Methods of Lean Production to Improve Quality in Manufacturing

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ABSTRACT

Purpose: Quality in manufacturing can be improved by using lean production methods. The paper discusses traditional and modern methods of lean production and their use in different enterprises.

Methodology/Approach: Through a questionnaire survey and research, 90 industrial enterprises were classified by the size, production scope and their ownership. The research results were analyzed by means of statistical methods to determine the differences in the use of lean production methods.

Findings: Regarding the lean production and its different methods, the size of the enterprise is an important factor. The statistics revealed that large enterprises tend to use lean production more. It was also proved that some methods of lean production are not completely common in the Czech Republic. Moreover, some methods are quite new to the majority of the enterprises.

Research Limitation/implication: Some questionnaire surveys conducted in different countries (especially in the US) use a different enterprise size classification. As the research results show, there is still a large potential for the introduction of lean production methods in small and middle-sized enterprises that can help enterprises to improve the quality of their production.

Originality/Value of paper: The application of lean production methods has been investigated so far, especially in large engineering enterprises. The paper deals with the use of these methods also in small and medium sized enterprises. The authors focused their research also on non-engeneering enterprises in the field of the food industry and production of products for domestic use too.

Category: Research paper

Keywords: lean production; lean production methods; size of the enterprise; quality of production

1 INTRODUCTION

The producers keep looking for possibilities of increasing the efficiency of their production and competitiveness. This might be done by a number of ways, such as the purchase of new technology, improvement of the services, quality and waste reduction. Cutting out waste was originally an idea of Toyota, a Japanese company, after the Second World War. Their methods were later called "lean production". The aim of such lean production is to "produce more with less resources" (Krafcik, 1988; Womack, Jones and Ross, 1990; Womack and Jones, 1994). The most popular methods include Just-in-Time, ABC, Kanban; currently supplemented with new methods such as 5S, Andon, etc.

In the references, different authors describe the methods of improving quality of the production, and their application in an enterprise. Pettersen (2009) argued that there is absence of a clear definition of lean that lead to communication difficulties, complicate education or researching the subject. Many authors define lean production as an integrated system of a large number of different methods and principles (Womack and Jones, 1994). However, it is obvious that the better performance, quality and efficiency of production processes is not provided by the methods themselves but their concurrent application and interaction. The methods are complementary to each other.

Levy (1997) noticed that one of the cornerstones in the lean production is a renewed approach towards quality management compared to the practices (methods) within traditional mass production. More important than different methods and techniques is an integrated approach to quality management that emphasizes lean thinking (Lamming, 1993). That's the foundation of total quality management (TQM), which in the long-term simultaneously involve all members of an organization (including management) to participate in the continuous improvement of processes, products and services to achieve success through customer satisfaction.

The aim of the paper is to discuss the use of both traditional and new methods of lean production in the enterprises according to their different characteristics such as enterprise size or scope.

2 STATEMENT OF A PROBLEM

Management of production went through a lot of changes in the past. At first, there are the methods used mostly in the first half of the 20th century at the time of mass production development. Such methods were promoted by Frederick W. Taylor, Henry Ford and others. Their aim was to cut the production time out, by using performance standards, assembly lines and similar methods. The methods were created by the top management, promoted from the top to the bottom as the factory workers were neither educated nor motivated enough to support the initiative. The state changed after the Second World War when the market of the producer was replaced by the market of the customer, much more demanding in

availability of products, their variability, price quality and speed of delivery. Suddenly, it was impossible to ensure the requirements from the top only. It became necessary to engage the workers into the process. Instead of engaging their physical strength only, it was necessary to add their brain, abilities, and initiative. At first, such requirements were applied in Toyota, a Japanese automotive company. After the influence of the requirements on competitiveness increase was proved, the methods started to be popular in other companies. In Toyota, they applied the method called Just-in-Time, followed by other methods, such as Push and Pull, Kanban (maintaining inventory level) and the method for continuous improvement (quality control) promoted by W. Edwards Deming (Liker and Hoseus, 2008). The above mentioned, together with the ABC method, as known before, are referred in the paper as traditional. The ABC is described by Keřkovský and Valsa (2012) as the principle of differentiated management. Tomek and Vávrová (2014) noticed that ABC might be connected to XYZ, creating groups by forecast accuracy.

