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Industry 4.0 readiness in Hungary: model, and the first results in connection to data application

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Abstract: Hungary is one of the most industrialized countries in Europe, since many leading car companies together with their suppliers and related industries have production sites in this area. In the paper, a comprehensive questionnaire with 99 questions is introduced in detail, which aims to assess the Industry 4.0 readiness of companies in Hungary – taking into consideration some general information about the participating organization, the relevant company level Industry 4.0 maturity topics on the one side and, also issues related to national economy policy on the other side. The first results are presented here: the focus is on questions related to data collection, processing and utilization, in terms of the manufacturing processes, machines and products, as well. Based on the answers given by Hungarian organizations, it can be stated that most of them collect data about their production, but in general, the use of this data has not yet been integrated into the manufacturing and production processes.

Keywords: Industry 4.0, Smart manufacturing systems, Maturity model, Readiness assessment, Digitalization

1. INTRODUCTION

The development path of the Hungarian economy is approaching a turning point. The growth of the 2009-2015 period was largely based on the performance of export-oriented international companies, who built their business on the availability of high-value-for-money workforce. Nowadays, Hungary is one of the most industrialized countries in Europe: industry share of GDP was 22.4 % in 2014, due to the car manufacturing and related industries (Nick and Pongrácz, 2017). At the government level – and in line with the European Union's reindustrialization strategy (Probst et al., 2018) – the Hungarian government intends to facilitate the digitisation of industry and, as a result, its development. As a declared objective, industry's share in GDP should rise to 30% by 2020. In order to achieve this goal, traditional industries and existing business models need to be transformed since innovation is increasingly the key to value creation. In conclusion, Hungary needs to move forward from mass production to a country which is offering quality, added value and knowledge in conformance with our role in the global value chain – and the application of Industry 4.0 is certainly the decisive element of success.

Established in 2016, the Hungarian Industry 4.0 National Technology Platform (2016, NTP) launched its first questionnaire project that explores the Hungarian Industry 4.0 ecosystem, i.e. the technological and business maturity of individual companies from the digitization perspective, and provides also an overview of the current trends in relevant macroeconomic developments. The purpose of this paper is to introduce a model for the assessment of the Hungarian Industry 4.0 ecosystem and then to present the first results of the related empirical research. The scope of this paper – with regard to the boundary limits – is the assessment of processes connected to data collection, processing and utilization.

The basis of the anonymous online questionnaire survey is an empirical research model created by the authors. The formulation of the questionnaire was finalized by using existing sources, updating and extending them, making in-depth interviews with experts, and incorporating their own ideas (explained in detail in Section 2). In terms of formalization, the questionnaire contains open and closed questions, whereas in terms of measurement levels nominal, ordinal and proportion questions are included (Babbie, 2008). Due to the ambitious 2020 target of industry share, questions about the planning period up to 2020 were also added. The sampling phase took place between April 2017 and September 2018.

Nowadays, the relationship between service providers, manufacturers, suppliers, and customers is becoming more and more integrated. Consequently, sensors, machines, workpieces, and IT systems are integrated in a vertical (within the company) and horizontal (between companies) way across the entire supply and value chain. The vision of Industry 4.0 must bring the following four goals (Monostori et al., 2016; Bauernhansl et al., 2014):

- *Vertical Integration*: In a smart factory, people, machines, and other resources are mapped into a digital model and communicate with each other through cyber-physical systems.

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- *Horizontal Integration*: The smart factory adapts itself to its environment (i.e. order stock and availability of materials), and optimizes its production processes itself in real-time.
- *Smart products*: Products have information about their own manufacturing processes and are able to collect and transfer data from all phases of their life cycle. This will enable the digital modelling of the smart factory and the development of a product based service offering.
- *Human beings* are the drivers of added value. They are in the focal point.

