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Practical Experience in Improving Production Efficiency Through the Introduction of Lean Production

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***Abstract*— the article presents practical experience of reducing losses at a Russian industrial enterprise through the use of a logistic approach to production process organization through introduction of "lean" production, namely the 5C system**

***Keywords*— logistic approach, "lean" production, 5C system.**

I. Introduction

One of the important issues at the present stage is the reduction of costs, i.e. through logistic approaches to production organization. Among the logistic tools, one should specially point out "lean manufacturing", which is based on the principle of value for the consumer, with its core being the process of eliminating losses. Losses include any operations and processes that consume resources, but do not create any value for the consumer.

According to Toyota classification, one can distinguish between seven types of losses of material and information type (1, 2, 3).

Thus, the hypothesis of the study is that, according to the authors, the effectiveness of the company depends on the addition of value, which is reduced due to losses.

II. The Main part

A. Theoretical aspect

The 5C System is the first step of "lean" production implementation, which starts with creation of optimal conditions for performing operations at the workplace through maintaining order, cleanliness, tidiness, economy of time and energy (4, 5, 6).

The 5C System components are: SEIRI – sorting, getting rid of the unwanted elements; SEITON – self-organization, order maintenance, defining the right place for every object; SEISO – maintaining everything shiny clean, systematic cleaning; SEIKETSU - process "standardization"; SHITSUKE - sustaining order and discipline (1, 3).

B. Industrial enterprise portfolio

"TOREX" LLC has been on the market since 1989, starting from 1994 the major activity of the enterprise is the production of steel doors, which ensure safety for people and their property. The company produces and sells more than 20 standards of products (more than 200 types manufactured by individual measurements, considering the requirements of the customer). The range of products is constantly updated. The company has a well-developed sales network in 80 regions of Russia. The company uses the following production equipment: automatic lines (28%), semi-automatic lines (19%), CNC machines (47%), robotic equipment (6%). The enterprise is constantly working towards reducing the cost of production through reducing the number of support and administrative personnel, adjusting production rates, bringing them in line with the level of productivity of new equipment, adopting technological innovations that can lead to reduction of labor intensity and material intensity of products.

However, an increase in the cost of produce has led to the need for a 5C system at the production enterprise. To this end, the existing value streams in the EURO-2 production shop were analysed, since it produces 65% of all products. The main specialization of the production shop under study is doors of standard dimensions, manufactured from blanks (rough material), which are produced on the most manufacturable equipment, which includes the rough material (panel) rolling lines, door frame rolling line, the four-post robotic complex, and the automatic painting line with a maximum capacity of up to 1000 doors per day.

Analysis of the value streams was carried out in the following areas: value stream map design with losses detection (MUDA) on the spot; material flow analysis in the pouring preparation area and "spaghetti" diagram design; analysis of existing schemes for casting process organization; flow mapping for the final assembly site (7, 8).

III. Results of the Study

In the process of designing the site flow map (of the business processes), we identified the problems presented in Table 1.

TABLE I. CHARACTERISTICS OF LOSSES AT THE EURO-2 SITE

Operation title	Type of Loss
Panel selection	Repeated examination
Insulation gluing	2 types of glue, 2 types of insulation
Hinge welding	Hinge sorting
Locks and bolts welding	Selection of lock braces by models and designs
ERW	Panel-frame sorting
	Examination for model compliance
	Bottle replacement wait time (10-20 minutes)
	Repeated count of sets
Panel search and laying	Search for boxes with panels according to availability of boxes with panels
Extraction of templates, cleaning, scanning	Cleaning from duct tape
Installation of templates, clamping and gluing of upper insulators	Cleaning of templates from foam
	Various assortment
	Installation of S010 molding, S10 sheet
Search for and installation of panels + sheets	Panel examination
	Large assortment
Installation of protectors and pan-tilts	Unpacking of pan-tilts and takedown screws
	Bolt cutting
Installation of locks and latches	Unpacking of locks and latches
Finishing	Repeated examination. Finishing.
Packaging of handles and keys	Unpacking of industrial packaging
Packaging	Lift platform
Sorting by pallets	Forming the customer’s order
Installation of doors into the box	Scanning of shipping documents
Dispatch of finished doors to the warehouse	Waiting for transportation

Location of losses can be seen in Fig.1.

The loading of work stations of the casting section can be seen from Figure 2.

