# PROCESS IMPROVEMENT TRENDS FOR MANUFACTURING SYSTEMS IN INDUSTRY 4.0

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**ABSTRACT**: Manufacturing system's process improvement plays a relevant role in the competitiveness of companies. Industry 4.0 creates some new possibilities for the manufacturing companies with the appearance of cyber-physical systems, the big data concept and spread of the "Internet of Things" (IoT). This paper gives a detailed review of the fourth industrial revolutions' most important achievements and tools. Furthermore, the most important process improvement trends of manufacturing systems are also outlined for Industry 4.0.

**KEY WORDS**: Industry 4.0, process improvement, manufacturing

## 1 INTRODUCTION

Customer needs can be only satisfied with creation of appropriate manufacturing technologies and logistics processes (Bohács et al., 2013; Tamás, 2016). The realisation of process improvement becomes necessary for both areas in the interest of maintaining or increasing competitiveness. Nowadays the improvement of up-to-date manufacturing technologies (Shukla & Lawrence, 2010; Markopoulos & Kundrak, 2016) (turning, grinding, etc.) has less improvement potential than the improvement of the logistic systems. This is the result of the emergence of Industry 4.0, which has created some new possibilities (Internet of Things (IoT), cyber- physical systems, big data, etc.) in the formation and improvement of manufacturing logistics systems (Ashton, 2009; Mayer et al., 2013).

In the past continuous production was widely applied, but recently intermittent manufacturing has come to the fore because of the continually changing customer needs. In our opinion, those companies will be competitive in the future that are able to satisfy the unique customer needs before the order deadline and at lower cost than their competitors.

The reconsideration of process developmental methods has become necessary because of increase in the complexity of the processes, such as joint application of the value stream mapping method and simulation modelling techniques (Mahfouz & Arisha, 2013).

New efficiency improvement possibilities have become available using the devices of Industry 4.0 and lean philosophy. Here we introduce the essence of the lean philosophy, briefly review the history of Industry 4.0 and its more important devices, and finally outline the most important process improvement trends for manufacturing systems.

## 2 LEAN PHILOSOPHY IN MANUFACTURING

There are some definitions in connection with the lean philosophy's explanation. In our opinion the essence of this philosophy was best expressed by Taichi Ohno. He said that the essence is the lead time's reduction between the ordering and the money receipt with the elimination of the waste (Womack & Jones, 2008).

Basically, the philosophy has two principles namely the reduction of the wastes and respect for human (Rother & Shook, 2003). Lean philosophy starting from the TPS (Toyota Production System) has developed into a well-defined device and rule system, which is usable for reduction of logistics waste in both production and service fields. The lean concept basically separates the 3 MUs, namely fluctuation (Mura), the overload (Muri) and the 8 essential types of waste (Muda) (Rother & Shook, 2003). We can state that Muri and Mura can result in Muda in all cases, and therefore much of literature speaks only about eliminating Muda. The 8 wastes are: overproduction, unnecessary inventory, unnecessary transport, unnecessary motion, unnecessary waiting, unnecessary defects, unnecessary over-processing and unused skills (Rother & Shook, 2003).

Numerous very important new solutions have appeared in connection with the lean philosophy in manufacturing areas:

- The kanban system,
- heijunka (production levelling),

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- jidoka,
- andon,
- Poka-Yoke,
- SMED,
- Kaizen,
- value stream mapping,
- 5S.

Formation of the workers' problem-solving ability is very important to create continuous improvement within the examined area. Toyota has been realising this with application of the improvement kata and the coaching kata (Rother, 2009).

The coaching kata's aim is teaching the improvement kata. The improvement kata is a routine for realisation of efficient process improvement. We can reach the aims of process improvement more easily with practice of the mentioned katas.

## 3 FORMATION OF THE INDUSTRIAL REVOLUTION

Basically, the industrial resolutions are related to social, economic and technological changes. The appropriate economic and social environment is necessary for the invention and spread of technologies. We can define the beginning of the first industrial revolution from the invention of the steam engine (1769, James Watt). Characteristics of the industrial revolutions are introduced in Table 1.

