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L. Fükő, B. Illés, P. Tamás, R. Skapinyecz,
Á. Cservenák, Miskolc, Hungary

METHODS FOR DETERMINING MATURITY EVALUATION SYSTEM IN INDUSTRY 4.0

Abstract. *Nowadays, developments are being started to implement in the companies' production and logistics systems based on the so-called Industry 4.0 concept as an increasing role. On the one hand, market competition generates this need, but in many cases the use of Industry 4.0 solutions is the main driving force, in order of the truly higher level of automation with significant cost savings. On the other hand, the different levels of development individual companies are an achievement, which is further complicated by different industry characteristics. Therefore, a great benefit can be from developing a methodology that can help across the industry to determine the level of development required to make a particular Industry 4.0 development feasible. Partially laying down the theoretical foundations is the goal of this publication for the creation of such a maturity evaluation system in the field of Industry 4.0.*
Keywords: *Industry 4.0; lean; digitalization;, autonomy; maturity.*

1. INTRODUCTION

Today, the application of the Industry 4.0 concept can be observed in almost all areas of the economy. One of the primary reasons for this is that, from an economic point of view, the application of Industry 4.0 makes it possible to meet individual customer needs at the production costs typical of mass production. [1] The fact that this is possible is, of course, due to the combined use of the new technologies behind the concept, including the creation of so-called cyber-physical systems and the exploitation of the potential of big data. [2] Automation and the use of state-of-the-art artificial intelligence applications play a huge role, especially in the creation of the former systems, while large-scale data analysis allows for the innovative use of data collected from the resulting systems to shed light on previously unknown relationships. Exploring the latter can play a particularly important role in increasing efficiency, for example by predicting equipment failures and product failures with unprecedented accuracy [3], but also by predicting changes in customer demand with previously unattainable accuracy. The role of Industry 4.0 can be increased also in the academic scetor, such as in a laboratory [4].

It is no coincidence, then, that the application of the Industry 4.0 concept has already had a huge impact on both logistics and production. [5] As a result, there has been a need for some time to develop models that can help define the so-called 'Industry 4.0 maturity' for a given organization. Here, it is important to specify that the maturity models measure the maturity of the organization or process actually

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achieved during development in relation to a certain target state.

We are also talking about so-called preparedness models, the purpose of which is to record the initial state, which makes it possible to start the development process. Some typical maturity and readiness models from [6] are summarized in the following Table 1. Further maturity models can be found in the literature, for instance a fuzzy rule-based [7], for machine tool companies [8], for SMEs (Small and medium-sized enterprises) [9] or for the defence sector [10]. There is solution for metananalysis of Industry 4.0 maturity models [11].

Table 1 – Overview of Existing Industry 4.0 Readiness and Maturity Models (Evaluation Models) [6]

Model name	Institution / source	Evaluation approach
IMPULS - Industry 4.0 Preparedness (2015)	VDMA, RWTH Aachen, IW consult	Assessment in 6 dimensions, which includes 18 units, showing readiness at 5 levels.
Empowerment and Implementation Strategy for Industry 4.0 (2016)	Lanza	Assessing the maturity of industry 4.0 as a quick check and as part of the implementation process model
Industry 4.0 / Digital Operations Self-Assessment (2016)	Pricewaterhouse Coopers	Online self-assessment in 6 dimensions; focus on digital maturity at 4 levels
Graduation model of the affiliated company (2014)	Rockwell Automaton	The graduation model is part of a five-step approach to implementing Industry 4.0; technology-centric evaluation in 4 dimensions
Schumacher (2016)	TU Wien, Fraunhofer Austria	Evaluation in 9 dimensions. Further details in 62 graduation units
ACATECH Schuh (2017)	acatech – National Academy of Science and Engineering	Assessment in 6 dimensions which is further detailed in 18 areas and shows the level of maturity at 6 levels
SIMMI 4.0 (2016)	TU Dresden	Evaluation in 4 dimensions. Shows the graduation level in 5 levels

2. DEFINING THE BASIC ASPECTS OF THE METHOD TO BE DEVELOPED

It was clear from the above that the existence of prerequisites is important for the assessment of Industry 4.0 maturity. In this chapter, therefore, our goal is to define the basic characteristics of a method that can be used well to determine both Industry 4.0 readiness and maturity for a process or organization. This also means that the method must be applicable both to the so-called readiness assessment before the start of the preparation process and to capture the state during the preparation process (the latter is the maturity assessment). The following general objectives and findings should also be taken into account when designing the method:

- In terms of evaluation, the emphasis should be on production processes. Although digital data collection and processing from non-production areas is not strictly an Industry 4.0 application, the solutions and experiences used there can be a good starting point for its implementation.
- The first step is to create the preconditions for a functioning corporate governance system. This requires the existence of a functioning corporate governance or management system. This ensures basic integrity and controlled operation. Processes must be controlled and repeatable.
- Processes need to be simplified and made transparent. To do this, we need to know and use the principles of lean, which are necessary to be able to identify the losses that occur and to work systematically to reduce them.
- Defined and repeatable processes need to be stabilized and continuously improved. This requires the use of various statistical methods that can be used to perform capability tests and process control. We can evaluate results and identify trends.
- The digital form of data collection facilitates subsequent data processing. It creates the possibility of fast and efficient data processing.
- The computer network within the company speeds up and helps the collection, flow, storage and processing of data. The storage and processing of data and access to them must be managed at the system administrator level. This requires adequate storage capacity and IT infrastructure. In addition, proper user rights management must be provided.
- The use of enterprise management software is both important for the management of the company and can greatly increase the efficiency of processes. The more processes it covers, the higher the level of integration it implements.
- A higher level of capabilities means having software development capabilities, expertise within the company. This can ensure that the data that can be collected and to be collected is stored in an organized form and processed

efficiently. It creates the possibility of customized software data processing from the use of user software.

