MATURITY LEVELS FOR LOGISTICS 4.0 BASED ON NRW'S INDUSTRY 4.0 MATURITY MODEL

Marjan Sternad
University of Maribor, Faculty of logistics in Celje, Slovenia
E-mail: marjan.sternad@um.si

Tone Lerher
University of Maribor, Faculty of Mechanical Engineering, Slovenia
E-mail: tone.lerher@um.si

Brigita Gajšek
University of Maribor, Faculty of logistics in Celje, Slovenia
E-mail: brigita.gajsek@um.si

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Abstract

The development of logistics sector is strongly connected to the development of industry, which just now transforms its production and business models according to Industry 4.0 concept. Industry 4.0 is a current trend of automation and data exchange in manufacturing technologies that includes cyber-physical systems, the Internet of things/services, cloud and cognitive computing. Logistics, an ubiquitous activity, consequently follows this trend and strives to realize the vision of Logistics 4.0, which expands the concept of industry 4.0 in the field of logistics. In doing so, traditional logistics in industrial environments has to lead the development along the evolutionary path determined by the control points, named as maturity levels, in which the development reaches previously defined characteristics, typically in the form of specific assessment items. Maturity is the state of being fully developed and implies an evolutionary progress in the accomplishment of a target from an initial to desired end stage, in our case Logistics 4.0, over a certain number of maturity levels. Maturity models are supportive tools to assess the as-is state, derive and prioritize improvement measures and control the progress. Paper contribute to the development of Logistics 4.0 maturity model, which would help companies to develop needed characteristics for seamless connectivity with mature Industry 4.0 companies.

Although a number of maturity models for industry 4.0 have been developed, maturity models for Logistics 4.0, as an emerging phenomenon, are still in their infancy. Because no dominant design for Logistics 4.0 company is find already, NRW's Industry 4.0 maturity model is studied with purpose to deduce a rough outlines of Logistics 4.0 maturity model.

Key word: logistics, Logistics 4.0, Industry 4.0, maturity model

1. INTRODUCTION

Globalization has become synonym for liberalization, economic openness and accessibility to world markets, which are (synergistically) more and more merging into the global market. Parallel to this trend the needs of markets and consumers are changing (faster and faster). The ability to cope with this trend is an essential competence of organizational and business systems, which proves their quality and the ability to respond to change in a comprehensive manner. Yet unknown business situations are intertwined with the problems that need to be addressed, but cannot be managed or resolved easily, as they are often very complex. The practice is constantly facing with increasingly large and complex problem situations that cannot be (relatively easily and without adequate knowledge) addressed with the known methods and models (Sternad & Knez, 2008).

Logistics is a supportive activity within companies and supportive industry along supply chains (SCs) and in society. As such mostly adapts its capabilities and properties to the needs of customers and society. Logistics tries to achieve requirements with cost acceptable changes in its resources and services by combining existing and new strategies and innovation. The examples of existing, widespread strategies are just-in-time (JIT), make-or-buy, outsourcing etc. Crucial features of these strategies are integration, concentration, cooperation, coordination and specialization. Integration, as crucial feature of SCs strategies, is one of the most important because of its effect on companies' performance and efficiency. The efficiency of the individual entity in SC results in a significant influence on the efficiency of others along the same SC (Dragan et al., 2018).

Production companies are reducing and relocating their stocks with use of IT and analytical tools. For the first time in history, they have the opportunity to decide on basis of real time information on market conditions or more likely predictions. The need to transport goods is lowering. Instead of physical goods technical plans, production instructions, ideas, knowledge etc. are starting to be transported. In work processes, human labour is starting to be as much as possible replaced with automated systems and robots. Already today, algorithms are substitute to human analytical work regarding market research, planning, operations research etc. Digitized processes allow human independent control and automated communications between technical systems, which are becoming more responsive and reliable. Flexibility is being improved with adding interconnected multifunctional machines, robots and autonomous vehicles in production environment to implement the strategy of covering market niches and to satisfy customers' individual demands. All and other advances in production sector is summarized under the term Industry 4.0, covering automation and data exchange in manufacturing technologies. In SCs manufacturers are only one entity in a whole chain, which elements are connected through logistics activities resulted in material flow between suppliers, manufacturers, distributors, retailers and customers. Non-digitized interorganizational data is becoming an obstacle to reach the maximal effects of transformation of traditional industrial environment into industry 4.0. This is the reason for the need to upgrade traditional logistics to Logistics 4.0, automated, digitalized and organizationally transformed.

