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INDUSTRIAL ENGINEERING METHODS AND TECHNIQUES IN INDUSTRY 4.0

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Abstract: The paper analyzes the importance of the application of methods and techniques of industrial engineering in the business environment of Industry 4.0. Survey done indicates that in the new business environment, the methods and techniques of industrial engineering come to full expression because cyber-physical systems give a complete insight into the nature of production processes. Accordingly, an example of an IE method application and ways of its integration in I4.0 environment is given and discussed.
Key words: industrial engineering, industry 4.0.

INTRODUCTION

Industry 4.0 - a new business philosophy of the factories of the future is a concept made possible by connected elements: the internet, machines and people. In such an environment, computers communicate and process large amounts of data using artificial intelligence. The system consists of autonomous systems, cyber physical systems, sensors, robots, smart machines, people, and the whole concept from the point of view of business management allows understanding what happens in the production process. Detailed insight into the nature of functioning of production processes allows to make better decisions about planning, scheduling, strategic planning, maintenance, production efficiency, quality, etc. In that sense it can be spoken Management 4.0, Logistics 4.0, Supply Chain 4.0, Maintenance 4.0. The whole philosophy of business is changing, approaching business from a different aspect, which opens up numerous possibilities.

INDUSTRIAL ENGINEERING METHODS IN I4.0

In environment Industry 4.0, we have the opportunity to really manage business and production processes. So far, we have had input data and output data, we have changed the input data to get the desired output according to the feedback principle. Each business-production process represented the so called a black box because there was no information from the production itself. Industry 4.0 enables the storage of a large amount of data on the very characteristics of business and production processes thanks to sensors, Internet of Things (IoT), Big Data, Claud Technology. I4.0 technology allows permanent storage of many data/characteristics of all relevant factors (such as temperature, vibration, pressure, but also downtime, bottlenecks, failures, etc.) that allow insight into the flow of production processes, operations, movements, materials, energy, human resources and all other available resources. By applying Data Analysis concept from a multitude of stored data (where there are good data, but also there are so-called messy data (unclear type different form, wrong entry, etc.) and some data that are unusable) using appropriate techniques cleans data and extracts good data for further analysis. Data analysis includes:

- descriptive analysis – what happened,
- predictive analysis – what should happen,
- prescriptive analysis – what we would like to happen.

Furthermore, different industrial engineering methods and techniques can be applied in factories depending on the goal of the company to be achieved. The application of these methods and techniques of industrial engineering enables the increase of business efficiency, maintenance, quality, management, etc. [1-4].