In the literature, several Industry 4.0 readiness evaluation methods and maturity models can be found. A recent review of these models is published by Mittal et al. (2018). Here, the authors enumerate 15 different maturity models in terms of the method they use, the focus, and also the gaps found in them. These models assess the Industry 4.0 maturity in different dimensions that contain questions or maturity items. The organization or company is evaluated based on these elements by choosing an appropriate level of scale, which contains in general four to ten levels. In terms of these dimensions, the most common ones are the following: strategy and organization, technology, IT, smart factory, smart products, data utilization and employees. In some models, additional dimensions appear, too, for example security policies (Rockwell Automation, 2014), performance (Jung et al., 2016) and customers (Schumacher et al., 2016). The number of maturity items vary on a wide scale, e.g. the VDMA's online self-assessment questionnaire (VDMA, 2015) contains altogether 18 items, but in another maturity model, the authors present a survey with 65 questions (Schumacher et al., 2016). From the aspect of the company level maturity, the survey presented by the authors is a moderately detailed one, as it contains 46 questions related to the maturity assessment of the company (questions 16-61) in 6 dimensions: strategy and organization, smart factory, intelligent processes, smart products, services based on product data and employees. Nevertheless, the survey comprises 99 questions in total. Compared to other models found in the literature, it is a novelty that general questions about the participating organization (questions 1-15), and issues regarding the national Industry 4.0 economy policy (questions 62-98) are also taken into consideration.

The aim of our survey is to provide results related to Hungarian national economy as well, not only about one organization. In the survey, the authors adapt some items from VDMA, NTP and define new maturity items, also.

2. MODEL OF THE EMPIRICAL RESEARCH

The constitution of the 99 questions in the questionnaire is the following: 16% of the questions were created by the designated persons in the NTP Workgroups, knowing the issues of previous surveys – they have identified issues that reflect the specific needs of their field of expertise. Typically, aspects of education, training, employment, and access to financial resources have been introduced here. Additionally, the authors clarified their own view on the digitisation of industry during personal in-depth expert interviews (66% of the questions). The Industrie 4.0 readiness questionnaire and the associated study (VDMA 2015) provides the framework for the second part of the questionnaire with the company level questions (18% of the questions). Table 1 shows the number of questions with their sources.

Table 1. Source of questions

Source	***Sequence number of the questions***								
Authors	1	2	3	4	5	6	7	8	9
	10	11	12	13	14	15	16	19	20
	21	23	24	25	29	30	31	32	33
	37	40	42	53	54	55	56	57	58
	59	64	65	66	67	68	69	70	71
	76	77	78	79	80	81	82	83	84
	85	86	87	88	89	90	91	92	94
	95	99							
I4.0 NTP	28	34	36	46	47	60	62	63	72
	73	74	75	93	96	97	98		
VDMA	17	18	22	26	27	35	38	39	41
	43	44	45	48	49	50	51	52	61

The empirical research aimed to create a map of the Hungarian Industry 4.0 ecosystem. In the presented work, the main goal was to explore to what extent Industry 4.0 criteria appear in the operation and business model of Hungarian companies. What are the differences in the expectations of individual companies towards the national economy policy? In order to get to know adequately both the current and future situation, it is necessary to assess the needs and expectations of the industrial digital ecosystem in terms of strategic economic governance and also to explore the current status of Industry 4.0 awareness, acceptance and implementation both at the individual (company, academy, social organization) ecosystem level and the national economy level, as well. The openness for R&D&I cooperation, the competitiveness potential and conditions, the situation of education and training are also important aspects. The persistent challenges to human resources, the local expectations and effects of industrial digitisation, and above all, the unique Industry 4.0 capabilities of companies are taken into consideration here, too. Table 2 shows the main parts of the questionnaire.

2.1 General questions about the organization

In this section of the questionnaire, one part of the questions relates to the number of the production sites, their geographical location, and the industry sector(s) the organization operates in. We are also looking for answers to important questions that affect organizational philosophy, such as where they see their role in the supply chain and how much added value is produced by them. The territorial embeddedness in the innovation system is determined by examining cluster membership and R&D&I cooperation willingness.

Table 2. Main parts of the questionnaire

Name of part	*Aim of the specific part*	*Questions*
I. General questions about the organization	Collection of management and statistical data about the organization.	1-15
II. Company level questions about Industry 4.0	Assessing the individual Industry 4.0 capabilities at the micro level.	16-61
III. Issues on Industry 4.0 connected to national economy	Comprehensive understanding of the situation in Hungary.	62-98
IV. Feedback	Contact details (to send feedback on the results if asked for)	99

2.2 Company level questions about Industry 4.0

The second part of the questionnaire contains questions for the assessment of the individual Industry 4.0 capabilities of the respondent companies (summarized in Table 3). These questions are not only suitable for qualifying the companies in terms of their industry 4.0 readiness, but also to highlight the strengths and weaknesses of today's situation in Hungary in general. The Industry 4.0 phenomenon is commonly perceived as the integration of the physical and virtual worlds in the development of information and communications technology and manufacturing automation. Therefore, the dimensions Smart factory and Smart products are related to the physical world (12 questions), whereas Services based on product data is related to the virtual world (12 questions). The Strategy and organization and the Employees dimensions introduce two general aspects (22 questions in total) that also support the ecosystem approach.