The main advantage is reached in digitized information that invisibly accompanying or overtake the physical flow without the required contribution of the human work.

Many have a vision of Industry 4.0 output, but only pilots are built in practice. There is no full picture about final list of requirements from production to logistics. For sure future logistics must develop to something compatible to Industry 4.0 formation, often named with Logistics 4.0. If production companies help themselves to progress with Industry 4.0 maturity modes, logistics could do the same with Logistics 4.0 maturity models. Maturity models from theoretical perspective could be an appropriate tool to help direct the transformation to Logistics 4.0. Their basic purpose is to describe evolution stages and maturation paths to the desired end state (Gajšek et al., 2018).

In literature, we trace various Industry 4.0 maturity models, which differ in terms of the structure and complexity of the questions. Some are publicly available and allow companies to self-assess their Industry 4.0 maturity level. With their help, companies can place themselves on the maturity scale. Literature lacks of Logistics 4.0. maturity model, but some Industry 4.0. maturity models cover some logistics areas. Their extraction can form a starting point for a hint of future logistics or the so-called Logistics 4.0. Previous study (Gajšek et al., 2018) revealed NRW's Industry 4.0 Maturity model as on logistics content reach Industry 4.0 maturity model.

In the paper, NRW's Industry 4.0 Maturity model is studied with the purpose to deduce a rough outlines of Logistics 4.0 maturity model, a model that would help logistics companies and functional department to assess their readiness for future business requirements, recognize their weaknesses and plan development steps. We focus on three logistics subsystems: purchasing logistics, internal logistics and distribution logistics. The result is also a list of requirements for logistics companies and functional departments which want to fit into a certain Industry 4.0 maturity level.

2. THEORETICAL BACKROUND

2.1 Maturity Models

Software Engineering Institute has launched the Capability Maturity Model (CMM) more than twenty years ago (Paulk et al., 1993), as a precursor to their rich variety today. Based on the assumption of predictable patterns of evolution and change, maturity models usually include a sequence of levels (or stages) that together form an anticipated, desired, or logical path from an initial state to maturity (Pöppelbuß & Röglinger, 2011). Typically, three application-specific purposes of maturity models use are distinguished (Pöppelbuß & Röglinger, 2011; Iversen et al. 1999; de Bruin et al., 2005; Maier et al., 2009), descriptive, prescriptive and comparative. A maturity model serves a descriptive purpose of use if it is applied for as-is assessments where the current capabilities of the entity under investigation are assessed with respect to given criteria (Becker et al., 2009). It serves a prescriptive purpose of use if it indicates how to identify desirable maturity levels and provides guidelines on improvement measures (Becker et al., 2009). Comparative purpose of

use is achieved if it allows for internal or external benchmarking (Pöppelbuß & Röglinger, 2011).
Since their provenance, maturity models have been subject to criticism (Pöppelbuß & Röglinger, 2011):

- they have been characterized as "step-by-step recipes" that oversimplify reality and lack empirical foundation;
- they tend to neglect the potential existence of multiple equally advantageous paths;
- they should be configurable because internal and external characteristics (e.g., the technology at hand, intellectual property, customer base, relationships with suppliers) may constrain a maturity model's applicability in its standardized version;
- they should not focus on a sequence of levels toward a predefined "end state", but on factors driving evolution and change;
- we are witnessing multitude of almost identical maturity models.

Maturity model from theoretical perspective could be an appropriate tool to help direct the transformation to Logistics 4.0. Its basic purpose is to describe evolution stages and maturation paths. Excellent maturity models explicate characteristics for each stage and the logical relationship between successive stages. If Logistics 4.0 Maturity model would exist, it should disclose current and desirable maturity levels and include respective improvement measures for progression to higher levels. We see the main obstacle in not exactly knowing the result of the transformation to Logistics 4.0. A lot of effort should be invested in a sufficient degree of details based on strong empirical foundation.

