LEAN PRINCIPLES APPLICATION TO DESIGN A PRODUCTIVE WORKPLACE

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Abstract

A great deal of research claims that Industry 4.0 is the future form of industrial development. By contrast, managers of Czech companies claim that their processes are not ready for this conception. Usually they only try to optimize existing production systems. The aim of the paper is to find out whether partial optimization can cause a substantial increase in the productivity. This article focuses on verifying the use of lean principles in production.

It is a simpler way of implementing one of the basic ideas of Industry 4.0. The goal of such a workplace is not only to increase productivity but also to optimize material flows in an enterprise and meet customer demands. Methods of industrial engineering (layout optimization, workplace standardization, work-studies) are used in the article. The desired production cycle was used in the search for a suitable layout and production line balancing. Also, the essential number of operators was considered. In order to find the best layout, we counted time consumption of all operations using two different methods and compared the results.

Keywords: Productivity increase, industrial engineering, production lines balancing, work-study

1. INTRODUCTION

Current general tendencies in the industrial sector are heading toward Industry 4.0, but what is the reality in Czech companies like? Strategic plans of many companies include innovations and investment in new equipment directed at the concept of a "smart" factory. However, the actual implementation is complicated. Any new automated workplace needs to be immediately compatible with all other company information systems and activities (logistic, production and maintenance planning, etc.), which is a problem. Suppliers of fully automated equipment try, quite logically, to convince companies to place as extensive offers as possible. Typically, companies would have to switch to a completely new concept at once, which is impossible. That is the reason why companies keep optimizing their current production systems as much as they can.

One of the possibilities of optimization in production is to find a suitable spatial arrangement of the production line in the given logistic and material flow conditions. The purpose of this article is to check whether this optimization will cause the productivity gains you want. The aim of this paper is to analyse ways how flexibility of two production lines could be increased so that costs linked with ensuring the required performance do not grow due to frequent changes required by customers. Partial aims of this study are determining the optimum number of operators and workplace standardization in order to eliminate wastage. When conducting the analysis, we used general concepts of a lean workplace. Following a timeline of the operations, we suggested sequencing of the lines and a new layout for ensuring an efficient material flow. We also focused on comparing two analytical tools used for determining time consumption - shot of time and micro-mobility study Basic MOST.

2. METHODOLOGICAL BASES

The most frequently generally specified procedures [1-3] applicable to a production cell (line) optimization mention several steps leading to a lean workplace. It is necessary to start by selecting a principal product (or a family of products), set the line´s tact, understand assembly procedures, and know how much time each task takes. Subsequently, it is necessary to determine the line capacity, calculate theoretic need for the number of operators and perform line balancing. It is also necessary to consider the shape of the production line (placement of the machines and partial workplaces), placement of preparations, tools and materials on the line [4,5] Eventually, work procedure standardization and visualization and “shopfloor management” are performed.

Following customer´s information about how many products a customer will buy in a certain time unit we set the line tact time (*TT*). The calculation [6] is made following this simple formula (1):

$$TT = \frac{F_S}{Q_n} \quad (1)$$

where:

F_s - net time available (s)

Q_n - total customer demand (pcs.)

Ideally, tact time equals the total cycle time (*CT*). *CT* is a total of all partial tasks. Task times can be determined by direct measuring or using systems of predetermined times (mircromovement studies). Additionally, in order to balance the line it is necessary to determine the time of operators (*p*) needed [6,7] which is made using the following formula (2):

$$p = \frac{CT}{TT} \quad (2)$$

where:

CT - total time of all operations (s)

If the number of operators is not a whole number, it is usually rounded up. For instance, if p = 4.2 it is either possible to round up the number or to define tasks that will be performed by four operators, while the fifth operator will only perform some tasks and in the remaining time he can be assigned other work (either on another product, supplying the line or with paperwork) [4,7].

Another frequently used indicator [8] is the balance index (*BI*) which shows at what rate the line takt is utilized on average, it is calculated following relation (3). When redesigning existing processes, the BI value should exceed 85 % [7].

$$BI = \frac{CT}{p \cdot TT} \cdot 100 \quad (3)$$

Another indicator used is the coefficient of variation (v_x) [7,8]. If the value of the coefficient of variation in expressed in percentage it informs us how various values differ from the arithmetic mean and it, in fact determines the imbalance of the line (equation 4):

$$v_x = \frac{s_x}{\bar{x}} \cdot 100 \quad (4)$$

where:

s_x - standard deviation

x - arithmetic mean

When designing a lean workplace, it is necessary to take into account the new layout of manufacturing equipment so that it suits operation sequence. Four basic workplace layouts are described [9]: Direct Flow, L Shape, U Shape and Spine Shape. In practice they are commonly combined. Each layout is distinguished with some feature.