**Table 1. Industrial revolutions**

| | |
|---|---|
| Industrial revolution 1<br><br>Beginning: 1760s<br>Most important things:<br>- steam engine,<br>- mechanisation of textile plants,<br>- steamships,<br>- steam railway, etc. | Industrial revolution 2<br><br>Beginning: 1870s<br>Most important things:<br>electricity,<br>- oil industry,<br>- steel industry,<br>- invention of the internal combustion engine,<br>- mass production, etc. |
| Industrial revolution 3<br><br>Beginning: 1930s<br>Most important things:<br>- nuclear power,<br>- new technologies,<br>- CAD/CAM systems,<br>- CIM systems,<br>- processes, networks, etc. | Industrial revolution 4<br><br>Beginning: from today<br>Most important things:<br>- Internet of Things (IoT),<br>- Cyber-physical systems,<br>- logistics 4.0, manufacturing 4.0,<br>- hospital logistics 4.0., etc. |

## 4 MOST IMPORTANT DEVICES OF THE INDUSTRY 4.0

Nowadays Industry 4.0 has numerous elements of which the most important are the Internet of Things (IoT), cyber-physical systems and big data. These devices will transform the whole world, according to a number of experts (Mayer et al., 2013; Guban & Kasa, 2014). These will create new possibilities for the improvement of production and services processes. This section presents the most important terms which will be used in following sections.

Internet of Things (IoT): This term was first used in 1999 by Kevin Ashton (Ashton, 2009). The IoT enables the access of different equipment through the internet/networks, as well as in certain cases the communication between equipment. In recent decades people have recorded the majority of the data that we can find on the internet. In essence, this has significantly determined the available data's quantity. For more efficient improvement of logistics systems we need to collect more information about the systems' things (e.g. products, machines, material handling equipment, humans, etc.) with use of the IoT. On the basis of these data we can analyse more information about our system and we can optimise it more efficiently. For example, if we put some sensors on important parts of technological equipment that will send signals on the status of the parts, then we can get information before the failure of the technological equipment. This concept is very serious which is supported in the case of Figure 1.

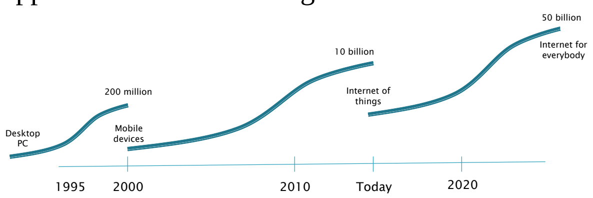


**Figure 1. Important trends and number of associated devices [11]**

The eNet company made an online research through the internet about what kinds of IoT solutions the population knows. These solutions are the following:

- smart alarm at home (we can get a message in the case of abnormality),
- smart car (the car can sense its environment and give a message or brake in case of emergency),
- smart reading device (we can get real time information about the status of the gas- or electric meter through a network, consequently the provider can work efficiently),

- smart home (we can control the equipment in our house from our mobile phone, e.g. heating, lighting),
- online cash register (communication between the National Tax and Customs Administrations and cash registers).

*Cyber-physical systems:* Development of informatics and automation, as well as their increasing cohesion, have enabled the application of cyber-physical systems (if an electronic device contains a control and network connection then we can call this system a cyber-physical system). Cyber-physical systems are able to collect data from their environment, and after analysing these data they are able to modify their positions. Cyber-physical systems are connected through a network, and their significant parts are also connected with each other; because of this we can apply swarm intelligence, which can result in more efficient work (Figure 2). In everyday life there are numerous areas where application of cyber-physical systems can lead to higher efficiency. These areas are the following:

- we can reduce the air resistance, consumption and the number of the accidents in the traffic by connecting the cars,
- we can reduce manufacturing waste by coupling the manufacturing system's elements,
- in the formation and actuation of supply chains.

