The impact of *Industry 4.0* on the value chain: the case of Lithuanian traditional industries

Kristina Kovaitė [1,2 a] , Jelena Stankevičienė [3]
[1] Faculty of Creative Industries, Vilnius Gediminas Technical University, Trakų str. 1., Vilnius, Lithuania
[2] Vilnius Business College, Kalvarijų str. 125, Vilnius, Lithuania
[3] Faculty of Business Management, Vilnius Gediminas Technical University, Saulėtekio 11, Vilnius, Lithuania

Received 26 June 2017, in revised form 30 July 2017, accepted 15 September 2017

Abstract. *Industry 4.0* brings changes within only a few decades after the third industrial revolution to all the spheres of industrial, business and social life. The article aims to identify the technological characteristics of *Industry 4.0* using literature review method and to evaluate the impact of each of them on the value chain using expert evaluation method. Overview of *Industry 4.0* concepts used in the literature identified the characteristics of *Industry 4.0*. Experts indicated two groups of importance of the described characteristics of the *Industry 4.0* to the value chain and scored the characteristics to the each of the part of the value chain. Internet of things, digital infrastructure, vertical/ horizontal integration and robotics are very important nowadays in the development of industries. The rest characteristics such as 3D printing, artificial intelligence, etc are indicated as having less importance at present. The transfer of findings in the process of implementation of *Industry 4.0* technological pillars across different industries as well as other actors – public, SMEs - different types of enterprises and sectors are to be researched further on.

Citations: Kristina Kovaitė, Jelena Stankevičienė. The impact of *Industry 4.0* on the value chain: the case of Lithuanian traditional industries – *Innovative Infotechnologies for Science, Business and Education,* ISSN 2029-1035 – **1(22)** 2017 – Pp. 3-10.

Keywords: *Industry 4.0*; value chain; technological characteristics; internet of things; robotics; vertical and horizontal integration; digital infrastructure; impact evaluation.
Short title: Industry 4.0 on value chain.

Introduction

Industry 4.0 brings numerous changes in industrial and social life within only a few decades after the third industrial revolution. *Industry 4.0* focuses on technological issues and cyber-physics interactions in the value chain and challenges all the areas: inequality, security, consumer and social behaviour, new ways of organising work and social life, ageing society and education.

Experts from traditional industry in Lithuania participated in the research. As a result, two groups of characteristics were identified with a high and low score of significance. Technological characteristics such as Internet of things, robotics, vertical and horizontal integration and digital infrastructure are indicated having a high significance in the traditional industries in Lithuania. High impact on inbound and outbound logistics, services, manufacturing and sales in the value chain has been indicated. Even with a lack of systematic scientific research a big interest from different actors (industries, government, funding agencies, SMEs) of *Industry 4.0* has been noticed.

The article aims to identify the technological characteristics of *Industry 4.0* and to evaluate the impact of each of them into the value chain using expert evaluation method.

[a]Corresponding author, email: kristinakovaite@gmail.com

1. Development of *Industry 4.0*

The term *Industry 4.0* was introduced by the German Ministry of Education and Research as a guide to promote German high technology industry and its development strategy in 2011, and the Hanover Fair in 2012 followed by formation of a working group chaired by Siegfried Dais (Robert Bosch GmbH) and Henning Kagermann [1] as Scheer [2] reported. Nowadays different terms with a similar meaning have been used by different countries.

The term *Industry 4.0* indicates the "*fourth* time when technological developments bring revolutionary changes in industry and it has big impact not only on manufacturing but also on the way of operating and living" [3]. The first industrial revolution refers to the period after the introduction of steam and water-powered production methods. Some publications indicate that the first industrial revolution in reality started when the first mechanical loom was invented in 1784. "The start of the second industrial revolution is indicated with the introduction of electricity and the assembly lines which allowed mass production between late 19th and early 20th century" [4]. The discussions show that it is complicated to have a clear and definite identification about the starting of such processes and technological changes and the impact

Table 1. Comparative analysis of the concepts related to *Industry 4.0*.