2.2 Logistics 4.0 and Industry 4.0 Maturity Models

The term Industry 4.0 is apposite to Logistics 4.0 already widely recognized between all kind of stakeholders. Logistics 4.0 is amerging field because highly technologicaly developed production is and will start end end with material flows, which will have to enter and leave production facilities through seamless connections. Logistics 4.0 is an obvious consequence and next stop of Industry 4.0. Querying Logistics 4.0 Maturity model in scientific bases does not give results in a form of scientific paper. We can trace only recent conference papers, for exmple those from Oleśków-Szłapka & Stachowiak (2018) and Terstenjak & Ćosić (2017). In order to contribute to development od Logostics 4.0 Maturity model, Industry 4.0 maturity models will be studied wth focus on context concerning logistics.
Kese and Terstegen (2017) divide Industry 4.0 Maturity models in four groups:

- general models: BMWi, HNU-Digitaler Reifegrad-Analysetool, Deutsche Telekom-Digitalisierungs Index. Among them only the ″Digitalisierungs Index″ precisely and more systematically analyzes individual business functional areas. The logistics functional area is modestly covered. The focus is on entire value chain, where logistics represents the flow of information between business processes. Individual areas of logistics activities are not covered in the model.
- models with focus on technological aspects with the possibility of self-assessment: IMPULS model, IHK model, the Connected Production model. All

three of them cover the logistics area. The IMPULS model includes logistics as part of the vertical and horizontal integration between the company's departments. In the IHK model, logistics is a part of the Smart Organization. This part emphasizes the digitization of business processes and organization. The significance of digitization of logistics is verified as the integration of internal processes. The Connected Production model involves logistics as a key component of the model and covers the various areas of logistic activity within the model. The logistics area is placed in one of the maturity stages. The lowest level of logistics development is ″Manually″, which is characterized by the non-use of computers to manage logistic processes. By using a computer higher level ″Digitization″ is achieved, which means easier handling logistics documents. Introduction of networking and information exchange within company means achievement of next, higher maturity level ″Networking″ with improved information flow. Central information systems, such as the ERP system, are used to exploit consistent and consolidated data, which the company places in the next level ″Structuring″. At the level of ″Automation″, individual or specific parts of processes are automated and the need for manual intervention is eliminated. Companies at this stage have automatic stock checking and ordering goods. In the degree of ″Predictability″, based on the current state, it is possible to predict how the processes, numbers and events will develop, which enables the overall management of the warehouse and the planning of transport routes. At the highest level of ″Autonomization″, the system can independently respond to external influences and independently adapt to the circumstances in the entire supply chain and optimally directs the goods and information flow.

- models focused on technological aspects with an emphasis on the cooperative assessment of maturity. Logistics is not specifically specified in the models. Self-assessment of the company is not possible, since the questionnaires are not publicly available.
- models focused on the entire value chain. The maturity model of Acatech study Industrie 4.0 Maturity Index base on a value model that helps companies navigate through individual maturity levels. The model envisages six maturity levels (computerization, connectivity, visibility, transparency, predictive capacity and adaptability), with the first two stages representing digitization, the other four being placed in Industry 4.0. Transformation of the company takes place through four structures of the field: resources, information system, culture and organizational structure. In Acatech Study Industrie 4.0 Maturity Index, structural areas are considered for each function area in the company separately. Functional areas (development, production, logistics, services, marketing and sales) are studied at the level of business processes. The maturity model 4i covers five areas of operation that form the basic principles of the order execution process. At Level 0, organizational and structural prerequisites for introducing the industry 4.0 in the enterprise are in place. The first stage allows the creation and availability of data and information on all activities in real time. In the second stage of information processing and networking, knowledge is developed and aggregation of old available information and data sources. In stage 3, the interaction of cyber-physical systems provides systems for mobile help and

cooperation between people and devices to support decentralized decision-making processes. Intelligent self-control processes at the highest level enable self-optimization processes and independent production control in the value chain. In individual stages, the logistics area is not specifically specified. For our research, the most useful model is Kompetenzzentrum Mittelstand NRW's Industry 4.0 Maturity model, which will be further described in next chapter.

2.3 NRW's Industry 4.0 Maturity Model

For our research, the most useful model is Kompetenzzentrum Mittelstand NRW's Industry 4.0 Maturity model, which enables self-evaluation of the company and covers the following development areas:

- business models,
- IT systems,
- quality management,
- process management,
- planning of production,
- control of production,
- logistics, distribution and management of public procurement, and
- human-machine communication.

No other in literature observed Industry 4.0 Maturity model covers logistics area in comparable scope.

NRW's model defines five Industry 4.0 maturity levels that represent the transition from largely analogue to networked, automated production. Production and logistics present building blocks of the model, as most self-assessments questions are devoted to these two areas. Logistics related questions are:

- What is the external exchange of information with customers and suppliers?
- How is the order processed in your company?
- Is the information and material exchange between different areas within the company supported by the system?
- How are your inventories recorded?
- How are data from production and logistics reported back?
- How are data from production and logistics used?

