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Assessment of innovativeness level for chosen solutions related to Logistics 4.0

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Abstract

The paper presents an overview of "Logistics 4.0" term in chosen scientific databases in order to describe the potential of research connected to this phenomena. As many solutions and devices concerning Logistics 4.0 were found, the authors of this paper decided to develop a mathematical model which allows subjective (calling it the expert-oriented method) evaluation of solutions in terms of their level of innovativeness. The application of this model is based on actual solutions currently used in industry and logistics (both management logistics and logistics engineering), exactly 8 years after the existence of the Industry 4.0 concept in the consciousness of scientists and managers. The first section of the paper is connected to the introduction of main ideas and embedding the subject matter in the professional literature and scientific databases. In the second section, the authors defined a mathematical model in order to make an assessment of the innovativeness level for selected solutions connected to Logistics 4.0. In the third sections, authors focused on the assessment of selected solutions as such. And the fourth section consists of a particular conclusion.

Keywords: Logistics 4.0; Industry 4.0; innovativeness level; innovation

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1. Introduction

Logistics 4.0 is relatively new concept straightforwardly connected to Industry 4.0 (Industry 4.0 is a term that describes the general overview of the future "smart factory", so does the term of "smart logistics" as well; Industry 4.0 implications in logistics are described in [1]). This relativity of novelties might be confirmed e.g. by the analysis of trends in Google Trends browser or analyses used based on documents collected in scientific databases such as Web of Science, Scopus, Science Direct, etc.

Google Trends assure checking the interest in terms of region or interest in time for any keyword searching.

Interest by region assures to estimate which locations was most popular for a particular keyword in a given period. Whereas, interest in terms of time estimates numbers that represent individual interests towards the highest point in the chart printed in the browser. A value of 100 indicates the highest popularity of a particular keyword. In order to check the worldwide potential in the aspect of Logistics 4.0, checking of interest by region was sufficient. It occurred that while introducing the keyword "Logistics 4.0" into Google Trends browser only one country was analyzed. It was Germany, the origin country of Industry 4.0 term (date of analysis: February 22nd, 2019; Fig. 1), even after the heading "Include regions with low number of search operations" has been marked. This does not mean that the subject matter of Logistics 4.0 is not being discussed in other countries than Germany, which is due to the fact that the browser has too little data at its disposal (as it is explained in the commentary on Google Trends, a value of 100 indicates the highest popularity of particular keyword, meanwhile a value of 0 indicates that there is not enough data for the given keyword – therefore, it is not reasonable to say that the data are unreliable, since it could happen that Internet users searched for data in other browsers than Google). At the same time, however, it is worth noting that the global approach to the topic of Logistics 4.0 is still very rarely used and it is worthwhile to address this subject matter.

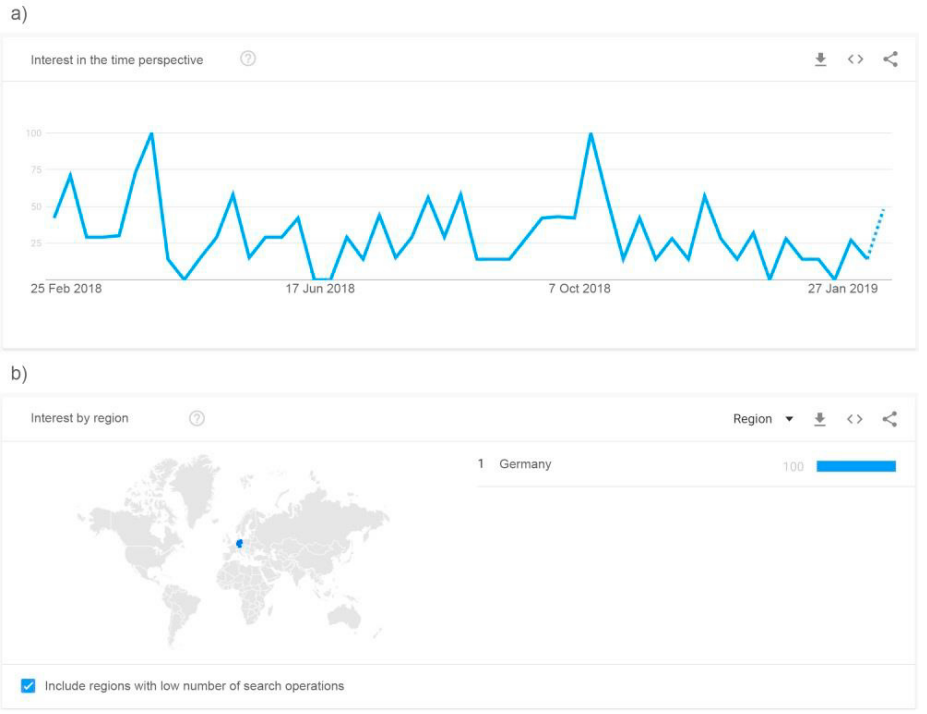

Fig. 1. Effects of Google Trends searching in the case of "Logistics 4.0" keyword: (a) interest in terms of region, (b) interest in time. Source: https://trends.google.pl/trends/explore?q=Logistics%204.0, last accessed 2019/02/22.

