INDUSTRY 4.0 IN THE CZECH REPUBLIC – STATE OF THE ART

Petr Jirsak – Felipe Martinez – Miroslav Lorenc – Jakub Jancik

Abstract

The paper focuses on the scope of the definition for the concept Industry 4.0 (i4.0) in the Czech Republic. It presents a review of relevant literature about i4.0 published abroad and in the Czech Republic. The output of this paper comprises the initial phase of authors´ research in the area. i4.0 is a new topic in the Czech Republic following the hype from Germany where it was initially institutionalized in 2011 as a government strategy to become an industry leader in 2020. The main aspect of the strategy is virtualization and automation of the entire value chain of the company by distributing the decisions over it while looking for the overall effectiveness of the chain. i4.0 expands from Germany to other countries such Switzerland and Great Britain. These countries also endeavour to gain leadership in industry. The Czech Republic also needs to establish appropriate conditions to support companies on the adoption of this new approach in order to keep and improve its competitive advantage in these areas. This paper outlines the state of the art of i4.0 in the Czech Republic based on the content analysis. The body of knowledge contains specific approaches to develop this type of researches.

Key words: Industry 4.0 (i4.0), value chain, competitiveness, effectiveness, strategy

JEL Code: M11, M15, L60

Introduction

Permanently intensified market changes which are realized in the area of customer demand, risk and corporate sustainability (ecology, social and economy) require significant reshaping of production and supply chain approach (Christopher, 2010). Rapid growth of SKUs in company portfolio, shrinkage of product life cycle, demand on delivery time reduction, requirement on downsizing of purchase batches and growth of delivery frequency, pursue of product and process variability reduction have been so far dealt mainly by process improvements and by insular implementation of new technologies (automatic identification, software e.g. warehouse management system, demand planning system, transportation

management system etc., robots, sensors etc.). However, this step by step changes had sometimes weren't able to keep pace with the market changes in the area of costs reduction especially. Therefore, many companies shifted their production and supportive processes to low cost regions such as Southeast Asia, South America and Central and Eastern Europe or to Russia. Moreover, outsourcing gave companies significant advantages to companies in 90´s and the first decade of 21th century because of labour cost savings in production and supportive processes. Nonetheless, wage, material and utility cost inflations caused by massive grow of demand on them in the off-shoring regions have led to melting of differences between costs in traditionally industrialized countries and the off-shoring countries (Aronson, 2008; Ferreira & Prokopets, 2009). Moreover, the second decade of 21st century is characterized by even greater intensification of market changes for instance variety of product portfolio offered on a market, product quality, logistic service level in terms of delivery time, delivery accuracy, frequency, delivered information, traceability and supply chain visibility. Thus, off-shoring strategy has failed in terms of competitiveness. In addition to that, there are concerns among professionals and academics if gradual change of processes and technological improvements can provide a level of supply chain performances desired on both B2B and B2C markets. That issue has been recognized not only on a company level but even more on a country level. The vision to meet customer demand and to establish competitiveness on both company and country level has been recognized in massive implementation of digitalization and automation in company and supply chain processes (Wang, Wan, Li & Zhang, 2016). Managing of material and information flows has become critical factor for competitiveness (Bearzotti, Salomone & Chiotti, 2012).

Such vision has been materialized by foundation of Industry 4.0 (i4.0) (or similar name based on a particular language mutation) in the countries aspiring to world industry leaders or their major supplying countries to become more attractive proximity for company processes rather than off-shoring countries offering lower labour costs. The main public attention started in Germany when i4.0 was officially introduced in 2013 at the Hanover Fair (Sommer, 2015). However, the roots of that are in Smart Factory initiative established in 2005. Similar initiatives to i4.0 could be found in several European countries (Germany – Industrie 4.0, Mittelstand 4.0, Smart Service World, Autonomik fur Industrie 4.0; Great Britain – High Value Manufacturing catapult, Inovate UK; France – Industrie du Futur; Sweden – Produktion 2030; Netherlands – Smart Factory; Belgium – Made different; Portugal – Produtech; Spain – Industria Conectada 4.0; Italy – Fabbrica inteligente; Internet of Things and Industry 4.0; Finland – FIMECC PPP Programmes, Industrial Internet Business

Revolution; Latvia – Demola; Poland – Innomed, Innolot, CuRR, Biostrateg; Austria – Produktion der Zukunft, Czech Republic – Průmysl 4.0) in USA (Smart Manufacturing Leadership Consorcium, Industrial Internet Consorcium, Advanced Manufacturing Partnership), China (Made in China) and Japan (Industrial Value Chain initiative) (Digital European Industry, 2016).

