCM. Thus, due to the foreground role of such technological innovations as cyber-physical systems (CPS), IoT and the Internet of Services, the authors underline the impact of Industry 4.0 in such directions as meeting individual customer requirements, flexibility,

optimized decision-making, resource productivity and efficiency, creating value opportunities through the new.

According to Buhr and Stehnen (2018), the potential of digitalisation seems enormous and affects a large number of industries, from agriculture and energy, logistics, IT and communications, to mechanical engineering and vehicle manufacturing. However, nobody knows what the exact consequences for manufacturing operations are, although there's a clear notion that the later-movers will most likely be forced out of the market (Almada-Lobo, 2015, pp. 16–21). And also, there's still a lot of confusion about what matters in Industry 4.0. For example, a cohort of Polish researchers (Adamczewski, 2017, pp.11–22; Corcoran & Datta, 2016, pp. 73–74; Perra *et al.*, 2015, p. 58) focus not just on the use of CPS, IoT, smart technologies, but also on the use of SMAC (social, mobile, analytical and cloud) technologies, automation and robotisation of any processes undergoing in the economic system of companies, regardless of their activity profile. According to some researchers (Almada-Lobo, 2015, pp. 16–21.; Vlasov *et al.*, 2018; Afonasova *et al.*, 2018, pp. 292–302; Cook & Das, 2005), DT of Industry 4.0 also include a huge number of other technologies — big data analytics, 3D printing, wireless sensor networks, blockchain technology, electronic currency, and so on.

At the same time, while analysing the researches (Buhr & Stehnen, 2018; Schrauf & Bertram, 2018; Geissbaueret *et al.*, 2016; Asthana, 2018), it is worthwhile to say that there is no unique, sustainable understanding and interpretation of modern concepts as well as related terms in the field of SCM, like 'Digital Supply Chain', 'Supply Chain 4.0' etc. All these terms stand for a vision of the growing digitalisation, networking and automation of industrial production and SC. However, they do not explain the exact changes that will occur in SCM when DTs have been implemented. Also, all of them make an emphasis only on the DT role and do not explain correlations with other trends in the theory and practice of SCM.

The current situation makes it considerably more complicated to identify the key drivers of SCM, since it does not allow shaping a clear understanding of the benefits and threats posed by business processes, digitalisation, and practical activity of managers. In fact, 41% of enterprises in the European Community still do not seize on DT, and only 2% harness every single opportunity of new technologies (Afonasova *et al.*, 2018, pp. 292–302). As noted in the research (Bruskinet *et al.*, 2017, pp. 264–274), it is paradoxical, but corporations themselves are a significant barrier to digital transformations. According to these authors, the major barriers to the digital transformation of modern corporations lie in the management, methodological and information fields.

Due to the importance of the problem of adjustment of modern enterprises to the challenges accompanying the process of penetration of DT into all the aspects of economic life, this research aims to promote solution to this problem through the prism of studying the above aspects or ‘white’ spots of the theory and practice of SCM in the Industry 4.0.

Research methodology

The scientific hypotheses of the work are as follows:

1. In spite of increasing the digital economy paradigm, there is a considerable gap between the requirements of activity digitalisation and the value of digital changes for entrepreneurs.
2. The necessary condition of adjustment of modern business to digitalisation is the growing competence of the key managers, which will ensure their capacity to identify opportunities and threats as well as the economic effect of investment into DTs.

The paper suggests the following research methodology for the hypotheses verification:

Step one: Identification of supply chain development drivers in the ‘Industry 4.0’ conditions on the basis of critical analysis of sources and systematization of data of the recent researches and publications in the field of topical trends and key market requirements to SC development.

Step two: Determination of the DT effect on some aspects of SC functioning in the cross-section of strategic and operational changes on the basis of data systematization and comparative analysis of the recent researches and publications.

Step three: Clarification of the readiness and capacity of the Ukrainian enterprises, involved in different SCs, to implement DTs in their activity on the basis of processing of the results of the online questionnaire. The survey was conducted over the period of February-March, 2019, applying stratified proportional sampling, with enterprise size taken as the classification characteristics, while the number of strata was 4 (large, medium-size, small and micro-enterprises). standard error in the results of sample shaping makes up 5%, and variation factor is 25%. In fact, 102 respondents were surveyed. The choice of the method ensures proportionate representation of enterprises of a certain type in proportion with the share of this stratum in the overall integrity.