Aspect	Scientific literature	Grey literature	Funding policy papers
Internet of things; M2M	Schwab [5] Bauer [12] Dujin [13] Marika [14] Liao [15] Zhou [3]	Germany Trade & Invest, Scheer [2] Capgemini Consulting, Bechtold [16] McKinsey&Company [17] Rüßmann [18]	Smit [19]
Digital infrastructure; cybersecurity	Marika [14] Liao [15] Zhou [3]	McKinsey&Company [17] Rüßmann [18]	Smit [19]
Vertical and horizontal integration	Dujin [13] Liao [15]	Rüßmann [18]	Smit [19]
Artificial intelligence	Schwab [5] Liao [15]	Germany Trade & Invest, Scheer [2]	Smit [19]
Robotics	Schwab [5] Dujin [13] Liao [15]	Germany Trade & Invest, Scheer [2] Capgemini Consulting, Bechtold [16] McKinsey&Company [17] Rüßmann [18]	Smit [19]
Autonomous vehicles	Schwab [5]		
3D printing	Schwab [5] Dujin [13] Liao [15]	Capgemini Consulting, Bechtold [16] McKinsey&Company [17] Rüßmann [18]	Smit [19]
Nanotechnology; biotechnology; material science	Schwab [5]		
Energy storage	Schwab [5]	McKinsey&Company [17]	
Quantum computing	Schwab [5] Liao [15]	Germany Trade & Invest, Scheer [2]	
Virtual/augmented reality	Liao [15]	Germany Trade & Invest, Scheer [2] McKinsey&Company [17] Rüßmann [18]	Smit [19]
Cloud technology/ computing; Big data and analytics	Liao [15] Zhou [3]	McKinsey&Company [17] Rüßmann [18]	Smit [19]

they bring to the society.

On the contrary to the first two revolutions it took only a few decades - starting from the 70's - for the rapid adoption of electronics and IT to enable automation of production in factories and a few more decades later - in 2012 - the Industry introduces again a concept that foresees revolutionary changes.

The phenomenon of *Industry 4.0* has been mostly explored in German scientific researches (Schwab [5], Brettel [6], Sendler [7], Kagermann [1], Burmeister [8] etc) though in recent times more scientists are involved into the research. Some of them explore *Industry 4.0* as a concept [5] and some of them relate to specific areas as the term *Industry 4.0* is associated with the terms of "Internet of Things", "Big Data", "Advanced Manufacturing", "Smart Manufacturing" "3D printing", "additive manufacturing", and related issues [3, 8, 9, 10, 11]. Table 1 represents comparative analysis of *Industry 4.0* concepts.

K.Schwab in his book "The Fourth Industrial revolution" [5] considers the challenges of *Industry 4.0* "staggering confluence of emerging technology breakthroughs, covering wide-ranging fields such as artificial intelligence (AI), robotics, the Internet of things (IoT), autonomous vehicles, 3D printing, nanotechnology, biotechnology, materials science, energy storage and quantum computing". Above mentioned innovations are just starting, "but they are already reaching an inflection point in their development as they build on and amplify each other in a fusion of technologies across the physical, digital and biological worlds" [5].

2. Research in *Industry 4.0*

The ongoing discussions among researchers on the necessary balance of theory-based research and application-oriented research show the scientific interest to the issue from all different sectors. On one hand, Sanders et al. [20] wrote: "Some researches in *Industry 4.0* were purely theory-oriented, not readily adaptable to an application. Application-oriented research need to be developed pertaining to the criteria of implementing lean manufacturing. Future research needs to be focussed on creating a conceptual framework and cyber physical working system, integrating these parameters in a fully functional production environment" [20]. On the other hand, numerous publications mostly found in the Research Papers of world-wide consulting companies such as Boston Consulting Group [18], McKinsey&Company [17] show the bottom-up need for further research on *Industry 4.0*.

Ref. [2] initiated by Germany Trade & Invest defines areas to research funding indicating the expectations for the future development of *Industry 4.0*. The authors define "software systems and knowledge processing" and divide research into the three specific categories naming "software-intensive embedded systems with links to electronics, communication technology and microsystems technology, simulated reality for grid applications and infrastructure, software development for high-performance computing, human/machine interaction with language and media technologies, bio-analogous information processing, service robotics and usability".

The extended attention found in Strategy and Funding Priorities papers [2, 19] allows to emphasise the importance and lack of research of *Industry 4.0* and its implications.

Different sources provide the different technological changes that *Industry 4.0* brings; though most of them agree upon changes in technological environment and business paradigms and changing Supply chain. Dujin et al. [13] write about "the fully connected way of making things" describing as data is gathered from suppliers, customers and the company itself and evaluated before being linked up with the real production. "The latter is increasingly using new technologies such as sensors, 3D printing and next-generation robots. The result: production processes are fine-tuned, adjusted or set up differently in real time" settles [13].

