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INTEGRATION OF SIMULATION AND LEAN TOOLS IN PROCESS OF TECHNICAL SYSTEMS OVERHAUL – CASE STUDY

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Abstract: This paper presents the influence of certain lean tools as well as application of statistical analyses and, simulation for achieving greater effectiveness and efficiency of overhaul systems. Application or integration of these tools enables shortening of the repair cycle, reduces the degree of complexity of material flows, an increased degree of functionality of the organization, the use of human resources, the arrangement of the workspace, etc. Combination of different Lean tools presented in this paper can valorize new technological, organizational and informational achievements in process of overhauling technical systems that will secure an even better position on the market for overhaul systems.

Keywords: Lean, effectiveness, efficiency, process, overhaul, technical system, Nagara system, Just-In-Time, Layout, simulation

1. INTRODUCTION

Under the conditions of modern market, the aims in a working process of overhaul systems have to be set up for introduction of functional organizational arrangement of a certain working process which will enable a high level of flexibility in an organization and management oriented to a customer, with defined quality system, competitive prices on the market and as short as possible delivery time.

The design of functional organizational arrangement, measured through the effectiveness and efficiency of a working process, includes in itself organizational arrangement of variety groups of influential factors that are interdependent in many ways. Their effect intensity affects the successful result of every working process and the development of overhaul-production systems. The final aim is to achieve as huge as possible effects using minimal invested resources, in other words, costs per a unit of technical system in overhaul process and/or services need to be as less as possible. In that way, the managers who lead a working process are forced to constantly eliminate those activities which cause loss for the enterprise using certain efficient methods, procedures and tools. Additionally, the minimizations are also transmitted to individual elements of organizational structure as spatial dimensions (object) retaining for that the power and position on the market. Therefore, the overhaul system is reduced to meager, thin, relayed on something, dependant, and its structures become Lean (lean management, lean engineering, lean development, lean production, etc.). The approach to building this kind of state is referred to as a Lean concept (for a more detailed description of Lean concept see [1] to [10]).

By applying different Lean tools, there is an attention to standardize, and then permanently improve the quality of work process in production systems. The reasons for that should be found in the fact that a standard process gives the standard quality of product.

From the above, it is derived the main research problem which is defined in the form of question, and the research in this paper will look for answering the question: How much the application of appropriate Lean tools can contribute to increase the efficiency of enterprises engaged in the overhaul of technical systems, and, in that way, the satisfaction of their customers?

On the basis of seeking answers to these questions, the main hypothesis of this paper has arisen: By applying different Lean tools in the overhaul process of technical systems it is possible to increase the effectiveness and efficiency of companies.

How to know what are the Lean tools that need to be applied in order to increase effectiveness and efficiency? It is one of the most frequent questions that is set in front of companies of every kind now. For this purpose, it will be examined the impact of three different Lean concept tools on increasing the effectiveness and efficiency of enterprises engaged in the overhaul of technical systems. This primarily refers to:

1. Just-In-Time (JIT),
2. Nagara system,
3. Layout.

Effects of applying above mentioned methods and techniques on increasing the effectiveness and efficiency of enterprises will be considered by:

- balance of capacity utilisation, and
- shortening overhaul cycle.

In this paper, effectiveness is a dependent variable. The independent variables are three Lean tools.

2. METHODOLOGY

Reaching shorter duration of overhaul cycle with more effective and efficient work processes in the reparation process of technical systems is in close relation with application level of lean concept, its principles, tools and methods. Experimental researches on its application are carried out in a real overhaul-production system in the overhaul process of the turbojet engine VIPER 632-41/46 with the simulation of a work process by Microsoft Project software tools and they are oriented to three Lean tools:

- Nagara system – it is observed the allocation of workers serving more workplaces or machines before and after introducing this tools by application of the interdisciplinary of an individual. (A factor);
- Just-In-time (JIT) – in the research JIT was treated as a factor which observes time reduction in the work processes applying certain methods, tools and techniques, in other words, as a set of methods and procedures which has for its aim to design a production process in the way to enable much more precisely reply to delivery demands (B factor);
- Layout reconfiguration – Layout is observed before and after the introduction of this tool (C factor).

The tools were treated as factors and their analysis of effects on overhaul cycle time was processed by factor plan 2^3.

The degree of shortening of the overhaul cycle by applying the mentioned Lean tools in the process of overhaul of the turbojet engine VIPER 632-41 / 46 was compared to the mean time of the overhaul cycle in the observed overhaul system, which amounts to 334.92 hours.

3. SIMULATION AND STATISTICAL ANALYSIS

Simulation of the integrated Lean tools (Nagara system, Just-In-Time and Layout) in the process of repair of the the turbojet engine VIPER 632-41/46 in the observed overhaul system was carried out using the Microsoft Project software tool, and it is focused on:

- work distribution, and
- the duration of the overhaul cycle.