Hence, i4.0 has become world spread course followed by countries significant for world economy. This paper will further focus on content of i4.0.

Industry 4.0

The idea of forth industrial revolution embeds 3 main pillars that should ensure superiority of Germany and related countries in an industry sector by meeting and exceeding customer expectation and beating traditionally cost oriented off-shoring countries.

The concept of i4.0 is based on linkage of virtual and physical parts of business processes along a supply chain. The virtualization is gained by Internet of Things (IoT), Internet of Services (IoS) and Internet of people (IoP). Virtualization of material and people by attached barcode or RFID tag, electronic devices and tools by new IPv6, integration of IT systems that currently insularly support supply chain processes can create cyber physical system (CPS) in which task can be simulated from product engineering to aftermarket services. The main aspect of the transition to physical cyber system is digitalization (Lasi, H., Fettke, P., Kemper, H. & Feld, T., 2014). However, it is not the only part of i4.0, there are other aspects e.g. organization impact of i4.0 on procurement (Glas & Kleeman, 2016). There are 3 main pillars (technology, management, social aspect) that that have to be well established similarly in both a company and a country. I4.0 is not solely based on automation. It can go hand in hand with lean and help to achieve additional benefits where traditionally low investments measures of lean cannot enable further process performance improvements (Kolberg & Zuhlke, 2015).

Hereinafter, there is a brief description of the main pillars which are: Technology, management and social aspect.

Technology

Technology covers all hardware and software needed to build and connect different part of CPS into one seamless system capturing physical components of SC and its virtual mirror. Detail parts of CPS from technology point of view is shown below:

a. Big data and sensors e.g. RFID, bar codes – real time monitoring and data processing from vast number of resources finds essence for end to end visibility and virtualization. However, it also leads to processing and data storing of huge volume of data that today.
b. Autonomous active (e.g. robot) and passive parts (material) - passive items are those that are manipulated and processed within SC processes, active item is the one that manipulate and processes within SC. Thanks to IoT items can become agents that can distributively control their SC processes because of their visibility and interconnectivity in a virtual SC model.
c. Simulation – simulation is indispensable for decentralized controlling to identify and assess all reasonably optimized variant of process execution.
d. IT horizontal and vertical integration – horizontal and vertical integration of process is discussed in management part. However, effective and efficient execution of processes require seamless transfer of data from transaction systems and their availability in multiple dimensions for each SC system item. That is condition for effective Big data utilisation.
e. The industrial internet of things – active and passive SC items are assigned of IPv6 and so they become virtually visible, easily identifiable and are mutually interconnected. The system provides a certain level of controlling to active and passive process items and established decentralized system
f. Cyber security and data security –technology advancement brings a lot of benefits, however, it also creates condition for new form of crimes based on hacking IT system, stealing and abuse of data. Supply chain system is less sensitive to human errors in processes but more vulnerable to system hacking. Thus, data security has become an issue in i4.0.
g. The cloud, data centres, data network – Big data require huge volume of data to be processed and shared, hence, clouds, data centres and networks enabling sufficient connectivity are important part of the system. Their capacity and security is an issue.
h. Additive manufacturing, 3D printing – production process is changed in some areas from centralized to the decentralized one. This is enabled by new technological devices for instance 3D printing. Thus, customers can print out a product at their location instead of organizing production and distribution from a remote distances. Additionally, it brings complete product customization.

i. Augmented reality, virtual reality, artificial intelligence – Virtual reality of the supply chain can help detect issues that have to be sorted out. Virtual copy of the physical system can boost immediate action and provides more relevant data in decision making process.