During numerous interviews and speeches in World Economic Forum and similar occasions, Schwab [5] envisions the changes and impact on the individual in a global level: in ways of leadership and governance system involving:

i) multi-stakeholders (5 ways leaders can fix the world);
ii) economy (especially for growth, employment and the nature of work);
iii) business (consumer expectations, data-enhanced products, collaborative innovation and new operating models);
iv) global and national level (governments, countries and cities, and international security);
v) society (increasing inequality and community issues);
vi) the individual (identity and ethics, human connection and managing public and private information.

Vanysek [4] writes about changing business paradigms as "the changes to the value chain require companies to embrace new business models", safety and security, legal issues and IP; standardization.

The Fourth Industrial Revolution brings shifts not only in production, consumption, transportation and delivery systems all across of the industries vertically and horizontally

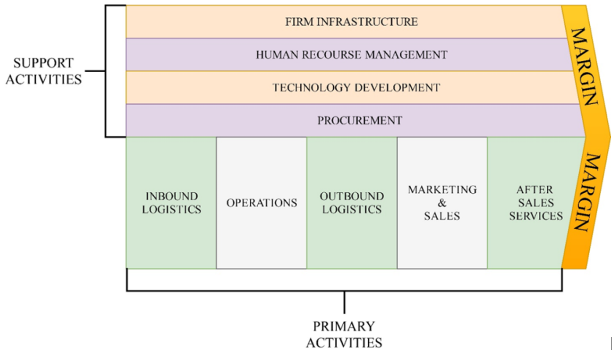

Fig. 1. The Diagram of Value Chain. Modification of Porter model. Adapted according to Ref. [10].

but also it *is marked by the emergence of new business models, the disruption of incumbents and the reshaping of the traditional way* [5].

Scientists agree that the new ways of using technologies change in behaviours, consumption, decision making, communication. Entertainment and other societal areas will emerge according to Schwab: "The changes are historic in terms of their size, speed and scope" [5].

Dujin A. [13] argues that "the roles of designers, physical product suppliers and the interfaces with the customer (contractor) will change" the way to communicate and it is "the first step is the fragmentation of the value chain". Dujin tells that "countless small entrants have lower barriers to entry". This indicates that new ways of organising participation in a value chain will be modelled. Internet, 3D printing, participation in a vertical integration chain, cloud technologies are expected to play a big role.

3. Value Chain related to *Industry 4.0* technological changes

Porter [10] discusses the impact of smart and connected products has on transformation of companies and competition and capture of the value.

Several models of Value Chain are known, including M.Porter's model, described in Refs. [9, 21] and modified due to exploring purposes [1, 19]. Fig. 1 represents the diagram of Value Chain as modification of Porter model where primary activities as well as support activities take place. Dujin [13] suggests that "after fragmentation of the value chain" new ways to participate in the value chain will appear and new models will be developed.

4. The situation in Lithuania: case of traditional industries

Traditional industries and their progress in introduction of *Industry 4.0* are especially important for investigating the topic in Lithuania as industry represents approximately 35% of annual GDP in Lithuania. Almost half of it is created by manufacturing industries. In 2017, platform *Industry 4.0* has been

Table 2. Kendall's Concordance Coeficients of Experts' Assessments

N	Value chain	Kendall W	$\tilde{\chi}^2$	p
1.	Procurement	0.9791	68.5385	< 0.0001
2.	Technology development	0.9801	68.6085	< 0.0001
3.	Human Resource Management	0.9633	67.4342	< 0.0001
4.	Firm Infrastructure	0.9878	69.1473	< 0.0001
5.	Inbound logistics	0.9701	67.9061	< 0.0001
6.	Manufacturing	0.9810	68.6734	< 0.0001
7.	Outbound logistics	0.9586	67.1026	< 0.0001
8.	Marketing&Sales	0.9682	67.7741	< 0.0001
9.	Services	0.9850	68.9497	< 0.0001

established in Lithuania under the initiative of the Lithuanian Confederation of Industrialists with participation of government, industrial institutions and industries and science. As mentioned above, in the survey more approximately 52% of Lithuanian companies declare that *Industry 4.0* is relevant and important to them [22].