The highest maturity level represents an automatic exchange with businesses throughout the value chain. The internal exchange of information about the integrated functionality of the existing system is taking place in all areas. The transfer of information takes place automatically in real time. In the information system, there is a complete picture of the position of the order in which the new incoming orders are automatically entered in real time. The links and interactions of different types and quantities of orders are known and taken into account in the ordering processes. Based on comprehensive forecasts, the expected orders are linked to the stock position. Collecting and organizing supplies are carried out by specially cargo carriers, storage technology and products themselves. With the help of sensors, they can constantly communicate with the software and transmit relevant information. Manual scanning is not required. With analytical methods, the inventory management system can also predict different situations and respond appropriately.

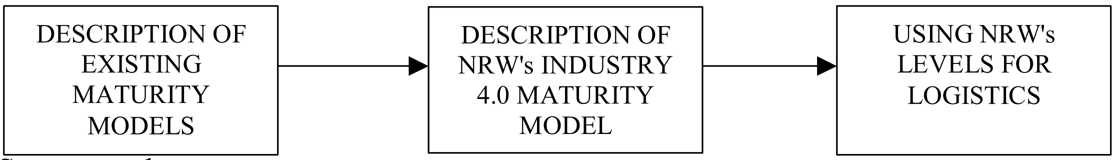
Because NRW's Industry 4.0 Maturity Model analyses the maturity levels for each logistic subsystem separately, the model represent an excellent starting point for scratching the outlines for Logistics 4.0 Maturity model.

3. METODOLOGY

The theoretical background on Industry 4.0 Maturity models was compiled from scientific literature review. Scientific papers were found in Google Scholars, Web of Science and Elsevier. Practical examples of Industry 4.0 Maturity models are mostly published by consulting organizations to attract new customers. Only minority of practical examples were found in scientific papers.

In the paper we have used the first step of Backer's methodological step-by-step process for the development of maturity models (Becker, et al., 2009). Figure 1 illustrates how methodology was divided into three stages.

Figure 1. Research model



Source: authors

In the first stage we make a description of existing maturity models. For further research we choose the model with high level of complexity in logistics content. NRW's Industry 4.0 Maturity model is a five-level model. The first level is the unconnected analog production. In the second level, digital data processing is introduced, which in the third level turns into automatic data collection in most of the dedicated programs. The fourth level defines a high level of networking of individual processes through a software solution that performs automated data analysis and enables easy exchange of data from other programs. Fifth level describes completely networked production. The software used is capable of identifying real relationships in production independently (Kompetenzzentrum Mittelstand NRW, 2018).

From the systemic point of view, we include the selected NRW's Industry 4.0 Maturity model into individual logistic subsystems and define different maturity levels of each subsystem. We use NRW's Industry 4.0 Maturity model levels for logistics subsystem. The levels are developed based on the definition of automation in the concept of Industry 4.0 and represent the transition from analogue or isolated software systems to network systems (Kompetenzzentrum Mittelstand NRW, 2018). For each subsystem, the characteristics of each maturity level were recorded.

4. MATURITY OF LOGISTICS FOR INDUSTRY 4.0

The structure of the system shows the interconnection and relationship between the elements of the system and can be multileveled (super systems, subsystems) (Rosi &Mulej, 2005). Production company's logistics system is according to functional characteristics divided as follows (Sternad & Rosi, 2009):

- purchase logistics,
- internal logistics,
- distribution logistics and
- after sales logistics.

The basic task of the purchase logistics is the supply of companies with raw materials, construction materials, services, energy, support material, as well as with machinery, equipment, etc. For companies' effective performance, it is not only important to have the appropriate amount of material, but also that the material is of adequate quality, purchased at a reasonable price and that it is available on time.

Deciding on the most important purchasing activities, based on the study of the procurement issues and their possible solutions, is the core of the purchasing policies. The successful creation of procurement policies requires the knowledge of market conditions, purchase conditions, demand for the material, resulting in cheaper purchasing and risk reduction. In addition to quality, price, quantity and other conditions of purchase, the continuity of supply, the minimum cost of purchasing and the suppliers' confidence should be considered in establishing the purchasing policies. The costs of the purchasing function within the company are defined primarily in a broader sense; namely, in addition to the purchase the procurement function includes mainly the following activities: purchasing market research, purchase planning, designing procurement policies, concluding purchase agreements, the quantitative and qualitative material receipt, storage, analysing and recording of the purchase operations. The basic operations of the core purchasing function incur logistical costs, which are intertwined mainly with other fundamental logistics operations.