Management

Technology can be only beneficial when there is a perfect compliance with an organization vision, goals, strategies culture, continuously improved processes and with cooperative supply chain environment (suppliers and customers on different levels). Otherwise, technology can become an obstacle for adaptation to social technical economic changes. There are main part of the management area mentioned below which should be considered when establishing supply chain on 4.0 level.

a. Organization structure and capabilities – transformation of organization structure to flatted flexible system of teams that can be established just for particular project (product life cycle, customer etc.). This trend was established long before I4.0 initiative but will remain. Moreover, digitalization simplifies access to the relevant data and enables reduction of information transfer intermediaries in an organization.
b. Vertical and horizontal process integration, value chain – seamless interface between internal processes procurement, production, inventory management, marketing, sales and distribution can highly reduce lead time and response time in material, information and risk flow. Moreover, work in process is reduced. Vertical integration help reconcile requirements, goals related communication flow across organization level (strategic, tactic and operational).
c. Partnership (customer, supplier relationship) – partnership with external suppliers and customers is inevitable to extend horizontal integration beyond company boundaries to enable on-line visibility of SC e.g. shared collaborative forecast, stock, exception and failure visibility. The main concern here is on establishment of trust and relationship management between the related parties.
d. New business models – progress in digitalization and application of technologies cited in above mentioned technology part can on one hand enable design and execution of new business models in terms of customization discussed below, orientation on customer needs satisfaction via service not on product that is just a medium of service provision e.g.. Vendor Managed Inventory of household supplies rather than offering product on retail store shelves. On the other hand, new business model can be an engine for further progress in technology advancement.

e. Company competitiveness – redefine of source of competitiveness and focus mainly on service than on a product itself. The dominated factor of competitiveness will be rate of individual customization, agility and quality of servicing including scope and quality of SC visibility and also total cost of servicing.
f. Process standardization – evaluation of performances based on current standards and monitoring of process standard fulfilment both in real time can automate standard corrections and reveal any non-conformity with standards.
g. Productivity – continuous monitoring of OEE and TTE can enable immediate intervention into a process to stop making defects or adjust intensity of operation to meet required takt. Moreover, productivity as an indicator measured by sold output divided by inputs rather than any output divided by input would increase visibility of productivity along SC. Thus, overproduction and defects wouldn´t be involved in the formula.
h. Logistics, supply chain management – logistics and SCM have significant role in I4.0 as increased visibility enabled by CPS can establish seamless information and physical flow across supply chain processes. Moreover, CPS can reduce Muda waste mainly overproduction, stock, improper manipulation, transportation and defects. Therefore, i4.0 initiatives anticipate significant supply chain cost reduction 50% (Russman et al., 2015).
i. Benefits, cost reduction – impact of CPS can be recognized both in cost reduction and revenues increase. Additional revenues can be achieved by new business models and extended scope of product and service customization. Cost reduction are gained by above mentioned aspects of management associated with CPS.
j. Product customization – CPS is the system in which supply chain processes including production can completely customize products and services regarding customer specification because of lead time reduction. When P-time is shorter than D-time than a process can be customized.

Social aspect

a. Education (primary, secondary, vacancy, tertiary) – CPS is not a system without human beings but people have different role in CPS. Humans work is highly supported by technologies cited in technology part of this paper and because of digitalization and automation many traditional manual and administrative jobs are replaced. People have to more understand technology, mathematics, and physics to service that properly, to

design it, to program that and to use that. Therefore, technologically skilled people are needed across all organization levels. Thus, education has to reflect that necessity to implement more technology into curriculum.

b. Requalification – i4.0 changes labour market and structure of demand on jobs. Hence, Ministry of Labour and Social Affair has to intervene and reshape requalification courses to more technically oriented ones.
c. Data privacy – Virtualization of SC brigs many positives, nonetheless, traceability of people and material can break privacy of employees or product users. Therefore, legislative a and technical measures protecting private data abuse have to be taken.
d. Change of work, content of work – CPS enables people not to be present at the place of operation but execute their work from remote distance. Thus, home office, flexi working time, part time job are extensively utilised.
e. Unemployment – i4.0 changes labour market and structure of demand. It is obvious that unemployment can growth in certain segment (administrative jobs, manual workers) but there are other new jobs that are created by i4.0 across all organization levels (technically skilled maintenance staff, data security specialist, engineers etc.)(Buhr, 2015).
f. Qualification requirements, middle level, specialised, highly qualified employees, technicians, engineers, skills – traditionally T shape prevails, just there is significant orientation on technical disciplines.
g. Financial support, funds, grants, government support, government strategy – companies of SMC sector are not able to manage transition to i4.0 without financial support of government or of their well-established customer. There has to be a financial support and knowledge base that help companies to adapt to changes associated with i4.0.

