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COMPARATIVE ANALYSIS OF PRODUCTION SYSTEMS IN THE AUTOMOTIVE INDUSTRY

Abstract

Purpose of the following text is to compare three production systems, which are especially popular in automotive industry: Toyota Production System, World Class Manufacturing and Nissan Production Way. For it purpose, a comparative study was carried out based on three categories: system, design, popularity and versatility. For each of the comparison categories, a method was adjusted. System design: comparison of assumptions and system construction schemes according to the authors of a given solution. Popularity: analysis of search engine results from Google, Google Scholar, Bing and Yahoo! obtained from searches for the phrases *Toyota Production System, World Class Manufacturing* and *Nissan Production Way*. Versality: case studies of system implementations by other organisations than authoring automotive corporations.

As a result of the comparison, it can be seen that the most complex and elaborate system is WCM, which has a multi-element structure as well as predetermined levels of sophistication. Relatively the simplest of the compared solutions turned out to be NPW. In the case of popularity, the leader is TPS in Google's search engines, WCM in Bing and Yahoo!, while the least popular solution in the Internet's space is the system by Nissan Motor Corporation. The versatility category indicates that the TPS and WCM systems have similar implementation capabilities, while NPW turns out to be a specific and exclusive solution for the Renault-Nissan-Mitsubishi Alliance and has no external implementations.

The results provide an overall picture of the situation regarding production systems in the automotive industry and can provide a starting point for more advanced analysis of existing solutions and allow the design of other systems. The production solutions presented are sophisticated and advanced systems with an extensive range of possible uses.

Keywords: *production system, WCM, TPS, World Class Manufacturing, Toyota Production System, Nissan Production Way, NPW*

Introduction

Ensuring the efficient production processes was an issue, which made problems in production enterprises from the beginning of industrial revolution in the 19th century. With the technical progress, new options and problems had influence in production tasks Today, the requirements for products and

manufacturers are much higher than a few decades ago. Currently consumers as well as stakeholders, make higher demands on products and producers, than they were several decades ago. Today not only price or quality are important, but also methods of production and they influence on the environment which is the subject of interest. These circumstances make a lot of challenges for companies and they production systems. The last years of the additional layer from the SARS-COV-2 pandemic and the outbreak of war between Ukraine and Russia, make manufacturers struggle with the disruption of chains, sources of supply, transport costs, and due to instability and constant also volatility. Are modern production systems ready for such working conditions? Will the production systems be ready to cope requirements from their customers and society? The text includes the comparison between the most popular systems: TPS WCM and NPW. All of them have been in terms of level and complexity, popularity and implementations possibilities.

The production system can be defined as: "intentionally designed and organized material-information layout, which is exploited by human and served to producing specify products (goods or services) to satisfy different customer demands. (Durlik, 1992) There are five components of this type system:

1. X input vector
2. Y output vector
3. The processes of processing input vector to output vector,
4. System management process
5. Material, energy and information coupling. (Durlik, 1992)

The underlying classical approaches distinguished three primary goals of creation and keeping production systems:

1. Quality and modernity of products,
2. productivity increase,
3. Control cost reduction (Durlik,1992).

It can be assumed in the elementary meaning of statements that are up-to-date, the current contemporary market and broadly understood economic association impose different requirements related to enterprises and to their products, rather than mentioned before pro-quality and cost

objectives. Currently, customers and stakeholders, in addition to the requirements of the quality of the product itself, pay attention to the way it was created and how the production activity influences the environment in local reference as well as whole world.

Among the operating production solutions, the most popular are: Toyota Production System, abbreviated as TPS, World Class Manufacturing, abbreviated as WCM and Nissan Production Way abbreviated as NPW.

The Toyota Production System can be defined as the entire philosophical-practical system dealing with production. The origins of the system are indicated at the beginning of the 20th century when Sakichi Toyoda implemented improvements in the spinning looms, in order to reduce mistakes needed on the handling device (LeanSensei,2020). The formalized system was developed in the mid-20th century by Eiji Toyoda. He was a son of one, of the Toyota founders in assist of Taiichi Ohno, an engineer responsible for production planning.

