RESEARCH IN LOGISTICS & PRODUCTION

PRODUCTION LINE WITH EMBEDDED LEAN APPROACH

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Abstract: The paper describes the course of the process of starting up a new assembly line with embedded Lean Management approach in one of production companies in Wroclaw. There were documented the processes of implementing and maintaining the manufacturing and logistics solutions as well as organizational and behavioural solutions that provide the basis for the new system. Then the results of the improvements to be implemented were analysed in relation to the area functioning in accordance with the old system within the same production hall. The issue of disturbances in the system approach in connection with the introduction of changes was discussed only for a single process.

Paper type: Case Study

Published online: 10 July 2017
Vol. 7, No. 3, pp. 221–235
DOI: 10.21008/j.2083-4950.2017.7.3.4

ISSN 2083-4942 (Print)
ISSN 2083-4950 (Online)

Keywords: *Lean Management, help chain, pull system, right size packaging, milk run, kaizen*

1. INTRODUCTION

Nowadays, the implementation of Lean tools by companies becomes something common and obvious due to a high level of awareness of the necessity to focus on the needs of customers when planning and executing all types of activities (Górnicka, 2016, p. 23). Currently, the attention is no longer paid to the fact whether these tools exist or not, but to their impact on the results, which still constitutes a problem for many companies. The surveys conducted by "Industry Week" in 2007 showed that only 2% of companies achieved the intended results (Podobiński, 2015, pp. 113–114). The main reasons of failures include the problem of keeping the process of continuous changes (Liker & Franz, 2013, p. 43; Podobiński, 2015, p. 117) due to a lack of involvement and support of the leadership (Mann, 2015, pp. 193–194; Bicheno & Holweg, 2009, p. 44; Podobiński, 2015, p. 117), emphasis on tools rather than organizational culture (Miller, 2011, p. 52) and employee resistance (Bhasin, 2012, pp. 406-407; Grycuk, 2016, p. 76; Podobiński, 2015, p. 118). This problem was also observed in one of production companies in Wroclaw. Attempts were made to improve the current system, but the effects did not meet the goals. In the meantime, a decision was taken to launch next production lines, which created new perspectives due to instilling the Lean culture principles into employees. Therefore, a thorough change in the current approach was planned. The new assembly line quickly became known as "line with embedded Lean approach". Already at the initial stages of the project, a decision was made that the line must be based on the concept of Lean management. The potential effects of the implementation of various kinds of tools and methods were analysed in order to make a decision on embedding the Lean approach primarily in the organizational, production, logistics and behavioural solutions. In line with the assumptions, the Lean management approach at the base of these four areas was to contribute to the success of the new line in relation to the old one functioning on the basis of a long-standing system. Based on several months of observations, from the very beginning of the process of building the line until the time of its operation in accordance with the daily rhythm of work in the company, the results of the introduced improvements were monitored. The aim of the studies was to analyse the possibilities and effects of the implementation of Lean management tools along with the start-up of a new production line and then to compare them with the results obtained on the lines functioning on the basis of a long-standing system which has been improved over time.

2. SOLUTIONS IN THE AREAS OF ORGANIZATION, PRODUCTION AND LOGISTICS

2.1. Help chain

After making a decision to introduce the Lean culture, the first step should be strengthening of the process approach in the company by creating a system of cross-functional teams (Wyciślak, 2015, p. 363). The support chain was formed to structure the operational activities and build the responsibility at every organizational level. The team composed of representatives of the engineering, production, logistics, quality and maintenance areas was assigned to the value stream being created. A common place of work was arranged for this team. Such a solution was to significantly facilitate the processes of management and problem solving, thanks to a smooth flow of information and the introduction of group responsibility. When creating the new help chain, the time for daily meetings held to discuss problems, analyse indicators or report on statuses of actions was taken into account. It has become much easier to manage the line due to the possibility of discussing any problems in real time and solving them faster thanks to the availability of the expert knowledge of each member of the interdisciplinary team and an immediate assignment of tasks.