Methodology

The main goal of proposed paper is to identify how "i4.0" is understood in the Czech Republic and to compare the findings with interpretation of this term worldwide.

Two-step approach was applied in this paper. In first step extensive literature review was realized in order to gather relevant articles from various resources. In second step frequency analysis was done in order to examine understanding of i4.0 in the Czech Republic and abroad.

The review is based on principles of PRISMA and using its Flow Diagram.

Main databases used were full text general resources Anopress IT and Theses for screening the Czech environment and ProQuest Central and EBSCO for foreign sources. The main basis was supplemented by ACM Digital Library specialized in information technology.

Keywords used in the search strategy were "i4.0", "Advanced manufacturing and processing", "Cyber-physical systems" in title or abstract for foreign papers and "Průmysl 4.0" and "Kyber-fyzické systémy" (alternatively "Kyber-fyzikální" or "Počítačově-fyzikální" or "Počítačově fyzické") for articles in Czech.

Only titles published between 2012 and 2016 where took under consideration. Articles were additionally limited by English or Czech language. As relevant sources for review were used scholarly journals, trade journals, magazines, dissertations and theses, newspapers, published reports or interviews, conference papers and credible websites.

The preliminary screening process was realized according to inclusion criteria defined above by scanning titles and abstracts (where available). In second phase next screening was realized and duplicates were removed. In order to validate eligibility of records, full-text assess was done with look-through approach. This practice ensured basis of relevant articles for identification of subjects and keywords mostly related to fourth industrial revolution (i4.0).

First step of frequency analysis was data preparation. Main activities were cleaning and normalizing of gathered records. It included for example data format unification, elimination of typos or redundant spaces. Main goal of this step is to ensure sufficient data quality for further analysis.

Due to large number of keywords found was realized clustering of terms. Keywords were categorized by similarity and meaning using thesaurus. The goal was categorize keywords into groups defined in theoretical part of this paper and count number of keywords belonging to each category. In order to significant variability of number of keywords was calculated *strength index* for each category within one record using following formula:

$$i_S = \frac{n}{\sum n}$$

Where i_s stands for *strength index* and n stands for number of keywords in separate category. The index shows coverage rate of each category and let us compare articles while recognizing how much is separate aspect important to article. For final analysis and heat map creation were took under consideration following attributes: article type, year and quarter of publication, language, *strength index* for each category.

Analysis is based on 76 relevant articles gathered from review of Czech literature and 504 relevant papers gathered from foreign literature review.

Findings

Overall term *Průmysl 4.0* and related[1] occurs mainly in technical magazines and news. Coverage of this term in scientific articles is very poor - less than 1% of found articles were published in scholarly journal. Great attention is paid to national initiative *Průmysl 4.0* published by Ministry of industry and trade in September 2015. This document is discussed in more than 50% of examined articles.

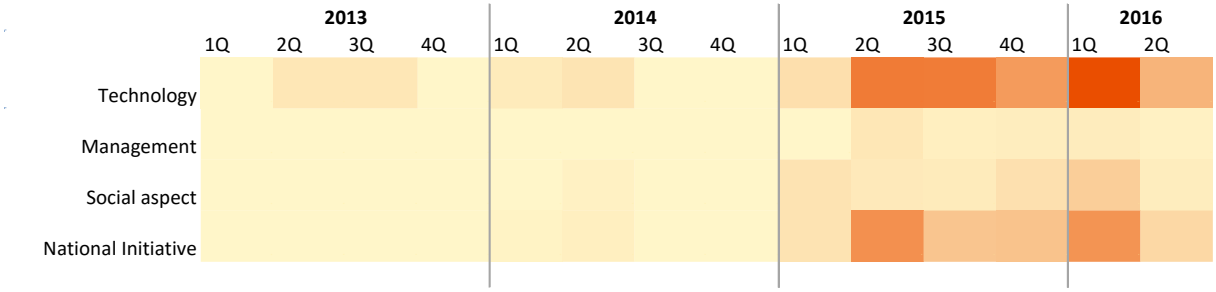
The main focus is given to areas of manufacturing and technology, then to robotization, digitalization and automation which means that the Czech Republic is aware of importance of technology aspect to fourth industrial revolution. In the other hand other aspects as management, integration or supply chain management are generally neglected.