Step four: Verification of the hypotheses, making conclusions.

Results

Identification of supply chain development drivers under the conditions of 'Industry 4.0'

In order to identify the key drivers of supply chain development under the conditions of 'Industry 4.0', let us make a detailed analysis of the key trends in logistics and SCM.

Thus, Table 1 presents the core trends determining SC development in the nearest future, according to the versions of the world's leading consulting and logistics companies, like LogisticsBureau, Cerasis, as well as the German logistic association BVL International.

The increasing customers' expectations are among these significant trends, along with the traditional focusing on the capacity of internal process, structure improvement and increasing DT role.

The primary requirements of the generation X, Millennials, and even the generation Z, which in total make up 70% of today's global population (The Nielsen total audience report, 2017), to market offer include not only the requirements of high quality along with low product cost, quickness of order performance, accurateness and transparency of the manufacturing processes, environmental friendliness, but also requirements of high vendor's reputation, their social responsibility, integrity of content in social media, representation of offers in a convenient format on mobile devices, availability of innovative products.

Thus, a critical analysis of the abovementioned trends, as well as the due account of the primary market requirements, allow pointing out key requirements to SCM in the times of digital transformations (Figure 1).

Analysis of the core trends and requirements to SC development allow for identifying the key supply chain development drivers in Industry 4.0. In the broad sense, they reflect the SC economic growth sources under the conditions of increasing digitalisation. In the narrow sense, this term stands for the integrity of special mechanisms capable of raising network relations in SC to the new development level due to adjustment and transformation of business processes at all management levels to meet the current market requirements. Their composition is represented in Figure 2.

Thus, in order to achieve economic growth under the conditions of increasing digitalisation, SC must be efficient, flexible, and responsible. There are two fundamental mechanisms of achieving such heteropolar orienting points, and they are the following: 1) a well-balanced decision on partial or total use of DTs with a significant capacity in the field of optimisation, acceleration and improvement of the quality of processes and deci-

sions; 2) cooperation and partnership in network communications that will ensure not just stability and predictability in the SC, but will also serve as the source of avoiding the risks of passing unsynchronized decisions undermining the participants' capacity to achieve balance between efficiency, elasticity and responsibility.

Determination of the DT effect in the cross-section of strategic and operational changes in SC

Figure 1 also visually reflects the opinion of the authors about the role of DTs as an integral part of SCM. At the same time, it may play either a supporting or a key role. In the former case, one may speak about preservation of the classical approach to SCM, while in the latter case — about complete transformation of SCM and transition to the digital model of management.

While the classical SCM model is conceptually and methodologically well-developed, the concept of the digital SCM model is just under development. In spite of the fact that there's a huge practical contribution into the total digital transformations made by the global IT industry leaders (Google, IBM, SAP, etc.), there is no well designed approach of transition from the classical to the digital model of management (Bruskinet *al.*, 2017, pp. 264–274). Therefore, DT is the primary interest of this study, as it plays a supporting role in SCM and can improve classical SCM models.

On the basis of the analysis of the latest researches and publications dedicated to the review of global DT, we have determined the basic composition of DTs that can be used at two levels of SCM: strategic and operational, with regard to the key business effects and respective strategic or operational changes (Table 2).

In order to identify the readiness and capacity of available enterprises involved in different SCs to introduce DTs into their activity, an online questionnaire survey of the enterprise representatives is provided.

Clarification of the readiness and capacity of available enterprises to implement DTs into their activity on the basis of the online questionnaire survey

Statistical analysis of the empirical material collected in the course of the survey showed the following: managers of large and medium-sized enterprises are trying to follow the latest trends in the field of DT only 'from time to time' — 50% and 71.4%, respectively, and about one fourth of the surveyed managers (25% of large enterprises and 28.6% of medium-

sized enterprises) carry out ongoing monitoring of the DT market. Managers of 10% of small and 7.2% of micro-enterprises are not familiar with the effects of DT implementation into practical activity at all, and only about a half of the surveyed representatives of those enterprises (55.6% of small and 48% of micro-enterprises) are trying to at least sometimes follow the trends in the field of DTs.

Answering the question ‘Which recent DTs are you already using in your activity?’, most of the respondents mentioned wireless communication, remote access to the enterprise IT infrastructure, including the one from mobile devices (remote & mobile access), cloud computing, IoT, GPS and big data analytics. There are almost no differences in dependence on the size of the enterprise. At the same time, 10% of the surveyed small enterprises and 18.5% of micro-enterprises are not using any advanced DTs in their activity.