During the following decades, there was a fast development in technology so that new methods of improvement were needed. The method of Value Stream Management (VSM) has become popular in large industrial enterprises. This method reduces production time and focuses on creating value added for a customer. Another method known as Total Productive Maintenance (TPM) focuses on better approach to machine maintenance. The method uses analyses of production system data and sensors to identify possible failures before they occur, using models of dependency (Mařík, 2016). The development of electronics makes it possible to improve communication between enterprises through the Electronic Data Interchange (EDI) method. The modern computers have programs to manage individual parts of the production process, even production as a whole. These methods, which have been applied since the 1970s, are referred to as the new methods and we are exploring their implementation both in relation to traditional methods and in terms of their application in various large enterprises and in enterprises with different production scope.

As far as quality management is concerned, the lean production emphasizes integrated management systems between companies in a defined value stream (Soderquist and Motwani, 1999). The integrated quality systems support lean production methods and improve performance measurements, core competencies and management processes of enterprises. Quality management contributes to the implementation and integration of lean production methods. On the other hand, it is just lean production methods that improve the quality of the organization processes, products or services. The link between quality and the application of lean production principles (methods), for example, presented Roriz, Nunes and Sousa (2017). They show how improvements based on the 5S technique and visual management achieved an average reduction of 47% setup time in a carton company. Nicholas (2016) describes the factors related to successful implementation and sustainment of TQM/lean production initiatives. Lee and Peccei (2008) analyzed determinants of employe quality commitment in the high

lean plant sample. Their study finds that the employee quality commitment differs in relative importance at different stages of lean production implementation.

3 METHODOLOGY

The paper deals with using different methods of lean production, considering their acceptability. It discussed if the enterprises prefer traditional methods or if they try to use the new methods too. The aim is to suggest possible methods, which are not so common, but useful for small and middle-sized enterprises.

The methods of lean production are partial tools, useful under particular conditions, such as mass production, single-piece production, for enterprises with high/low number of employees etc. The system of lean production methods is not strictly limited; there are new methods applied if they better suit to new technology of production.

The authors of the paper deal with the use of new and traditional methods of lean production in different enterprises and their preferences. The complementary implementation of lean production methods enhance the performance, efficiency and quality of the production processes.

The students of the University of South Bohemia in České Budějovice, the Faculty of Economics, were able to obtain ninety questionnaires dealing with applying lean production in the enterprises, in 2016. The questionnaires are classified into the following categories:

- By the industry of enterprises into: 1. engineering, 2. electro-technical production, 3. food industry, 4. production of products for domestic use;
- by size (according to the number of employees) into: 1. small enterprises (up to 49 workers), 2. medium-sized enterprises (50-249 workers) and 3. large enterprises (over 250 workers);
- by the owner (a part of a foreign enterprise or not);
- by the importance (whether an enterprise is considered a key or dependent article) in the supply chain.

Since there were only 4 businesses in the “electro-technical”, we do not lit them as a separate item in the tables, but they are counted in sets classified by enterprise size, ownership and supply chain. In the paper, the distribution by importance in the supply chain is not further analysed.

The results obtained were then subjected to statistical analysis by “individual tests of equal and given proportions without correlation to continuity”. In particular, statistical hypotheses were formulated for each category of lean production methods. The null hypothesis is that the observed phenomenon has the same proportion. The statistical alternative hypothesis is that this proportion

is different in at least one case. The following statistical hypotheses are fomulated in this paper:

H_1: *The enterprises differ in using traditional methods of improving production.*

H_2: *The enterprises differ in using new methods of improving production.*

In the case of multiple comparisons of relative frequencies, Holm's method of adjusting the level of significance reached was used. The results are interpreted at significance level of 0.05 (resp. with 95% reliability). For reasons of clarity, only significant results, including achieved level of significance (p-value), are given in the text. Statistical evaluation of individual tests was performed using R 3.3.3 programming environment.

4 RESULTS

Using the method of lean production is not an end in itself. It should take the targets as set by the enterprise and possible future trends as the starting point.

The present might be seen as a turning point of a quick development of new technology (known as Industry 4.0) due to which there might be a change in applying digitization, robotization and artificial intelligence in a short-time period of 10 to 15 years. The communities of experts have become familiar with such trend. The question, however, is whether the enterprises are ready for the future development. It is possible to predict that in spite of possible changes in technology, the current methods of lean production will be used as long as the current production procedure is used.

The results of the research are divided into the traditional and new methods.

4.1 Traditional Methods

The traditional methods in our results include such methods that have been known since half of last century: Just-in-Time (JIT) followed by Kanban, ABC method related to both suppliers and customers, and continuous improvement processes (CIP).