Nearly 10% of articles are aimed at education and qualification requirements. Key publication focusing on labour market is study *Development and changes in qualification requirements of labour market in the Czech Republic between 2000 and 2025.* The study proposed trends and projection of employment and structure of labour market in the Czech Republic.

As can be seen on heat map the Czech Republic (**Error! Reference source not found.**) despite the term Industry 4.0 (or Industrie 4.0) is recognized from 2013 in Czech Republic it is widely discussed from 2nd quarter of 2015. Furthermore the heat map shows obvious increasing trend in discussing technological subjects as in first quarter of 2016 was published more than 26% of whole sample. Regarding findings displayed on **Error! Reference source not found.** it can be expected continual increase of articles especially in relation to technological aspect. It is necessary to take into account that during this analysis the 2nd quarter of 2016 has not ended.

Fig. 1: Articles in the Czech Republic

[1] Meant terms *Kyber-fyzické systémy, Kyber-fyzikální, Počítačově-fyzikální, Počítačově- fyzické*

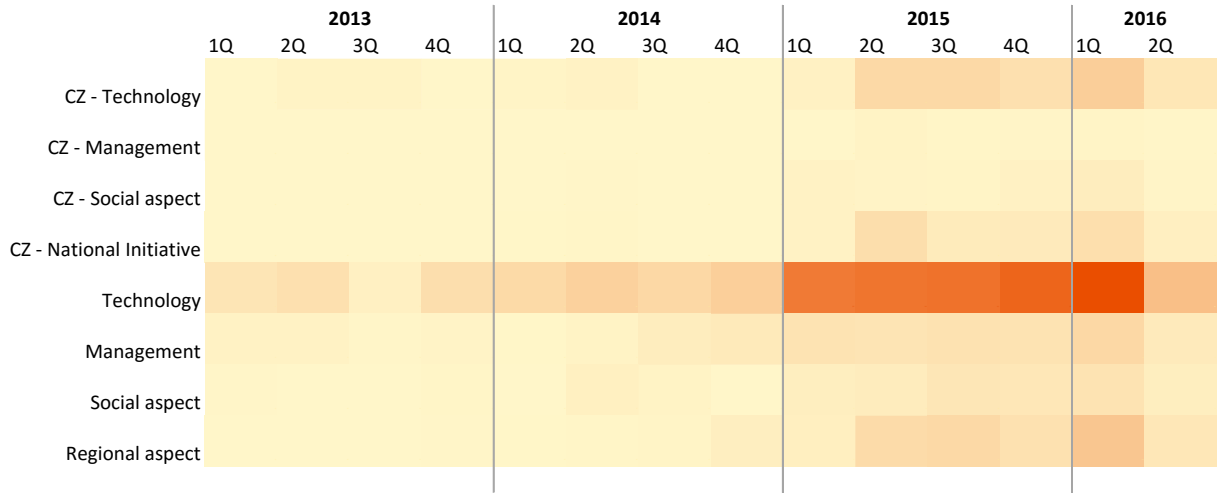


Source: own research

Worldwide is term *Industry 4.0* and related[2] systematically discussed from 2014 when initiator was business sphere as well as in the Czech Republic. Examined terms occur mainly in trade journals focusing on computing or engineering. Scholarly journals discuss more than *Industry 4.0* term *Cyber-physical system* but also in relation to technological aspects. On the other hand there can be observed strong emphasis to regional aspect in scholarly journals. It indicates analogy to situation in the Czech Republic where a lot of articles refer to national initiative. Worldwide most frequently listed countries in connection with *Industry 4.0* or *CPS* are Germany, United Kingdom, The United States of America and China.

The main focus is given to area of manufacturing and automation in connection to computerization, embedded systems and data analysis and management. Concerning most frequent keywords listed and tendency to refer to national initiatives there can be observed same pattern in perception of *Industry 4.0* or *CPS* in the Czech Republic and worldwide. The comparison of Czech and foreign articles propose **Error! Reference source not found.** that indicates same patterns but significant difference in the amount of articles.