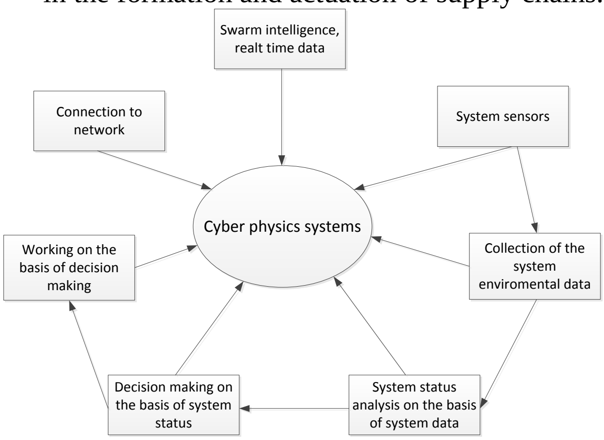


**Figure 2. Operational concept of the cyber-physical systems**

*Big Data concept:* The amount of data approximately doubles every two years (Mayer et al., 2013), which results in huge volume of data in the different areas of life (astronomy, logistics, trade, the stock exchange, etc.). We can create new services and useful conclusions with the elaboration of the data's correlation. An example of such a service is forecasting flight prices with software that is able to determine the estimated flight price on the basis of the previous period's data (in this case we don't need to know the process of the price determination) (Mayer et al., 2013; Golosova & Grigorieva, 2015). Big data's essence is determination of probabilities with mathematical methods and procedures. According to many experts, big data analysis will change significantly the future; with it we can make decisions on the basis of the huge amount of data without knowing the causes-effects.

The expressions which were explained in this chapter are related to each other. We cannot speak of cyber-physical systems and big data without IoT.

## 5 THE MOST IMPORTANT PROCESS IMPROVEMENT TRENDS FOR MANUFACTURING SYSTEMS

Basically the aim of Industry 4.0 is the realisation of the intermittent manufacturing with mass production's productivity and specific cost. If we would reach this aim then we can satisfy the unique customer needs quickly and efficiently. This seems to be unreachable but the most significant parts of the technologies are available nowadays. In order to reach this aim, three areas need to be improved:

- application of simulation modelling
- improvement of the value stream mapping method,
- elaboration of new intelligent logistics solutions.

### 5.1 Application of simulation modelling

The complexity of the processes grows continuously because of the increasing variation in product types, and consequently the importance of simulation also grows. If we would like to explain the essence of the simulation modelling then we can call it a method that enables the realistic modelling of processes and systems thus we can evaluate their behaviour (Cseleyi & Illes, 2006). Some objectives can be defined in connection with simulation modelling:

- elimination of planning failures at the complex logistics systems,
- optimal planning of the procurement, manufacturing and distribution logistics systems,
- comparison of planning variations,
- determination of the highest performances and boundary status,
- support of kaizen workshops,
- comparison of the system control variations,
- modelling of system failures and their elimination.

There are several simulation frameworks (for example: Plant Simulation, Arena and Simul8) on the market that are able to significantly simplify the system investigational process. The steps of a simulation-based investigation are (Tamas & Illes, 2015):

- Determination of the simulation's aim, defining the examined logistics system's boundary**:** we have to determine clearly the investigational aims before making the simulation program and after that we can assign the logistics area to be examined.
- Understanding the working of the examined system: investigators have to understand the material flow properties and working principles of the assigned logistics system in order to take into consideration the most important things when creating the simulation model.
- Determination of the logistics indicators' set: In this phase we have to determine the set of logistics indicators that will enable the comparison and evaluation of the investigational results (operational workstations' utilisation, lead time, etc.).
- Determination of the input and output data: the input and output data of the simulation model must be defined in order to determine the final data request to the investigated enterprise. The requested data are not available in every case, so we have to decide whether we will create these data with estimations or field measurements.
- Creation of the simulation model: the simulation model is created on the basis of the available information. After this we can examine the working of the modelled logistics systems with the use of the given input data.
- Control and repair of the simulation model: we have to calibrate the investigational model together with enterprise professionals (for example: with comparison of the current status' logistics indicators and/or with control of the modelled material flow). Numerous cases can occur when we have to modify the created model for better accuracy.
- Evaluation of the investigational results, elaboration of the proposals: using the calibrated model we can determine the working characteristics of the examined logistics by changing selected parameters. With the analysis of the given data we can elaborate proposals for the examined enterprise. In many cases the task is the optimal determination of several parameters, so we need to use optimisation algorithms.

