Waste reduction possibilities for manufacturing systems in the industry 4.0

P Tamás, B Illés and P Dobos
Institute of Logistics, University of Miskolc, Hungary
E-mail: alttpeti@gmail.com

Abstract. The industry 4.0 creates some new possibilities for the manufacturing companies’ waste reduction for example by appearance of the cyber physical systems and the big data concept and spreading the „Internet of things (IoT)‟. This paper presents in details the fourth industrial revolutions’ more important achievements and tools. In addition there will be also numerous new research directions in connection with the waste reduction possibilities of the manufacturing systems outlined.

1. Introduction
The customer needs can be only satisfied with creation of the appropriate manufacturing technologies and logistics processes [1, 2]. The realization of the process improvement becomes necessary for the both areas in the interest of the competitiveness’ observing and/or increase. Nowadays the improvement of the up to date manufacturing technologies [3, 4] (turning, injection moulding, …, etc.) has less improvement potential than the improvement of the logistic systems. This is the result of the industry 4.0 which was created some new possibilities (Internet of Things (IoT), cyber physics systems, big data, …, etc.) in the formation, improvement of the manufacturing logistics systems [5, 6].

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

The process developmental methods’ reconsideration has become necessary because of increase the processes’ complexity, such as joint application of the value stream mapping’s method and the simulation modeling techniques [7]. The new efficiency improvement possibilities have become available with using the devices of the industry 4.0 and lean philosophy. In this essay are introduced the essence of the lean philosophy, history of the industry 4.0 and its more important devices and finally there is outlined the research and waste reduction possibilities.

2. Lean philosophy in the manufacturing
There are some definitions in connection with the lean philosophy’s explanation. In our opinion the essence of this philosophy was the 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 wastes [8].

Basically the philosophy has two principles namely the reduction of the wastes and respect for human [9]. In the last period the lean philosophy starting from the TPS has developed into a well-
defined device and rule system, which is usable for both production and services fields’ reduction of logistics wastes. The lean basically distinguishes the 3 MUs, namely the fluctuation (Mura), the overload (Muri) and the 8 essential wastes (Muda) [9]. We can state that the muri and the muda can result in all cases muda, therefore a lot of literature speaks only from the muda’s elimination. The 8 wastes are the followings: overproduction, unnecessary inventory, -transport, -motion, -waiting, -defects, -over-processing, not used skills [9].

There are appeared numerous very important new solutions in connection with the lean philosophy at the manufacturing areas, which are the followings:

- kanban system,
- heijunka (production leveling),
- jidoka,
- andon,
- Poka-Yoke,
- SMED,
- Kaizen,
- 5S.

Formation the workers’ problem solving ability is very important to create the continuous improvement inside the examined area. The Toyota has been realizing this with application the improvement- and the coaching Kata [10].

The coaching kata’s aim is teaching the improvement kata. The improvement kata is a routine for realization of the efficient process improvement. We can reach easier the aims of the process improvement with practice of the mentioned katas.

| Table 1. Industrial revolutions |
|--------------------------------|
| **Industrial revolution 1**    |
| Beginning: from the 18th century’s sixties |
| More important things:         |
| - steam-engine,                |
| - mechanization of the textile plants, |
| - steamships, steam railway, ..., etc. |
| **Industrial revolution 2**    |
| Beginning: from the 19th century’s seventies |
| More important things:         |
| - electricity,                 |
| - oil industry,                |
| - steel industry,              |
| - technological equipments’ manufacturing (lathe, drill, miller, ..., etv.), |
| - invention of the internal combustion engines, |
| - formation of the service industry, |
| - mass production.             |
| **Industrial revolution 3**    |
| Beginning: from the 20th century’s thirties |
| More important things:         |
| - nuclear power,               |
| - new technologies,            |
| - CAD/CAM systems,             |
| - CIM systems,                 |
| - processes, networks,         |
| - closed material flow systems. |
| **Industrial revolution 4**    |
| Beginning: from today           |
| More important things:         |
| - Internet of Things (IoT),    |
| - cyber physics systems,        |
| - industry 4.0,                |
| - logistics 4.0,               |
| - manufacturing 4.0,           |
| - lean 4.0,                    |
| - hospital logistics 4.0, ..., etc. |
3. Formation of the industrial revolution

Basically the industrial resolutions are related to changing the social, economic and technological. It can be told that the appropriate economic and social environment is necessary in the interest of the technologies’ invention and spread. We can define the beginning of the first industrial revolution from the invention of the steam-engine (1769, James Watt). The industrial revolutions’ characteristics are introduced with table 1.

4. More important devices of the industry 4.0

Nowadays the industry 4.0 has numerous devices from which the more important are the Internet of Things (IoT), cyber physics systems and the big data. These devices will transform the whole world according to a lot of experts [6, 15]. These will create new possibilities for the improvement of the production and services processes. This chapter’s aim the presentation of the more important terms which will be used in the next chapters.