2.2. Maximization of productivity

The character of the assembly processes taking place on the new line enabled an effective application of MTM (Methods Time Measurement), thanks to which there was designed a more economical way of manufacture as compared with the previous one. Then the method of value stream mapping was used. The solutions developed with the use of these methods contributed to a reduction of non-value-added activities by a few percentage points.

2.3. Pull system

In the area of logistics, an emphasis was put on a well-functioning pull system. The kanban system was successfully used for as many as 78% of the components, while the remaining 22% was to be based on a sequential system. The kanban method was introduced in several forms: starting with kanban plastic containers of various size for small and medium components (taken away each time by logistics employees), through kanban boards for bigger and heavier components (only moved from the beginning of a rack to its end by workers), to typical kanban cards (fixed to packaging units received directly from suppliers, put into pockets, and then fixed to full carton boxes). Despite the simplicity of the system itself (Silva

Ferreira, Thürer, Stevenson 2016, p. 658), the introduction of the kanban method on such a large scale caused problems at the beginning. There were empty boards and containers due to the lack of understanding of the new rules. In addition, cards went missing very often. They were put away somewhere in the warehouse instead of being fixed to new packaging. However, the problem was solved quite quickly thanks to training sessions. To each employee of the logistics department, who did not follow the kanban rules, one Lean specialist was assigned, who went through the whole process of supplying the line with the employee several times and explained all the rules on a current basis. After a certain time, the kanban system was understood and accepted by workers, who had seen the effects in the form of a smooth delivery of necessary components.

In order to make the process visible "at first glance", a very strong emphasis was put on the visual management (Mann, 2005, p. 35), which become present practically in every sphere of the system. From explicit instructions, through colours of lines (also used in packaging, trolleys, kanban cards, etc.), to the signs used along the entire transport route. The use of explicit colour marking was the biggest success. This facilitated the work of line-feeders, who could see from afar which components were short in supply as well as the see the locations of next planned stops.

2.4. Right size packaging

The logistics department decided to control the inventory level. This was regarded as one of the priorities due to the enormous scale of this problem on the old lines. This problem was visible particularly in the case of interrupted sequences. The company manufactures different variants of product on each line. Thus, each unplanned change in the schedule (which occurs on average a few times a week) requires a change of components which are different depending on the type of product. It happened that the number of WIP inventories was sufficient only to assemble a few dozen pieces of a particular product type and therefore the transport to the warehouse required a significant time expenditure, which depended also on the availability of trolleys or even on the space available on shelves. What's more, the inventories often occupied all the available space, so in order to provide components for a new variant of the product it was necessary to remove the previous ones as quickly as possible. Thus, the problems included not only a lack of space at workstations resulting from an enormous level of WIP inventories or the costs of these inventories and their unnecessary transport, but also the risk of downtimes due to the inability to provide the necessary components to the line. An attempt was made to control the inventories at the new line by establishing a unit referred to as a pitch which describes the optimal size of a transport batch. The aim was to ensure that the components are delivered according to the pitch or, if necessary, with a multiple of the pitch. Following further this path, efforts were made in connection with the introduction of right size packaging for sequential components,

consistent with the pitch. If possible, such packaging units were negotiated directly with suppliers, while in the absence of such an option, the duty of repacking was assigned to a picker. For as much as 85% of the sequential components of the new line, a system of right size packaging was successfully implemented. Among them, as much as 74% came directly from the supplier (some of them were transported simply in smaller cardboard boxes, while for others there were introduced divisions in the form of partitions or foil); the remaining 26% requires repacking. In addition, the focus on the right size packaging consistent with the pitch caused that a vast majority of the components were transported in small packaging units. This fact was utilized – there were designed racks and shelves with space sufficient only for the necessary amount of each type of packaging, so that it would be not possible to supply excessive inventories. There occurred a problem associated with the racks and shelves designed for a larger number of components as well as with the places where vertical stacking of packaging units one on another was possible. However, this problem was solved over time with the use of simple poka-yoke methods. The goal of the implementation of the pitch and right size packaging has been achieved; inventory levels have decreased significantly and their control has become much easier. It has been calculated that the inventories at the new line were maintained for no more than approx. 1.5 h, which gave a two times better result than that obtained in the case the old lines, where this time exceeded 3 hours. In addition, there were planned appropriate places for the replacement of components due to a change in the sequences, thanks to which this process was considerably streamlined. After approx. 3 months of functioning of the line, a problem of interrupted sequences has been observed more rarely (not every day as in the earlier system, but 1–2 times a week) and on a smaller scale (not within the entire line, but only at 2 or 3 workstations). These ideas were also liked by employees. They quickly noticed the benefits resulting from higher comfort of work in the form of much better order and more free space at workstations thanks to a low level of inventories, but also a greater sense of security due to a lack of components with sharp ends being piled up. Currently the company is working on getting 100% of returnable right size packaging units directly from suppliers.