Regarding the business fields, where the implementation of innovative DTs is the most expedient (in the respondents’ opinion), the survey results have shown the following (Figure 3): large companies see the greatest prospects of DT use in the accumulation and analysis of the large scope of data, business process management, marketing research and establishment of close cooperation with partners; for small and micro-enterprises, the use of DTs is the most prospective in the search of clients, conclusion of agreements with clients/partners, automation of order development/processing, accumulation and analysis of large scope of data.

The key benefits of the DTs for large companies (Figure 4) lie in quick analytics (15.2% of all answers), process optimization (13%), increased flexibility (10.9%), reliability and accuracy of prognosis, improved quality (some 9%). For small and medium-sized companies, the process optimization (22.6% and 15.8% respectively), increased quality (19.4% and 9.8%), reduced mistakes (16.1% and 18%), quick analytics (9.8% and 6.7% respectively for small and micro-enterprises) are the most valuable.

The greatest challenges on the way to DT implementation in business, pointed out by the entrepreneurs, are the following ones (Figure 5): shortage of skilled labour, the need for staff retraining (25.7% of all the answers), the need for considerable investment (23.9%), the need for organizational changes, process reengineering (17.1%). If we compare the data by the types of enterprises, the most significant threat (barrier) for large enterprises is the need for organizational changes and process reengineering (30.4%); regarding the medium-sized ones — the need for considerable investment and the need for organizational changes, as well as process reengineering (over 26%); as far as small and micro-enterprises are concerned — shortage of skilled labour, the need for staff retraining (40% and

28.1% respectively) and the need for considerable investment (40% and 19.2%).

Verification of the hypotheses

Statistical analysis, comparative analysis and data systematisation presented in the article point out the trend associated with the increasing role of DTs in doing business, digitalisation of offer and purchasing process, priority of agile decisions, increasing customer expectations, competition and partnership in SCs, etc.

However, the survey has shown that managers of only half of Ukrainian enterprises are trying to just sometimes follow the trends in the field of DT. About a quarter of the surveyed managers carry out ongoing monitoring of the DT market, while about 10% of them are not familiar with the effects of DT implementation in the practical activity and generally do not use any advanced DTs in their activity.

That confirms the hypothesis about the existence of a gap between market and consumer requirements to the activity digitalisation and realisation of the value of changes resulting from digitalisation by entrepreneurs.

Also, almost one-third of those surveyed have emphasized the absence of skilled labour on the way to DT implementation in business. Based on the above, the hypothesis about the need to increase competence of the key managers can also be considered reliable.

Discussion

The results of the studies obtained correlate well with the results of other researches. According to Solis (2018), more than a third of organisations in the world (44%) have already started implementing a digital approach into business processes, operations and customer engagement. As noted by Gorelova (2016), a considerable part of company heads in the Russian Federation has started using DTs in the management. The situation in Ukraine is the same — according to the results of our survey, only 10% of the surveyed small and 18.5% of the surveyed micro-enterprises do not use any advanced DTs in their activity. Russian respondents are of the opinion that reluctance of the staff to change as well as shortage of staff possessing digital competences constitute the key problems in the introduction of new technologies. The results of our survey reflect the same problems.

According to the Spencer Stuart survey (Gorelova, 2016), DTs have the greatest impact on the business processes in the field of personnel man-

agement (39% of respondents), customer relations (20%), sales (16%), operation management (13%), logistics and purchasing (12%). At the same time, according to the IDG survey (Gorelova, 2016; Vovchenko *et al.*, 2017, pp. 193–212), the benefits of DTs lie in the increase in labour productivity (52%); capacity to improve business productivity management (49 %). For approximately one third of the respondents that stands for the satisfaction of client expectations (46%), understanding of client needs (44%), ensuring uninterrupted and optimized access to resources in any place and at any time (39%), digital modification of business processes (37%), and growth of proceeds due to improved/new digital products or services (31%).

According to our study, enterprises consider DTs to be the most expedient for order shaping/processing automation (12.6% of answers), establishing close cooperation with partners and in the field of marketing research (10.8%), client search, conclusion of agreements with clients/partners (9.1%), accumulation and analysis of the client database, the market as well as business process management (some 8.5% of all the answers).

