International Journal of Academic Research in Business and Social Sciences
2017, Vol. 7, No. 7
ISSN: 2222-6990

Measuring the Maturity of a Factory for Industry 4.0

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DOI: 10.6007/IJARBSS/v7-i7/3077 URL: http://dx.doi.org/10.6007/IJARBSS/v7-i7/3077

ABSTRACT
In recent years, the industry is evolving to fully digitize and intelligentize its production processes. This study primarily aims to be a guide to managers who want to raise their plants to the industry 4.0 level. Second objective is to help a manufacturing operation find out the answers to the questions of “which industry level we are in?” and on which level we want to be? According to the findings, this research shows that the chosen company is far from the industry 4.0 level. The company's industry maturity average was 2.44, which is also the middle of the 20th century, when the industry represented 2.0.

1. INTRODUCTİON

Global competition is more and more increasingin the manufacturing industry. At the same time, the markets are becoming progressively volatile and heterogeneous due to constantly changing customer expectations and needs, such as customized products on demand (Hecklau et al., 2016: 1). Modern Age has transformed thousands of concepts in Production. New World is a variety box emerging from digitalization of all areas of production. Production is indispensable for company life.

In spring 2014, VDMA, Bitkom and ZVEI, three leading German associations of mechanical engineering, ICT and electrical industry, released a definition for Industry 4.0. According to them, Industry 4.0 aims for optimization of value chains by implementing an autonomously controlled and dynamic production (Kolberg and Zühlke, 2015: 1871).

Recent technological developments where the internet and supporting technologies (e.g. embedded systems) serve as a backbone to integrate human and machine agents, materials, products, production lines and processes within and beyond organizational boundaries to form a new kind of intelligent, connected and agile value chain (Erol et al.,2016: 13).
Fully integrated and networked factories, machines and products then will be able to act in an intelligent and partly autonomous way that requires minimal manual interventions (Monostori, 2014:10). Recent concepts such as the Internet of Things, Industrial Internet, Cloud-based Manufacturing (Gao et al., 2015) and Smart Manufacturing address these requirements in part and are commonly subsumed by the visionary concept of a Fourth Industrial Revolution (Industry 4.0) (Berger, 2014:7). Industrial companies are currently facing the challenges of increasing individualization of products, the need to increase the resource efficiency and reducing time-to-market. These challenges they encounter in particular with increasing digitization, IT penetration and networking of products, manufacturing resources and processes Rennung et al., 2016: 373).
This study mainly aims to be a guide to managers who want to raise their plants to the industry 4.0 level. Second objective is to help a manufacturing operation find out the answers to the questions of “which industry level we are in?” and “on which level we want to be?”. The origin point of the research problem is that the manufacturing enterprises operating in the Kahramanmaraş province are willing to move to industry 4.0. But they are worried because they do not have enough knowledge about the industry 4.0. So it is thought that this study will be an example of providing information and guidance for businesses.
The study was conducted in a manufacturing operation in Kahramanmaraş province which is a leader in its sector. Survey technique was used in the research. Questionnaires were asked by grouping according to the process from the industry 1.0 to the industry 4.0. The questionnaires were answered with face-to-face interviews with five experts. This study consists of two parts, including literature review and methodology. Detailed information on the research is given in the section on methodology.

2. INDUSTRY 4.0

There have been four major industrial revolutions throughout history. (1) The availability of mechanical benches for more efficient use of water and steam power. (2) Henry Ford's production band design and use of electricity in serial production, development of the production line. (3) The use of digital technology and programmable machines in production in the 1970s. (4) Industry 4.0 is an industrial strategy plan that is supposed to launch the 4th Industrial Revolution.
Lean Production principles are widely accepted in industry since their first broader appearance in the early 1990s (Kolberg and Zühlke, 2015: 1870). Lean manufacturing involves these principles; Elimination of Waste, Continuous Improvement, Respect For Humanity, Levelized Production, Just In Time Production, Quality Built In.
With wirelessly connected mobile devices, an age of unparalleled connectivity has descended upon society.We are now able to communicate with most anybody at almost any time and from nearly everywhere. This degree of connectivity and communication is increasingly finding its

utility in technical systems (Mosterman and Zander, 2016: 17). Examples of this trend are the Internet of Things (IoT) (Vermessan ve Friess, 2014), Machine-to-Machine (M2M) (Gyrard et al., 2014), technologies, Industry 4.0 (National Academy of Science and Engineering, 2013), and Cyber-Physical Systems (CPS) (National Academy of Science and Engineering, 2011).

