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THE IMPACT OF INDUSTRY 4.0 ON THE PRINCIPLES OF LEAN MANUFACTURING

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Abstract: Methods and techniques used in industrial engineering have long been developing. Mostly they are related to the optimization of production processes. However, industrial engineering is increasingly moving into the non-productive sphere (design, service, consulting, coaching, service processes, strategic management, etc.). However, it is not a mechanical application of commonly used methods and techniques, but a sophisticated way of adapting to optimization requirements in non-production processes. Many of them lost their practical significance during their development respectively have been modified into forms that still have their justification. This article discusses the impact of Industry 4.0 on lean production that is part of industrial engineering methods.
Keywords: Industry 4.0, lean, waste, tools, comparison.

Introduction

The philosophy of a substantial part of industrial engineering methods is to eliminate waste and losses across the value chain, in a non-investment way. The goal is to ensure a sustainable and sustainable state of the business, process lean and high economic efficiency. Waste means all costs that are embedded in the product during its development, production and sales that are not covered by the proceeds. The most widespread waste includes surplus inventories, losses due to mistaken operations, waiting for various reasons, absence of the system, inadequate maintenance of machinery and equipment, unskilled workers, lack of professional competence, inelastic logistics, poor communication, etc. An overview of the basic 8 types of loss from waste is processed in table **Tab. 1**.

The beginnings of introducing lean manufacturing into serial production in the automotive industry may be dated to the post-World War II era, when Japanese manufacturers have been in a difficult position as compared to the Western ones due to lack of production resources, material, financial and working resources. The demand for Japanese cars on the Japanese market was not as large as that of the US in the US and the global market; rather it was the production of several variants in smaller quantities. The Toyota Production System/TPS are historically based on the Ford system, aimed at eliminating all types of losses in mass production of cars. The elimination of waste could be made with a great deal in the mass production easier. One of the pioneers of lean manufacturing in Japan was Toyota's Taiichi Ohno factory manager, who "updated" Ford's waste reduction system and created the Just in Time production system. The Toyota production system differs from Ford's lean production in two fundamental principles:

1. Focus on small quantities with parameters customized to customer requirements - customization compared to the mass production of one product,
2. Fast machine set-up when changing the production program according to customer requirements - custom production compared to production according to market forecasts.

Tab. 1 8 type of loss from waste [modified by 5,7,8,9]

Preparation of production	**Production**
1. Excessive documentation - drawings, product processes, preparations, tools. 2. Search - information, documents, undelivered data files, email. 3. Waiting - for information, material. 4. Unnecessary Relocation - Information, Documentation for Signatures, 5. Lengthy process of approval, control. 6. Unnecessary operations and additional work - poor processed directives, procedures, redundant information in the documentation, drawings, excess accounts, reports, duplication of the information flow. 7. Unnecessary movements - related to obtaining and clarifying information in other departments. 8. Correction and removal of errors, changes in documentation - inadequate control of production feedback.	1. Incorrect working procedure - surplus movements and activities of the operator, resp. machine, improper operation. 2. Unnecessary movements - unnecessary manipulation and transfer of material and things not adding value, searching for material, tools, documentation, and other information. 3. Overproduction - production in advance, resp. with a delay, production of a larger quantity than the need of the customer or the downstream process. 4. Losses on machines - dwell time (failures, planned and unplanned downtimes, alignment). 5. Waiting - material is waiting for processing, operator waiting for material - unused wait time. 6. Surplus stocks - inter-operational stocks, stocks of raw materials, auxiliary materials, finished products. 7. Correction of errors and deficiencies in quality. 8. Low motivation and support of workers in the production of proposals for improvement, low interest in decision making.
Logistics	**Administration**
1. Surplus stocks - raw materials, materials, spare parts, repairs and maintenance. 2. Overproduction - finished products of finished production 3. Waiting - for material, spare parts, information, transportation. 4. Surplus manipulation - overlaying, translating, shifting, incorrect organization of warehouses, material flows in production. 5. Searching - material, documentation, information. 6. Unnecessary actions and movements - in human work, manipulation, movement and storage. 7. Unnecessary activities - duplicate information, selection from IT systems, rewriting reports. 8. Damage to stored items - errors in ordering items, material in terms of quantity, time, location.	1. Excess - information, transactions, documents. 2. Waiting - for documents, transactions, creating queues in front of workstations, workstations, processing. 3. Excessive document shifts in connection with signatures, multilevel control, approval. 4. Incorrect process design - Incorrect organization of workplaces and material flows, shifts between remote workplaces, buildings. 5. Ineffective communication - complex procedures, unclear details, ignorance of procedures and IT systems. 6. Searching - information, documents, incorrect and missing data. 7. Errors and duplicities - repeated evidence, rewriting of data. 8. Untapped skills and talents of staff - insufficient motivation and support for improvement suggestions.