Conclusions

In accordance with the goals of this research and on the basis of the research methodology suggested by the authors, the following results have been obtained in the article:

- Supply chain development drivers under the conditions of Industry 4.0 have been identified.
- The effect of basic DTs on the strategic and operational level of the classical model of management, including SCM, has been identified.
- The survey of 102 Ukrainian enterprises in different fields of activity has been conducted, the results of which make it possible to assess the readiness and capacity of modern enterprises involved in different SCs, and introduce DTs into their activity.
- Survey results have been contrasted, and the hypotheses made in the paper have been verified.

The results obtained in the paper have made it possible to confirm both scientific hypotheses made concerning the existence of a considerable gap between the requirements of activity digitalisation and the value of digital changes for entrepreneurs, as well as the need to increase the competence of the key managers as the determining factor of successful adjustment of modern business to the Industry 4.0 requirements.

We consider that this study will be valuable to both scientists and practitioners. Scientists will be able to understand the conceptual transformation of SC under the influence of DTs. Practitioners will become aware of the following issues: current SCM trends and requirements; DT effects on the strategic and operational levels of the classical model of SCM; the level of readiness and ability of the Ukrainian enterprises to implement DTs in their activities as compared to the enterprises in other countries. Obtaining such knowledge is necessary in order to be able to successfully use DTs to create competitive advantages.

In view of the differences in the economic conditions of enterprises in different countries, the level of readiness and the ability of enterprises to implement DTs into their activities may slightly deviate from the relevant data obtained on the basis of the survey of Ukrainian enterprises.

The object of further scientific research is the development of methodological recommendations for the DT implementation in every part of SC, along with the identification of changes that may occur at the operational and strategic levels of SCM.

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Annex

Table 1. Trends determining SC development in the nearest future in the version of the leading consulting and logistic companies

| Logistics Bureau | Cerasis | BVL International |
|--|---|-------------------------------------|
| 1. Increasing IT dependency and software applications. | 1. Data-visualization | 1. Increasing Customer expectations |
| 2. Priority of Agile decisions. | 2. Increasing Perfect Order Deliveries | 2. Digital economy, new technology |
| 3. Increasing Customer expectations | 3. Sustainable Practices | 3. Cost pressure |
| 4. Knowledge | 4. Dominating Service SC | 4. Globalization |
| 5. Cooperation and partnership | 5. Standard Certification Process of SCM | 5. Talent shortfalls |
| | 6. Increasing the Role of Social Media | 6. Volatility |
| | 7. Flexible Processes and Elastic Systems | 7. Sustainability pressure |
| | 8. Omnichannel SC | 8. Increased risk and disruption |
| | 9. Focus on Integrating the Long Tail of SC | |
| | 10. More 3PLs | |
| | 12. Attracting New Talent | |
| | 13. Digital Supply Chains | |

Source: the study based on Logistics Bureau (2018); Cerasis (2018); Handfield *et al.* (2013).

Table 2. Basic DTs, their effect on the strategic and operational level of the classical model of management including SCM

| Innovative DTs* | Level of management changes | Business effects |
|---------------------------------------|--|--|
| Artificial intelligence | Strategic (change corporate system of information management) Operational (change operational planning) | Increase prognosis reliability Increase business process efficiency Reduce planning costs Reduce risks |
| Advanced analytics, Big Data analyses | Strategic (change strategic planning, corporate system of information management) Operational (change operational planning, especially logistics, purchasing, distribution) | Optimize of business processes by quickness, quality and efficiency Reduce planning costs |
| Internet of Things (IoT) | Strategic (change corporate system of information management) Operational (change operational planning, especially logistics, purchasing, distribution, production, asset management) | Optimize of business processes by quickness, quality and efficiency Increase Perfect Order Deliveries Reduce costs |
| Intelligent things, Smart objects | Operational (change system of asset, logistics, product and service management) | Optimize of business processes by quickness, quality and efficiency |