A graphic representation of the simulation effect of the observed Lean tools on the distribution of work in the average response of the turbojet engine VIPER 632-41/46 in the observed overhaul system is given in Figure 1 [11].

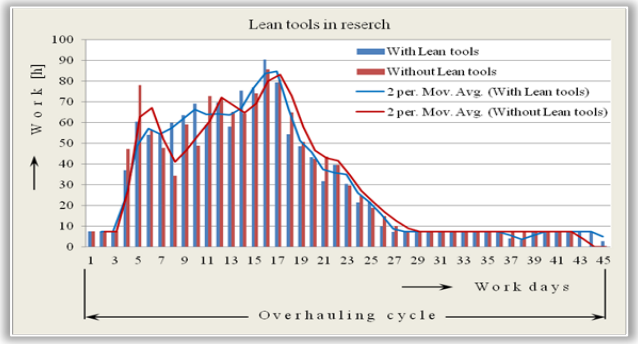

Figure 1. Diagram of work distribution as a function of Lean tools in research

From the diagram in Figure 1, we notice that there is a significant balance of work distribution between the fourth and fourteenth work day, which suggests that the implementation of these Lean concept tools may lead to a overhaul-production system whose balance of work distribution in the overhaul process of technical systems will be acceptable as well as the level of its efficiency.

However, further research should be directed at Nagara system in a business process in order to define the number of workers and interdisciplinary nature of individuals as a function of overhaul-production program of observed overhaul-production system.

Analytical data obtained by simulating the impact of the observed Lean tools on the duration of the overhaul cycle in the average response of the turbojet engine VIPER 632-41/46 in the observed overhaul system are shown in Table 1.

Table 1. The time of overhaul cycle – T_{rc} in hours: initial matrix of experiment

LAYOUT		JUST-IN-TIME			
		without NAGARA SYSTEM		with NAGARA SYSTEM	
		without	with	without	with
with	LAYOUT 1	334.92	338.75	323.75	333.67
	LAYOUT 2	333.67	337.75	321.08	332.67

The layout of experiment plan is shown in Figure 2. The numbers next to the top of the square represent the mean duration of the overhaul cycle.

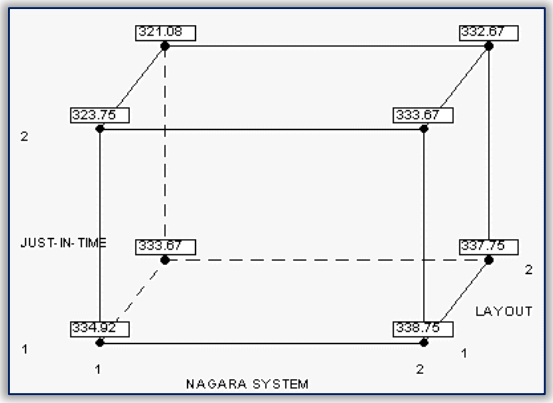

Figure 2. The layout of experiment plan. Cube plot (data means) for Trc

Table 2. The estimated effects and coefficients for T_{rc}

Factorial Fit: T_{rc} versus NAGARA SYSTEM. JUST IN TIME. LAYOUT		
Estimated Effects and Coefficients for T_{rc} (coded units)		
Term	Effect	Coef
Constant		332,033
NAGARA SYSTEM	7,355	3.678
JUST-IN-TIME	- 8,480	- 4.240
LAYOUT	- 1,480	- 0,740
NAGARA SYSTEM*JUST-IN-TIME	3,400	1,700
NAGARA SYSTEM*LAYOUT	0,480	0,240
JUST-IN-TIME*LAYOUT	- 0,355	- 0,178
NAGARA SYSTEM*JUST-IN-TIME*LAYOUT	0,355	0,178

The estimated effects, coefficients for the regression model and the analysis of variance – ANOVA are given in Table 2. The diagram of the impact of observed factors on overhaul cycle (Pareto diagram) is given in Figure 3.

The Diagram shows that the greatest impact on overhaul cycle duration has the B factor, and the A factor comes after it and then the AB factor combination. It is observed that the C factor and AC, ABC and BC factor combinations does not significantly affect the overhaul cycle duration. The regression analysis discovers and sorts the importance of individual factors according to the order:

1. Just-In-Time (JIT),
2. Nagara system,
3. Layout.

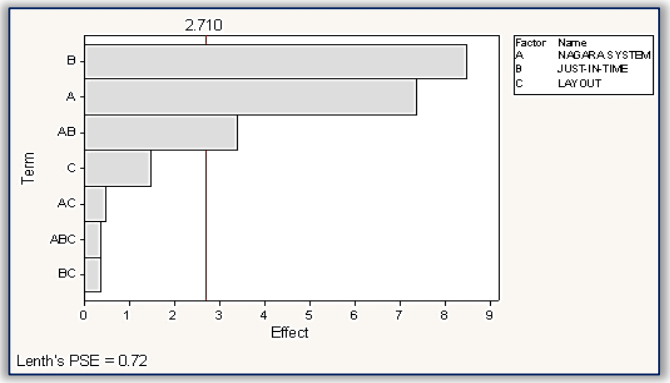

Figure 3. Pareto diagram of the impact of factors on overhaul cycle – T_{rc}

The behaviour of main effects of factors (Nagara system, Just-In-Time and Layout) on overhaul cycle – T_{rc} is shown in Figure 4, and their interaction in Figure 5.