Table 1 – Traditional Methods of Production Improvement (%) (Author's Own Work)

Categories of Companies	Number	JIT is Used	Kanban is Used	ABC for Suppliers	ABC for Customers	CIP
Small	26	19.23	**3.85**	**34.62**	38.46	**11.54**
Middle-sized	34	17.65	**8.82**	**44.12**	52.94	**35.29**
Large	30	23.33	**46.67**	**70.00**	53.33	**63.33**
Engineering	45	20.00	**33.33**	60.00	48.89	**51.11**
Food industry	17	35.29	**17.65**	41.18	58.82	**11.76**
Household supplies	24	16.67	**0.00**	33.33	41.67	**29.17**
Foreign owner	35	22.86	**34.29**	57.14	51.43	**60.00**
Czech owner	55	18.18	**10.91**	45.45	47.27	**23.64**

Tab. 1 summarizes the use of methods in enterprises. The percentage for each method shown in the table is always calculated from the number of enterprises in column "Number". The statistically significant differences at the significance level of 5% are marked in bold.

Regarding the using of five traditional methods, the differences between enterprises were determined by three criteria (size, specialization and ownership). The following working hypothesis was formulated:

H_1: *The enterprises differ in using traditional methods of improving production.*

- By size – COMFIRMED (for Kanban, ABC used for suppliers, and continuous improvement)

Based on the statistics, it was proved that the enterprises differ in three (out of five) traditional methods. The statistically significant difference was found in the Kanban method (p-value = 4.05 · 10-05), especially between the large and small enterprises (p-value = 0.0028), and the large and medium-sized enterprises (p-value = 0.0034). The differences in enterprise size were further significant in the supplier-centred ABC (p-value = 0.020). In the case of the CIP, the differences are also statistically significant (p-value = 0.0003289), in the case of small and large enterprises (p-value = 0.00069). No significant differences were found for other traditional methods classified by the size of enterprises.

- By specialization – CONFIRMED (for Kanban, and continuous improvement)

Using the traditional methods, the enterprises are different in Kanban (p-value = 0.004876) and continuous improvement (p-value = 0.01058) only. Regarding the Kanban method, the significant differences were found comparing engineering

enterprises and household supplies producers (p-value = 0.012). Using continuous improvement is far superior in engineering enterprises compared to food industry (p-value = 0.034). No significant differences were found for other traditional methods classified by the scope of enterprises.

- By ownership – CONFIRMED (for Kanban, and continuous improvement)

Similarly to specialization, the working hypothesis was proved for Kanban (p-value = 0.01499) and continuous improvement (p-value = 0.001171). No significant differences were found for other traditional methods classified by the owner of enterprises.

Further, the paper will focus on traditional methods where the statistically significant differences are highlighted in the tables.

4.1.1 Just-in-Time and Kanban

The Just-in-Time method was developed and successfully applied in Japan in the 1970s. The basic prerequisite is delivery of the necessary items only, in the necessary quantities, the correct quality and at the latest allowable times. This reduces inventory and production and reduces storage space.

Kanban is a self-regulatory production control system. It is a label (card) that fulfils the function of the order. Individual workplaces order with the same Kanban cards the same, limited amount of items that correspond to the permitted level of inventory of finished parts and products. Kanban is part of the Just-in-Time method.

The questionnaires revealed that Just-in-Time method is only applied partially in enterprises, mostly in large enterprises. Although it was created for the needs of the automotive industry, it has approximately the same application in food industry and household supply production. It is less used in enterprises with Czech owners and in dependent supply chain links.

The Kanban method, as a part of Just-in-Time, reported more significant differences in use. Similarly to Just-in-Time, is it applied mostly in large enterprises, in particular in manufacturing enterprises of mass production, foreign owners and if changes of production are not very common.

Both methods have been known for more than fifty years. There has been enough time for the enterprises to test the methods and their advantages and disadvantages of their use. Therefore, their further expansion is not probable.

4.1.2 ABC Method

The method is based on dividing the inventory into three groups: A, B, C. Group A consists of a small number of elements (about 20%) with a high share in total value (around 80%). A proper management of this group helps the manager managing the whole inventory easily.

Using the ABC method, an enterprise can also diversify services between its customers; and it can evaluate its suppliers and focus on the most important customers and suppliers to simplify and streamline their services. However, if the number of suppliers or customers is small, the use of the ABC method is useless.

Applying the ABC method is increased towards large enterprises. For suppliers, this trend is more pronounced than for customers, which may indicate a tendency to deal with all customers equally.

Regarding the specialization of production, ABC is the most common in engineering enterprises. In household supply production, it is not used in almost sixty percent, possibly due to a small number of suppliers. Similarly, in food industry, almost a half of the participants reported that the method cannot be used in their enterprise.

The ABC is an easy method. It does not require any expensive measures and it is appropriate to use it almost in all enterprises, first of all in some small enterprises.