4.1. Porter model for research

The research aims to evaluate the impact of technological characteristics related to *Industry 4.0* for the value chain in business in Lithuania. The expert evaluation using semi-structured interview was selected as a research method.

Five experts were selected according to their experience and competences in manufacturing industry and representation of a specific sector:
1) at least 10 years of working experience in their specific industry;
2) experience related to *Industry 4.0* issues;
3) previous or present leadership positions of a membership based industrial associations.

The concordance of the experts' evaluation was analyzed by means of the Kendall's concordance coefficient W routine, described by Kendall [23] and Podvezko [24]. Concordance coeficient W (presented in range $[0 \leq W \leq 1]$) allows estimating the agreement among assessments of experts. Minimum and maximum values can be defined as follows:
i) when experts are unanimous in their assessment and this occurs when all experts are in full agreement, then $W \to 1$;
ii) when experts' assessments vary, then $W \to 0$.
The Kendall's coefficient W was calculated according to the formula:

$$W = \frac{12 \cdot S}{r^2 m \cdot (m^2 - 1) - r \sum_{j=1}^{r} T_j)} \quad (1)$$

when r represents number of experts, and m - number of objects to evaluate by mentioned experts. S represents a sum-of-squares statistic over the row sums of ranks m_i, where e_i represents sum of ranks, and $\overline{e}$ – average of sums of ranks:

$$S = \sum_{i=1}^{m} (e_i - \overline{e}) \quad (2)$$

T represents an indicator of tied ranks of j expert:

$$T_j = \sum_{k=1}^{H_j} (t_k^3 - t_k) \quad (3)$$

H_j represents number of ranks of the same value of the j expert, and t_k represents the number of equal tied ranks in each (k) group of ties. Chi-squared distribution could be calculated using following expression:

$$\tilde{\chi}^2 = Wr(m-1) = \frac{12 \cdot S}{r \cdot m \cdot (m+1) - \frac{1}{m-1} \sum_{j=1}^{r} T_j} \quad (4)$$

By solving the practical concordance calculation task, W coefficients were calculated for each ranked object. Table 2 represents Kendall's Concordance Coeficients W of Experts' Assessments. All the W coefficients are presented in interval [0.958÷0.980] confirming the concordance of experts' evaluations. Therefore, we can rely on the evaluation of the experts.

The model of value chain proposed by M. Porter [10] was chosen for the research. In this context, two different terms - concepts and characteristics - will be used in the same manner.

The following characteristics of *Industry 4.0* were indicated to evaluate: Internet of things, digital infrastructure, robotics, horizontal and vertical system integration, 3D printing / additive manufacturing, artificial intelligence, autonomous vehicles, nanotechnology, biotechnology, energy storage, quantum computing, big data, virtual/augmented reality, cloud technologies.

The research was organised into two steps: expert evaluation of the characteristics and interview. The experts were asked to evaluate the significance of each technological characteristics (from the first column) in each of the part of the value chain in the industry in Lithuania in 2017. The experts were asked to:

i) indicate the significance of each technological characteristics giving 0-1 to each of them and in this way rating the characteristics in the sequence of importance;
ii) evaluate the importance of each of technological factor/segment to each part of the value chain giving 0-1.