It is essential to know what technological solutions are already implemented in the company, and how consciously they are being developed further. Are they pursuing active innovation management? The number of their partnerships, the role of these in their value chain and company organization are also important aspects that are investigated in the dimension *Strategy and organization.* In the dimension *Smart Factory*, the companies are assessed by looking at specific topics, such as robot density, data collection fields and extent, production and logistics devices (from qualitative and quantitative perspective). In *Intelligent processes,* IT relevant security and regulatory issues are addressed, together with the questions if there is an example where the product autonomously controls its production or if there is a production process that can react automatically to the changing production conditions in real-time. It is important to know, how active the participants are in innovation of *Smart Products* and related services*,* and if they are collecting product data or not. If the company use the data that was collected during the product's life cycle, the next question is how it is used; the company can offer specific *Services based on product data* in different areas, as well. The product usage data can be utilized in different fields, for example to develop new product features, optimize services, or to monitor customer patterns. As mentioned, humans should be in the centre of the future development of industry, as they are the drivers of value creation. In the *Employees* dimension different training programs, employee competences, processes in connection to the human resources are investigated.

Table 3. Company level questions about Industry 4.0

Dimension	*Dimension topic*	*Questions*
Strategy and organization	An implementation strategy defines the company's development path and assigns its position within the value chain.	16-34
Smart factory	Identifies the existing equipment and the future development plans of the production system	35-42
Intelligent processes	Assess smartness and self-adapting capabilities of the processes and their characteristics relevant from the production, logistics and IT perspective.	43-50
Smart products	Innovation in products and related services	51-54
Services based on product data	Utilisation rate and areas of the information that are collected on product usage throughout its life cycle.	55-58
Employees	Availability and retention of human resources, in what direction(s) should they be trained.	59-61

2.3 Issues regarding Industry 4.0 with respect to the national economy policy

A group of macro level questions aiming at a comprehensive understanding of the situation in Hungary can be found in the third part of the questionnaire (Table 4). In this part, the view of the participants was queried in connection to the future development prospects, and the possible options for, and the impacts of the government interventions. Additionally, organizational issues, parallel infrastructure developments, competitiveness preferences, financing and regulatory decisions are in the focus but it is essential that responses should not be linked to any given organization, but should always be interpreted at a higher general (i.e. industry or national economy) level. In case of *Resolving territorial inequalities*, the aim was to assess how satisfied the participants are with the domestic regional development policy and its results. What should the state do: either support the underdeveloped regions to catch up or prefer the already developed ones? In what form should the concrete subsidies arrive – tax deductions uniformly for everyone or should they compete for them? Or alternatively, should tenders be issued? Does it really mean any advantage to be a part of a cluster or an industrial park? The dimension *State involvement* is primarily an evaluation of government's activities so far, but also, it can be interpreted as a request for help: where should

the competent ministry's officials place their priorities in the future. Is the government strategy widely known? Do the initiatives that have been launched so far support or rather hinder the achievement of the development goals? What is the first priority: legislation, infrastructure development, or improving the quality of the workforce? Exactly what kind of funding programs are preferred? In the dimension *Energy and material efficient tools and production methods,* the following issues are investigated. Although it seems trivial to digitize business and production processes and to use robots both in production and in logistics, but is it really the way forward that everyone want to follow? It is known that many business services are available on a cloud basis. Shall the companies safely rely in their operation on them or, is it too risky and should they use them only in certain areas, e.g. as a storage device?