TABLE II. ANALYSIS OF THE DOOR PANEL CASTING SECTION WORK STATIONS LOADING

Work stations	Total time, sec.	Number of stations	Number of people at the station	Time with consideration of number of workers, sec.
Panel laying	26,93	1	1	26,9
Insulation	78,89	1	2	39,4
Panel assembly	71,5	2	2	35,8
Encapsulation	104,41	2	2	52,2
Imitators assembly	74,6	1	1	74,6
Packer and upper insulation assembly	51	1	1	51,0
Laying/unloading of panels	46,2	1	2	46,2
PU foam filling	38,9	1	1	38,9
Disassembly of imitators	32,6	1	1	32,6
Panel cleaning after casting	60	1	1	60,0
Door frame assembly	40,3	1	1	40,3
Panel presence in the press	960			
Total	1585,33		15	

For visual clarity, let us present the data for work stations’ loading in Figure 2.

Fig. 1. Work stations’ loading

The analysis results regarding organization of workers’ movement in the section where doors are prepared for casting are presented in the form of a “spaghetti” diagram, which clearly shows the trajectory of the worker, product, transport, tools or raw materials movement across the enterprise (Fig. 2).

Fig. 2. Spaghetti diagram for the section where doors are prepared for casting

Thus, analysis of the spaghetti diagram, drawn for the casting preparation section of the EURO-2 production shop, revealed a number of problems:

- Irrational mutual work station placement, which leads to unnecessary, non-organized movements of workers and materials, and, accordingly, to the loss of working time.
- Violation of the FIFO principle for the flow of panels from the beginning to the end of the casting stage leads to the lack of synchronization of the panel flow with the door frame flow, which leads to creation of additional amount of work related to searching the frames for the cast panels.

The next stage of our study was the analysis of existing schemes for casting process organization. To conduct the analysis, we used the Gantt chart design method to justify the number of press machines used in the production process (each row in the chart corresponds to one press). The result is presented in Table. 3.

TABLE III. GANTT CHART ANALYSIS

Number of press machines, pcs.	Production capacity of 1 press machine, units per shift	Production capacity of 1 site, units per shift	Number of production cycles, units	Cycle length, min.	Effective time, min.	Shift length, min.	Downtime, min.	Effective time coefficient
3	96	288	16	27	432	484	68	0,89
4	96	384	16	27	432	484	68	0,89
5	84	432	14	27	378	484	122	0,78
6	72	438	12	27	324	484	156	0,67

Table 3 shows that when using 3 and 4 press machines at the maximum productivity per unit of equipment, the productivity of the site increases proportionally. With an increase in the number of press machines by one unit, the productivity of one press machine decreased by 12.5%, but the productivity of the entire sector increased by the same value. The addition of the sixth press machine led to a decrease in the productivity of a piece of equipment by 14.3%, which also led to an increase in downtime with almost unchanged productivity throughout the site.

This brings us to the conclusion that the optimal number of press machines for this site is five.

The next stage of analysis was map design of the assembly line in EURO-2 workshop for the panel final assembly. To perform the analysis, let us present the scheme of the whole process in Figure 3.

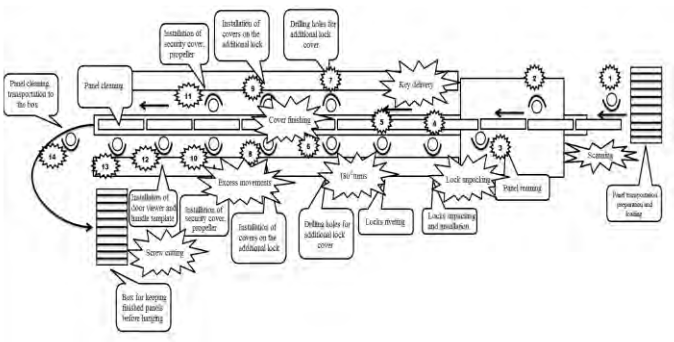

Fig. 3. The current scheme for assemply line organization – final assembly of EURO-2 panels

The figure shows that in the current state of production process there is a large number of losses associated with unnecessary movement of workers on the site, as well as with search and selection of necessary components. Another type of loss, which is typical for the current state of affairs, is the completion of components, for example, cutting screws, fine-tuning adjustments, etc.

Special attention should be paid to the process of providing workers with necessary components. The process is currently organized as follows: the first work station of the site receives the necessary amount of resources without taking into account the planned production operations, after which the worker independently selects the components that he/she needs, unpacks them and transfers the remaining resources to the next work station. This situation is not acceptable from the point of view of lean manufacturing theory, which is to be implemented at the enterprise.