2.5. Milk run

Changes have been made also in the method of delivering the components. The old system was based on forklift trucks which collected components from the warehouse and carried them directly to the line. This was determined to a certain extent by large dimensions of the packaging units. In the case of the new line, the use of forklift trucks was completely excluded and their role was limited to the warehouse only. The function of transporting the components was assigned only and exclusively to logistics trains in order to avoid the costs of maintaining the inventories and to speed up the process of delivering the components (Hosseini, Shirazi &

Karimi, 2014, pp. 567–577). Smaller components were put on shelves, while bigger ones were adapted to the shape of the cars. For each train, a milk run was planned, thanks to which unnecessary transport was eliminated. It has been estimated that such a solution allowed reducing the number of employees by approx. 5 persons, which was necessary to maintain the production rhythm of the old system.

3. LEAN CULTURE

3.1. Kaizen philosophy week

In accordance with the kaizen concept, production workers were also involved in the process of improvements in order to use their knowledge and creativity in pursuit of competitive advantage (Piasecka-Głuszak, 2015, p. 290). The company organized "kaizen philosophy week" aimed at the development of new ways of improvement by interdisciplinary teams (including operators of the line) and an immediate implementation of the proposed improvements. The focus was set on the observation of processes in order to identify waste, irregularities and hazardous aspects. Then an analysis of the activities was performed in breakdown by those that generate added value and those that are unnecessary. The next steps included the search for new solutions, which would allow eliminating the losses, as well as the tests aimed at checking what effects and problems they may bring about and how the potential problems can be prevented. The ideas, the simulations of which had been successful, were implemented in the process and corrected on a current basis, while all comments were recorded. Finally, the solutions that brought desirable effects were standardized. In total, 60 ideas were recorded, out of which 47 were implemented. The remaining solutions were excluded, because the use of the previous improvements solved also other problems. The methods developed not only helped improve the lines operating in the old system, but also became the foundations for new ones. The fact that production workers participated in their development facilitated considerably the acceptance of the methods by the new team. The implementation and maintenance of the new solutions allowed increasing the productivity by a few percentage points. It was estimated that the innovative ideas in the area of supply of components, which resulted in a reduction of unnecessary transport and damage to components, will bring annual savings at a level of over € 20,000.

3.2. TWI method

When putting the new line into the operation, an emphasis was put on focusing the attention on people, because they are one of the most important factors affect-

ing the change (Byrne, 2013, p. 101). It was easy, as the employees of the new line came from another factory. Considering the fact that they came to a new place and received new duties, they were open to acceptance of new rules. This is what allowed embedding the Lean principles as the core rules which will constitute an inherent element of the new place of work. The Lean approach to management wasn't a new concept for these employees, because attempts were made to improve previous workstations also in the spirit of kaizen, but then it was only an addition to the basic principles of work, while now they are to be the foundations. One of the first tools they met was the TWI (Training Within Industry) method. They could feel themselves the positive effects of this method during toolbox training, where they received full attention of the person conducting the training. Apart from an adequate preparation for independent performance of all activities, they had a comfort to work under the eye of a colleague, not a supervisor, so they felt more freely and were more willing to report any doubts. Currently, a competency matrix is widely expanded on the line. So far, 18 instructors and 9 trainers who educated 62 employees had been trained. It has been calculated that among all the problems occurring at the line, human errors constitute only 2%, i.e. more than twice less than in the old area.