- Industrial data collection is required for automatic data collection and efficient management of production assets. This creates the opportunity for a wide extension of networked production facilities within the company, which paves the way for the efficient use of various production management software.

The system moves to industry level 4.0 as a result of which a digitally mapped twin pair of the production process is created. It is a system that collects and processes specified data in real time. The processing is done by different algorithms automatically and the decisions made as a result of the physical system are actually actually executed automatically. By this time we were already talking about an autonomous system and we had reached the level of industry 4.0.

horizontal and Important to establish the level of vertical integration, which gives an idea of the scope and depth of the industry 4.0 application within the company.

Industry 4.0 readiness can be assessed according to the following criteria. The more conditions of the system of conditions are met, the higher the level of maturity of the company's Industry 4.0. In addition to each aspect, metrics and weightings can be defined to aid evaluation. The structure of the proposed criteria, taking into account the objectives and findings described above, is therefore as follows:

- Corporate Governance System - Management System
- Introduced and functioning system e.g. According to ISO 9000
- Applying lean principles
- Continuous improvement
- Application of statistical methods (eg statistical process control)
- Systematic digital data collection and processing
- In-house computer network
  - System administrator
  - User authorization management
  - Storage capacity (server)
  - Other IT infrastructure
- Use of enterprise management software (eg SAP)
  - Process coverage
- High level of IT expertise
  - Software development capability
- High level of mechatronic proficiency
  - PLC programming and industrial control technology
  - Industrial automation
- Networked production equipment

- Automatic collection of production data
- Use of production management software (eg MES)
- Digital twin
  - Real-time data collection
  - Algorithms for automatic processing of collected data
  - Decisions made as a result of data processing are automatically implemented in reality
  - Level of horizontal and vertical integration

Thus, the system of criteria laid down above, with an appropriate weighting procedure associated with it, may already be suitable to provide a starting point for the development of the general methodology to be implemented.

3. SUMMARY

The publication presents the significance of the Industry 4.0 concept in the fields of production and logistics. It has also become clear that the definition of Industry 4.0 readiness and maturity is crucial for an organization or process today. In line with this, some typical models for determining the former are also listed, along with their defining characteristics.

In the second part of the publication, we have summarized the objectives and findings that need to be taken into account in order to define an independent set of criteria that can be the starting point for the development of an evaluation method that does not yet exist. By creating the new method, our goal would be to provide a general-purpose tool for organizations that can be used to determine both Industry 4.0 readiness and maturity in any environment, including logistics applications.

On the one hand, possible future research directions should therefore focus on defining the basic steps of the method, which will allow for the development of more detailed procedures. On the other hand, it may be an important research goal to precisely define the possible user groups, which may be of further help in the precise specification of the processes to be developed. We plan to present these research directions in the framework of further publications.

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Ласло Фюко, Бела Іллеш, Петер Тамаш, Роберт Скапінець,
Акош Червеняк, Мішкольц, Угорщина

МЕТОДИ ВИЗНАЧЕННЯ СТУПЕНЯ ЗРІЛОСТІ СИСТЕМ У ПРОГРАМІ "ІНДУСТРІЯ 4.0"

Анотація. *В даний час в виробничих і логістичних системах компаній починають впроваджуватися розробки на основі так званої концепції «Індустрії 4.0», роль якої зростає. З одного боку, ринкова конкуренція породжує цю потребу, але в багатьох випадках використання рішень «Індустрії 4.0» є основною рушійною силою, щоб забезпечити дійсно більш високий рівень автоматизації зі значною економією коштів. Отже, велику користь може принести розробка методології, яка може допомогти у всій галузі визначити рівень розвитку, необхідний для реалізації конкретної розробки «Індустрії 4.0». Часткове створення теоретичних основ є метою даної публікації по створенню такої системи оцінки зрілості в області «Індустрії 4.0». У публікації представлена важливість концепції «Індустрії 4.0» в області виробництва і логістики. Також стало ясно, що визначення готовності і зрілості «Індустрії 4.0» має вирішальне значення для організації процесу сьогодні. Відповідно до цього також перераховані деякі типові моделі для визначення готовності, а також їх визначальні характеристики. У другій частині публікації підсумовані мети і висновки, які необхідно прийняти до уваги, щоб визначити незалежний набір критеріїв, які можуть стати відправною точкою для розробки методу оцінки, якого ще не існує. Створюючи новий метод, метою авторів було надати організаціям універсальний інструмент, який можна було б використовувати для визначення готовності і зрілості «Індустрії 4.0» в будь-якому середовищі, включаючи логістичні додатки. З одного боку, можливі напрямки майбутніх досліджень повинні бути зосереджені на визначенні основних етапів методу, що дозволить розробити більш детальні процедури. З іншого боку, важливою дослідницькою метою може бути точне визначення можливих груп користувачів, які можуть в подальшому допомогти в уточнюванні специфікації розроблюваних процесів.*
Ключові слова: *«Індустрія 4.0»; ощадливість; цифровізація; автономія; зрілість.*