We can clearly state that simulation modelling plays a relevant role in the increase in the efficiency of process improvement.

## 5.2 Improvement of the Value Stream Mapping Method

The value stream mapping method was created from Toyota's material and information flow diagram. Firstly this was published in "Learning to see" in 1999 by Rother & Shook (Womack & Jones, 2008; Rother & Shook, 2003). This method's relevant aim is the reduction of waste by improvement of the logistics processes. The value stream mapping method has so far been used for improvement of one product line's logistics processes. The basic method cannot be used with appropriate efficiency in the case of complex logistics systems (Tamas, 2016). We can distinguish two types of value stream mapping: the static and the dynamic mapping methods. Static value stream mapping can be used effectively for the examination of one product line's processes, while the other method can be used effectively for the examination of complex logistics systems (Solding & Gullander, 2009; Kost'al & Velisek, 2011).

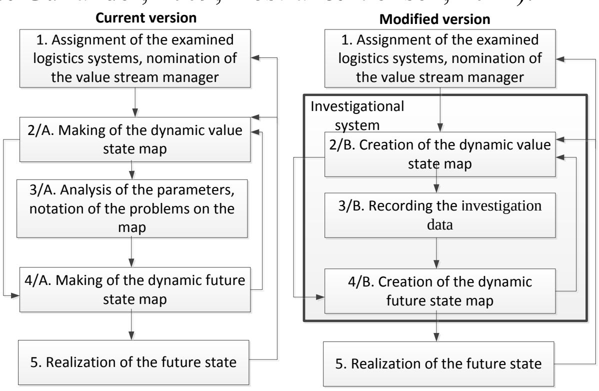


**Figure 3. Steps of the dynamic value stream mapping**

The dynamic value stream mapping method has become prominent because of the increasing complexity of the processes. This method's steps were clearly determined but process improvement modes and measurements are only realised on the basis of trial and error, prediction and experience (we examine the possibilities through an simulation model). In our opinion there is significant potential for elaboration of an examination system that is able to create best system version on the basis of the predefined data structures, goal functions and optimisation algorithms. Current and modified versions of dynamic value stream mapping are introduced in Figure 3. Application is done according to the following steps:

1. Assignment of the examined logistics systems, nomination of the values stream manager: firstly we have to determine the product lines. After that we have to assign the value stream managers to the product lines. The value stream manager is

responsible for the improvement of the product line value stream (Rother & Shook, 2003).

2/a. Making the dynamic value stream map: the value stream managers have to know the material- and information flow of their product lines and have to collect the data for the current state map (Rother & Shook, 2003). After this activity the experts have to make a dynamic value stream map with a simulation framework.

2/b. Creation of the dynamic value stream map: this step differs from Step 2/A in that the collected data has to be recorded in a predefined data structure; the simulation investigational model is then created by a simulation framework. We have to elaborate the different data structures, algorithms, and the necessary adaptation for a selected simulation framework regarding the manufacturing systems.

3/a. Analysis of the parameters, nomination of the problems on the map: we can analyse the effects of the logistics parameters' modification on the examined logistics system by the dynamic value stream map (for example: effects of the changeover time's reduction for the work in process and the lead time, effects of equipment failure for the production plan, etc.). We can determine the main problems on the dynamic value stream map regarding the assigned logistics system's material- and information flow by this parameter analysis [9].

3/b. Recording the investigation data: this step differs from Step 3/A in that we have to give the process improvement's data, conditions and goal functions in a predefined data structure. We have to work out a data model structure that is adequate for recording the analysis possibilities, conditions and the goal function data. Of course we have to carry out the adaptation of this data structure.