4.1.3 Continuous Improvement Process (CIP)

Continuous improvement in its organized form mostly appears in large enterprises. Such enterprises employ people necessary to implement, monitor and analyze the processes. The small enterprises do not have enough people to do this task, so they report the method as “not organized”, meaning that there are no obstacles to carry it out, but there are no people to support and manage it significantly.

However, there are still possibilities of better use of the method by small enterprises. They should support the initiative of their employees at least in a simple way. Continuous improvement is strongly supported in engineering and foreign-owned enterprises.

4.2 New Methods

In the paper, the new methods include 5S, TPM (Total productive maintenance), VSM (Value stream management), Electronic Data Interchange (EDI) and computerized management of production (CAM). Tab. 2 summarizes the use of these methods in enterprises.

The following working hypothesis was analyzed:

H_2: The enterprises differ in using new methods of improving production.

- By size – CONFIRMED (for TPM, computerized management, and 5S)

The working hypothesis was proved for the size classification in most of the new methods. There was a significant difference in enterprises for 5S (p-value = 0.01411). The difference was strong between large and small enterprises (p-value = 0.031). Similarly, there were differences in TPM method (p-value = 0.03256) and computerized management (p-value = 0.0236). In computerized

management, there were strong differences between middle-sized and large enterprises (p-value = 0.046). In using the other methods of production improvement, there were no differences found between the enterprises of different size.

- By specialization – REJECTED

Engineering enterprises seem to have higher levels of use of new production improvement methods than others. However, these differences were not significant in the analysis through statistical tests.

- By ownership – CONFIRMED (for VSM and 5S)

Comparing the enterprises owned by a foreign and a Czech owner, the working method was confirmed for VSM (p-value = 0.04314) and 5S (p-value = 0.03628).

The statistically significant differences at the significance level of 5% are marked in bold.

Table 2 – Five New Methods of Production Improvement (%) (Author's Own Work)

Categories of Companies	Number	5S	TPM	VSM	EDI	CAM
Small	26	11.54	**11.54**	**15.38**	30.77	**23.08**
Middle-sized	34	26.47	**32.35**	**41.18**	35.29	**29.41**
Large	30	46.67	**43.33**	**43.33**	56.67	**3.33**
Engineering	45	35.56	35.56	44.44	42.22	22.22
Food industry	17	23.53	23.53	23.53	58.82	17.65
Household supplies	24	20.83	25.00	20.83	33.33	20.83
Foreign owner	35	**42.86**	42.86	**48.57**	48.57	14.29
Czech owner	55	**20.00**	21.82	**25.45**	38.18	23.64

4.2.1 Method of 5S

The method of workplace organization is supposed to reduce waste by maintenance and organization of both production and offices. There are five steps to do that (sort, set in order, shine, standardize, and sustain).

The complex uses of 5S increases towards large enterprises. A quarter of enterprises uses the method partially. As it is a basic method, requiring discipline and workplace order, its use is not flawless.

4.2.2 TPM and VSM Methods

TPM aims to carry out the maintenance of equipment if necessary, neither earlier nor later. Maintaining is supervised by the workers who work with the machines

because they are best aware of possible issues in the normal operation of these machines and equipment.

TPM use increases towards large enterprises. The method is primarily based on the individual approach of individual operators so that it should be used more in small enterprises.

4.2.3 Value Stream Management (VSM)

Value Stream Management (VSM) is an entirely new method that aims to remove all activities that do not add a new value to the product. Implementation of the VSM is mostly a task for specialized customer-services firms. The method is based on an assessment of time when the value is added (by the standards) to total real production time (from the initial activity to sending the product to the customer). It includes revealing operations and placing the biggest potential for improvement.

As VSM is rather complicated to use, it is mostly used by large enterprises, in particular by engineering enterprises and those owned by a foreign owner, usually implemented by specialized firms. We assume that the method could be used in small or middle-sized enterprises, although in a simplified form with less precise results.

4.2.4 EDI

Electronic Data Interchange (EDI) is an important method of informational technology, making the communication of two subjects easier, by converting the data from one system to another easily, without the long procedure of rewriting the data.

EDI is mostly used by large enterprises (56.7%). Middle-size enterprises try to implement it and the method is partly used by 41.2% of them. The less common use of EDI was reported by small enterprises, with a number of employees of less than 49.

Regarding the specialization, EDI is mostly used by food industry enterprises (58.8) and by 42.2% of engineering enterprises only. The reason for this might be shorter delivery time and larger choice of products, favourable for the EDI system. Regarding the ownership of the enterprise, there are no significant differences. On the other hand, the key parts of the supply chain use EDI twice more compared to the dependent link.