World-class manufacturing is referred to a method of improving the production logistics cycle. Main objectives of the system are wide range cost reduction and increasing the level of quality (Górska, 2008). In general, it is a system which is improving the productions and logistics parameters of the company. The origins of the system date back to the 1980s. For the first time the formulation and concepts were used by Haynes and Wheelwright in 1984, and then by Richard J. Schonberger in the study entitled. *World Class Manufacturing* in 1986 had indicated an integrated concept of WCM system (Piasecka-Głuszczak,2017). The next step in the evolution of WCM was in 2005 when Fiat S.p.A. together with Hajime Yamashina, a professor at Kyoto University, developed a modernized version of WCM.

The third system discussed in the study is the Nissan Production Way. The origin of this proprietary solution by Nissan Motor Corporation dates back to the early 1990s (Netland, 2012). The production system focuses on integrating manufacturing capabilities with customer requirements and the constant, ongoing identification and improvement of production errors. The philosophy of kaizen plays a significant role in shaping the modern form of NPW, with its principles deeply rooted in the structure of the system.

Methodology

The analysis was based on three comparative categories. For each of them applied a set of methods for the transnational comparison of both production systems and obtaining results. Each of the categories has a separate section of materials collected for the comparison. The comparative categories are:

- System design: this category focuses on comparing both systems in terms of the complexity of the structure, the number of components, and the complexity of each element. The main body of comparison are theoretical models of both systems. Materials used in this category are: documentation and publications of promoters and thematic studies on individual production systems.
- Popularity: the category focuses on the popularity of each of the production systems. For this purpose, a set of methods were used, including calculating the percentage share in publications and search results. The data was obtained from the Google Google Scholar, Bing and Yahoo! search engines. The keywords analysed were: Toyota Production System, World Class Manufacturing, Nissan Production Way.
- Versatility: the category presents a comparison of possibilities and its implementing production solutions in organizations other than those represented by the promoters of the automotive industry. For this purpose, an analysis of the collected case studies concentrates on individual implementations of the mentioned above systems performances. Particular attention was paid to the size of enterprises, the industry, as well as the methods of implementation and possible problems that were identified during individual implementations;

Results

System design:

- When comparing the models that represents of the production systems, significant differences in the level of complexity can be noticed. Creators of two production solutions used architectural allegories, in the case

of TPS. The model is often referred as *Toyota house* (Art of lean Inc. 2019), while in WCM there is a term *WCM temple*(Kaizen Coach International,2022). Despite having similar components, i.e., the foundation, pillars and the roof, both systems present and detail individual parts in different ways. The Nissan Production System uses a different, cyclical scheme in which all essential elements are included.

- The Toyota Production System model consists seven to nine elements depending on the detail of the base. The model is based on t *rules of Toyota Way*(Liker, Meier, 2011). The pillars of the system are: the concept of Just in Time and Jidoka. Inside the system there is the concept of kaizen, i.e., continuous striving for perfection. All elements are the base and the purpose of the existence of TPS, i.e., broadly understood high quality and cost reduction. The TPS model is compact and clear. It indicates the most important issues, which, with greater involvement, are subjects for further detailing and specialization. Thanks to this form, it is easy to interpretated and it allows for smoother progress towards more advanced issues which are related to the implementation of the system.
- The model representation of World Class Manufacturing may have from eleven up to twenty-one elements. It's depending on the details of the model and its *foundation*. The sheer number of elements shows a higher level of complexity compared to TPS. There are up to ten elements in the foundation of the model, which are represent the basis for implementing the system. They are e.g.: time and money, WCM vademecum, qualified employees, motivation and focus improvement. Another part of the model is the previously mentioned pillars. In the documentation and studies, each of the pillars has its own extensive description, which are included and shown it purpose in the system. All twenty parts support the roof, which is the WCM system itself. As in the case of TPS, there is no direct indication of the target here. In World Class Manufacturing, the model has a dimension aimed at an ideological representation of the production solution. Information about goals and components are included in the documentation.