4/a. Making the dynamic future state map: we have to create the future state map without a determined problem.

4/b. Creation of the dynamic future state map: The dynamic future state map is automatically created on the basis of the investigational data, taking into consideration the investigational aims. We have to elaborate to this an algorithm that is able to generate the system variations for selection of the best variation.

5. Realisation of the future state: firstly we have to mark the value stream map loops on the future state map (pacemaker loop, additional loop). After that we have to create a task list regarding each loop.

After we have made the task list then we have to make a yearly value stream plan with the following contents:

- scheduling realisation of the assigned tasks,
- naming those responsible for the implementation,
- listing target indicators to be reached,
- monitoring the implementation.

The next step is the realisation and its monitoring (Rother & Shook, 2003). The value stream mapping contains basically five sequential steps where feedback can occur between the steps in the following cases:

- if the current state map does not contain the information that will be necessary for the future state map,
- if the future state was realised, then we can execute a new examination from the second step.

The current and the modified versions differ from each other in the following ways:

- the modified version is easier to use because we can use an elaborated data structure and algorithms (the current version determines only the investigational frames),
- the modified version requires less lead time, because the examination' steps were determined exactly,
- determination of the future state map is carried out with more efficiency because in this case a simulation optimisation algorithm will chose the best future state map, instead of trial and error and/or experience.

If the modified concept can be realised then we can achieve faster and more cost efficient process improvement than previously. This method can significantly increase the user companies' competitiveness.

### 5.3 Elaboration of New Intelligent Logistics Solutions

In our explanation intelligent logistics solutions are those using devices / (part) systems which are able to respond to changes of the external environment (with transmission of automatic information, control of their own operation) (Illes et al., 2013; Guban & Kasa, 2014). It can be possible to achieve more significant waste reduction with application and improvement of these solutions. Waste reduction will be obtained because of the reduction of the lead time of the tasks to be realised and the increase of optimised collaboration between the system objects (source and drain objects, material handling equipment, staff, etc.). The optimised collaboration will result in more efficient human and machine resource utilisation. The most important logistics solutions in the production area are the following:

- Intelligent identification devices (this device will send a message triggered by the external environment's disadvantageous changes, e.g. if the temperature or humidity drops under a pre-defined value).
- Intelligent technological equipment (automated manufacturing on the basis of the identifying devices' data, failure forecast with use of the sensors, etc.).
- Intelligent quality control (e.g. the machine will perform quality control on the basis of the RFID chip's data from the RFID chip that can be found on the product).
- Intelligent material handling equipment (e.g. automated working on the basis of the environmental data).
- Intelligent warehouse (automated ordering on the basis of stock reduction with use of sensors).
- Intelligent logistics systems (e.g. total or partial automated logistics systems with application of device system of Industry 4.0, which is based on human–machine and/or machine–machine communication).

Industry 4.0 will have a major effect on the formation and actuation of manufacturing systems. According to forecasts, the following changes are possibilities:

- Communication between different devices (technological equipment, material handling equipment, parts, unit loads, etc.) and the central unit, or between the devices themselves; because of this central control will be changed to decentralised central control in the future.
- Complex decision making will be changed to real time decision making with use of simulation tools.
- Narrowly planned production systems will be changed to production systems that are based on modularisation. This can be possible because of the increase in the flexibility of the technological equipment (e.g. the spread of 3D printing).
- Passive parts will be changed to intelligent parts that will be able to influence their environment with the use of pre-programmed information.
- Optimisation of larger systems by using data from devices with a network connection. The optimised creation and actuation of a company's total supply chain will become possible.
- New business models will be created with the processing of huge amounts of collected data from the logistics systems (e.g. we will forecast equipment failure or human disease through analysis of the previous period's data; consequently, the production downtime will be reduced).