3.3. Employee suggestion system

A suggestion system, which allows employees to submit any comments, has been launched. This system gained credibility thanks to the success of "kaizen philosophy week". Within 3 months, 35 new ideas were recorded, out of which 25 were implemented. In addition, 85 hazardous situations were reported, which subsequently were eliminated.

Table 1. Profits resulting from the implementation of improvements recognized as "good practice"

Area	Number of ideas	One off-cost [€]	Annual profit [€]
Transport	5	135 500	310 000
Packaging	5	6 000	45 000
Poka-Yoke	2	1 500	20 000
Ergonomics	7	1 100	66 500
Organization	3	300	92 000
Visual management	4	3 800	125 000
Computer systems	1	250	6 000

Thanks to the involvement of employees at various levels, many solutions classified as "good practice" were developed and incorporated into the international improvement program for divisions of the company around the world. The awarded solutions concerned primarily such ways of transporting individual components so

that they fully match the implemented system. Many of them were ideas for the use of different types of simple poka-yoke tools as a systematic practice for eliminating errors by locating their root causes (Middleton 2001, pp. 241–252) in order to perform individual activities faster. Estimated annual savings are given in Table 1.

During 3 months of the operation of the line, as many as 27 ideas recognized as good practices on an international scale were implemented. Their one-off cost was less than € 150,000, while annual profit was over € 650,000. It is worth noting that the achievements worked out probably would not be possible without reporting the problems and proposing solutions by employees of the lowest levels, on which the company based when developing good practices.

3.4. Internal audits

Against all appearances, internal audits proved to be a very good tool for collaboration between specialists and workers. The audit team was present from the very beginning of the implementation of the line and it knew the bases of all applicable rules as well as the problems that occurred. Thus the team was composed of the people who helped the production workers resolve difficult situations already at the beginning of the operation of the line. The introduction of audits did not disturb the principles of dialogue between these two parties. The employees felt that they were being evaluated, but they also knew that this was also an opportunity to work out further improvements that can bring them benefits. Results of each audit included not only the completed audit list, but also another list where all the problems and suggestions were recorded. Such a list had on average from 5 to 10 items. In order to sustain the willingness to cooperate, the audit team initiated a program intended for a specific production line. Under this program, all the issues that required improvement, along with the responsible person assigned, were recorded on a current basis. Such a system significantly facilitated the management and control of the planned changes and thus speeded up their implementation, which resulted in growing confidence among the production workers. Table 2 shows the degree of implementation of comments after the first 3 months of the operation of the line.

Table 2. Comments from internal audits

	In total	Implemented	Pending	New
Comments	190	89	101	13
Production	74	31	43	1
Logistics	52	36	16	3
Quality	7	5	2	1
Lean	54	17	37	8

It can be noticed that as many as 190 comments related to the need for improvement or streamlining have been recorded. It is worth noting that more than 46% of them were implemented in a relatively short period of time. Unfortunately, a little less than 7% of them related to the implementation of completely new improvements, while other comments concerned only the improvement of the current state – but these were also changes for the better.

4. THE PROBLEM OF THE SYSTEM APPROACH

4.1. Audit results

During the audit, the focus was set on the aspects that were most important from the point of view of the support chain team, that is:

- confirmation of the availability of the process components (question 1);
- preparation of an adequate number of components during the initial processes (questions 2, 5, 8, 10, 14);
- confirmation whether the number of pitches is adequate (question 3);
- adequate description of industrial trucks and containers (questions 4, 6, 9, 11, 12);
- adequate place for industrial trucks and containers (questions 7, 13, 21);
- adequate amount of the sequential material (question. 15);
- kanban card for each type of component (question 16);
- observation of the kanban rules by the production and transport workers (question 17);
- proper opening of right size cardboard boxes (question 19);
- proper collection of packaging from the line (question 20);
- adequate marking and storage of rejects (question 22);
- compliance with the standards (question 23);
- keeping workplace clean and tidy (question 24);
- maintenance of racks in the designated zones (question 25);
- correct use of the andon system (question 26).