Originally, the introduction of lean manufacturing has eliminated waste from defective work, excess processes, waste of time, inefficient movement of materials and workers, surplus stocks and overproduction. At present, it covers the entire business value chain, from the initial life cycle through development, supply, and production to distribution. It is implemented as a philosophy; a multi-dimensional approach is achieved through "Lean toolbox", which synergistically creates an efficient and flexible high-quality system with minimal cost. The philosophy of lean manufacturing is the elimination of all activities that do not create value for the customer and are superfluous. Value for customer, respectively added

value for the customer means the physical transformation of the product and the information that is necessary for the production, production without product error, willingness to pay for the realization of all value-related product-related activities. It can be measured by an index of added value, which expresses the ratio, the period during which the value of the product is added to the total continuous production time. The aim is to achieve the maximum, it is index = 1, lower index values mean loss and waste. The essence of leanness in the context of industrial engineering can be understood as:

- the process orientation of all activities in the enterprise bringing measurable value to the resulting product,
- elimination of waste and losses while preserving the flexibility, speed and transparency of the production process,
- applications of methods and tools that are of a varied nature and are usable in all manufacturing and service sectors, i.e. industrial and administrative (manufacturing, logistics, development, administration, employees).

A typical process of lean manufacturing is processed in Fig. 1.

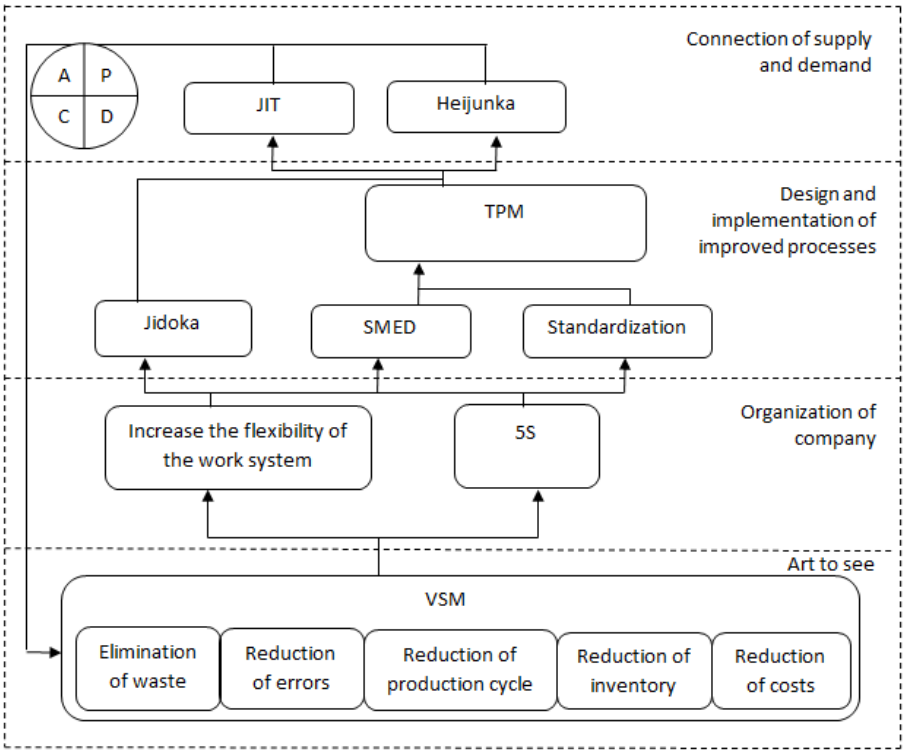

Fig. 1 Classic process of implementation of lean manufacturing [modified by 4, 14]

Lean production has become widely accepted in industrial practice in the 1980s and 1990s. It has become a very widespread approach to gaining high efficiency in enterprise production and logistics processes. In the manufacturing sector, a new paradigm of "Industrie 4.0" emerged in 2011, which enable the implementation of information and communication technologies to create an intelligent network throughout the value chain, smart factory/intelligent factory. The question arises, as these two approaches are related, how they can be interconnected. The comparison of Lean and Industry 4.0 is in Fig. 2.