Table 2. Continued

| Innovative DTs* | Level of management changes | Business effects |
|--|--|--|
| Conversational systems | Operational (change system of communications and transactions with clients) | Increase efficiency of communications with external environment |
| Robotic process automation | Operational (production process automation) | Optimize of production processes by quickness, quality and efficiency |
| Immersive technologies | Strategic (change goals, products) Operational (enhanced repair and maintenance capabilities in manufacturing, logistics and warehousing, obtaining of exhaustive information about freight via scanning) | Optimize of production, logistics processes by quickness, quality and efficiency |
| Blockchain, electronic currency | Strategic (change strategic planning, corporate system of information management, financial system, control system) Operational (change operating planning, financial basis of transaction with clients, format of contracts) | Optimize of through business processes along the SC by quickness, quality and efficiency Reduce the costs of economic agents' contracting |
| Predictive Maintenance Technology | Strategic (change corporate system of information management) Operational (enhanced repair and maintenance capabilities in manufacturing) | Optimize of production business processes by quickness, quality and efficiency |
| SMAC (social, mobile, analytics and cloud) | Strategic (change corporate system of information management) Strategic (change operational information management, relationship with clients) | Optimize of business processes by quickness, quality and efficiency |
| Cloud Computing | Strategic (change corporate system of information management) Operational (change operational information management) | Business process acceleration Reduce informational costs |
| 3D Printing | Strategic (change corporate manufacturing management, goals) Operational (change system of production) | Production diversification Reduce producing costs |
| Drones | Operational (change system of distribution) | Increase Perfect Order Deliveries Reduce delivery costs |
| Wireless communication (RFID, GSM, GPS, etc) | Operational (change system of distribution, logistics and assets management) | Increase Perfect Order Deliveries Reduce logistics costs |
| Remote and mobile assets | Operational (change system of assets, manufacturing and inventory management) | Reduce inventory costs |

* we have consciously not included CPS into the list. Because, we are talking just about the classical model of SCM.

Figure 1. Key requirements to SCM in the times of digital transformations

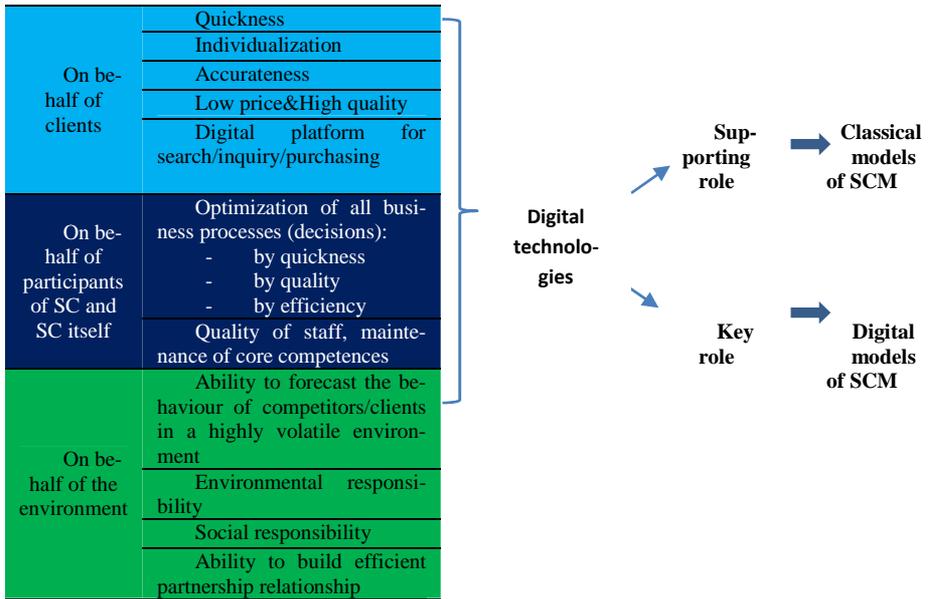


Figure 2. Supply Chain Development Drivers

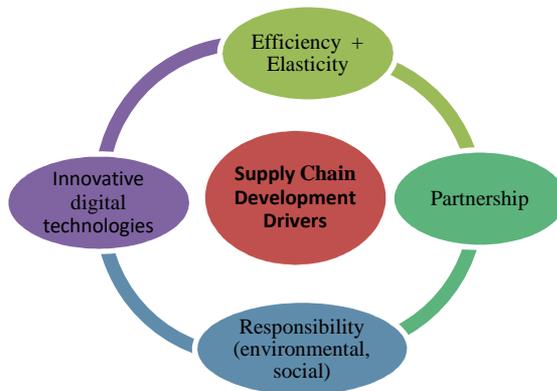


Figure 3. Structure of answers to question ‘In what field of your business would it be most expedient to introduce DT?’