4.2.5 Computerized management of production

The technology development has recently influenced production management through computers. Currently, there is a number of computer supported activities. The highest level of such system is known as computer-integrated manufacturing (CIM), including partial methods of computer-based management, such as CAD (computer-aided design), CAA (computer-aided assembly) and CAP (computer-aided planning).

Our research was carried out in four areas. It showed that enterprises are primarily focused on a more comprehensive approach to managing all important activities directly related to production; on the other hand, the use of computers for managing relations with suppliers and customers is quite rare. The differences between the enterprises in terms of their size, production structure and ownership are not very large.

5 DISCUSSION

At first, this part discusses the difference in use and implementation of lean production methods in the enterprises of different size. In general, there are two opinions on implementing new methods and changes in large enterprises. On one hand, an increase of the size is related to increased bureaucracy and administration, so that it is more difficult to change the current systems (Chandler, 1962). Large organizations are seen as slow and cumbersome, and it influences the implementation of lean production in a negative way (Hannan and Freeman, 1984). On the other hand, large enterprises have more capital, resources and tools to implement changes, compared to small enterprises (Ahmed, Tunc and Montagmo, 1991).

The results of our research suggest that there are significant differences in six out of ten methods of lean production when enterprises are classified by their size. These six methods are Kanban, ABC focused on suppliers, continuous improvement, 5S, TPM and Computer-aided management. The results can be compared with the research by Shah's and Ward's (2003), which divides the lean production into four bundles – JIT, TPM, TQM and HRM (human resources management). Shah and Ward (2003) found that there is a significant difference of all 22 practices, with the exception of cross-functional work force and quality management programs. Their research agrees with White, Pearson and Wilson (1999), which focuses on JIT in small and large enterprises. In these studies, the size of enterprises is certainly an important factor. However, our research did not show differences in the same size range of enteprises categories. The reason why the results of our research are more subtle might be due to different classification of enterprises sizes. In foreign studies have small enterprises less than 250 employees, middle-sized enterprises have 250-999 employees, and large enterprise have more than 1,000 employees. To the contrary, our research is based on the European enterprise size classification (see methodology) which is defined in EU recommendation 2003/361.

Considering the difference in lean production methods use classified by different specialization of enterprises, the dominance of engineering industry, and automotive industry in particular, such as Honda, GM, Suzuki, Mazda, and Nissan, is often discussed (Berggren, 1993). In our research, the difference was confirmed for two methods out of ten - Kanban and continuous improvement. Regarding this, the findings are surprising as increased use of the methods in

engineering was supposed. Also, the enterprises prefer the new methods to the traditional ones.

At last but not least, the enterprises were classified by their owner. It should be noted that foreign authors use different classification. In this case, the category is mostly related to the size of the enterprises and majority of large enterprises in the research have a foreign owner. In our research, the results revealed a greater use of four methods out of ten, if classified by the owner. There were the methods of Kanban, continuous improvement, 5S and VSM. It is possible to assume, that the differences were not reflected clearly, however, they are apparent for some methods of lean production.

The result of the research also showed that lean production methods are not as popular in the Czech Republic to confirm more significant differences in some categories. Furthermore, some of the methods (such as 5S) are rather new in most of the enterprises.

6 CONCLUSION

The size of enterprises is very important factor in implementing and using the methods of lean production. The use of both traditional and new methods increases towards large enterprises. There are significant differences between different sizes confirmed for three traditional and new methods out of five. The results for both groups are rather similar. It means that the enterprises prefer neither the traditional nor the new methods of production improvement.

Regarding the specialization, it was confirmed that the enterprises generally prefer the traditional methods to the new ones. In particular, engineering is active in implementing new methods, followed by the food industry and household supply production, using EDI and computer-aided management a lot. Regarding traditional methods, a less interest in Just-in-Time is noticeable, together with the considerable use of ABC method and focus on continuous improvement in engineering.

Regarding the owner, it was proved that the enterprises with the foreign owner use traditional and new methods of lean production more, compared to the Czech enterprises. Significant differences were found for Kanban and continuous improvement, as the traditional methods, and for VSM and 5S, as the new methods. However, there are no major differences between the use of new and traditional methods.

Regarding the aims of our research, it was showed that there is still a big potential for implementation of new methods of production improvement in small and middle-sized enterprises. Some of the methods even might be easy and financially available and help enterprises to improve quality of their production. On the other hand, it seems that the enterprises try to use new methods of

computer-aided management. However, such methods should be extended to the management of relations with both suppliers and customers.

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