Characteristics	significance	Procurement	Tech development	HR Management	Firm Infrastructure	Inbound logistics	Manufacturing	Outbound logistics	Marketing & sales	Services
Internet of things	20	↘ 2.2	↓ 1.4	↘ 2	→ 2.4	→ 2.4	↓ 1.4	↘ 2.2	↑ 3.6	→ 2.4
Digital infrastructure	24	→ 2.88	↑ 3.84	↘ 2.16	↘ 2.16	→ 2.88	↓ 1.44	→ 2.64	↑ 4.08	↓ 1.92
Robotics	20	↓ 0	→ 3	↓ 0.2	↓ 0	↘ 1.6	↑ 6.6	↘ 1.8	↓ 0.8	↑ 6
Horizontal and vertical system integration	23	↓ 1.15	↘ 2.53	↓ 0.46	↓ 1.15	↘ 1.84	↑ 6.9	↘ 2.07	↘ 2.3	↗ 4.6
3D printing and prototyping/ Additive manufacturing	1	↓ 0.01	↑ 0.45	↓ 0	↓ 0.01	↓ 0.05	→ 0.25	↓ 0.05	↓ 0.06	↘ 0.12
Artificial intelligence	1	↓ 0	↑ 0.66	↓ 0.01	↘ 0.15	↓ 0	↓ 0.02	↓ 0	↓ 0.1	↓ 0.06
Autonomous vehicles	1	↓ 0	↑ 0.25	↓ 0	↓ 0	↑ 0.2	→ 0.1	↑ 0.25	↘ 0.05	↗ 0.15
Nanotechnology	2	↓ 0	↑ 0.9	↓ 0	↓ 0	↓ 0.14	→ 0.4	↓ 0.16	↓ 0	→ 0.4
Biotechnology	3	↓ 0.15	↗ 0.75	↓ 0	↓ 0	↓ 0	↑ 1.05	↓ 0	↘ 0.3	↗ 0.75
Energy storage	1	↓ 0.02	↘ 0.15	↓ 0	↓ 0	↘ 0.08	↑ 0.4	↓ 0.07	↓ 0.03	↗ 0.25
Quantum computing	1	↓ 0	↑ 0.9	↓ 0	↓ 0	↓ 0.01	↓ 0.01	↓ 0.01	↓ 0.05	↓ 0.02
Big data	1	↗ 0.15	↗ 0.15	→ 0.1	↑ 0.18	→ 0.1	↓ 0.05	→ 0.1	↗ 0.13	↓ 0.04
Virtual/augmented reality	1	↘ 0.1	↑ 0.3	→ 0.15	↘ 0.1	↓ 0.05	↓ 0	↓ 0.05	↗ 0.2	↓ 0.05
Cloud	1	→ 0.15	↑ 0.25	↓ 0.03	↓ 0.05	↓ 0.05	↓ 0.07	↓ 0.06	↑ 0.25	↘ 0.09
TOTAL	100	↓ 6.81	↗ 15.53	↓ 5.11	↓ 6.2	↘ 9.4	↑ 18.69	↘ 9.46	→ 11.95	↑ 16.85

Fig. 2. The impact of the characteristics of *Industry 4.0* to the value chain
(by authors according to the experts' evaluation results, 2017)

Experts also were asked to explain results and share their vision about the development of characteristics of *Industry 4.0* in Lithuania.

Fig. 2 represents the comparison of the characteristics of *Industry 4.0* to the value chain. The indicator arrow shows the comparison of the individual characteristics to the value chain. Each characteristics is indicated in the scale between the highest significance (marked by a green arrow up) and the lowest significance (marked by a red arrow down). Orange arrows indicate the intermediate scores in between.

By analysing Fig. 2 in the framework of indicator's dynamics, it is possible to conclude that technology development is seen having the biggest influence by the characteristics of *Industry 4.0*. Eight characteristics put of 14 are indicated as very important (marked by a green arrow). Also manufacturing and marketing & sales are having influence (4 and 3 characteristics are indicated as very important marked by green arrows), services, inbound and outbound logistics are indicated once as very important (marked by green arrows).

Fig. 2 represents the impact of *Industry 4.0* to value chain according to the experts' evaluation results. The scores at line "Total" represent the importance of all the characteristics to the specific part of the value chain.

The results of evaluation made by experts show that impact of each characteristics is distributed not equally. Technology development, manufacturing, marketing & sales and services are having most influence by *Industry 4.0* characteristics. Impact on logistics (both inbound and outbound) is also important. Very low impact is seen in human resource management. Procurement and firm infrastructure also gets low evaluation of impact of the characteristics.

Experts giving scores divided characteristics into two groups: high significance and low significance. High significant characteristics are: Internet of things, Digital infrastructure, robotics, horizontal and vertical integration. Low significant characteristics are: 3D printing/ additive manufacturing, artificial intelligence, autonomous vehicles, nanotechnology, biotechnology, energy storage, quantum computing, big data, virtual/augmented reality, cloud technologies.

Fig. 3 shows how experts evaluated the interrelatedness between technological characteristics and the value chain. I was calculated by multiplying average score A given by experts by a weight ratio W (in %):

$$I = A * \frac{W}{100\%} \qquad (5)$$

Score value is placed in interval [0÷7].

Due to experts evaluation, vertical and horizontal integration and robotics have a big impact on manufacturing (6.9 and 6.6 respectively) and services (6.0 and 4.6 respectively) in the value chain. Digital infrastructure (score varies from 1.44 to 4.08) and internet of things (score varies from 1.4 to 3.6) are having a significant impact on all the parts of the value chain. Digital infrastructure has the highest impact on marketing & sales (4.08) as well as Internet of things (3.6).

