Review Article

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Design of production lines and logistic flows in production

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Abstract: The study deals with the topic of the implementation of modern production methods with emphasis on the solution of a new production with the utilization of lean principles and respecting the limiting conditions of the production company. In the summary, an economic assessment of the designed concept using the Lean Method is presented. The outcomes of the researched problem are a performed analysis, its acceptance of the user and the acceptance of the designed concept of the new production line.

Keywords: production line, analysis and work standardization, lean production, visualization

1 Introduction

Lean is an innovative yet time-tested way to lead organizations to efficiency, productivity and continuous process improvement. The implementation of lean methods ensures organizations high quality, efficiency of all processes, work productivity and at the same time, reduction of costs or at least their control [1].

By analysing the work, we obtain information about work processes, which are then analysed in order to discover waste. It can be stated that it focuses on finding the best way to do the activities without all the unproductive actions – simplifying the work performed. The result is

higher productivity by eliminating waste. The output is a new, optimal workflow, which should be defined by an appropriate standard [2].

The study of working methods is a systematic record and critical examination of the ways in which things are done so that improvements can be made [4].

Due to the rising total cost of production of individual products, there is increasing pressure to increase productivity to minimize the risk that, from an economic point of view, there will be a turning point when the company will increase the loss with each piece produced instead of profit. Therefore, while today the concept of lean production is no longer just a foreign word, the analysis and measurement of work are one of the basic knowledge of industrial engineers and lean specialists [3]. It is a relatively simple and at the same time very effective tool in the fight against waste and inefficiency in processes and at the same time the first step on the path to standardization. Under the name of analysis and measurement of work, we can imagine activities leading to the definition of the optimal work procedure and determination of time consumption for individual activities [4].

How to be productive and innovative, how to go slow and fast, how to create your own future from the present, how to create a “blue ocean” and put the competition out of the game? These are the issues whose solutions determine the existence and non-existence of companies in global markets at the beginning of the twenty-first century [5].

There are a number of tools that help with the introduction of lean manufacturing in the company – the 5S method, kanban system, spaghetti diagram and preparation, and their strength flourishes in combination with their use, then the maximum effect is achieved [5].

When making a strategic decision with respect to the risk and uncertainty, it is possible to use various methods and tools, whereas every one of these methodology elements has some advantages and disadvantages and their implementation in practice must correspond to the environment in which the company operates [6].

Tomáš Baťa was an example of the use of work measurement and new knowledge in production processes.

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It was especially typical for the company Baťa that it paid considerable attention to the introduction of new technology into production, product innovation and new thinking at work in general [7]. The main motto, written in large letters on the factory wall, “People of thought, hard work,” was not a phrase, but a project that was carried out literally every hour in every workplace [8].

Automated logistic systems are becoming more widely used within enterprise logistics processes. Their main advantage is that they allow increasing the efficiency and reliability of logistics processes [9]. Kodym *et al.* [10] investigated the use of the logistics chain model (train transport system) as a source for data processing. Fedorko *et al.* [11] resolved the design of production lines and logistic flows in production by optimizing method for layout of workstations, triangular method and computer simulation by program EXTEND. One of the possible ways of effective waste management is environmental consciousness, but the science brings different ways of solution, for example in connection of waste management and simulation of wastes flow [12]. Mikušová *et al.* [13] dealt with the optimization of the production of a selected component in the automotive industry.

Industry 4.0 philosophy and the associated method of digital factory require a wide range of tasks and skills to be managed for their successful application and efficient operating. One of the key competencies for their reliable operation is mastering computer simulation of various logistics processes that take place within the enterprise [14].

2 The theory of work analysis and measurement

The growth of total production costs of individual products causes higher pressure on productivity growth with the aim to minimize the risk that with every piece produced, the loss will increase too. Lean production requires a detailed analysis of work measurement.

These are simple and very efficient tools to prevent wastage and ineffectiveness in processes and they are the first step towards standardization at the same time. The analysis and measurement of work include activities leading to the definition of optimal work process and the determination of necessary time for individual activities (see Figure 1).

The activities linked to the analysis and measurement of work can be divided into two groups as follows: (a) The study of work methods or the work analysis provides information about work processes which are

Figure 1: Scheme of analysis and measurement of work.

further analysed to discover any wastage. It can be stated that it focuses on finding the best processes of how to perform the analysed activities without unproductive operations, i.e. to simplify the performed work. Its result is higher productivity and elimination of wastage. The output is a new, optimal work process that will be defined by a work standard.