The visualization of the Nissan Production Way construction consists of three basic components:

1. Cycle Ring: This can be considered as the carrier of the other parts of the system, indicating the continuity and repeatability of the production process.
2. Intention:
   - Douki-seisan: Sequential and synchronized production: The production attitude focuses on full correlation with current requirements and customer orders. It involves assigning all components of the vehicle at the very beginning of the production process, ensuring a connection between the manufacturer, dealer, and suppliers to create an uninterrupted flow of all required elements until the completion of production and delivery of the vehicle to the customer.
   - Genba kanri: Never-ending identification of problems and finding solutions on the spot. This element of the system is responsible for continuously identifying gaps between the assumed production state and the current situation. The crucial aspect is to solve problems where they occur, i.e., at specific locations in the production hall, with simultaneous implementation of necessary improvements.

3. *Four Boxes* Method:
   - Box 1 – Current Methods: The first stage involves studying and trying to understand current methods of operation – *what we currently deliver and how we do it.*
   - Box 2 – Current Values: The second stage attempts to analyze and understand quantitative data derived from the implementation of current methods, along with an objective look at those methods.
   - Box 3 – Target Values: The third stage of the method focuses on determining target values for the established production goals.
   - Box 4 – Target Methods: The final stage of the method involves designing specific action plans to achieve the set values, along with necessary corrections in the system if required. This is inspired by the philosophy of kaizen, involving a four-element cycle of continuous improvement and meeting customer requirements.

When discussing models of production systems, there is one more difference to note. The TPS is a homogenous system. All elements should be included in the implementation as a small enterprise and in a large corporation. There is no demarcation which element of the system is the most important or which should be introduced first. TPS should be introduced harmoniously and smoothly.

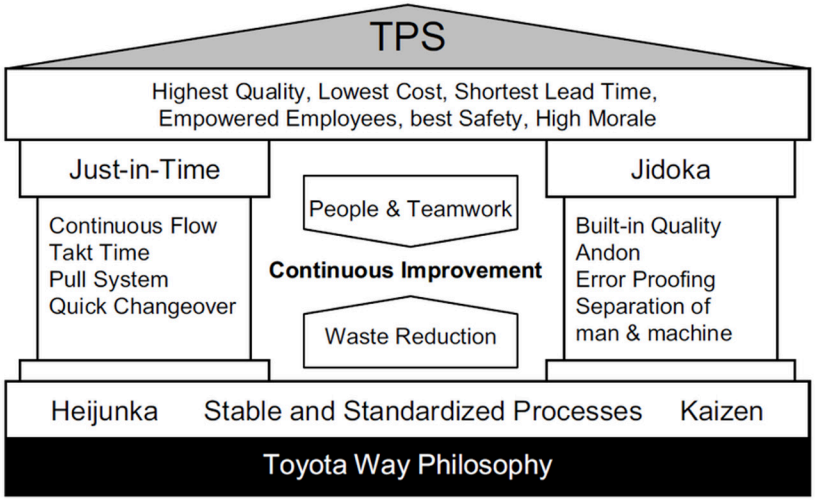

Figure 1. C. Herrmann, S. Thiede, J. Stehr, and L. Bergmann, "An environmental perspective on Lean Production", Proceedings of the 41st CIRP Conference on Manufacturing Systems, pp. 83-88, Tokyo, May 26-28, 2008.

The situation is different for WCM. The authors of the system distinguished four levels of system advancement in the enterprise: (Midor, 2012)

- Bronze medal: basic level of advancement of the WCM system in the enterprise.
- Silver medal: WCM intermediate level.
- Gold medal: the highest WCM rank
- World Production Class: special rank in the WCM, awarded to organizations that have achieved results exceeding the requirements of the gold medal, have implemented innovative solutions within the system and constantly strive to improve the achieved results.