The development of purchasing logistics is closely linked to the use of modern technology in the procurement process. The flow of information between the internal and external systems must follow the changes in information technology. On the way to industry 4.0 it is necessary to evaluate the current state based on maturity models, whose assessment is the starting point for planning. The table 1 shows five maturity levels in the field of information flow in purchasing logistics.

Table 1. Maturity levels in the field of information flow in purchasing logistics

LOGISTICS 4.0 ↓	NO DATA EXCHANGE WITH THE SUPPLIER
	EXCHANGE OF SPECIFIC DATA
	EXCHANGE OF ADDITIONAL DATA
	AUTOMATIC DATA EXCHANGE
	AUTOMATIC EXCHANGE IN SUPPLY CHAIN

Source: Own table based on NRW's Industry 4.0 Maturity model

Data about order will not be exchanged at the basic maturity level during the processing of orders. Orders are delivered via direct call by phone or in person, and they are recorded manually in paper form.

In the second maturity level, specific data on the order will be exchanged for the supplier. Orders are released by telephone or personally and digitally recorded, for example through an office solution. There is a history of ordering processes. Further information, e.g. in relation to the planned orders, the time of special promotions, delivery points, forecast data can be manually transmitted after consultation.

In the third maturity level, there is an intensive exchange of additional data, such as scheduled orders, time of special promotions, delivery points, forecasting data to be performed automatically. The information system has a complete picture of the position of the order, with new orders being automatically entered in real time.

In the fourth maturity level, information on the integrated functions of individual IT systems is automatically exchanged with direct partners in the value chain. Access to relevant external company information is also enabled. In the information system, there is a complete picture of the position of the order in which the new incoming orders are automatically entered in real time. The links and interactions of different types and quantities of orders are known and taken into account when ordering.

In the fifth maturity level information on the integrated functions of the relevant information systems is automatically exchanged with companies across the entire value chain. Access to relevant external company information is also enabled. In the information system, there is a complete picture of the position of the order in which the new incoming orders are automatically entered in real time. The links and interactions of different types and quantities of orders are known and taken into account when ordering. On the basis of comprehensive forecasts, the expected quantities of orders are linked to inventory, preparatory work, etc.

Given the phase classification of business logistics the internal logistics is classified between the purchase logistics and distribution logistics and also connects both of them. Internal logistics covers all the activities that are related to the supply of the production process with the input elements (raw materials, semi-finished products, materials and ancillary materials, and commercial components or goods) and with the sale of semi-finished products and stored products into the distribution storage and discharging for a sale. The object-internal logistics area is marked by the fact that objects are moved in accordance with the process of change or handling, in terms of the material flow of the process of manufacture of goods or their discharge due to the sale. Manufacturing processes and logistics services are strongly intertwined, partly inherently, since the focus of systems thinking is to achieve optimum comprehensive solutions. Many a time this is not paid attention to in practice and sequential manufacturing processes are mutually optimized, but they lack consistency with logistics activities in all sub-systems of business logistics (e.g. just in time delivery).

In companies, often there are problems in the flow of information from the basic production process. Data is mostly transmitted classically and is not supported in modern information solutions. In companies where they use modern IT solutions, the given information is not used in the way, which would enable optimization of processes in the company. The table 2 shows five maturity levels in the field of information flow in internal logistics.

Table 2. Maturity levels in the field of information flow in internal logistics

LOGISTICS 4.0 ↓	PAPER TRANSFER OF DATA
	TRANSFER OF PAPER DATA IN DIGITAL FORM
	ERP SISTEM
	DIGITAL DATA COMPLETENESS
	AUTOMATIC TRANSFER OF DATA

Source: Own table based on NRW's Industry 4.0 Maturity model

In the basic maturity level, the data is transmitted in paper form. Data from production and logistics are not used in further analyses.

In the second maturity level, feedback is in paper form, which later is converted into a digital format. The data is documented.

In the third maturity level, feedback from production and purchasing logistics are transmitted via a terminal with short time delays in the ERP system. The data are used to measure key indicators in real time.

In the fourth maturity level, the information from the machines is fully accessible in real time. Process data and quality data are analysed in real time and used to plan resource use and maintenance, and to detect errors.

In the fifth maturity level, manual work data is subsequently digitized. Automatic real-time feedback is completed. Data is used to proactively prevent interference by adjusting the use of resources.