When collecting the results of subsequent audits, the focus was set on the aspects that were correctly built into the system, but their maintenance was still a problem. The results are shown in a graph (Fig. 1).

It has been shown that many solutions could be implemented and maintained successfully. The employees understood and shared the idea of using the andon system. They also noticed that the system of explicit marking of components facilitated considerably their work. They quickly saw the benefits arising from the use of a well-functioning kanban system and other logistics solutions. It can be observed that the biggest problem concerned the maintenance of order at workstations.

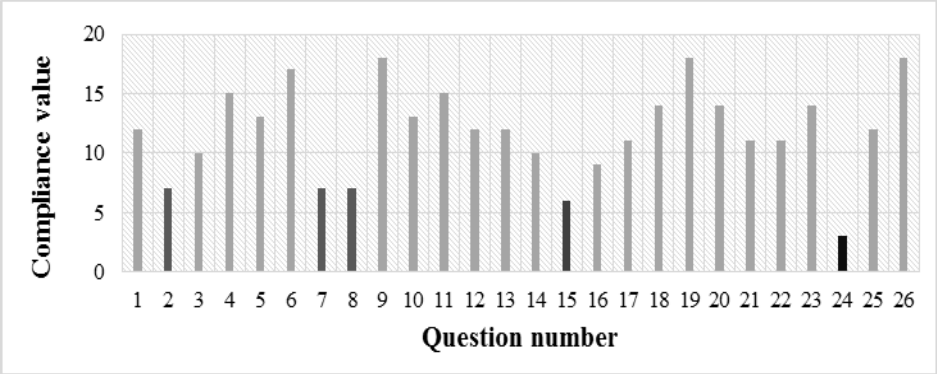

Fig. 1. The compliance value for next audit questions

This inconsistency manifested itself most often in a premature removal of components from containers and their storage near the line. Employees accepted many changes that had a positive impact on the ergonomics of work, but could not understand why some solutions that facilitate their work are implemented, while other are suppressed. Keeping the right number of components on the sequential line was also difficult. This has been mentioned earlier, but a gradual implementation of the poka-yoke tools reduced this problem during the subsequent audits. The third area in terms of the frequency of non-compliances concerned the delivery of an insufficient or excessive number of process components. It turned out that this issue caused most problems in connection with the implementation of the line in the completely new system. All the production and logistics processes concerning a new line were developed simultaneously, but there was no complete system approach that would put emphasis on a proper synchronization of the sphere of assembly with the sphere of initial processes. It is worth noting that in the assembly area there are several different production lines operating both in the old system and in the new one, but at this stage they are not linked with each other in a way that would cause problems. There is a difficulty consisting in the fact that the area of initial processes provides components to lines of both types, so it must remain possibly versatile. Despite a well-developed and efficient way of operation of the new line, its potential cannot be fully utilized because it is hindered by the problems occurring in the previous production area.

4.2. Causes of andon

The analysis of the data from the andon system has also indicated this problem. A complex system based both on light and sound signals was introduced. It was not limited to prompt interventions only, but was used also for recording all problems and finding their causes. Their categories are illustrated in Fig. 2.