The analysis performed with the use of the Scopus scientific database (date of analysis: February 22nd, 2019) is also worth considering. When the keyword "Logistics 4.0" was introduced in relation to the search of three records at the

same time, i.e. title, abstract, keywords, the following results were obtained. Twenty three documents were found, e.g. five in 2018, three in 2017. In previous years, one or two articles were published each year, which are indexed in the database. As it can be expected, taking into account the ideological issues of Industry 4.0 and Logistics 4.0 focused on engineering and programming, these publications are foremost grouped in subject areas as: computer science and engineering.

Meanwhile, Web of Science database was searched in all fields with the same keyword ("Logistics 4.0") – date of analysis: February 22nd, 2019. Also in this case not too many records have been achieved. Only ten documents were found, e.g. two in 2019 up-to-date, five in 2018.

The analysis performed with the use of the Google Scholar scientific database (date of analysis: February 22nd, 2019) is worth considering as well. Two hundred seventy records were noted in that database, of which thirteen were published in 2019 and one hundred eleven in 2018.

Table 1. Desk-research results of keyword ("Logistics 4.0") searching in selected databases (February 22nd, 2019)

Year of analysis	Scopus database	Web of Science database	Google Scholar database
2019	N/A	2	13
2018	5	5	111
2017	3	N/A	56
Total (previous years than mentioned above are included)	23	10	270

The statistics given above and summarized in Table 1 prove that Logistics 4.0 is still worth researching and its research potential might become very high in the nearest future.

Several aspects of Logistics 4.0 were described up-to-date. Authors defined maturity levels and models for Logistics 4.0 [2, 3]. Another considered aspect was the role of lifelong learning and education of new specialists connected to subject matter [4] (which is highly important especially that "changes in the working environment in the operative field of Logistics 4.0 lead to completely new competence requirements regarding the operational employees", [5]). Researchers emphasized also business models connected to Logistics 4.0 [6] and its challenges and opportunities [7]. Rarely, authors were focused on analysis of technical and engineering aspects of solutions connected to subject matter, especially in the context of their innovativeness (it does not mean that technical aspects of solutions are not debated in literature – these were described in e.g. [8,9]). Taking into account the fact about growth of IoT (Internet of Things) connected devices installed base worldwide (Fig 2.), highly more significant increase of interest in Logistics 4.0 is expected among entrepreneurs and scientists. In order to clarify, it must be underlined that IoT is strongly connected to idea of Industry 4.0 and Logistics 4.0 and what is more these ideas are connected to digitalization of processes what would not be assured without IoT technologies. Therefore, based on data given in Fig. 2, it is assumed that interest among entrepreneurs and scientists in Logistics 4.0 might arouse similarly to the subject matter of IoT in the same groups of specialists.

In the paper, an innovativeness level is given under question. Therefore, this term should be defined adequately. Innovativeness level in opinion of scientists of engineering needs less qualitative assessment methods since they believe more into numbers and quantities than in qualitative assessments. Therefore, innovativeness level assessment should be quantified. Some authors defined the appropriate level of innovation in terms of efficiency. They specified the number of implementations in relation to all submissions initially considered as innovative ideas. For example, it can be referred to the results given by Toyota and Cognizant in the publication [10].

In this paper, first of all the mathematical model for innovativeness level assessment is defined and described and next chosen solutions of Logistics 4.0 are given under consideration and assessment with usage of the mentioned model. At the end of this paper, it is concluded and several ideas for potential research are presented.