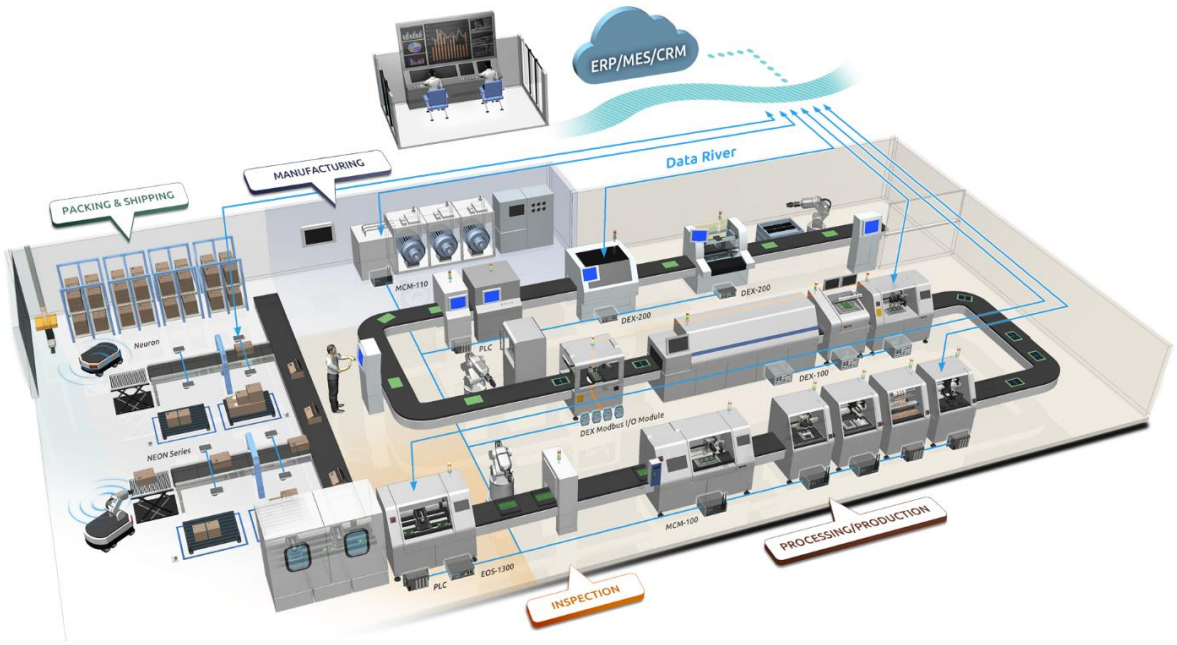

Fig. 1. Smart factory [5]

For example, in I4.0 environment, when there are the above data from the Cloud, it can be applied different methods of planning, scheduling, SWOT, TMP, SKK, BSC, failure structure, bottlenecks in the production process, methods of optimization of production processes [6]-7]. Decisions can be made based on data from the production process itself, and not after the end of the production cycle. It means that costs and production cycle times can be minimized. Until now, unit costs of production precisely because of the lack of information within the production process have always been unknown. Also, Lean production can be adequately applied according to Toyota's concept, in which the consumption of all production resources is reduced to a minimum while maintaining product quality, exactly on time (JiT concept) and with minimal wastes [8-11]. That is, everything that is set as target criteria for optimizing production processes, in environment I4.0 is enabled to be applied thanks to the concept that provides insight into the production process itself, as well as the ability to manage systems in such an environment.

The application of artificial intelligence (AI) in the I4.0 environment has several domains: the first segment refers to the application of AI over a large amount of data for the purpose of descriptive analysis [12-15]. For example, machine learning as a tool for observing patterns of behavior and for predicting behavior in further work. Then, AI is used in the process of making decisions about further activities, planning, forecasting, strategy development, implemented in knowledge support systems based on knowledge, expert systems, artificial neural networks and the like. AI is also used to design algorithms for the operation of systems in IoT environment in order to express their synchronized effect.

The next aspect that should be mentioned is that the employee is freed from repetitive tasks, then tasks that represent a risky job, hazardous substances, etc. which improves the position of the employee in the I4.0 environment because it reduces the risk and possibility of injury at work, and on the other hand, employees are more engaged in creative and innovative work.

Also, collaboration in stable, reliable supply chains, based on long-term partnerships are not sustainable in the circumstances of today's global economy, so, concept of remote engineering proposed in [16] could be used in aim to enhance competitive advantages and provides a fast, economical and experience sharing method for the enterprises. Industrial engineering methods are usable to overcome issues in available, common conceptions of how to measure usability [17].

It is also necessary to mention augmented reality (AR) and virtual reality (VR) as tools that allow employees to perform their work tasks. AR and VR have a large share in the design of new products, design, marketing, etc. AR enables employees to perform complex business operation more easily, it enables great diversification of the production program, adjustment of products according to the

customer's wishes. It describes systems that superimpose computer-generated information that can be multisensory, in reality seeking to improve the real environment rather that replace it [17]. VR is a computer interface that allows the user to be a part of an experimental simulation and is successfully applied in many branches of the manufacturing industry [18].
Methods and techniques of industrial engineering of production processes applied in I4.0 in order to achieve greater business efficiency can be applied through:

- logical functions,
- production rules, network rules,
- decision tree,
- knowledge base,
- conditional formatting,
- statistical analysis, correlation, regression, factor analysis,
- multi-criteria decision making, etc.

For example, data stored in the cloud can be used for FMEA analysis (Failure Mode and Effects Analysis). FMEA analysis can be generated in the form of SQL queries, and plans and action measures for risk mitigation in the form of a knowledge base. In this way, by applying the generated module for FMEA analysis in I4.0, we are enabled online monitoring of failures and preventive maintenance of machinery, thus reducing maintenance cost and increasing the efficiency of the machinery maintenance process.