Today, we face a new paradigm called Industry 4.0, which on the first glimpse seems to be a rebirth of the old CIM idea (Kolberg and Zühlke, 2015: 1870). The young German term Industry 4.0 describes the increased integration of ICT into production. By this means, it could complement the established Lean Production to match future requirements (Kolberg and Zühlke, 2015: 1871).The major idea of Industry 4.0 is the introduction of internet technologies into industry. Currently, industrial production is facing serious challenges, because information and communication technologies – e.g. the Internet of Things (IoT), Cyber-Physical Systems (CPS), Embedded Systems (ES) – are entering the factory (Gabriel ve Pessl, 2016: 131).

Industry 4.0 was initially developed by the German government to create a coherent policy framework to maintain Germany’s industrial competitiveness. Related terms used internationally include Internet of Things, Internet of Services, Industrial Internet, Advanced Manufacturing and Smart Factory. The term “Industrie 4.0” was initially coined by the German government. It describes and encapsulates a set of technological changes in manufacturing and sets out priorities of a coherent policy framework with the aim of maintaining the global competitiveness of German industry.

Acquiring accurate and reliable data from machines and their components is the first step in developing a Cyber-Physical System application. The data might be directly measured by sensors or obtained from controller or enterprise manufacturing systems such as ERP, MES, SCM and CMM (Lee et al., 2015: 19).

The future of production as it is envisioned by Industry 4.0 is characterized by small decentralized and digitalized production networks which are acting autonomously and are therefore capable of efficiently controlling their operations in response to changes of the environment and strategic goals. The nodes of such a network are so called smart factories which are connected to a larger value-chain network that fulfils a certain customer demand. (Erol et al., 2016: 14).

Absolutely, Industry 4.0 creates many new opportunities for companies, but at the same time several challenges arising from the ongoing automation and digitization (Hecklau, 2016: 3). Especially small and medium sized enterprises (SMEs) have the difficulty to be highly skilled in applications and technologies of Industry 4.0. This is caused by the fact that those companies usually don’t have the manpower to look ahead and beyond their own product and production range to enter new areas and they usually don’t have the possibility to invest in emerging technologies as an early adaptor in order not to lose money by focusing on the wrong Technologies (Faller and Feldmüller, 2015: 88).

Industry 4.0 is based on six principles:

- ✓ *Interoperability:*The interaction of the Internet of objects and the Internet of services takes place between intelligent and connected machines and people.
- ✓ *Virtualization:* Provides monitoring of processes related to cyber-physical systems.

- ✓ *Cyber-physical system:*CPS which are made up of software embedded in hardware such as sensors, processors and communication technologies and can autonomously exchange information, trigger actions and control each other independently.
- ✓ *Autonomous Administration:* Cyber-physical systems have the ability to make their own decisions in smart factories.
- ✓ *Real-Time Ability:*One of the most important innovations in the design and production processes of Industry 4.0 technologies is the decision and operations usually made in "real time".
- ✓ *Modularity:* Modularity provides a smart factory flexible adaptation system for the changing needs of individual modules.

If successfully implemented, the potential benefits of Industry 4.0 relate to productivity gains, revenue growth, and competitiveness. There are advantages provided by industry 4.0 such as facilitating monitoring of the system and fault diagnosis, Sustainability of the system through eco-friendly and resource-saving behavior, greater efficiency, increasing flexibility in production, reduction cost, development of new service and business models. Industry 4.0 describes the organisation of production processes based on technology and devices autonomously communicating with each other along the value chain in virtual computer models.

3. EMPIRICAL INVESTIGATION

In this study, it is aimed to test the applications of industry 4.0 at a factory scale and finally to propose solutions for finding the deficiencies at the point of reaching the industry 4.0 standards and eliminating these deficiencies. Survey technique was used in the research. Thus, based on this study, it is aimed to be a guide to other companies in order to find out what they are in the industry and what they need to do to catch the industry 4.0 and what they are missing.

The questionnaire was prepared by considering the purpose, main mass, application area and characteristics of the questionnaire surveyed by Veza in the study conducted in 2015, and adapting it to the current work by making certain eliminations. The study was conducted in a manufacturing operation in Kahramanmaraş province which is a leader in its sector.