The advantage of the Direct Flow is easy access from both sides, easy manipulation and easy planning and management. The L Shape is favourable when we need to isolate dangerous or hard-to-place equipment to the corner. The U Shape is very advantageous when we want to assign a single worker with more tasks as it allows the worker to walk from one workplace to another and it allows for better balancing of the line [4,6]. The Spine Shape is distinguished with the fact that special equipment can be separated and it is suitable for lines with high variability of the manufacturing procedure [10].

In order to define standards of the individual tasks (defining time consumption) we used shot of time. It is a method of direct time consumption measuring, to be precise. On the basis of the defined partial objective we compared measurements using Basic MOST (Maynard Operation Sequence Technique) [8]. This method is used for determining time consumption of the movement study and a system of predefined times.

3. EXPERIMENTAL PART

This study describes optimization of two lines where three products, gear shift covers, are manufactured. Line I manufactures E2 product, line II 9G1 and C14 products. In terms of their manufacturing process the other two products only differ in the last operation, which is why they are placed on the same line. The lines are used in a single shift operation, the shift lasts 8 hours, operators have one break required by the law of 30 minutes and two other 10-minute breaks. The net time available (F_s) is 430 min (25,800s). **Table 1** shows default data.

Table 1 Demands for production, TT and current number of operators [own study]

	E2	**9G1**	**C14**
Demand/shift [pcs/shift]	280	250	300
Line tact TT [s/pcs]	92	103	86
Number of operators	5	4	6

The authors carefully analysed the material flow and the distribution of operations between the existing number of operators for each product. For this purpose, visual management methods were used (lay-out analysis). The original lay-out was unsatisfactory, a new lay-out was proposed. We did not allow the company to publish the layouts. An important conclusion for further analysis in the production of production was the sewing operation.

Leather sewing machine operators are not included in the line as they work about 25 times faster than the line and produce one-day supply for a full line that lasts for a full week, so the leather-like leather components are taken from the line view as an input component. Subsequently, time consumption of all operations was measured.

3.1. Determining time consumption

In order to determine the time consumption, we used motion pictures for stopwatch as well as for motion study Basic MOST that uses a system of predetermined times. The values resulting from stop watch (in tables marked as CHRONO) are arithmetic mean of 20 measurements. In order to define time consumption resulting from motion analysis (in tables marked as MOST) we used data tables [8].

The results of measurements are shown in **Table 2**. The results show disbalance of the lines and the fact that the time consumption of operations resulting from both measurements are almost identical.

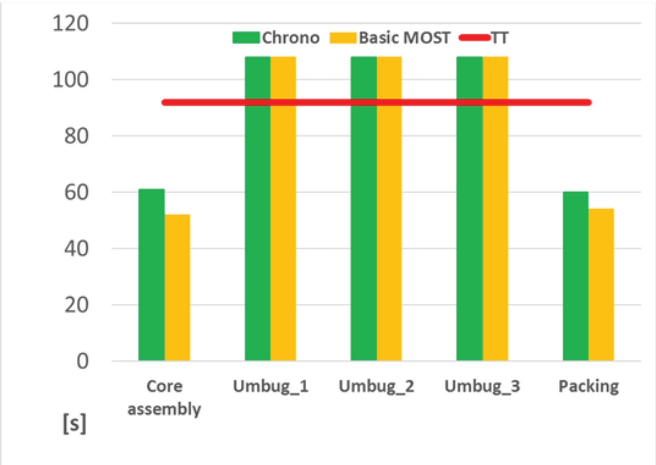

Figure 1 Chart showing the original layout of ine I - [own study]

For illustrative purposes, measurement results are also presented as a chart (**Figure 1**) for line I, i.e. for E2 product. These values represent the duration of each operation. The terms referring to the operations correspond with the terms the company uses in production. Workplace Umbug is on the line three times.