Distribution logistics deals with the flow of finished products from the manufacturer or the seller to end users, so that the product comes into the hands of the consumer in the required quantity and quality at the right time and at the right place, undamaged and at the optimum cost. Distribution logistics comprises the storage of finished products, external transport, the necessary handling operations and the related administrative work. Some authors also refer to distribution logistics as physical distribution, logistics of sales or marketing, which is less appropriate. There is also the concept of marketing logistics, in which the material flow is the same as in distribution logistics, in which the flow of goods is part of the entire material flow from the purchase through the manufacturer to the end user.

Supporting an effective material flow is the flow of information that must be accessible and up-to-date. The table 3 shows the maturity levels of distribution logistics.

Table 3. Maturity levels of distribution logistics

LOGISTICS 4.0 ↓	NO DATA EXCHANGE BY CUSTOMER
	EXCHANGE OF SPECIFIC DATA
	EXCHANGE OF ADDITIONAL DATA
	AUTOMATIC DATA EXCHANGE
	AUTOMATIC EXCHANGE IN SUPPLY CHAIN

Source: Own table based on NRW model

Order data will not be exchanged during the order processing basic maturity level.

In the second maturity level, special order data will be exchanged during the processing of orders. Further information, e.g. in relation to scheduled orders, the time of special promotions, points of sale, forecast data, can be manually transmitted after consultation.

In the third maturity level, there is an intensive exchange of additional information, such as scheduled deliveries, time of special promotions, points of sale, information on future orders. The exchange is done automatically. In the fourth maturity level, information is automatically exchanged with direct partners in the value chain. Access to relevant external company information is also provided.

In the fifth maturity level, the information about the integrated functions of the relevant information systems is automatically exchanged with companies throughout the value chain. Access to relevant external company information is also provided.

Companies should integrate all their logistic subsystems under logistics system to achieve seamless material flow through supply chain. Ensuring an efficient internal information flow between individual logistics subsystems should include real time data that is automatically exchanged between logistic subsystems. The table 4 shows the maturity levels of logistics subsystems.

Table 4. Maturity levels of logistics subsystems

LOGISTICS 4.0	NO DATA EXCHANGE BETWEEN SUBSYSTEMS
	DATA EXCHANGE THROUGH ERP
	REAL TIME DATA
	AUTOMATIC DATA ENSURE
	AUTOMATIC DATA EXCHANGE

Source: Own table based on NRW model

There are no specific system functions in the basic maturity level, such as file sharing folders that are shared with all areas, and specifically support the exchange of information and material between sites.

In the second maturity level, it is possible to access information from other areas through the management system (for example, through the files exchange files installed for this purpose) and to control the internal material exchange.

In the third maturity level, it is possible to access all relevant information / data from other areas in real time through the management system and control the internal exchange of materials. For example, all accounts can be equipped with individual access and read permissions.

In the fourth maturity level, there is automatic provision of prepared context data from other departments that can be used to design the internal material exchange. This can be done, for example, through the general control panel.

In the fifth maturity level, the internal exchange of information on the integrated functionality of the existing system takes place between all domains. Data do not need to be reviewed, but they are provided with credibility and are automatically used to design material exchange.

5. CONCLUSION

The importance of logistics in time, when industry is transforming itself according vison Industry 4.0, is increasing. Companies are in the phase where they need to determine their maturity and plan their further development actions to achieve the final goal – the full maturity. The complexity of subsystems in the company, for example logistics, several times prevents the finding of the actual situation. Therefore, it is important and logical to determine the maturity level at the level of the subsystems. Logistics as a subsystem can be further divided on its subsystems that are interdependent in certain scope, but interconnected. The interconnections of individual logistics subsystems enables faster information flow, which enables more comprehensive process management. In the paper, the characteristics of different potential Logistics 4.0 Maturity levels were defined for individual logistic subsystems using the NRW's Industry 4.0 Maturity model, which unlike other observed Industry 4.0 Maturity models, deals with the logistics in a more complex way. Our research focuses on the development of first level of Backer's step-by-step process, where we determined levels for logistics. The contribution of this research is in the systematic analysis of maturity levels in the logistic content in the NRW's Industry 4.0 Maturity model. The research is the basis for researchers for the further development of the maturity model for Logistics 4.0.

Future research activities will mainly aim at creation on road maps to improve maturity models in logistics. Based on the findings in research, a more specific maturity model for logistic is planned.

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