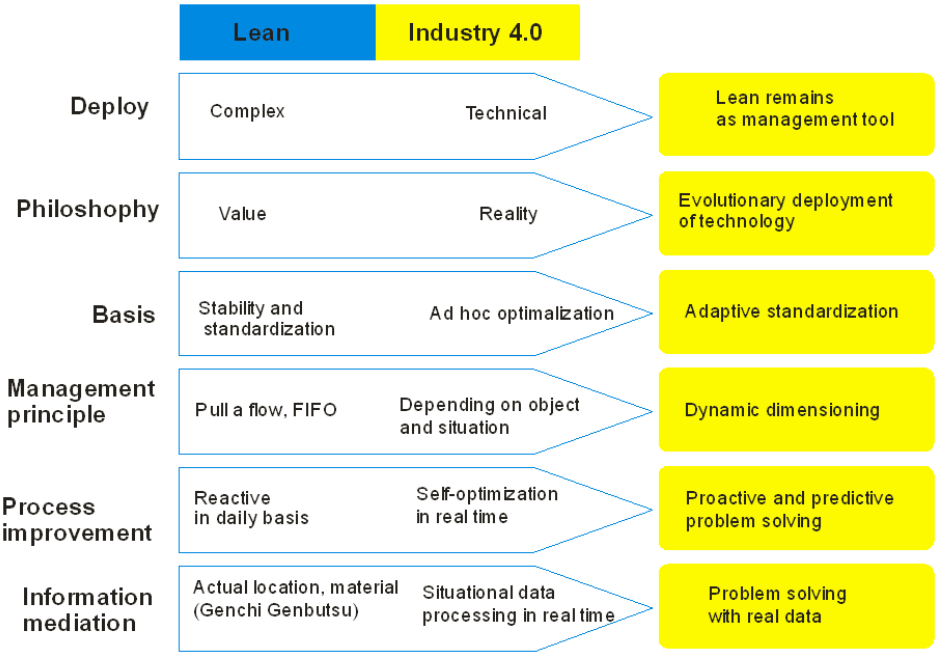

Fig. 2 Comparison of Lean a Industry 4.0 [modified by 17, 18]

Based on the research of 260 applications of Industry 4.0 tools in the German industry [15], an analysis of the interdependence of the lean manufacturing elements with Industry 4.0 was performed. This study has shown, that lean manufacturing is a great potential for successful and sustainable deployment of Industry 4.0 to industry. Industry 4.0 essentially improves the lean manufacturing system and moves it to a much higher level. From an analysis of literary sources dealing with Industry 4.0 vs. Lean production, cited in Source [15, 2017], showed four interdependencies of these principles: Lean production as the basis for Industry 4.0 (2/3 authors), Industry 4.0 as Lean production, Industry 4.0 as Lean production efficiency, Industry 4.0 as a change to the Lean production principles (in connection with the integration of specific tools and industry methods 4.0).

The impact of Industry 4.0 on companies using lean manufacturing principles is not adequately explored. A concept that combines the established principles, methods and tools of lean manufacturing with information and communication technologies from Industrie 4.0 is lacking. According to source [4, 2017], the first research was launched on successfully implemented projects in the automotive industry (24 workshops were a survey of workshops). The goal was to identify the Industry 4.0 framework for industry-leading sophisticated production systems. In the first phase, the main principles and methods were identified on the basis of lean manufacturing research. The second phase was focused on structure analysis and the identification of specific Industry 4.0 technologies. The outputs of these phases were processed into the Industry 4.0 impact matrix on Lean production systems, Tab. 2. The impact / synergy of Industry 4.0 with lean tools is + (+ / weak, ++ / higher, +++ / highest possible impact). Since research in this area is at the beginning, this matrix is to be understood as a dynamic framework that can be further supplemented by new knowledge.

Tab. 2 Matrix of impact Industry 4.0 on Lean Manufacturing [modified by 4, 14, 16]

Lean tools	DATA COLLECTION AND PROCESSING				COMMUNICATION MACHINE-MACHINE		INTERACTION MAN - MACHINE	
	Sensors and regulators	Cloud computing	Big data	Data analysis	Integration vertical	Integration horizontal	Virtual reality	Augmented reality
5S	+	+	+	+	+	+	++	+++
Kaizen	+	++	+++	+++	+++	+++	+++	+++
JIT	++	++	+++	+++	+++	++	+	++
Jidoka	+	+++	+++	+++	++	++	+	+
Heijunka	++	++	+++	+++	+++	++	++	+
Standardization	++	+++	+++	+++	++	++	+++	+++
Tact	+	+	+++	+++	+++	+++	+	+
Pull	++	+	+	+	+++	+++	+	+
man - machine	+	+	+	+	+	+	+++	+++
People and teamwork	+	+	+	+	+	+	+++	+++
Reducing of waste	+	+	++	+++	+++	+++	+	+

In Tab. 3 are processed influences Industry 4.0 and Lean tools, following seven kinds of losses in production.

Tab. 3 7 types of losses vs. Industry 4.0 and Lean Tools [modified by 4, 9, 14, 16]

Tools		7 types of losses in production													
Lean	**Industry 4.0**	**overproduction**		**transport**		**moves**		**waiting**		**inventory**		**unnecessary processes**		**mistake**	
Cell production	Sensors and regulators	+		+	+	+	+	+	+	+	+		+		
Reduction of set up	IoT	+	+					+	+	+	+	+		+	+
Quality control	Cloud computing						+		+	+			+	+	
TPM	Data analysis		+		+			+	+		+			+	+
Production balancing	3D printing		+					+	+	+	+		+		+
Kanban	Simulation and virtualization	+			+		+	+		+					+
Reduction of WIP	Robotics	+			+		+		+	+			+		+
Supply relationship	Augmented reality	+			+		+	+		+				+	+
Jidoka						+		+						+	
CIM						+		+				+		+	

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Conclusion

Based on the above, it is possible to state that the potential created by the introduction of the information and communication technology Industrie 4.0 is suitable for companies based on the principles of lean manufacturing. The industry tool 4.0 can be considered as a non-frontier exchange of information between any real-time value chain endpoints. This is possible

through digital and internet technologies. Industry 4.0 aims to increase competitiveness by speeding up vertical and horizontal integration of material, energy and information flows to deliver more value-creating processes, value-added for customers and new market opportunities through data strings.

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