- **Internet of things (IoT):** Firstly this term was used in 1999 by Kevin Ashton [5]. The IoT enables the access of the different equipment through internet/some networks, as well as in certain cases the communication between these equipment. In the last decades the peoples were recorded the majority of the data what we can find on the internet. In essence this was significantly determined the available data’s quantity. In the interest of the realized logistics systems’ more efficient improvement 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 analyze more information about our system and we can optimize more efficient as before. For example if we put some sensors on a technological equipment’s more important parts which will send signals from the status of the parts, then we can get information before the failure of the technological equipment. The eNet company made an online research through the internet about that what kinds of IoT solutions do the population know. These solutions are the followings:
  - 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 push a brake in the case of emergency),
  - smart reading device (we can get real time information about the status of the gas- or the 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, …, etc.),
  - online cash register (communication between the National Tax and Customs Administrations and cash registers).

- **Cyber physics systems:** Development of the informatics and automation, as well as the increase of the cohesion enabled the application of the cyber physics systems (if an electronic device contains a control and network connection then we can call this system as cyber physics system). The cyber physics systems are able to collect data from their environment, as well as after analyzing of these data they are able to modify their positions. The cyber physics systems are connected through network, their significant part are also connected with each other because of this we can apply the swarm intelligence, which can result more efficient work. In the practical life there are numerous areas where application of the cyber physics systems can result the increase of the efficiency. These areas are the followings:
  - we can reduce the air resistance, consumption and the number of the accidents in the traffic with the coupling of the cars,
  - we can reduce the manufacturing wastes with coupling the manufacturing system’s elements,
  - at the formation and actuation of the supply chains.

- **Big Data concept:** The data amount in the world is approximately doubled in every two years [6], which result a huge amounts of data in the different areas of the life (astronomy, logistics, trade, stock exchange, …, etc.). We can create new services and useful conclusions with the elaboration of the
data’s correlation. Such service can be e.g. forecast for the flight prices’ with a software, which is able to determine the estimated flight price on the basis of the previous period’s data (in this cases we don’t need to know the process of the price determination) [6, 11]. The big data’s essence is determination of the probabilities with mathematical methods and procedures. In according to a lot of experts the big data will change significantly the future, because of that we can make decisions on the basis of the huge amount of the data without know of the causes-effects.

The expressions which were explained in this chapter are related to each other. We can’t speak from cyber physics systems and big data without IoT.

5. More important research directions in the manufacturing systems’ process improvement

Basically the aim of the industry 4.0 is the realization of the intermittend 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 looks like unreachable but the significant part of the technologies are available nowadays. In the interest of this aim’s reach there is needed development of two logistics areas. These are:

- improvement of the value stream mapping’s method,
- elaboration of new intelligent logistics solutions.

5.1. Improvement of the Value Stream Mapping’s Method

The value stream mapping’s method was created with use of the Toyota’s material and information flow diagram. Firstly this was published in the “Learning to see” in 1999 by Mike Rother & John Shook [8, 9]. This method’s relevant aim is the reduction of the wastes with improvement of the logistics processes. The value stream mapping’s method has been simultaneously used for improvement of one product line’s logistics processes so far.

![Figure 1. Steps of the dynamic value stream mapping](image)

The basic method can’t be used with appropriate efficiency in the case of complex logistics systems [2]. We can distinguish the value stream mapping’s two types that are the static and the dynamic value stream mapping’s method. The static value stream mapping can be used effectively at examination of one product line’s processes. The other method can be used effectively at examination of complex logistics systems [12, 13]. The dynamic value stream mapping’s method come to the front because of the increasing complexity of the processes. This method’s steps was clearly determined but the process improvement’s mode and measure is only realized on the basis of trial and error,
anticipation, experience (we examine the possibilities through a simulation model). In our opinion there is a significant potential in elaboration of an examination system, which is able to the creation of the best system version on the basis of the predefined data structures, goal functions and optimization algorithms. The dynamic value stream mapping’s current and modified versions are introduced on the figure 1. Application of the dynamic value stream mapping is realized according to the next 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 lines’ value stream [9].

2/A. Making of the dynamic value stream map: The value stream managers have to know their product lines’ material- and information flow and have to collect the data for the current state map [9]. 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 differ from the step 2/A therein that the collected data we have to record in a predefined data structure and on the basis of this data are created the simulation investigational model 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 analyze the effects of the logistics parameters’ modification regarding 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 the equipments’ 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 steps differ from the step 3/A. therein that we have to give the process improvement’s data, conditions and goal functions in a predefined data structure. We have to elaborate this the data model’s structure to be applied which is adequate for recording of the analysis possibilities, conditions and the goal functions’ data. Of course we have to realize the adaptation of this data structure.

4/A. Making of the dynamic future state map: We have to create the future state map without the 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 with take into consideration the investigational aims. We have to elaborate to this an algorithm which is able to generation of the system variations and the selection of best variation.

5. Realization 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 every loop.

After we have made the task list then we have to make a yearly value stream plan with the following contents:
- scheduling the assigned tasks’ realization,
- responsible(s) for the implementation,
- to be reached target indicators,
- monitoring of the implementation.