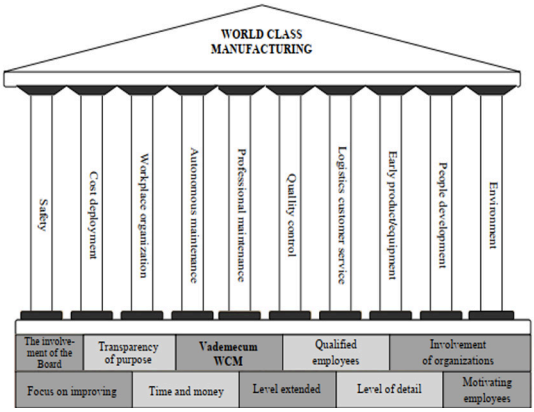

Figure 2. Temple of World Class Manufacturing source: K. Midor, World Class Manufacturing - characteristics and implementation in an automotive company, [in:] Zeszyty Naukowe, Akdemia Morska in Szczecin, 32 (104), 2012, Szczecin. p. 44

Nissan Group's system, like TPS, is a homogeneous solution. There are no levels of sophistication or modules attached as part of obtaining higher stages of implementation. NPW is implemented in its entirety at the new site on both a technical and personnel level through a training program implemented by the Global Training Center at the Oppama Plant in Yokosuka City, Kanagawa Prefecture (Nissan, 2020).

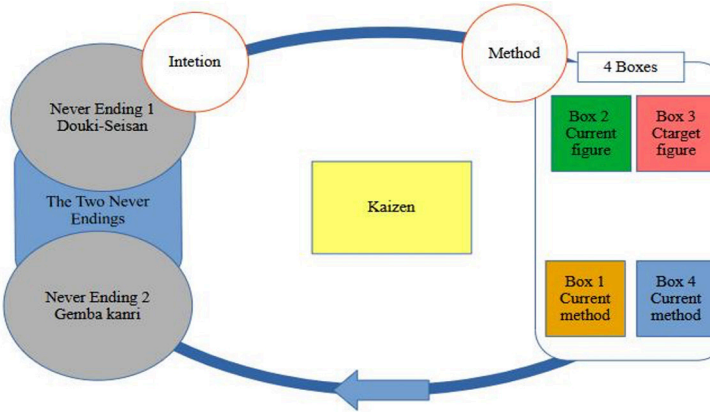

Figure 3. Scheme of Nissan Production Way, own study based on: Nissan, Nissan Pro-

duction Way (online) https://www.nissan-global.com/en/license/pdf/consulting01.pdf [access date: 20.11.2023)

Popularity

The study of the popularity for production systems, showed a significant difference between the area of the number of available publications and the popularity of searching for individual phrases. The tables below present the collected data from the Google and Google Scholar ,Bing and Yahoo! search engines, regarding the number of search results for individual terms. The results were enhanced with charts showing the percentage of each production system in the search resultsThe data was obtained on November 24, 2023.

Table *1 Search resoults for phrases*

Search engine / phrase	Toyota Production System	World Class Manufacturing	Nissan Production Way
Google search	1510000	1280000	4330
Google scholar	45700	20300	145
Bing	2340000	4240000	175000
Yahoo!	2270000	4140000	169000