Fig. 2: Comparison of Czech and foreign articles



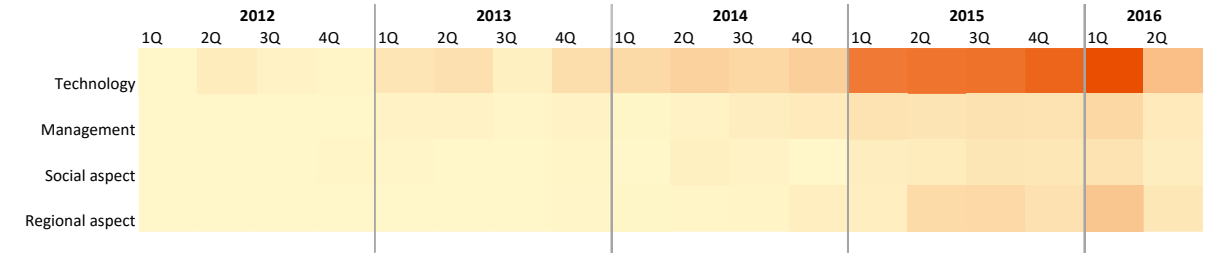
Source: own research

[2] Meant terms *Advanced manufacturing and processing*, *Cyber-physical systems*

Attention is increasingly paid also to cyber security and data protection.

Error! Reference source not found. shows heat map of aspects discussed in foreign literature. The can be seen very similar pattern as in the case of the Czech Republic but worldwide there is greater emphasis on technological aspect.