Thus, it was found out that there are problems related to various losses, and an uneven loading of work stations of the production site in the organization of the production process at the enterprise.

Therefore, in our opinion, it is necessary to perform the following actions aimed at minimizing consequences of the identified losses:

a) implementation of assembly line technology at the door casting preparation site;

b) creation of “minimarkets” and implementation of external finishing at the final assembly site;

c) using the information panel for business processes’ visualization.

IV. PRACTICAL IMPLEMENTATION

A. *Implementation of assembly line technology at the door casting preparation site*

Construction of the assembly line production process on the site under investigation should lead to redistribution of transitions between workplaces, equalization of work stations loading, and streamlining of the material and labor flow movement. According to the data obtained during the implementation of this technology at the enterprise, as a result of application of the assembly line technology for production process organization resulted in the work station period reduction by 3 sec.

Let us show the change in the loading of work stations after technology implementation in Table 4 and Figure 4.

TABLE IV. CHANGE IN THE LOADING OF WORK STATIONS AFTER ASSEMPLY LINE TECHNOLOGY IMPLEMENTATION

Work stations	Number of work stations	Number of persons per station	Total time, sec.		Time with consideration of the number of workers, sec.	
			Before event	After event	Before event	After event
Panel laying	1	1	26,93	48,93	26,9	48,9
Insulation	1	2	78,89	94,89	39,4	47,4
Panel assembly	2	2	71,5	82,41	35,8	41,2
Encapsulation	2	2	104,41	55,5	52,2	27,8
Templates assembly	1	1	74,6	53,6	74,6	53,6
Packer and upper insulation assembly	1	1	51	51	51,0	51,0
Laying/uploading of panels	1	2	46,2	46,2	46,2	46,2
PU foam filling	1	1	38,9	38,9	38,9	38,9
Disassembly of templates	1	1	32,6	53,6	32,6	53,6
Panel cleaning after casting	1	1	60	60	60,0	60,0
Door frame assembly	1	1	40,3	40,3	40,3	40,3
Panel presence in the press machine			960	960		
Total		15	1585,33	1585,33		

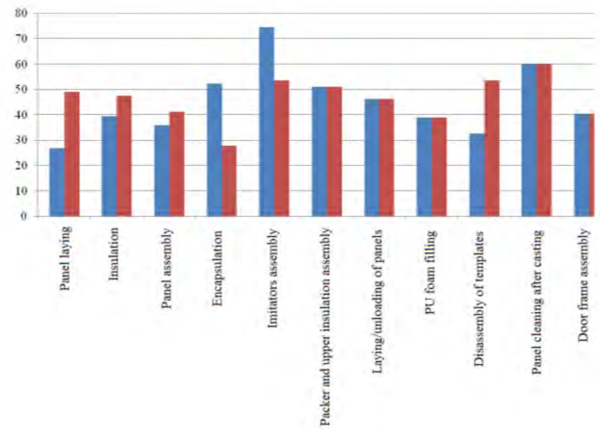

Fig. 4. Loading of the door panel casting work stations after implementation

Figure 4 shows that there is work station period clearing relative to the optimal value of 60 seconds, as well as a decrease in the loading of the previously overloaded template assembly site.

Reduction in work station period leads to the increase in the number of production cycles per time unit, which, consequently leads to the increase in the number of products manufactured.

The estimated period for the EURO-2 workshop is 67 seconds. After event implementation it will be estimated at 67-3 = 64 seconds. Taking into account the fact that working time is 960 minutes per day, one can calculate that after the implementation of the event, the enterprise will be able to produce 900 doors per working day, which will increase the output by 4.44% if compared with the existing production process organization.

B. Creation of "minimarkets" and implementation of external finishing at the final assembly site

For timely receipt of work objects by the production process, we suggest organizing the so-called "minimarkets" of components, which are racks with containers with already unpacked components. Unpacking and packing of these containers is carried out at the warehouse. Containers are delivered by the employee of the warehouse - "mizusumashi" to the work stations (Figure 5).