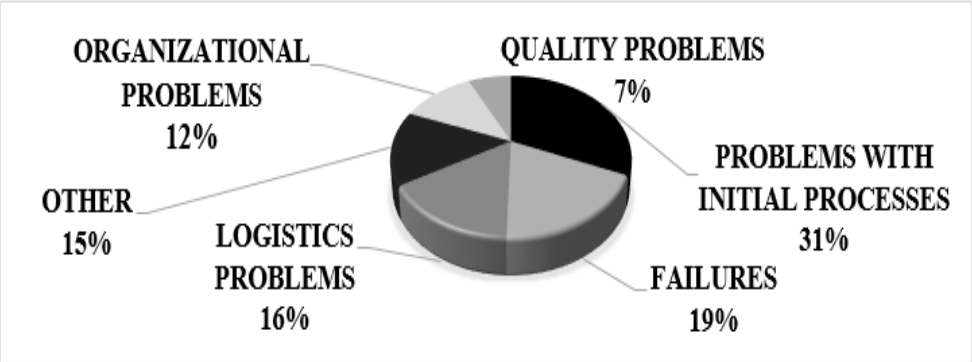

Fig. 2. Causes of andon signals

4.3. Effectiveness of improvements

The new approach has allowed developing the new line in spite of the problems arising from the dependencies within the entire system. The changes in the number of reported losses observed in the course of the implementation of the new solutions are shown in Fig. 3.

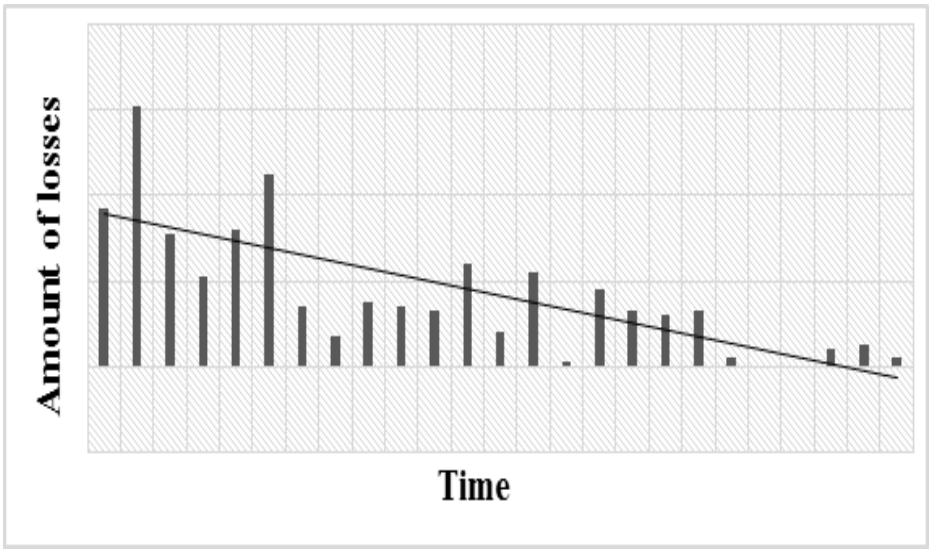

Fig. 3. Amount of losses

It is not difficult to notice the emerging trend line showing that the amount of losses on the line decreases over time.

5. CONCLUSION

To sum up, the introduction of the new line with deeply embedded Lean approach was successful as it met the goals. First of all, the instillation of the Lean management culture has ended with satisfactory results – also in relation to production workers. In this case, a very significant role was played by the fact that it was a new line, a new workplace and new rules built from the very beginning together with rank-and-file employees. This could not be achieved on the old production lines over many years of effort. Another aspect which encouraged employees for cooperation under the new approach was the comfort of work. The new line has been kept in order from the very beginning and a strong emphasis was put on the ergonomics and occupational safety. The employees saw that by working together for the benefit of the company they often worked out better working conditions for themselves. What's interesting, the production workers in certain moments identified themselves more with the Lean culture than the higher-level employees. They willingly reported new ideas, expecting their quick implementation, which allowed improving the line in the spirit of kaizen. The profit from the implementation of the ideas proposed by employees or solutions to the problems presented by them was estimated at a level of approx. € 670,000 per year. The safety on the line and in the warehouse also increased significantly. The effects achieved thanks to the involvement of the production workers proved that their attitude was of crucial importance, while a correct utilization of their potential by the management was a prerequisite for the success of the changes introduced in the spirit of Lean approach (Czerska, 2014, p. 19). In the production area, the ease of making improvements in the new system as compared with the old system resulted mainly from organizational aspects. The use of the value stream mapping or supply chain methods was started with the use of the data collected in the old system area, even before the line has been built. In fact, the new solutions were not really new, because there was no need to change the previous ones, but simply to build them from the scratch. Therefore, some of them had not been possible in the old area just because of the already existing system, which could have not been demolished in order to build it anew – it had been only possible to adapt the solutions to it. Changes made in the logistics area would not require "demolition" of old lines, but only the reorganization of the system. In terms of organization, it would be possible to introduce similar changes in the area of the previous system – racks, trolleys and packaging should be changed, but this would not be difficult (as in the case of attempts to change the layout of the production hall). Thus the ease in relation to the old area resulted mainly from the attitude of the employees and their openness to changes. A well-functioning pull system (in 78% of the kanban type) was successfully implemented. A big success was achieved in the scope of the control of inventory levels thanks to the implementation of the pitch and the right size packaging (74% of which came directly from the suppliers). The time of presence of