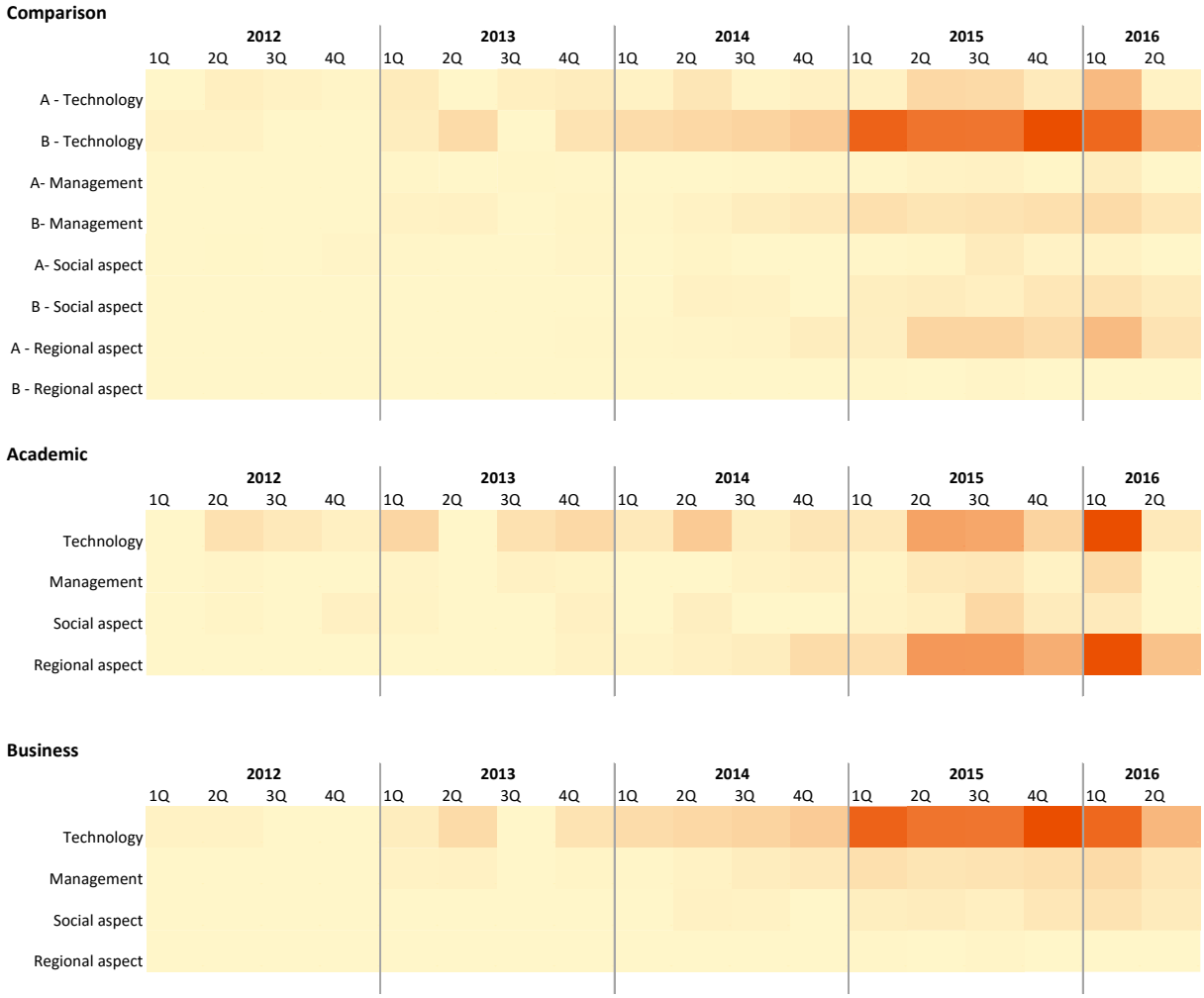
Fig. 3: Articles worldwide



Source: own research

Error! Reference source not found. shows comparison of scientific articles with articles from business/trade journals. First heat map shows complete comparison. Prefix A - means scientific (Academic) article and prefix B – means Business. It is evident that examined subjects are driven mostly by business units which are oriented primarily on technological aspects. Heat maps Academic and Business displays detailed structure of both sources of articles.

Fig. 4: Comparison of academic and business articles worldwide



Source: own research

Error! Reference source not found. propose executive summary of realized literature review and analysis. First part shows shares of aspects regarding publishing year and character of publication. The displayed percentage represent share within context of whole research sample (504 articles). Second part of table represents shares within review of Czech literature. Last part of table represents synthesis of foreign and Czech literature and foreign literature regardless character of publication.

Fig. 5: Significance of aspects within examined types of articles

		Technology	Management	Social aspect	Regional aspect/ national initiative
Foreign literature					
2012	Academic	0,6%	0,2%	0,4%	0%
2012	Business	0,4%	0%	0%	0%
2013	Academic	1,59%	0,60%	0,60%	0%
2013	Business	2,98%	1,19%	0,00%	0,2%

2014	Academic	1,59%	0,6%	0,6%	0,2%
2014	Business	7,74%	2,78%	1,39%	1,98%
2015	Academic	4,76%	2,38%	2,78%	0,99%
2015	Business	32,14%	10,12%	6,15%	12,5%
2016	Academic	3,37%	1,19%	0,99%	0,00%
2016	Business	13,29%	5,16%	3,37%	7,94%
Czech Republic					
2012		0%	0%	0%	0%
2013		1,47%	0%	0%	0%
2014		4,41%	0%	1,47%	2,94%
2015		54,41%	7,35%	16,18%	47,06%
2016		33,82%	4,41%	11,76%	27,94%
Total					
2012		0,87%	0,17%	0,35%	0%
2013		4,2%	1,57%	0,52%	0,17%
2014		8,74%	2,97%	1,92%	2,27%
2015		38,99%	11,89%	9,79%	17,48%
2016		18,71%	6,12%	5,24%	10,31%

Source: own research

Conclusion

Authors of this paper have described the pillars of i4.0 and analysed the state of the art of i4.0 in the Czech Republic based on review of published papers dedicated to i4.0 or containing key words associated with i4.0. Authors have found out that there are numerous articles dedicated to national initiatives focusing on i4.0, names of the national initiatives are cited in the introductory part. Moreover, there is increasing trend in discussing subjects as cyber security and data protection. Then, basis of academic articles in the Czech Republic is insufficient. Additionally, authors have uncover that the similar patterns can be observed in Czech and foreign literature regarding examined aspects and time. The main concern is dedicated to technology aspect of i4.0 and the other two management and social aspects are overlooked. Finally, the term Cyber-physical system is more discussed than i4.0. It outlines that the i4.0 is more business oriented.

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Contact

Ing. Petr Jirsak, Ph.D

University of Economics, Prague

W. Churchill Sq. 4

130 67 Prague 3
Czech Republic
petr.jirsak@vse.cz
Ing. Felipe Martinez, Ph.D
University of Economics, Prague
W. Churchill Sq. 4
130 67 Prague 3
Czech Republic
bedrich.rathousky@vse.cz
Ing. Miroslav Lorenc, Ph.D
University of Economics, Prague
W. Churchill Sq. 4
130 67 Prague 3
Czech Republic
miroslav.lorenc@vse.cz
Ing. Jakub Jancik
University of Economics, Prague
W. Churchill Sq. 4
130 67 Prague 3
Czech Republic
jakub.jancik@vse.cz