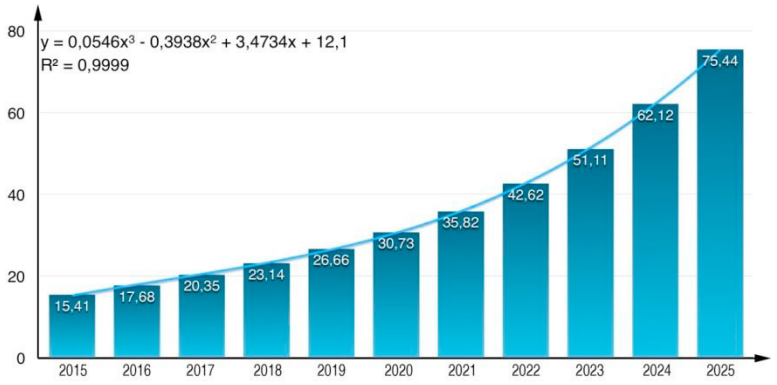

Fig. 2. IoT connected devices installed base worldwide from 2015 to 2025 (in billions). Source: https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/, (February 22nd, 2019).

2. Innovativeness level

First of all, it should be mentioned that innovativeness level is understood here as ratio between two numbers. The first number is the quantity of solutions released after Hannover Fair of Industrial Technologies event, that are considered as innovative. Hannover Fair of Industrial Technologies event has taken place in 2011, according to [1,11]. The second number is the total number of post-trade fair solutions presented in this paper. The innovativeness level ratio is expressed as a percentage and is a subjective value determined as a result of the expert method application. Meanwhile, innovativeness is understood as tendency to innovate, or introduce something new or different, characterized by innovation, [12]. However, the authors stipulate that they do not analyse which solutions are really innovative and which are not.

This section presents the proposal of the tool for assessing the innovativeness level of the discussed solutions in relation to Logistics 4.0 as a compound of Industry 4.0. The date of Hannover Fair of Industrial Technologies event is useful in the proposed equation (tool redefined after [13]).

At first stage of assessment the following datasets should be given:

- $\boldsymbol{A}$ – a set of numbers of presented and assessed solutions, $\boldsymbol{A} = \{1,\ldots,a,\ldots,A\}$,
- $\boldsymbol{S}$ – a binary set explained by its elements, $\boldsymbol{S} = \{0,1\}$, where $s = 0$ if the solution in question existed before or during 2011 and $s = 1$ if the solution in question existed after 2011,
- $\boldsymbol{P}$ – a binary set that explains whether a chosen solution has been implemented, $\boldsymbol{P} = \{0,1\}$, $p = 0$ if the solution in question was not implemented before, during or after 2011, $p = 1$ if the solution in question was implemented before, during or after 2011.

The Cartesian product shall then be appointed as in equation (1), the elements of which are transformed into the set $\boldsymbol{I}$ as it is given in equations (2) and (3).

$$i(a,s,p):\ \boldsymbol{A}\times\boldsymbol{S}\times\boldsymbol{P}\rightarrow N\cup\{0\} \tag{1}$$

$$\boldsymbol{I} = \{i(1,0,0),\ldots,i(a,s,p),\ldots i(A,S,P)\},\quad a\in\boldsymbol{A},\quad s\in\boldsymbol{S},\quad p\in\boldsymbol{P} \tag{2}$$

$$i(a,s,p) = \begin{cases} 0: & \exists s=0\wedge\exists p=0\vee p=1 \\ 1: & \exists s=1\wedge\exists p=1 \end{cases} \tag{3}$$

As the next stage, the parameter $\bar{i}$, specifying the number of solutions taking the value $i(a,s,p)=1$, should be computed – according to equation (4). This parameter quantifies solutions which determines the number of solutions that can be considered as potentially innovative.

$$\bar{i} = \sum_{a\in \boldsymbol{A}} \sum_{s\in \boldsymbol{S}} \sum_{p\in \boldsymbol{P}} i(a,s,p) \tag{4}$$

The prerequisite for innovative solutions are as follows:

- $\exists \frac{\bar{i}}{card(\boldsymbol{A})} \leq 0.50$ – solutions from set $\boldsymbol{A}$ (taken together) are not considered to be innovative,
- $\exists \frac{\bar{i}}{card(\boldsymbol{A})} > 0.50$ – solutions from set $\boldsymbol{A}$ (taken together) can be considered as innovative, where: $card(\boldsymbol{A})$ – cardinality of a set $\boldsymbol{A}$.

3. Assessment of innovativeness level

The mathematical model described in section 2 of the paper is applied for 24 solutions and results of its application are given in Table 2. In the first column of Table 2 names of solutions are given. These solutions are not described in detail (solutions No. 1-4, 6-13 are a matter of discussion in [13]). Authors give references only, whereby more information about each solution can be found. The presented solutions are only examples – there are plenty of other solutions which might be taken into consideration, however it was not a point to bullet them all in the paper.