Source: own study, 24.11.2023

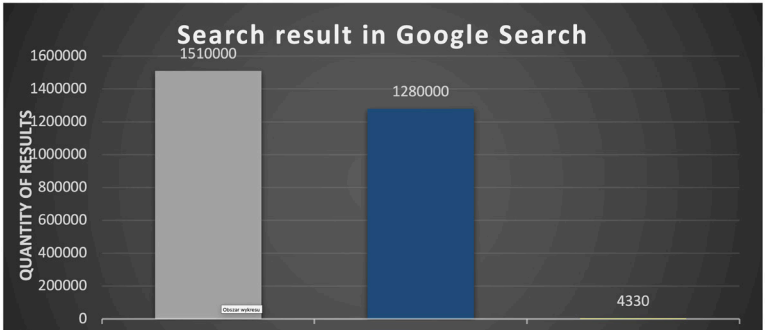

Figure 4. Popularity of production systems in Google Search, own study

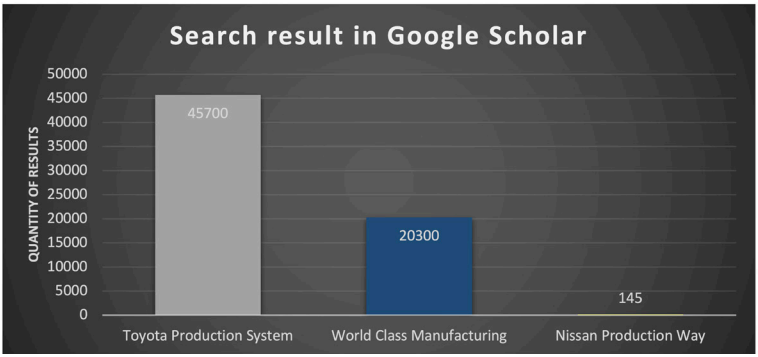

Figure 5. Popularity of production systems in Google Scholar, own study

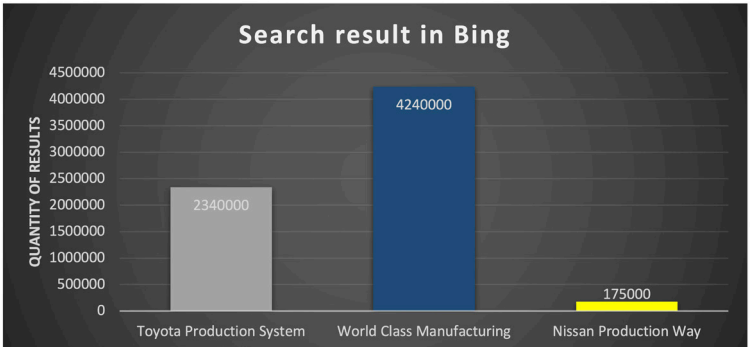

Figure 6. Popularity of production systems in Bing, own study

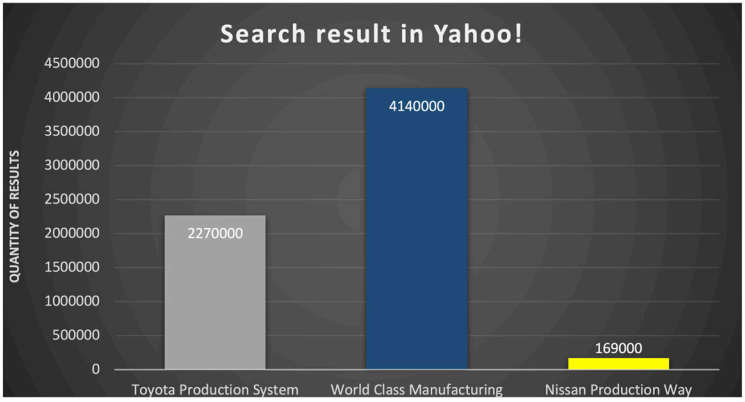

Figure 7. Popularity of production systems in Yahoo!, own study

- Versatility

When comparing the implementation possibilities of production systems. On the first one it can be noticed a large variety of companies that have decided to use two of particular systems. One of the examples for TPS is the implementation by IBM GSDC sp. z o.o. in Wroclaw (W Josek, 2012). The implementation of the TPS in described enterprise has been determinate by customer needs identification and willingness to meet that needs. IBM GSDC as a new unit in the structure of IBM has been built with a completely innovative strategy called *SO Delivery production systems* (W. Josek, 2012). The strategy was created directly for TPS by applying the solutions to the specifics of the company's operations. The system introduced in IBM has been focused on the concept – better, faster, cheaper – which is necessary to achieve the goals of TPS in present model appearance. The core of the implemented solution consists three elements:

- Elimination of improper use of resources (wastage losses) – focus on the process;
- Development of employees and partners;
- Continuous improvement of the services provided by solving problems related to problems and preventing them (kaizen philosophy).

These are also activities that have their important place in the structure of TPS. The entire system is based on repeatable processes that are subject to four basic assumptions:

1. the use of continuous and smooth problem disclosure;
2. use of a pull system;
3. process standardization and automation;
4. visual control.

The premise are also integral parts of this TPS.