Table 4. Issues on Industry 4.0 connected to national economy

Dimension	***Dimension topic***	***Questions***
Resolving territorial inequalities	What kind of government support is preferred and what region specific policy decisions are expected by the companies?	62-70
State involvement	Specific suggestions for the strategic decisions of the government: the way of funding, the target area for support, the regulatory needs.	71-75
Energy and material efficient tools and production methods	Importance of tools and technologies to support sustainability.	76-80
Applying new and digital technologies	The current acceptance level of Industry 4.0 technologies, the challenges these raise to the stakeholders.	81-88
More efficient use of resources	To what extent the implementation of Industry 4.0 represents a competitive advantage and what are the obstacles it creates?	89-92
Employment expansion, job creation	The significance of robots, changes in the expectations and needs of employees.	93-98

Applying new and digital technologies is the dimension where the present and future of the technologies that are most closely focused on Industry 4.0 were investigated. For example, what role will big data, IoT, M2M communication, RFID, sensors and embedded systems play in the future? Where is the greatest challenge to the implementation of these technologies: in the research, development, standardization or implementation phase? On the other hand, technologies need to be matched to the actual level of our existing systems and also continuously enhanced. Thus, one of the most effective ways is to use an external partner to follow an open innovation process. The range of expert services available on the domestic market in terms of quantity, quality or price is also an important question. In dimension *More efficient use of resources,* the characteristics of the local market and its relationship with the potential increase of competitiveness due to the implementation of Industry 4.0 is examined. Where are the obstacles? What about the available R&D&I services? Is there an appropriate infrastructure and how old are the commonly used production technologies? In addition to competitiveness, in which area can we expect a positive shift? Is it possible to break into new markets, will production and logistics processes be more transparent? From the point of view of horizontal integration, is it possible to use domestic producers as suppliers? Is the implementation of vertical integration of corporate processes a preferred task for increasing competitiveness?

The mostly articulated question or warning in connection to Industry 4.0 is the spread of robots. The dimension *Employment expansion, job creation* investigates the expectations of how the labour market will be affected by the growth of robots. How do human working conditions change? The success of Industry 4.0 depends heavily on knowledge, expertise and capabilities, and the human resources management strategy must therefore be tailored accordingly, by developing and educating staff with new in-depth digital capabilities at different levels.

2.4 The evaluation process

For evaluation, the data and metadata about the questions and answers of the survey have been loaded into a relational database. The evaluation logic of the individual questions was formalized with a simple declarative language. Then each answer was converted to a simple scalar number (point). The process was automatic and was executed iteratively, manually tweaking the evaluation logic of each individual survey questions until the statistical properties of the evaluated answers regarding the question seemed satisfying, i.e. the empirical distribution of the points have fitted the theoretical distribution. This way it was ensured that the process was free of calculation or algorithmic errors.

4. FIRST RESULTS

The focus of the questionnaire is twofold as previously described: assessing the individual abilities and the level of readiness of enterprises at micro level, and gaining a comprehensive understanding of the situation in Hungary at macro level. At the beginning of the questionnaire, to draw further conclusions, the participants were asked about the type and size of their organization. As Fig. 1 shows, mainly industrial enterprises of different sizes are represented in the results: 75% of the participants are small, medium or large enterprises.

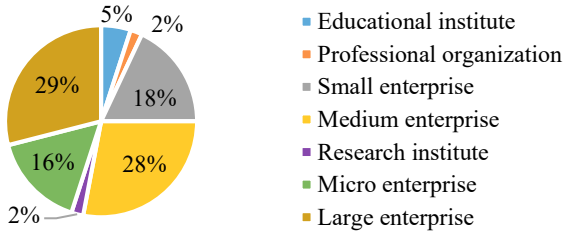

Fig. 1. Type and size distribution of respondents

One of the most important pillars of Industry 4.0 is the real-time availability of all relevant information, which assumes that all of the objects in the value chain are connected in one network, and the optimal value stream can be determined from the data at all times (Monostori et al., 2016; Kagermann et al., 2013). The data comes from everywhere: production line sensors, smart products, social media, digital images and videos, shopping transactions, GPS position data from mobile devices – this new type of resource is constantly being produced and is expected to be accessible anywhere. When a large amount of data is being collected, that is shared among the partners in the value network, it is necessary to clarify who are the owners of the industrial data. In case of a specific company, which data can it access, which one can it use, which one is it authorised to see in full, partly or anonymously. The first results are presented in the following sections. The focus is on questions in connection to data collection, their processing and utilization.

As one can see in Fig. 2, most Hungarian companies have recognized that data collection is indispensable if they want to remain competitive in the future: in total, about 78% of them collects production data at least partially.

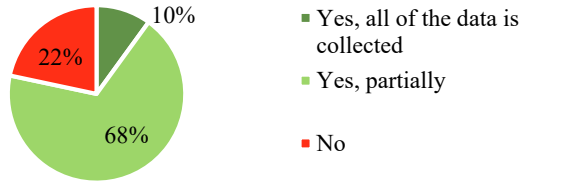

Fig. 2. Question: Does your company collect data about production processes and machines?