Based on information given in Table 2, it can be stated that more than 71% of presented devices/solutions were released after the Hannover Fair of Industrial Technologies which took place in 2011. This might mean that the idea of Industry 4.0 utmost significantly contributes to the innovation of products in the sphere of Logistics 4.0. It can be said that the innovativeness level of solutions suggested as belonging to Logistics 4.0 in the context of Industry 4.0 is about 71% ($\bar{i} / card(\boldsymbol{A}) = 0.71$), therefore it is satisfactory. Although, it should be noticed that some of these solutions were developed before the significant date of 2011. When digitalized and innovative technologies in the context of Logistics 4.0 are discussed, human factor should not be omitted. In aspects connected to Industry 4.0 and Logistics 4.0, predispositions of employees are important one. As Oskar Verkamman mentioned in [55]: "(…) more than half of the current workers entered the workforce without mobile telephony and smartphones. Half of them even started without any computers at all. So, if we look back, it is amazing how easily and quickly we embraced all those new technologies, almost without any hesitation." This is positive opinion about the changes that occur during several last years. This is also promising statement in the case of Industry 4.0 and Logistics 4.0.

4. Conclusion

The innovativeness level of solutions suggested as belonging to Logistics 4.0 is significant, as it was mentioned before. It is evident that the development of Industry 4.0 based on digitization and automation represents for Logistics 4.0 not only huge challenges but also opportunities for increasing efficiency. It is also worth mentioning that the similarity of logistics and production processes blur the differences between Logistics 4.0 and Factory 4.0 and consequently also Industry 4.0. Solutions focused around Logistics 4.0 should be evaluated in terms of effectiveness and efficiency according to known and commonly used modeling methods, including in particular modeling with the use of simulation methods. It is also worth paying attention to forecasting these solutions which was not subject matter of this paper but might be worth mentioning as future research option. Logistics 4.0, as well as Industry 4.0, is setting high demands not only in technological, engineering or economic aspects but foremost on the education process, as smart factories (or any other smart facilities) and smart logistics need highly skilled employees and management personnel. One of main assumptions of Industry 4.0 is that not only specialists, but also operational workers will soon

perform mainly organizational and conceptual tasks. This is the reason of the necessity for adapting educational process to a new situation. The objective of future works is to present the analysis of the challenges for logistics education – this aim was taken in e.g. Universities of the Future project (https://universitiesofthefuture.eu, last accessed 2019/02/23).

Table 2. Application of equation presented in section 2 of the paper

Device/solution	Year of release	a	s	p	$i(a,s,p)$
Vecna [14]	2017	1	1	1	1
Kiva [15,16,17,18]	2006/2008	2	0	1	0
CEIT* [19,20] *) automated guided vehicles started to be used already several decades ago, however are developed with methods of control and localization	2007	3	0	1	0
Geodis and Delta Drone [21]	2018	4	1	1	1
ERP system plus APROL – control in a high bay warehouse, optimization of production logistics [22], [23] *) ERP as such existed in XX century	2014	5	0*	1	0
Digital HR Assistant [24]	2018	6	1	1	1
EDI [25]	XX century	7	0	1	0
butlers [26]	2018	8	1	1	1
CarryPick KMP600 [18]	2012	9	1	1	1
BinGo [27]	2016	10	1	1	1
MALTA, Multiple Autonomous forklifts for Loading and Transportation Applications [28,29]	2009	11	0	1	0
e–Palette, [30]	2018	12	1	1	1
KUKA mobile platform (KMP) 1500 [31]	2017	13	1	1	1
RFID tags on pallet boxes [23,32]	XX/XXI centuries	14	0	1	0
Racrew [33,34]	2014	15	1	1	1
Hibrid Parcelopter 3.0 [35,36]	2016	16	1	1	1
Baxter [37]	2011	17	1	1	1
Roberta [37]	2015	18	1	1	1
SERVUS ARC3 [40,41,42] *) estimated date based on date of award obtaining [39]	2013*	19	1	1	1
Agile1500 [43,44,45]	2017	20	1	1	1
TUG - AMR [46,47] *) estimated date based on date in [47]	2013*	21	1	1	1
MiR100, MiR200, MiR500 [48,49]	2016	22	1	1	1
LD-60, LD-90 [50,51] *) estimated date based on date in [50]	2017*	23	1	1	1
AutoStore [52,53,54] *) estimated date based on date in [51]	2011*	24	0	1	0

The authors realise that relying only on date (Hannover Fair of Industrial Technologies event date) to determine the level of innovation is not a complete approach. This may be considered a necessary but not sufficient condition for determining the level of innovation. The actual innovativeness will be verified over time as a result of the analysis of the usefulness and effectiveness of the proposed solutions. What is more, the authors are aware that many fragments of this paper are treated briefly. Nevertheless, it is a contribution to further work on these topics.

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