The objective of the analysis is a detailed observation of work activities. We repeatedly ask questions whether the operation observed is performed in the best possible way, if any operations could be eliminated, merged or simplified? To perform the work analysis, supportive analytical tools are used, e.g. process diagrams, assembly diagrams or spaghetti diagrams (see Figure 2).

Workers often perform some operations in a needlessly complicated way because they were taught that way and they do not realize it is wasting. Unbiased point

Figure 2: Example of spaghetti diagram.

of view and the right questions can set new and easier work methods.

- (b) Measurement of work – the time determination for given activities. It is a numeric representation of time consumption for individual operations or performed activities. The standards in the observed company were set incorrectly and therefore they failed to meet the workers' productivity performance and deadlines for goods production considering the capacity planning based on incorrect data.

The knowledge of precise time periods for individual operations and setting the optimal work procedure guarantees the best productivity in the given conditions.

3 Analysis of current status

The initial snapshotting of production operations was carried out according to the workers structure (mechanic, electro-fitter, preassembly, floors, testing and packaging) and the stairlifts models. The objective of these snapshots was to discover the potential of unemployed workers from the reasons of wastage or their insufficient equipment with work tools. The output of the snapshots was the data of work times, i.e. time X for the original duration of the operation, time Y lowered by discovered wastage that will be eliminated within lean production implementation and time Z , so-called optimized time providing the production line with the lean production technology will be implemented.

Within the analysis, it was essential to focus on pre-assembly as well because even these activities created a substantial part of the total time consumption. For each activity, a detailed snapshot that summarizes time consumption for the work operation was made.

An example of the output of initial snapshotting during the platform stairlift production is in Figure 3. Technological times refer to mechanic worker 1.

Improvement potentials of technologic times for mechanic worker 1 are stated in the scheme (see Figure 4).

The optimized time consumption of mechanic worker 1 counted 1:38:14 h in total. The total time consumption without pre-assemblies to produce the platform stairlift is stated in Table 1 and it reached the value of 8:51:20 h.

After the elimination of wastage and production adjustment in the perspective of lean production, the time saving goes up to around 18% of the original time. The analysis output is the comparison of the company's standard (Altech) and the standard measured during snapshotting. The result of these measurements for the platform stairlift is stated in Table 2. The required standard is higher by 47.02% than the measured one.

4 Realization of production lines concept

Relating to the results of the snapshots, a new production concept was realized. It was necessary to carry out a

Figure 3: Snapshot example of mechanic worker.

- **Measured time 2:07:05 hours**
- **Working without wastage and activity surcharges 1:59:59 hours**
 - » **Surcharge 5.59%**
- **Optimized time according to the operation frame 1:38:14 hours**
 - » **Potential 18.7 %**
 - » **Unnecessary walking and manipulation**
 - » **Preparation and cleaning of tools**

Walking for material and tools total 26x

Figure 4: Time consumption example for mechanic worker 1.

Table 1: Total optimized time consumption to produce platform stairlift

No	Whole	Total time (h)
1	Mechanical part 1	1:38:14
2	Mechanical part 2	1:31:43
3	Electrical connected	4:19:40
4	Testing	1:07:13
5	Packaging	0:14:30
	Line 2 time consumption	8:51:20

Table 2: Comparison of company's standard and measured standard

Meeting standards		
Date	Product	Product number
Time consumption standard		605.00
Measured time consumption standard		320.55
Difference (%)		47.02

detailed analysis of assemblies in which recommended corrective measures will be used. In terms of production type segmenting, the future assembly concept can be ranked among series production. Serial (repetitive) production refers to the production of one or more similar products. An advanced level of applied standardization enables to reach a significant level of effectiveness. Typically

for the series production, a certain number of specialized devices, including partial flexible automation, are employed.

As a follow-up to the next stage, it was essential to set the number of individual products manufactured daily and the number of workers. The analysis with the utilization of snapshots was carried out within four months using the form of video shooting. The attained snapshots of product manufacturing showed the observed workers' activities and technological work procedures.

On the basis of the attained data, joining the assembly with the pre-assembly was recommended and it was proposed to relocate the electro-assembly working place into a parallel area. The vertical storage system for small-sized parts was relocated into the area of the final assembly and so lower level of elaboration was achieved.

The latter part of snapshotting was focused on the detailed analysis of technological times which would be subsequently used to design the production line with the utilization of so-called balance index.