Table 1. Example SQL query for FMEA analysis

Database_Failures					
IDfailure	IDcategory	Name	Date	Time in fault	Severity

Database_knowledge		
IDcategory	Name	Corrective action

1:1

```
SELECT *
FROM Database_failures
LEFT JOIN Database_knowledge ON
Database_failures.IDcategory=Database_knowledge.IDcategory
ORDER BY Database_failures.IDfailure
```

```
SELECT
Database_failures.IDfailure,
Database_failures.IDcategory,
COUNT(database_failures.IDfailure) AS Failure_Frequency,
Database_failures.Failure_Frequency * Database_failures.Failure_Frequency.Severity AS RNP
FROM Database_failures
LEFT JOIN Database_knowledge ON
Database_failures.IDcategory=Database_knowledge.IDcategory
GROUP BY database_failure.IDCategory
ORDER BY RNP DESC
```

Above query gives as calculation of Risk Priority Number for determination order of application corrective measures for maintenance of observed machine.
I4.0 also characterizes the introduction of cyber-physical systems that are reflected in the use of smart devices (sensors, actuators). A smart device is a machine with the properties of a computer. One of its main features is the ability to communicate with other smart devices in the environment (data transmission) and perform smart operations.

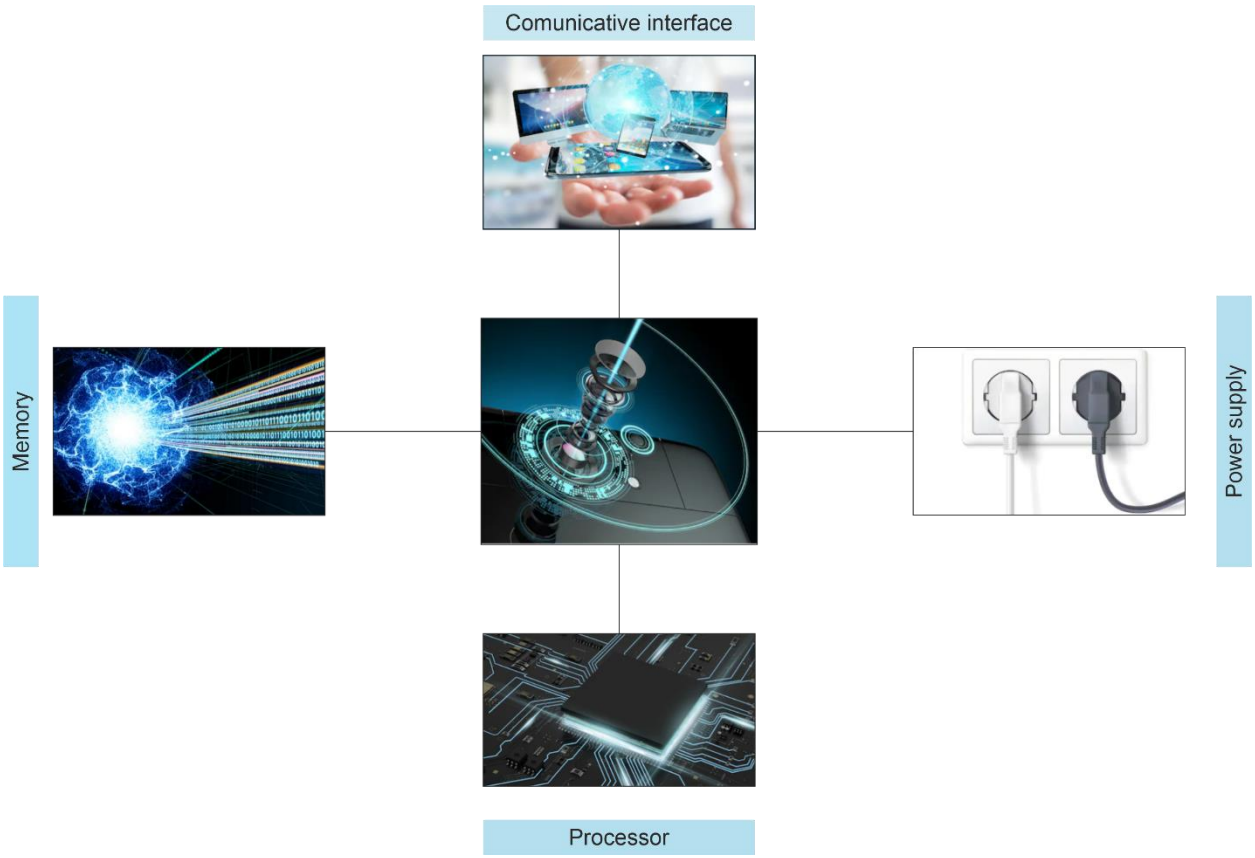

Fig. 3. Smart sensor

One smart device must have a power supply, memory, processor and communication interface. What needs to be satisfied from the aspect of business production industry are, first of all, low prices and low energy (Machine to Machine – M2M) of these devices. Figure 3 shows smart sensor, and Figure 4 shows smart actuator.