Table 2 Results of operation measurements [own study]

	Položka	E2		9G1		C14	
		CHRONO	MOST	CHRONO	MOST	CHRONO	MOST
Time reserve in TT [s]	Core assembly	31	40	33	53	16	36
	Umbug	-16	-16	-24	-24	1	1
	Cuff	-	-	-	-	-57	-47
	Packing	32	38	44	50	17	29
No. of operators needed *p* [x]		4.8 (5)	4.7 (5)	3.7.(4)	3.5 (4)	6.2 (7)	5.8 (6)
BI calculation *BI* [%]		96.5	93.3	93.0	86.5	98.2	95.9

3.2. Operation balancing

In order to balancing manufacturing operations correctly it needs to be considered what operations can be, in a sequence, divided between two operators so that such division makes sense; while it is of the same importance to take into account possible new workplace layout. A detailed analysis was conducted for each manufacturing process (for each product): their results based on time measurements are shown in **Table 3**.

Table 3 Results [own study]

	Operator	Task	TT [s]	CT [s]	Reserve in TT [s]	Operator workload [%]
E2	1	Core completion + glue application	92	90	2	98
	2	Umbug		91	1	99
	3					
	4					
	5	Packing		82	10	89
9G1	1	Core Completion	103	91	12	88
	2	Umbug		97	6	94
	3					
	4	Packing + glue application		100	3	97
C14	1	Core Completion	86	85	1	99
	2	Umbug		85	1	99
	3					
	4					
	5	Cuff fastening		76	10	88
	6	Cuff ringing		67	19	78
	7	Packing		54	32	63

The particulars of the analysis are shown in E2 product where the most important thing was to eliminate time loss at the Umbug workplace:

- The „screwing“ operation was removed from the Core Completion workstation that takes on average 22 seconds and it was transferred to the Packing workplace. The CT of the operator at the Packing workplace increased from z 60 s to 82 s;

- Furthermore, an operation of glue application a leather cut and a plastic ball was taken away from each operator from the Umbug workplace, which decreased their *CT* from 108 s to 91 s (decrease by 17 s/operator/pc). The operation of glue application was transferred to the Core Completion and the new CT is 90 s (61 s-22 s + 3*17 s = 90 s);

3.3. Comparing the results

The results obtained can be used to change the layout of the workplace. The suggested layout of both workplaces needs to be in line with the operation sequence for all three products so that e.g. operators do not have to change their work positions.

When suggesting the layout for line **I** it was necessary to respect the fact that the demand or E2 often fluctuates. That is why we used the Spine Shape so that a variable number of operators can work at the line while their productivity does not drop.

The suggested layout for line **II** was made with respect to its variability so that 9G1 and C14 products could be assembled as necessary. The layout shape combines the L and Spine shape.

The authors focused on analysing the results of the new spatial layout. We compared the results of the original and newly takted line using the coefficient of variation, which is an indicator of imbalance (see **Table 4**). The comparison was only based on data received from time measuring.

Table 4 Comparing the results on the basis of time measuring [own study]

	E2		**9G1**		**C14**	
	Original	**new**	**original**	**new**	**original**	**new**
Average value [s]	89.0	89.0	96.0	96.3	89.5	76.7
Standard deviation s_x [s]	23.27	3.52	31.2	3.27	24.91	11.25
Imbalance [%]	26.1	4.0	32.5	3.4	27.8	14.7
Change in imbalance [%]	-22.2		-29.1		-13.2	

4. CONCLUSION

The results show that ensuring higher efficiency of procedures can be achieved without an investment. It is true that in case of designing „lean workplace“ the procedures are still dependent on human resources, which are problematic to a certain degree. Once the change in takting and layout was made, the analysed procedures showed an increased flexibility with respect to customer demand. New workplace layout eliminated excessive manipulation and transport in the material flow. At the same time, after introducing the standards at the workplace, the work environment will also be more favourable for the operators.

Finally, we can say that the purpose of this contribution has been validated. The use of lean principles leads to the reduction of time, the optimization of the number of workers in the workplace and the improvement of the working environment, etc. For this purpose, it is necessary to analyse layout and time consumption, specifically:

- logistics and material flow analysis at the workplace,
- analysis of the spatial layout of the workplace and the follow-up of individual operations,
- a detailed analysis of the time consumption of individual operations and their interdependence.

A partial objective of this paper was to analyse the differences when using different tools for measuring time consumption, in particular shot of time and micromovement study Basic MOST. The results at both analyzed lines where very similar, regardless of what method of measuring was used. With respect to the experience gained, claiming that both tools are equivalent in terms of their use would be rather bold. Nevertheless, it is becoming apparent that companies can conduct many analysis concerning time consumption themselves and they do not need to pay for expensive services provided by consultancy companies that usually have experts who are capable of assessing correctly time consumption based on systems of predefined times. Having said that, it is true that these systems are irreplaceable when it comes to designing new workplaces.

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