The client's requirement was set at a product tact of up to 30 min on two lines of 6 tacts and supportive pre-assemblies. The most suitable in terms of universality seemed the concept of so-called super line and because of the fact that the production tact will be set up to 16 min with 12 tacts of the line and supportive pre-assembly. Any limits of this concept were given by the working area and human resources as the line must be operated by fully trained staff at each tact when in full shift performance.

Balancing	
Available time	8:00:00
Net time 80%	6:24:00
Daily requirement	12
Work line	5:30:00
Tact	0:32:00
Number of tacts	10.31

1 line => 16 workers

- 11 tact with a time 32 minutes
- Number of pieces produced per shift 12
- Calculated with 20% losses
=>Theoretically max. 10% potential for the production of 13 pcs per shift
 - » Loss of 10% of crossings
- the line is built as universal
 - » Loss of 10% due to unbalance
- indices reach 96%
- To start both lines at the same time 32 (with holidays and illness) workers (including pre-assembly) => start 1 line and 2 lines occupied as possible

Figure 5: Summary of planned output of Line 1, necessary number of tacts and number of qualified workers.

Figure 6: Design of working place layout.

The planned short production tact would be easier for the training of new workers.

Once the lines were made universal, work procedures and labour intensity were unified. The unified labour intensity got to 5:30:00 h. Balance indices were 90–96%. Two lines were set with the production tact of 32 min with 11 tacts (including packaging), where 22 workers are required. Within the optimization, a new position of handler was created due to the need of supplying individual workplaces during the course of the shift. In Figure 5, the capacity calculation of time needed for one line is stated.

Once the number of tacts was approved by the client, the setting of action plan followed – further implementation of the design and production lines realization to manufacture the final product. Within the concept of the production line, the tacts were divided in a mechanical and electric part with the respect of working position during the work performance (sitting down or standing) – this limitation was also taken into account. Within the project, a design of production working place was elaborated, see Figure 6.

The new layout of the production line involved a new working activity of a “logistician”, who will be responsible

for supplying individual workplaces with the material. Storage boxes create the basic supplying handling unit using the Kanban system. The size of the boxes was determined according to the consumption of particular materials in related workplaces.

The electronic transmission of requests to Kanban is also used for the supply of assembly lines. The electronic data transfer process was recommended to increase the efficiency of individual workstations by adding RFID chip readers, touch tablets and readers. The introduction will increase the accuracy of time consumption tracking at individual workplaces, and the workers will be able to consult the order documentation and, with the use of QR codes on individual fastener packages, create requirements for a new delivery. Thus, the traceability of planned and actual consumption of small materials will be improved.

Based on the steps implementation of the 5S method and the creation of the floor visualization, it was necessary to set standards of the individual workplaces so that it would be possible to check the compliance with these rules.

5 Conclusion

The objective of the study was to present subsequent steps leading to the production optimization in the given company with the setting of production layout and improvement of internal logistics. The research was focused on mapping of the current production status and the basis of obtained data to design and implement a new concept of production lines and afterwards to realize it. In the theoretical part, the authors present different approaches to the analysis and work standardization and they describe methods that are used in industrial engineering.

The analytical part of the study presents the calculated potential which can be achieved by implementing the new production concept. This potential is based on the snapshots of individual workers and on subsequent division in working activities and downtime as well as *Value-added* and *Non-value-added* activities.

The proposed changes in the production process are designed due to the year on year increase in product manufacturing and the present production process did not meet these requirements. The year on year 2018/2019 production growth was as high as 19.6%. The comparison of the initial status and the new capacity possibilities of the production lines shows a production increase by 61%.

Within the analysis of the work performance, the set standards in the company were compared with the actually measured times, including the relevant allowance.

Following the obtained data, a new production concept for the assembly of final products was designed. Not only the design but also the subsequent implementation of this new production concept was considered. In the course of the realization, it was necessary to decide which of the proposed solutions would be implemented. In terms of lean philosophy, one super line with several production tacts would be the best solution. Based on local space conditions, two production lines had to be designed. It was the right decision because the requirements for the final products are constantly changing and two lines are more flexible in responding to these changes. The new production concept was designed so that the planned production quantities could be produced in a single-shift operation without the need for overtime or extra weekend shifts.

As part of the production setup, the internal logistics in the supply of the individual lines and pre-assembly workplaces were changed and a stock rack with a standby stock of fasteners and small materials was designed. The supplied material will bring savings as it will be supplied according to actual consumption and the accounting records will record the actual quantity consumed. Deliveries will be made in so-called external kanban circuit. This setup will result in savings of the warehouse staff.

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