Survey questions were translated into Turkish from the original work and then pre-tested with a specialist from the firm to prevent possible mistakes and misunderstandings. After the necessary corrections were made, a meeting was organized with the participation of 5 experts from the firm on a suitable day and time, and the data collected from the company on the basis of detailed discussions on each questionnaire.

Survey questions are collected in 9 main headings representing production and each answer has a value ranging from 1 to 4 representing one of the four historical industrial maturities. For example, the practice of job order management based on verbal communication among employees is the first industrial revolution and the score is 1.0. However, the business order management, based on communication from the plant to the machine, belongs to the third industrial production, with a score of 3.0.

In addition to the basic questions about the establishment itself, nine sets of questions that represent the most important aspects of manufacturing consist of:

1. Selection of the status of the product development phase in operation,
2. The choice of technology in the production system,
3. Selection of work order management in the production system,
4. Selection of the state of production traceability within the production process,
5. Selection of material stock management (raw material, semi-finished product)
6. Selection of the management system of finished product stocks within the production process,
7. Selection of the quality management system within the production process,
8. Selection of the product life cycle system within the production process,
9. Selection of Toyota Production System (TPS) and Green and Lean Production Structure (GALP)

It was possible to select more than one answer on each question. Depending on selected answer(s), an overall score for each question was calculated as average value of all selected answers and their scores (Table 1).

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	Industry 1	**Industry 2**	**Industry 3**	**Industry 4**
Question 1	Product development is conducted by CAD system	Product development is conducted by CAD system	The use of digital factory and simulation for product development	The use of virtual reality, 3D scanning and rapid prototyping for product development
Question 2	Manual processing and/or manual assembly	CNC machines and/or automated production line	CNC machines and/or automated production line	Up-to-date machining centers with automated transport and/or robotic stations on automated production line
Question 3	Verbal man to man communication (a manager explaining working order to workers)	Written man to man communication (written working order is handled to a worker by a manager)	Man to machine communication (a worker operating CNC machines) or production line ----------------------------- Machine to machine communication (m2m)	Intranet communication via personal computer network
Question 4	No record on product	Product or transport case has	Product or transport case has an attched	Product or transport case has

	transition through production process	an attached production timeline tag	barcode which is read manually at every working unit	RFID-tag which is read automatically at every working unit
Question 5	The amount of raw material, parts and products currently avaliable in input stock as well as in certain intermediate stocks in production, can be partly estimated based on accessible data	The amount of raw material, parts and products currently avaliable in input stock as well as in certain intermediate stocks in production, can be partly estimated based on accessible data	The amount of raw material, parts and products currently avaliable in input stock as well as in certain intermediate stocks in production, can be scanned via computer server's database	The amount of raw material, parts and products currently avaliable in input stock as well as in certain intermediate stocks in production, can be scanned via personal smartphone or tablet computer application
Question 6	The amount of finished products currently avaliable in output stock can be partly estimated based on accessible data	The amount of finished products currently avaliable in output stock can be partly estimated based on accessible data	The amount of finished products currently avaliable in output stock can be scanned via computer server's database	The amount of finished products currently avaliable in output stock can be scanned via personal smartphone or tablet computer application
Question 7	Product control at the end of production process	In-process control (self-control) through entire process	Quality management according to Total Quality Management concept (TQM) ---------------------------- Quality management according to ISO 9000 standart system	Quality management according tos ix sigma concept
Question 8	Division distribution according to functions (PC and software are located in certain	Division distribution according to functions (PC and software are located in certain	Certain divisions are connected via computer integrated manufacturing (CIM)	Integration of PLM Enterprise Resource planning (ERP) and management execution system

	divisions (CAD, CAM, PPC)	divisions (CAD, CAM, PPC)		(MES) via information backbone and cloud
Question 9	Neither TPS or GALP principles are in use	Neither TPS or GALP principles are in use	Specific TPS and GALP elements are in use (e.g. Kaizen, SS, Just in Time, Value Stream Mapping, Jidoka, etc.)	TPS and GALP principles are implemented through entire business process so-called Lean Management 2.0 (e.g. software application for Kaizen via smartphone)