## 6 SUMMARY

A very important area was introduced in this paper, namely process improvement trends for manufacturing systems in Industry 4.0. The aim of Industry 4.0 is the realisation of intermittent manufacturing with the productivity and specific cost of mass production. We can only reach this aim if we improve our process continuously. The appearance of the IoT, ,cyber-physical systems and big data have created some new possibilities regarding more efficient actuation and continuous improvement of the manufacturing systems that are presented in paper.

In our opinion the communication between devices, information derived from product tracking, and the possibilities in network collaboration will provide more widespread process improvement for manufacturing companies.

## 7 ACKNOWLEDGEMENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 691942.

The described article was carried out as part of the EFOP-3.6.1-16-00011 "Younger and Renewing University – Innovative Knowledge City – institutional development of the University of Miskolc aiming at intelligent specialisation" project implemented in the framework of the Széchenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

## 8 REFERENCES

►Bohács G., Frikker I., Kovács G. (2013). *Intermodal logistics processes supported by electronic freight and warehouse exchanges Transport and Telecommunication*, 14:(3) pp 206-213

►Tamás P. (2016). *Application of value stream mapping at flexible manufacturing systems* Key Engineering Materials 686, pp. 168-173 doi:10.4028/www.scientific.net/KEM.686.168

►Shukla P., Lawrence J. (2010). *Mathematical modelling of the fibre laser surface processing of a zirconia engineering ceramic by means of three-*

*dimensional finite-element analysis*, Proc. IMechE 225 doi: 10.13140/RG.2.1.2769.9923.

► Markopoulos A.P., Kundrak J. (2016). *FEM/AI Models for the Simulation of Precision Grinding*, Manufacturing Technology, Vol. 16(2), pp. 384-390

►Ashton K. (2009). *That 'Internet of Things' Thing, in the real world things matter more than ideas,* RFID Journal, avalaible at http://www.rfidjournal.com/articles/pdf?4986.

►Mayer V., Kenneth Cukier S. (2013). *Big Data, A revolution that will transform how we live, work, and think*, ISBN 978-0-544-00269-2.

►Mahfouz A., Arisha A. (2013). *Lean distribution assessment using an integrated framework of value stream mapping and simulation,* Proceedings of the 43rd Winter Simulation Conference, IEEE Computer Society pp 3440–3449.

►Womack J.P., Jones D.T. (2008). *Lean thinking*, Simon & Schuster Inc. ISBN 978-963-9686-83-0.

►Rother M., Shook J. (2003). *Learning to See: Value Stream Mapping to Add Value and Eliminate Muda*, Lean Enterprise Institute ISBN 0966784308.

►Rother M. (2009). *Toyota Kata - Managing People for Improvement, Adaptiveness and Superior Results*, ISBN 978-0-0-7163985-9.

►Golosova M.V., Grigorieva M.A., Klimentov A. A., Ryabinkin E.A., Dimitrov G., Potekhin M. (2015). *Studies of Big Data metadata segmentation between relational and non-relational databases,* Journal of Physics: IOP Conference Series Volume 664 doi:10.1088/1742-6596/664/4/042023

►Solding P., Gullander P. (2009). *Concepts for simulation based value stream mapping*, Proceedings of the 2009 Winter Simulation Conference pp 2231-2237.

►Košťál P., Velíšek K. (2011). *Flexible manufacturing system In: World Academy of Science*, Engineering and Technology 77 ISSN 2010-376X. pp 825-829.

►Illés B., Trohák A. and Bíró Z. (2013). *Can message filter algorithms for remote diagnostics of vehicles* Applied Mechanics and Materials 309 pp 213-220.

►Gubán A., Kása R. (2014). *Conceptualization of fluid flows of logistificated processes*, Advanced Logistic Systems 7 pp 27-24.

►Cselényi J., Illés B. (2006). *Planning and controlling of material flow systems.* Textbook, Miskolci Egyetemi Kiadó.

►Tamás P., Illés B. (2015). *Simulation examination of logistics systems in the automotive industry,* Journal of Production Engineering 18:(2) pp. 69-72.