The next step after data collection is the data processing, with the aim of using it for a specific purpose. An interesting result is that not the entire volume of the collected data is evaluated: in general, 16% of the data is not used (Fig. 3).

Fig. 3. Question: To what extend does the company use the collected data?

The next question should be, for what purposes the data the participants collected is used for? In case of production data, the top three areas are Quality management, Production optimization and Technology development (Fig. 4). Interestingly, by almost 13% more companies use data for technology development, than for product development.

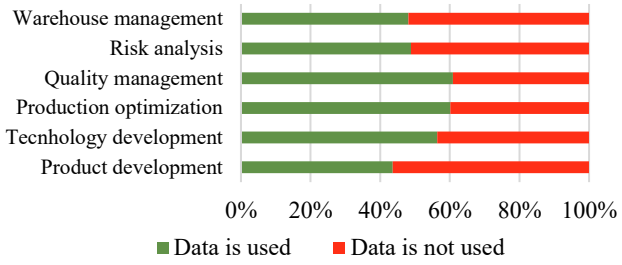

Fig. 4. Question: In which areas does your company use the collected data?

The survey contained questions about the Industry 4.0 technologies related to production data, too. The participants were asked if they have any examples where the production process reacts to the manufacturing conditions in real-time: 74% of them answered with “No”, as one can see in Fig. 5.

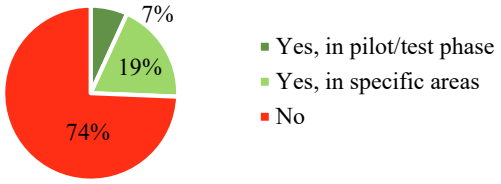

Fig. 5. Question: Are there any cases where a process reacts to changes in the manufacturing conditions in real-time?

Cloud based technologies are used by approximately the third of the participants, as Fig. 6 shows. The evolution of cloud usage is evident: based on IT security and cost considerations, it is primarily used for backups, data storage, or software run. However, the actual breakthrough, i.e. the use of cloud services in manufacturing, is still far away, although this could be the area where SMEs could be benefitted most by the cost savings.

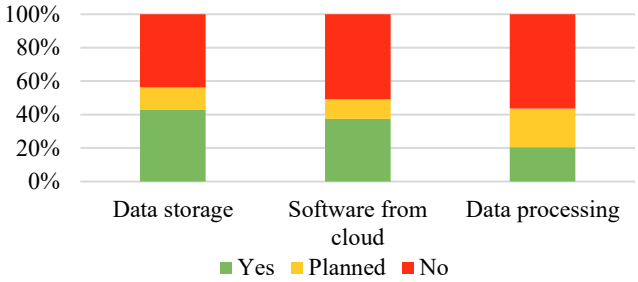

Fig. 6. Question: Does the company use cloud based services in the specified areas?

In case of product usage data, almost half of the companies use the data, 15% of them only collect information about products but never use them, and more than third of them (36%) do not collect product usage data at all (Fig. 7).

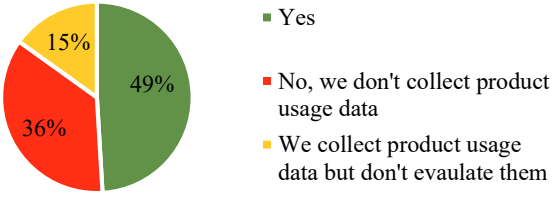

Fig. 7. Question: Is product usage data evaluated?

Comprehensive data collection and processing about product usage affect the enterprise business model, since additional services could be created by utilizing it. In our sample of respondents, most of this data is used for product optimization purposes, and are utilised to the smallest extent for developing new product features (Fig. 8).

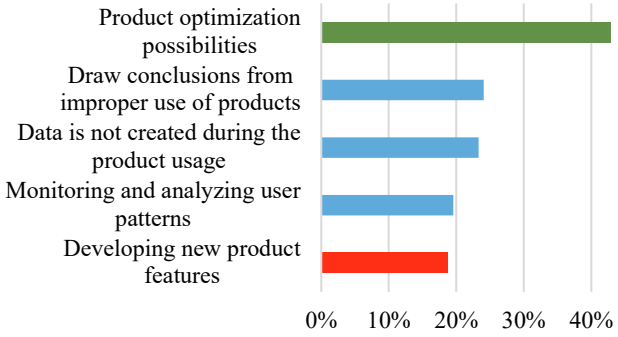

Fig. 8. Question: In which areas is the product usage data utilised?