Table 1. Questions for Industrial Maturity

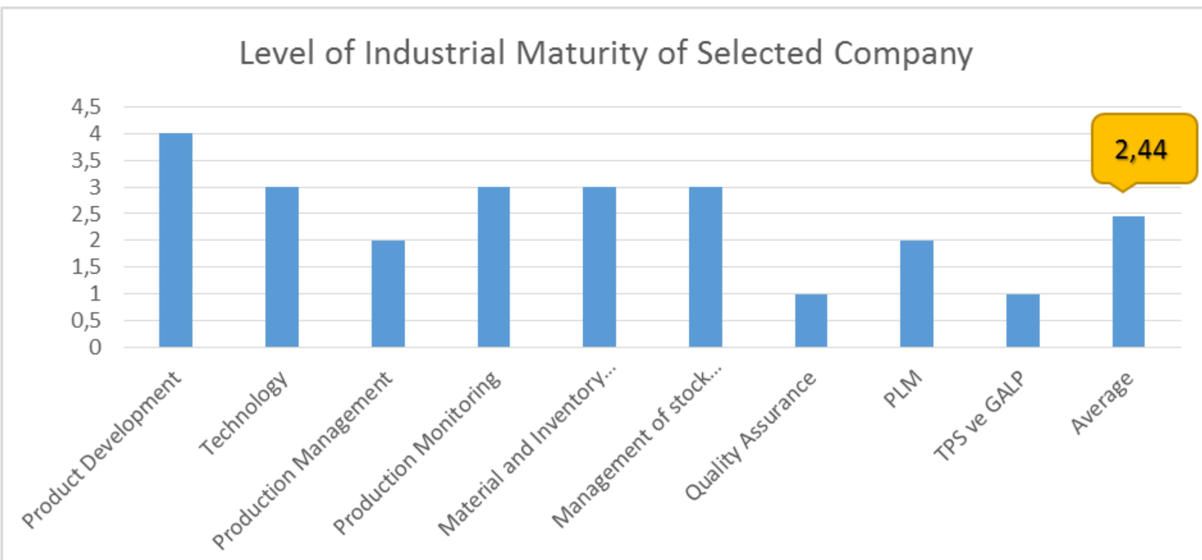

Figure 1. Level of industrial maturity for specific segment of production and average of selected company

In Figure 1, as you can see, the average score of the industrial generation level of the firm is 2.44, which means that the firm is at the industry 2.0 level, that is, it reaches manufacturing technology in the middle of the 20th century. It is also seen that the firm is at the level of 1.0, which is the most basic level in some activities where production activities are at different maturity levels and in some activities the industry has achieved level 4.0.

4. CONCLUSIONS AND RECOMMENDATIONS

The main focus of the enterprises is to make innovation in order to develop and get optimized. However, it is a point at issue that on what projects the focus will be on and selection of the

kind of applications. Thus, there is need for detection of innovation ability inventory (Fettahlıoğlu at. 2016:154).
This research shows that the selected company is far from the industry 4.0 level. The company's industry maturity average was 2.44, which is also the middle of the 20th century, when the industry represented 2.0. Moreover, when looking at the maturity levels of the firm's manufacturing activities, the lowest maturity levels are the quality assurance system, communication infrastructure used in production management, Product Lifecyle Management (PLM), and Toyota production system (TPS) and Green and Lean Production (GALP) issues.
It seems that the quality assurance system is the quality control at the end of the production and as a result there are some quality related problems. At this point, it is recommended that the company use 6 sigma methods for quality assurance. The 6 Sigma method focuses on three topics (Pande and Holpp, 2002);

- ✓ Increasing customer satisfaction
- ✓ Decrease cycle times
- ✓ Reduction of errors

The second issue is that the communication technology used in the delivery of work orders in production process is written by the managers in written to the workers and this corresponds to the 2.0 industry. Here too, as a remedy, work orders have to be developed by way of intranet communication by connecting personal computers to each other.
Another issue is the level of maturity in 2 for product life cycle management (PLM) and it is obvious that they need to make improvements in this regard. In this context, it is considered appropriate to integrate product lifecycle management with enterprise resource planning, as well as the backbone of the management and management execution system (MES) with the help of cloud computing technology.
Finally, it is understood that the TPS and GALP and any management approach is not applied and therefore the industry is at 1.0 maturity level. Again, it is thought that smartphone software application can be used during all business processes called lean management (eg Kaizen).
This article describes the significance of industry 4.0 and its important role in our future professional and everyday life. This research illustrated that Industry 4.0 has already been started and will affect business life and the future business model expressly. It is believed that this research will make an important contribution to guiding businesses in transition to 4.0. In addition, this study is significant with its applicability to different sectors.

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