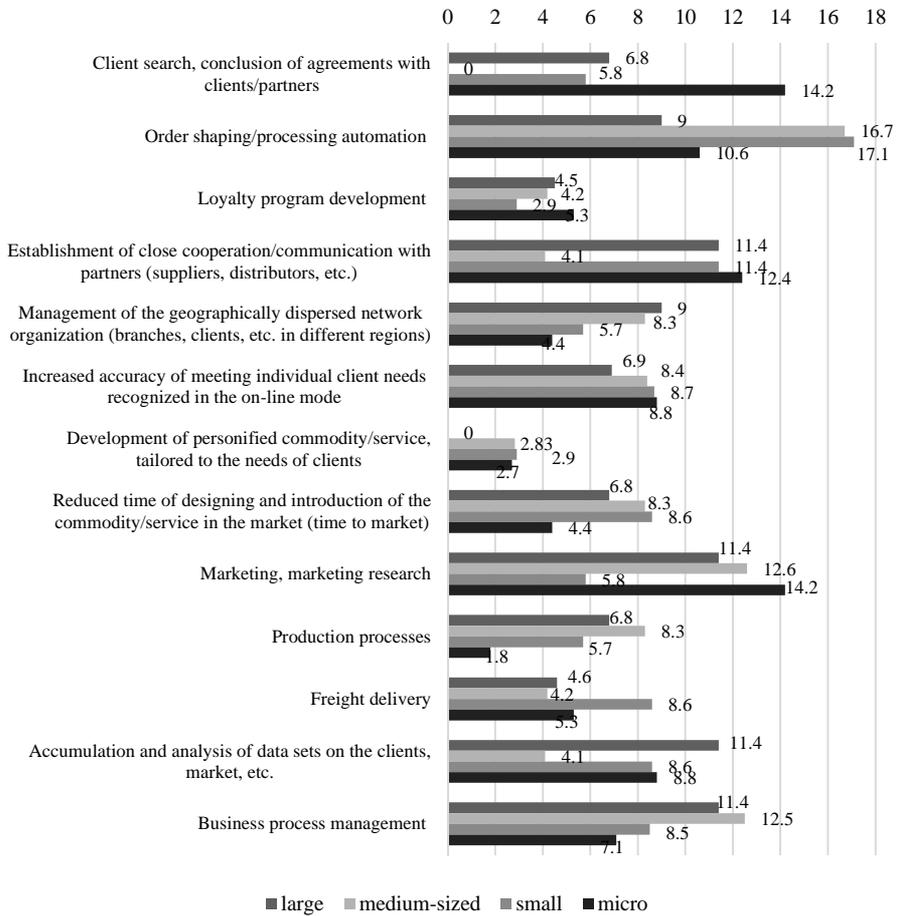


Figure 4. Structure of answers to question ‘What advantages are or would be the key value in the use of DT for your company?’

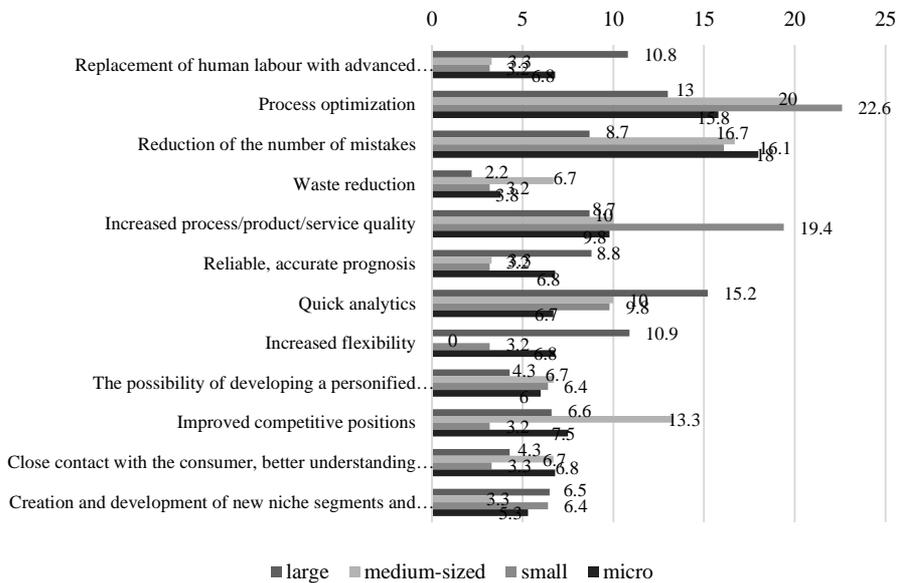


Figure 5. Structure of answers to question ‘What challenges stand in the way of introduction of DT in your business?’