Fig. 4 represents the impact of Industry 4.0 characteristics that have a high importance: internet of things, digital infrastructure, robotics and horizontal/vertical system integration, to the support activities of the value chain: procurement, technology development, human resource management and firm infrastructure as described according to the experts' evaluation results.

By exploring the second group of characteristics, the impact is obvious in following fields: biotechnology is important in manufacturing (1.05) and services (0.75), quantum computing and nanotechnology is seen important to technology development (0.9 each). Impact on the rest of character-

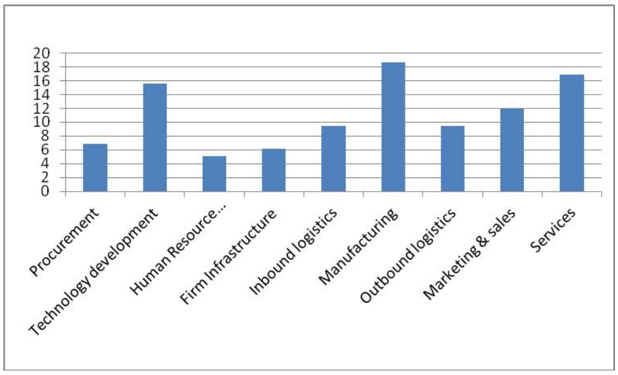

Fig. 3. Impact of *Industry 4.0* characteristics to the value chain: high significance
(according to the experts' evaluation results, 2017).

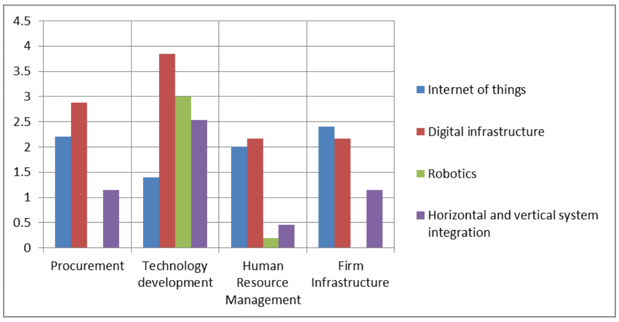

Fig. 4. Impact of Industry 4.0 characteristics of high importance to the support activities of the value chain, 2017
(by authors according to the experts' evaluation results).

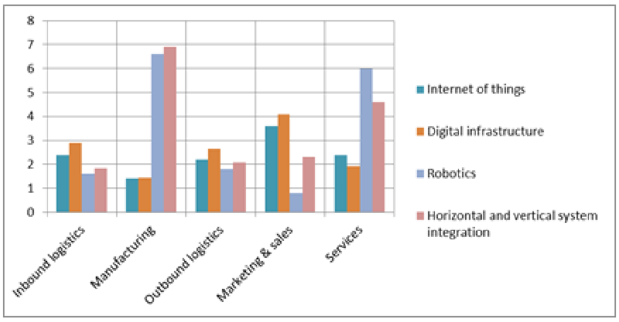

Fig. 5. Impact of Industry 4.0 characteristics of high importance to the primary activities of the value chain, 2017
(by authors according to the experts' evaluation results).

istics is not seen as having significant impact now, the scores are lower than 0.5.

Fig. 5 represents the impact of *Industry 4.0* characteristics of a high importance (internet of things, digital infrastructure, robotics and horizontal/vertical system integration) to the primary activities of the value chain (inbound logistics, manufacturing, outbound logistics, marketing & sales, services) as described according to the experts' evaluation results. Robotics and horizontal/vertical integration are seen having very high importance on manufacturing and services. The same characteristics have very low importance on marketing and sales and moderate importance on inbound and outbound logistics. Internet of things have high importance on marketing and sales, inbound and outbound logistics and low importance on manufacturing. Digital infrastructure is important in all the primary activities of the value chain.

The additional comments of the experts are described below.

One expert indicated that traditional industry uses the experts "segments of *Industry 4.0* according to the personal understanding and do not do research or make evaluation for long term investment". The expert said that the challenge comes in a several ways: "no education of computer science is introduced in the Lithuanian higher education system, lack of investment and lack of governmental policy and support to introduce *Industry 4.0* in Lithuanian industry".