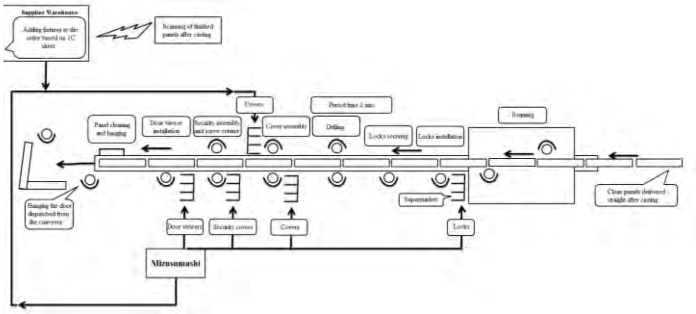

Fig. 5. The proposed scheme of production process organization at the final assembly site

Implementation of this site work scheme, similarly to the first event, allows reducing the production period by 2 seconds, thus, increasing the volume of produced goods per time unit. Estimated increase in labor productivity will be 2.98%.

C. Using the information panel for business processes' visualization

Implementation of this event will make it possible to understand more clearly what is happening at the production site and help to detect vulnerabilities in the work of the team.

Graphical representation of the information panel is presented in Figure 6.

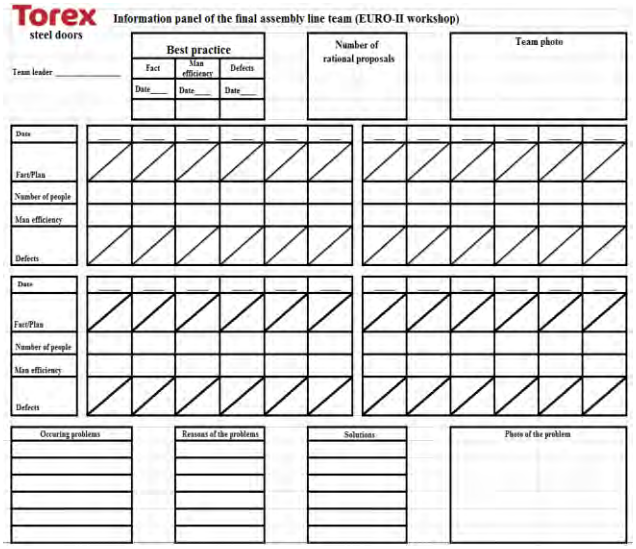

Fig. 6. Information panel sample

Information panel filling out procedure establishes the following stages (Fig.7).

1. The **Foreman** daily, at the beginning of the shift fills out the "Date" and "Plan" sections in a **black marker**.		
2. The **Team leader** daily, at the end of the shift fills out the "Fact", "Number of people" and "Man efficiency" fields in a **blue marker**. If the "Fact" is smaller than "Plan", the value is written in red marker. The team leader keeps blue and read markers.		
3. **«Plan»**	The amount of planned produce per shift	430
4. **«Fact»**	Factual number of produced goods per shift	430 / 430
5. **«Number of people»**	The sum total of hours for all team members / 8 hours. The value has to be fractional.	
6. **«Man efficiency per person»**	Fact / Number of people. The value can be fractional.	150 doors / 1,5 persons = 100 doors per 1 person
7. **«Defects»**	T0he left triangle is the number of manufactured items with a defect in the "pieces". The right triangle is the percentage of items released with a defect = Value of the left triangle / Fact · 100. The "Defects" field filled out by the foreman with a **red marker** every day until 8:40, based on the results of two shifts over the previous day, based on the 1C "Defects by checkpoints" report.	Number of doors with defect; Defect % from fact; 10; 2,33%. Defect % = 10 doors with defect / 430 (fact. doors)· 100 = 2,33%
8. Based on panel indicators and current production conditions, the team formulates problems that impede the improvement of indicators and form losses in the production process (defects, downtimes, unnecessary processing). Identified problems are fixed in the proper place of the panel at any time.		
9. The team fixes possible scenarios of problem occurence in the designated place on the panel at any time.		
10. The team submits proposals for the elimination of identified problems and fixes them in the appropriate place of the panel at any time.		
11. The «Best Practice» section is filled out by the team leader or foreman and shows best results of the team with the date of the event.		

Fig. 7. Information panel filling our procedure

According to specialists' evaluation implementation of this type of information panels leads to the increase in labour productivity by 1,75 % (9).

V. CONCLUSION

Thus, we can summarize the present study with the following conclusions:

- Implementation of the assembly line technology for performing operations at the casting preparation site;
- Designing "mini-markets" and the exterior complete set at the finishing assembly site;
- Visualization of business processes with the information panel.

All of the above allows increasing productivity by 9.6%, therefore, improving enterprise performance.

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