inventories on the production line was shortened over two times, while the responses to interrupted sequences were significantly improved. Thanks to the implementation of milk run and the fact that the use of forklift trucks was abandoned in favour of logistics trains, unnecessary transport was reduced to the minimum. Already after several months, all the implemented changes have resulted in an increase in the productivity of the new line as compared with the old one, which is shown in the graph (Fig. 4).

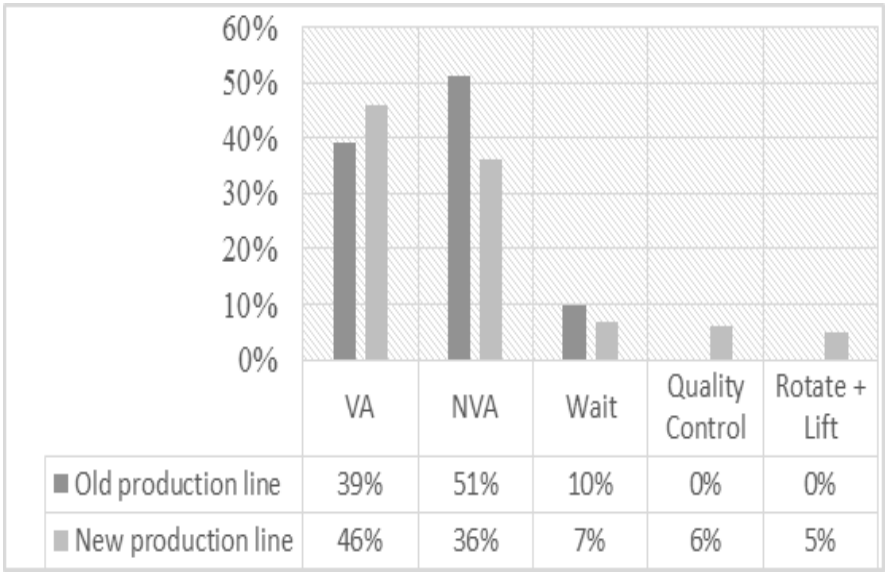

Fig. 4. Comparison of the productivity of the lines in the old and new areas

Thanks to all the efforts taken, the non-value-added activities on the new line were successfully reduced to 36%, which gave a result higher by as much as 15 percentage points as compared with the old area. The percentage of the activities creating the value for the customer was at the level of 45%, which in turn proves a 7 percent advantage over the old system. The waiting time was also reduced and more attention was focused, inter alia, on quality control.

The aim of the studies has been achieved. It consisted in analysing the possibilities and effects of the implementation of Lean management tools simultaneously with launching a new production line as well as comparing the obtained results with the results concerning the old system. The analysis of data showed that the implementation of the system with embedded Lean approach brought better effects than long-term improvements of the existing system, mainly because of the ease in the area of organization, but also due to a greater flexibility of workers. However it has been demonstrated that the potential of the new line was still hampered by the lack of a system approach. In this particular case, a decision has already been made

to rebuild also the remaining lines, and then to adapt the entire area of the production hall to the new system. It should be emphasized that such a fundamental change is associated with a huge investment and thus in many cases the return on the investment can be achieved only after a very long time.

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