Other examples of TPS implementations are described in the study of an application of Toyota Production System. It's represented in the non-automotive industry by Iveta Paulova and Ivana Mrovova (Paulová, Mrvová, 2011). The authors present the situations of three companies: a producer of semiconductor

elements, a producer of wood and a producer of wooden packaging, e.g., pallets. All of the described companies were looking for opportunities to reduce production costs and improve efficiency. Thanks to the implementation of TPS or customized elements in organizations, a significant positive change in the operation of production processes was noticed, e.g., a 12% reduction in the cost of producing a single semiconductor wafer.

An example of the implementation of the WCM system, apart from the main promoter, can be the tycoon of the steel industry on a global scale, ArcelorMittal.In the publication by B. Gajdzik entitled World Class Manufacturing in metallurgical enterprise (Gajdzik, 2012), presented how AcellorMittal has implemented WCM in its operations. The production system was based on ten pillars. Each of them has been adapted to the specifics of the company and implemented, for example, the implementation of the accident rate and keeping it below the value of 1 or the introduction of the 3xR principle (Reduce, Reuse, Recycle).

Another example of a functioning WCM system is presented in the article by Agnieszka Piasecka-Głuszak titled WORLD CLASS MANUFACTURING IMPLEMENTATION IN A PRODUCTION ENTERPRISE ON THE POLISH MARKET (Piasecka-Głuszak, 2017). It represents the company dealing in the production of household appliances. The author does not give the name of the company, however she gave a specifies number of employees: 100,000 employees, the number of production and technological facilities: 70. The implementation of WCM in the company had unusual circumstances, because the company already has a production system based on lean manufacturing and TPS methods. The management decided to make changes in the form of modifying the existing solutions to meet the requirements of WCM. The goals of the implementation were:

- financial: reduction of overheads, the lowest possible implementation costs, increase in the company's competitiveness, increase in financial results;
- social: improving environmental conditions, increasing employee productivity and motivation, improving communication and information flow;

- qualitative: elimination of product and service defects, elimination of difficult and dangerous work, increase of work safety;
- organizational and process: improvement of applied processes, meeting and shortening production and delivery deadlines, the fastest possible execution time, the most efficient and productive organization of the system, adapting production processes to the needs of customers, improving the flow of information and communication.

Reasearch for Nissan Production Way do not find examples for external implementations of system. Opisane rozwiązanie produkcyjne pozostaje obecne w przedsiębiorstwie autorskim oraz firmach Renault i Mitsubishi, które wchodzą w skład Renault-Nissan-Mitsubishi Alliance.

Summary

Toyota Production System and World Class Manufacturing show many common features and discrepancies. It is possible to indicate an elementary assumption to increase efficiency, reduce waste and improve quality. These matters are important in both production systems. Moreover, both systems are based on the same concept, e.g. The difference is certainly in the level of complexity. TPS on its model presentation focus on a simpler solution, and specific goals. It's presenting the main principles of the system in the *Toyota Way*. WCM is a complex system that applies to various, but strictly defined by the pillars, areas of the enterprise. It is characterized by a high degree of formalization. For example, through the system of leveling the implementation from bronze medal to world class. The popularity and universality of production systems also is worth attention. Two of described solutions find their place in a variety of production and service organizations. These are usually large organizations with a wide range of activities, e.g., operating on the global market, carrying out tasks in a large number of copies, e.g., hundreds of thousands of manufactured products. An interesting issue is the popularity of both systems. Toyota Production System is a much more searched phrase compared to World Class Manufacturing. On the other hand, the number of publications

concerning TPS is much smaller than those concerning WCM. This is the case for both web materials, that can be found using the Google browser and the number of publications indexed by Google Scholar.

The above analysis is of a review nature, trying to capture the widest spectrum of issues related to desrcibed systems and to compare production solutions in a universal form. It is possible to continue the above tasks by comparing individual aspects in more detail or by including other production systems in the analysis.

Some research limitations should also be indicated. Despite the great openness of the promoters for production systems, in the form of guides and high availability in literature which covers theoretical issues, each implementation of the production system is a serious challenge and is intended to be a competitive advantage. Therefore, organizations do not provide fully detailed information's on the implementation of the described solutions, which makes it difficult to obtain .

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