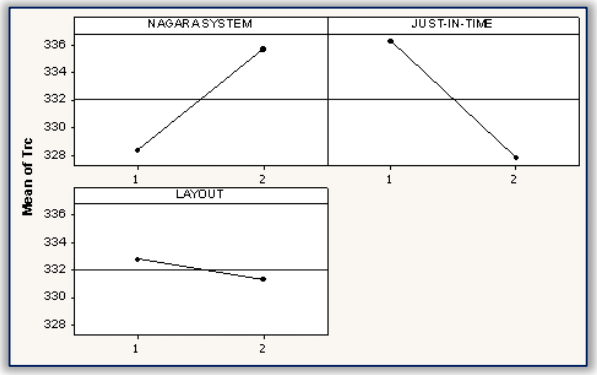

Figure 4. Effects of main factors in the observation of overhaul cycle time

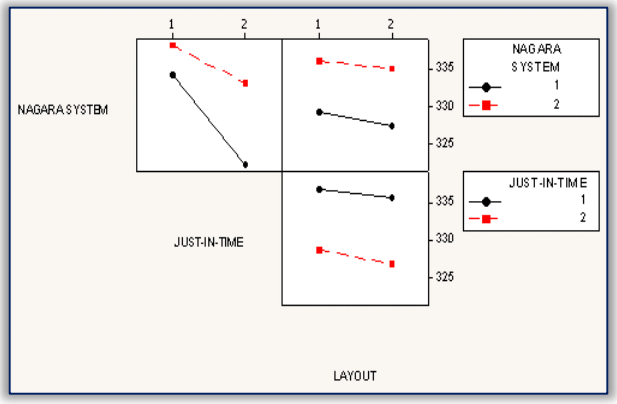

Figure 5. The interaction of observed factors

The regression equation of time behaviour of overhaul cycle – T_{rc} was obtained by regression analysis as follows:

$$Trc = f(A,B,C) = 336 + 7{,}36 \times A - 8{,}48 \times B - 1{,}48 \times C \quad (1)$$

The regression equation gives the rules of overhaul cycle performance bringing the effectiveness of the overhaul process of technical system in overhaul to the functional dependence on the efficiency of work process of overhaul-production system with the conclusion that the implementation of Lean tools may lead to the overhaul-production system with an acceptable level of effectiveness and efficiency of the overhaul process of technical systems.

4. DISCUSSION

The results of the research gave the legality of the distribution of the work and the overhaul cycle in the function of the analyzed Lean concept tools. It has also been shown that using the analyzed Lean concept tools would potentially result in:

- Reduction of the overhaul cycle by 28.3 to 47.8%;
- Reduction of the number of employees (workers) in the repair system by 51.5%. In particular this refers to the possibility of choosing the working potential of qualified and trained workers in performing key work processes;
- The entropy of the system created due to the presence of incompetent workers would be avoided, and they would refuse or prolong the execution of tasks due to the constant search for help in diagnosing the situation;
- Reconstructed spatial structures that would greatly regulate the flows of the subject of work, regulating them in progressive and irreversible flows.

Finally, it can be concluded that by analyzing the results it was found that a reconfigured overhaul system that takes into account in this paper the Lean concepts analyzed tools can reach an acceptable level of efficiency and efficiency of the working process through a satisfactory level of balancing the distribution of work in the process of repairing technical systems, the acceptable duration of the overhaul cycle as well as the regularity of course work flows.

5. CONCLUSIONS

The Lean concept presents a set of efficient and rational procedures in a systemic usage of principles, methods and tools in industrial systems for detection and elimination of useless activities (losses and mistakes) in work processes. This enables necessary conditions for harmonious performance of enterprise functions in a certain time and under certain environmental conditions. The Lean concept introduction affirms the tools which lead to effectiveness and efficiency of a working process what helps to create a productive atmosphere in overhaul-production systems to the satisfaction of workers, users of products/services and society in general. However, further improvements have to be directed towards Just-In-Time and the Nagara system. They are effective for the future work of an overhaul-production system, especially the Nagara system.

It is important to emphasize that the Lean concept is a continuous process and that the whole philosophy of overhaul-production system has to be adjusted to the constant process improvement and loss elimination in the system. Only in this way the overhaul-production systems will have long-term benefits from the Lean concept, and all that will contribute to the modernization of overall production and the rationality of mentioned systems in efforts to achieve as better results as possible under real work conditions.

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