One expert indicated that the impact and importance of technological characteristics is to be evaluated in a time frame "as it is difficult to see *Industry 4.0* as a stable situation and clearer - in a trend of change process". The experts also indicated that only "some characteristics have a clear role in the industry in Lithuania already". One expert said that "considering a long-term impact of other characteristics might increase and the weight of each factor will change ".

Through other experts expressed their hesitation to indicate concrete changes in a longer term "as *Industry 4.0* elements in some industrial sectors are very fragmented yet", all experts agree that "*Industry 4.0* is here and changes are inevitable". The experts raise the impact for the small and medium enterprises emphasising their possibilities in the Supply chain "if they are able to adapt to changes". Experts also indicated that "the most structured information is in the Research Papers of consulting companies such as Boston Consulting Group, McKinsey, etc" which is not considered as a "real scientific literature which is still fragmented and not enough to make conclusions" [17].

4.2. Limitations

The research is not without limitations. There was not a finalised list of technological characteristics found in the scientific literature and, therefore, the list consists of frequently used characteristics found in scientific and grey literature. Knowledge in industry in Lithuania about the opportunities *Industry 4.0* gives is agreed to be fragmented and based more on a personal interest than on overall know-how existing in the country and industry. Experts in this research are from traditional industries in Lithuania. Choosing experts from different sectors (e.g. public, research, etc) and industries (e.g. laser, service, etc) and sizes of enterprises (e.g. big companies and SMEs) will bring a wider prospective of the situation in Lithuania.

4.3. Future research

Research of scientific literature is to be explored and analysed to have a strong basis for the future exploration of the issue. The issues related to new business models, the new ways to organise a supply chain and connection with societal challenges are the topics of scientific interest though at a very early stage. The shift of technological changes from manufacturing to service industry as well as competences necessary in the context of *Industry 4.0* are important topics to explore. Practical application of the scientific research findings, new opportunities and models for different types and sizes of enterprises (e.g. SMEs) in the supply chain of industries within the technological developments of *Industry 4.0*, meeting societal challenges and other issues must be explored in later researches.

Conclusions and recommendations

Most of scientific literature explores *Industry 4.0* focus on a certain technological factor or a specific industrial sector, some literature explores challenges that *Industry 4.0* is expected to bring to the society, new business paradigms and security.

Most of future funding policy papers (egg. European Commission, German Trade and Invest, Recommendations for Implementing the Strategic Initiative of *Industry 4.0*,) indicate not only technological development in the context of *Industry 4.0* but also its impact on new business models (changes in value chain, consumer behaviour, etc), societal issues (ageing, employment, work structure and organisation, etc), culture development (ownership vs access), and legal issues (Intellectual property, data protection, etc).

There are four characteristics that experts call as the most significant to the development of *Industry 4.0* in Lithuania: internet of things, digital infrastructure, robotics, horizontal and vertical integration. The mentioned above characteristics related to *Industry 4.0* are far more developed and understood in Lithuanian industry than others and, therefore, it might be explored separately from those that are less developed.

Four parts of the value chain are most influenced by *Industry 4.0*: manufacturing, technology development, marketing and sales, after-sales services. Understanding the opportunities that *Industry 4.0* and technological changes bring to industries, and long term are less understood by industries in Lithuania.