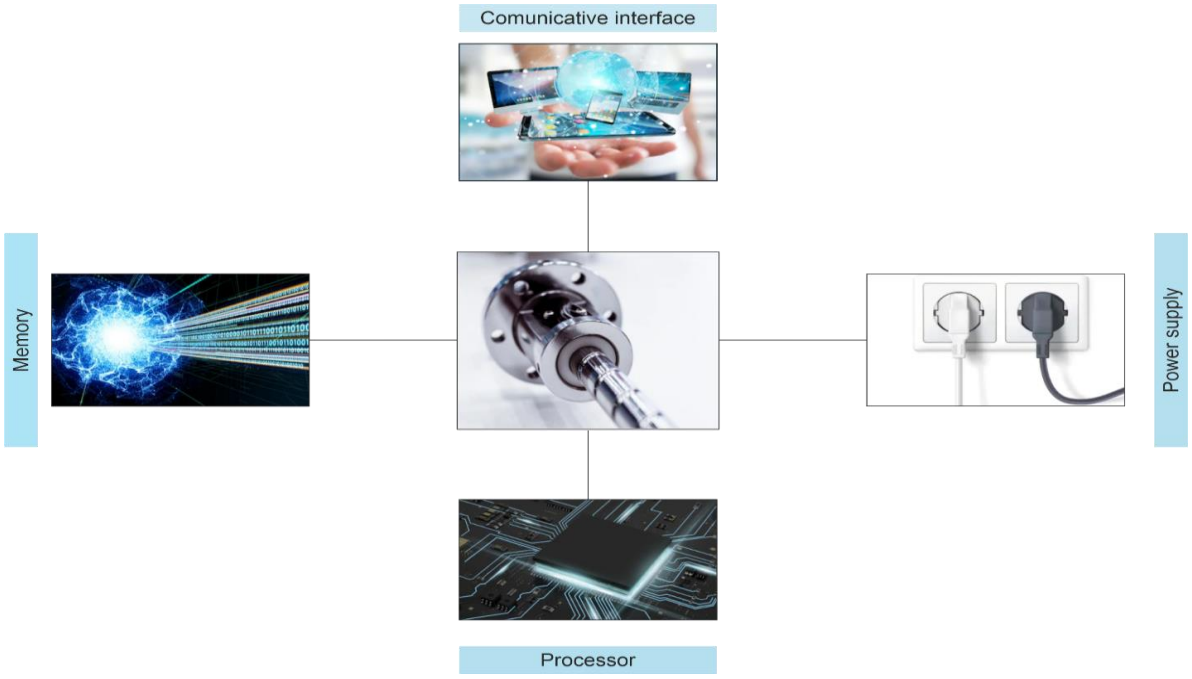

Fig. 4. Smart actuator

Presented model of integration of industrial engineering methods and techniques enables online monitoring of production process influence factors, and also enables increasing productivity and efficiency of the business production systems. Also, according to our previous results employees' behavior has to be in accordance with technological level – as in [18] upgrading of technological levels forces employment of proactive people with soft culture.

CONCLUSION

In a new business environment dominated by smart machines, the applied method and technique of industrial engineering can point to the internal potentials of manufacturing companies. Methods and techniques of industrial engineering are aimed at optimizing production processes, better utilization of available resources, reducing downtime and waste, more efficient production management and increasing profitability. In Industry 4.0, these methods and techniques implemented come to full expression as networking and communication between cyber-physical systems is raised to a higher level.

Future researches should be focused on implementing of presented model of integration of industrial engineering methods and techniques in the industry. Also, the research can be focused on employees and their satisfaction by implementing I4.0 in production factories, then how the implementation of the presented model can affect on workplaces.

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