The next step is the realization and its control [9]. The value stream mapping contains basically five sequential steps where feedback can occur between the steps in the next cases:
- if the current state map doesn’t contain such information that will be necessary to the future state map,
- if the future state was realized then we can execute a new examination from the second step.
The current and the modified versions differ from each other in the next ways:

- the modified version’s use is easier because in the case we can use elaborated data structure, algorithms (the current version determine only the investigational frames),
- the modified version’s use require less lead time, because the examination’ steps were determined exactly,
- determination of the future state map is realized with more efficiency because in this case a simulation optimization algorithm will chose the best future state map instead of our trial and error and/or experience.

We can state if we can realize the above concept then we can get a faster and more cost efficient process improvement method than in earlier. This method can increase significantly the user companies’ competitiveness.

5.2. Elaboration of New Intelligent Logistics Solutions

In our explanation the intelligent logistics solutions those devices/(part)systems which are able to respond to changes of the external environment (with transmission of automatic information, control of the own operation) [14, 15]. It can be possible the more significant waste reduction with application and improvement of these solutions. The wastes’ reduction will be realized because of the reduction of the lead time of the tasks to be realized, respectively the increase of the optimized collaboration between the systems objects (source and drain objects, material handling equipment, staff, …, etc.). The optimized collaboration will result more efficient human and machine resource utilization. The more important logistics solutions in the production area are the followings:

- Intelligent identification devices (this device will send a message from the external environment’s disadvantageous changes e. g. if the temperature or humidity will reduce under a defined value).
- Intelligent technological equipment (e. g. automated manufacturing on the basis of the identify devices’ data, failure forecast with use of the sensors, …, etc.).
- Intelligent quality control (e. g. the machine will realize the quality control on the basis of the RFID chip’s data which 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 the stock reduction with use of the sensors).
- Intelligent logistics systems (e. g. Total or partial automated logistics systems with application of device system of the industry 4.0 which is based on the human-machine and/or machine-machine communication).

The industry 4.0 will have a relevant effect on the formation and actuation of the manufacturing systems. According to the forecast the next changes are possibilities:

- There can be realized the communication between the different devices (technological equipment, material handling equipment, parts, unit loads, …, etc.) and the central unit, respectively between the devices because of these the central control will be changed to decentralized central control in the future.
- The complex decision making will be changed to real time decision making with use of the simulation.
- The narrowly planned production systems will be changed to such production systems which are based on modularization. This can be possible because of the increase the technological equipment’s flexibility (e. g. spread of the 3D printing).
- The passive parts will be changed to intelligent parts which will be able to influence their environmental with use of the preprogrammed information.
There will be possible larger systems’ optimization if we will use such devices’ data which have network connection. Actually there will be possible the optimized creation and actuation of a company’s total supply chain.

New business models will be created with the processing of the huge amounts of collected data from the logistics systems (e.g. we will forecast the equipment’s failure or the human’s disease on the based on analysis of the previous period’s data in the future consequently the production downtime will be reduced).

6. Summary
The industry 4.0 has been making a relevant changing at the manufacturing systems’ formation and actuation. The appearance of the IoT and the cyber physics systems, as well as the big data have created a significant research potential regarding the more efficient actuation and continuous improvement of the logistics systems. The communication between the devices, the information which are derive from the product’s tracking, as well as the possibilities in the network collaboration will provide a more widespread optimization possibilities for the manufacturing companies. This paper introduced in details the process of formation of the industry 4.0, as well as its current devices, possible improvement directions. In addition in this paper were also outlined the more relevant research possibilities in the case of the unit loads’ manufacturing process’ improvement/waste reduction.

Acknowledgment
“This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691942”. "This research was (partially) carried out in the framework of the Center of Excellence of Mechatronics and Logistics at the University of Miskolc."

References
[1] 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
[2] 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
[3] 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
[4] Felhő Cs, Kundrák J 2014 Investigation of the Topography of Machined Surfaces *Applied mechanics and materials* 693 pp. 412-417
[5] Ashton K 2009 That 'Internet of Things' Thing, in the real world things matter more than ideas *RFID Journal* (http://www.rfidjournal.com/articles/pdf?4986)
[6] 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
[7] 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
[8] Womack J P, Jones D T 2008 Lean thinking *Simon & Schuster Inc.* ISBN 978-963-9686-83-0
[9] Rother M, Shook J 2003 Learning to See: Value Stream Mapping to Add Value and Eliminate Muda, *Lean Enterprise Institute* ISBN 0966784308
[10] Rother M 2009 Toyota Kata - Managing People for Improvement, Adaptiveness and Superior Results, ISBN 978-0-0-7163985-9
[11] 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
[12] Solding P, Gullander P 2009 Concepts for simulation based value stream mapping, *Proceedings of the 2009 Winter Simulation Conference* pp 2231-2237

[13] Košťál P, Velišek K 2011 Flexible manufacturing system *In: World Academy of Science, Engineering and Technology* 77 ISSN 2010-376X. pp 825-829

[14] Illés B, Trohák A, Bíró Z 2013 Can message filter algorithms for remote diagnostics of vehicles *Applied mechanics and materials* 309 pp 213-220

[15] Gubán A, Kása R 2014 Conceptualization of fluid flows of logistificated processes, *Advanced logistic systems* 7 pp 27-24