References

1. Henning K. Recommendations for implementing the strategic initiative INDUSTRIE 4.0. – *Final report of the Industrie 4.0* 82 (2013) – DOI: 10.13140/RG.2.1.1205.8966.
2. Scheer A. W. Industrie 4.0. – Germany Trade and Invest, 2013. – <https://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Brochures/Industries/industrie4.0-smart-manufacturing-for-the-future-en.pdf>, accessed 2017.06.10.
3. Zhou K., Liu T., Zhou L. Industry 4.0: Towards future industrial opportunities and challenges. – In: 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD 2015) – (2015) 2147-2152. – DOI: 10.1109/FSKD.2015.7382284.
4. Vanysek P. From the Editor: Industry 4.0. – *Electrochemical Society Interface* 25(2) (2016) 3-4. – DOI: 10.1149/2.001162if.
5. Schwab K. The Fourth Industrial Revolution. – In: World Economic Forum, Switzerland, 2016. – ISBN-13:978-1-944835-00-2.
6. Brettel M., Friederichsen N., Keller M., Rosenberg M. How Virtualization Decentralization and Network Building Change the Manufacturing Landscape. – *An-Industry-40-Perspective* 8(1) (2014) 37-44.
7. Sendler U. (Ed.). Industrie 4.0: Beherrschung der industriellen Komplexität mit SysLM (Systems Lifecycle Management) – Springer-Vieweg, Berlin, Heidelberg, 2013. – 1-20.
8. Burmeister C., Lüttgens D., Piller F. T. Business Model Innovation for Industrie 4.0: Why the "Industrial Internet" Mandates a New Perspective on Innovation? – *Swiss journal of business research and practice; Organ der Schweizerischen Gesellschaft für Betriebswirtschaft (SGB)* 70(2)(2016) 124-152. – DOI: 10.5771/0042-059X-2016-2-124.
9. Vermesan O., Friess P. Internet of Things - From Research and Innovation to Market Deployment. – *River Publishers Series in Communication* 143 (2014) 1-143.
10. Porter M. E., Heppelmann J. E. How smart, connected products are transforming competition. – *Harvard Business Review* 92(11) (2014) 64-88.
11. Prause G. Sustainable business models and structures for Industry 4.0. – *Journal of Security and Sustainability* 5(2) (2015). – DOI: 10.9770/jesi.2015.5.2(3).
12. Bauer W., Hummerle M., Schlund S., Vocke C. Transforming to a Hyper-connected Society and Economy - Towards an Industry 4.0. – *Procedia Manufacturing* 3 (2015) 417-424. – DOI: 10.1016/j.promfg.2015.07.200.
13. Dujin A., Geissler C., Horstkötter D. Industry 4.0 The new industrial revolution How Europe will succeed. – *Roland Berger Strategy Consultants* (March):(2014) 1-24. – <http://www.iberglobal.com/files/Roland_Berger_Industry.pdf>, accessed 2017-07-10.
14. Iivari et al. Toward an ecosystemic business model in the context of industrial internet. – *Journal of Business Models* 4(2) (2016) 42-59.
15. Liao Y., Deschamps F., Loures E. de F. R., Ramos L. F. P. Past, present and future of Industry 4.0 - a systematic literature review and research agenda proposal. – *International Journal of Production Research* 55(12)(2017) 3609-3629 – DOI: 10.1080/00207543.2017.1308576.
16. Bechtold J., Kern A., Lauenstein C., Bernhofer L. Industry 4.0. – The Capgemini Consulting View, Capgemnini Consulting: 31 (2014) – <https://www.capgemini.com/consulting-nl/wp-content/uploads/sites/33/2017/08/industrie_4.0_0.pdf>, accessed 2017-07-10.
17. McKinsey&Company Industry 4.0 at McKinsey' s model factories: Get ready for the disruptive wave. – (2016) 1-12. – DOI: 10.1080/01969722.2015.1007734.

18. Rüßmann M., Lorenz M., Gerbert P., Waldner M., Justus J., Engel P., Harnisch M. Industry 4.0. – The Boston Consulting Group, Boston, 2015. – 1-20. – <https://www.bcgperspectives.com/Images/ Industry_40_Future_of_Productivity_April_2015_tcm80-185183.pdf>, accessed 2017 02 07.
19. Smit J., Kreutzer S., Moeller C., Carlberg M. Industry 4.0. – *Study for the ITRE Committee, European Parlament* (2016) 1-94. – <http://www.europarl.europa.eu/RegData/etudes/STUD/2016/570007/IPOL_STU(2016)570007_EN.pdf>, accessed 2017 02 07.
20. Sanders A., Elangeswaran C., Wulfsberg J. Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean manufacturing. – *Journal of Industrial Engineering and Management* 9(3) (2016) 811-833. – DOI: 10.3926/jiem.1940.
21. Koch V., Kuge S., Geissbauer R., Schrauf S. Industry 4.0 - Opportunities and challenges of the industrial internet. – PriceWaterhouseCoopers, 2014. – 1-51. – <https://www.pwc.nl/en/assets/documents/pwc-industrie-4-0.pdf>, accessed 2017 02 07.
22. Pramonė 4.0 - keičiasi įmonių požiūris į gamybos modernizaciją. – Lietuvos pramonininkų konfederacija, 2017.
23. Kendall M. Rank Correlation Methods. – Hafner Publishing House, New York, 1955.
24. Podvezko V. Agreement of expert estimates. – *Ukio Technologinis ir Ekonominis Vystymas* 11:2 (2005) 101-107. – DOI:org/10.1080/13928619.2005.9637688.