One can see in Fig. 9 that Hungarian companies are not strong at offering special services based on collected data. In a third of them there is no additional value produced in connection to the products, and only 9% of them indicated that more than 10% of their income comes from this type of services.

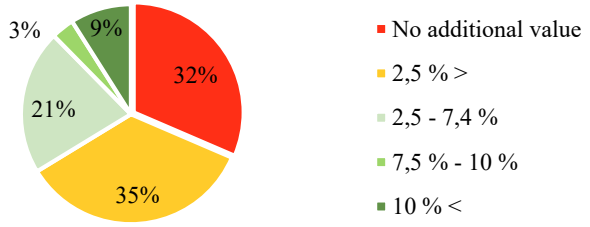

Fig. 9. Question: Income share of special services offered by manufacturers based on collected data

6. CONCLUSIONS

In the paper, a survey with 99 questions was introduced, which was created with the aim of assessing the Industry 4.0 readiness of companies in Hungary. The relevant parts of the questionnaire were described in detail, and the first results – namely the evaluation of questions with respect to data collection, processing and utilization were presented.

Smart products designed to satisfy the increasing customer demands know their own production process and are able to collect and transmit data about their entire life cycle, operation and use (Monostori et al., 2016). According to the survey, the majority of industrial companies in Hungary understood the importance of this fact: 78% of them had at least partial data collection, primarily for quality control and production statistics purposes. Although data is being collected, in most cases its actual use has not yet become the integral part of the manufacturing and production processes. Based on the survey, Hungarian companies are striving to use the collected product data, but they are yet far from fully utilizing the revenue generating potential of the additional services developed on this basis. They are thus ahead of a long familiarisation, technical development and innovation process affecting their entire operation in terms of business model and integration of the new technologies.

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REFERENCES

Babbie Earl (2008). *A társadalomtudományi kutatás gyakorlata.* Balassi Kiadó, Budapest, Hungary (in Hungarian)

Bauernhansl, T., Hompel, M. T, Vogel-Heuser, B. (2014). *Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung, Technologien, Migration*. Springer, Wiesbaden

Industry 4.0 National Technology Platform (2016). www.i40platform.hu

Jung, K., Kulvatunyou, B., Choi, S., Brundage, M. P. (2016). An overview of a smart manufacturing system readiness assessment. APMS 2016. *IFIP International Conference on Industry 4.0, Artificial Intelligence, and Communications Technology,* vol. 488, pp. 705-712.

Kagermann, H., Wahlster W., Helbring J. (2013). *Securing the Future of German Manufacturing Industry: Recommendations for Implementing the Strategic Initiative Industrie 4.0. Final report of the Industrie 4.0 Working Group*. Forschungsunion im Stifterverband für die Deutsche Wirtschaft e.V., Berlin

Monostori L., Kádár, B., Bauernhansl T., Kondoh T., Kumara S., Reinhart G., Sauer O., Schuh G., Sihn W., Ueda K. (2016). Cyber-physical systems in manufacturing. *CIRP Annals - Manufacturing Technology*, vol. 65(2), pp. 621-641.

Mittal, S., Ahmad Kahn, M., Romero, D., Wuest, T. (2018). A critical review of smart manufacturing & Industry 4.0 maturity models: Implications for small and medium-sized enterprises. *Journal of Manufacturing Systems*, vol. 49, pp. 194-214.

Nick, G., Pongrácz, F. (2017). Innováció- a fenntartható növekedés kulcsa Magyarországon. *Közgazdasági Szemle*, vol. LXIV. July-August, pp. 723-737. (in Hungarian)

Probst, L., Lefebvre, V., Martinez-Diaz, C., Bohn, N. U., PwC and Klitou, D., Conrads, J. (2018). *Digital Transformation Scoreboard 2018: EU businesses go digital: Opportunities, outcomes and uptake*. Publications Office of the European Union, Luxembourg

Rockwell Automation (2014). *The connected enterprise maturity model.*

Schumacher, A., Erol, S., Sihn, W. (2016). A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. *Procedia CIRP,* vol. 52, pp. 161 – 166.

VDMA (2015). *Industrie 4.0 Readiness*. VDMA's IMPULS-Stiftung, Aachen, Köln