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SIMULATION SYSTEMS SUPPORTING LEAN MANUFACTURING METHODS IMPLEMENTATION

Abstract: In the paper concepts and Lean Manufacturing methods on the example of manufacturing company have been described. Some presented Lean Manufacturing methods have been implemented to shorten the production cycle and reorganized existing production department. To that end, plans and feasible indicators have been used to improve the entire production and show how to use simulation modeling and computer visualization to help achieve those goals.

1. Introduction

Lean manufacturing refers to resource materials, products and facilities used during production cycle and elimination of any wastes that may occur. Concept of lean manufacturing systems is mainly to reduce production costs without the need of reducing employment. Whereas the main philosophy foundations in Lean Manufacturing are three rules: Total Quality Management (TQM), Just in Time (JiT) and clear production state. The most important for TQM is integration of the company's goals with the objectives of the clients and involvement of all employees and executives. For the implementation of TQM principles most commonly used methods are: KAIZEN, 5S, QFD, Six Sigma and Kanban. JiT allows synchronizing supply and production and the most important goals for that method are: minimizing inventory, ensuring timeliness and improving efficiency of production processes. Tab. 1 presents the most important Lean Manufacturing concepts and tools. In recent years, Lean Manufacturing methods have been implemented in many small and big enterprises [1,2,6], their ability and the results obtained were the subject of many scientific studies [1,2,3,6,7,8,9].

To achieve the goal of shortening production cycle and reorganizing production department, six methods have been used: Big Picture, Balanced Scorecard, process mapping, 5S, Visual Control and KAIZEN. Big Picture is an analysis allowing for graphic presentation of entire production cycle and determines value added time. The next method – BSC helps to define goals and indicators for the company, compatible with the existing strategy. Process mapping is similar to Big Picture and presents certain process with more details, so it is possible to see an other potential failure and prevent it. Further methods are 5S, Visual Controls and KAIZEN philosophy that help eliminate problems in the production department.

The results have been verified by using an advanced simulation system- Enterprise Dynamics [3,4].

Tab.1. Main Lean concepts and methods

<table>
<tr><th colspan="7">Lean concepts and tools</th></tr>
<tr><th colspan="2">Organizing</th><th rowspan="2">Unification</th><th colspan="3">Integration</th><th>Improvement</th></tr>
<tr><th>Analysis</th><th>Implementation</th><th>Production</th><th>Products</th><th>Contractors</th><th>Enterprises</th></tr>
<tr><td>Big Picture</td><td>5S</td><td rowspan="2">Single flow</td><td rowspan="2">Enterprise Resource Planning</td><td rowspan="4">Concurrent Engineering</td><td rowspan="8">Benchmarking</td><td rowspan="8">Learning organization</td></tr>
<tr><td rowspan="2">Supply chain matrix</td><td rowspan="2">Standardization of work</td></tr>
<tr><td rowspan="2">Balancing production level</td><td rowspan="2">Total Productive Maintenance</td></tr>
<tr><td>Analysis of the quality filters</td><td>Single Minute Exchange of Die</td></tr>
<tr><td>Analysis of changing in demand</td><td>Total Productive Maintenance</td><td rowspan="2">Kanban</td><td rowspan="2">Total Quality Management</td><td rowspan="4">Quality Function Deployment</td></tr>
<tr><td rowspan="3">Analysis of value added time</td><td rowspan="2">Visual inspection</td></tr>
<tr><td rowspan="2">Material Resource Planning</td><td rowspan="2">Flexible Manufacturing Systems</td></tr>
<tr><td>Correction of errors</td></tr>
</table>

2. Implementation of Lean Manufacturing methods

Analysis of options that will improve manufacturing process began with description of the subject of the research, in order to facilitate further analysis and making implementation of LM methods easier (Tab. 2). Company history, strategy, external and internal stakeholders, physical and human resources, products, services, technological process of selected boiler and SWOT/TOWS analysis have been presented. The analysis of SWOT/TOWS allowed showing specific company defects that are associated both with the production department and contributing to slowing of the entire production cycle (Tab. 3).

Rys.1. View of part of the production department

The next step was to describe the current state (Fig. 1), which presents the production department and a short draft of the final product ordered by the customer. Then, Big Picture analysis was conducted in order to determine the length of the production cycle (Fig. 2), after that Balances Scorecard and process maps were created, which allowed to propose appropriate solutions. The last phase was planning the LM implementation that helped reorganized production department.

Tab.2. External and internal factors in SWOT/TOWS

	External factors		***Internal factors***
	Opportunities		*Strengths*
0,40	A large number of potential customers.	0,40	Personal, modern machine park.
0,20	The increase in the energy market.	0,10	Good position on the market.
0,10	Extending the range of assortment.	0,20	High quality products.
0,30	The discovery of new technologies.	0,20	Competitively priced products.
		0,10	Production of unique products.
	Threats		*Weakness*
0,40	Increase in raw material costs.	0,25	Long-distance transport from customers.
0,30	The increase in production costs.	0,25	Difficulties with transport of oversized products.
0,25	Reducing the demand for the products.	0,30	Small selection of software available in the company.
0,05	Creating new laws and regulations relating to the energy industry.	0,20	High transport costs.

Tab.3. Results of SWOT/TOWS analysis

	Opportunities	***Threats***
Strengths	TOWS Number of interactions: 28/2 Weighted average number of interactions: 6,40 **TOWS/SWOT Number of interactions: 44/2** **TOWS/SWOT Weighted average number of interactions: 10,40** SWOT Number of interactions: 16/2 Weighted average number of interactions: 4,00	TOWS Number of interactions: 30/2 Weighted average number of interactions: 6,90 **TOWS/SWOT Number of interactions: 46/2** **TOWS/SWOT Weighted average number of interactions: 10,50** SWOT Number of interactions: 16/2 Weighted average number of interactions: 3,60
Weakness	TOWS Number of interactions: 6/2 Weighted average number of interactions: 1,85 **TOWS/SWOT Number of interactions: 8/2** **TOWS/SWOT Weighted average number of interactions: 2,70** SWOT Number of interactions: 2/2 Weighted average number of interactions: 0,85	TOWS Number of interactions: 10/2 Weighted average number of interactions: 1,70 **TOWS/SWOT Number of interactions: 22/2** **TOWS/SWOT Weighted average number of interactions: 4,50** SWOT Number of interactions: 12/2 Weighted average number of interactions: 2,80

The proposed method has been selected based on analysis of the existing enterprise state with regard to the current financial capacity of the company. The summary is to provide a schedule for the implementation of selected methods: Kaizen, 5S and Visual Controls that will help the company to apply those. The last step was to verify plans and to do that performed a simulation model of production process and carried on with experiments.

In order to analyze the Big Picture, a set of detailed questions about the requirements of the customers and the physical and information flows as well as their connections has been prepared. The answers to these questions presented in five stages. Then, according to the information contained in the data analysis stage, schematic map was created, depicting all the activities of the following consecutive in the company during the production process (Fig. 2).

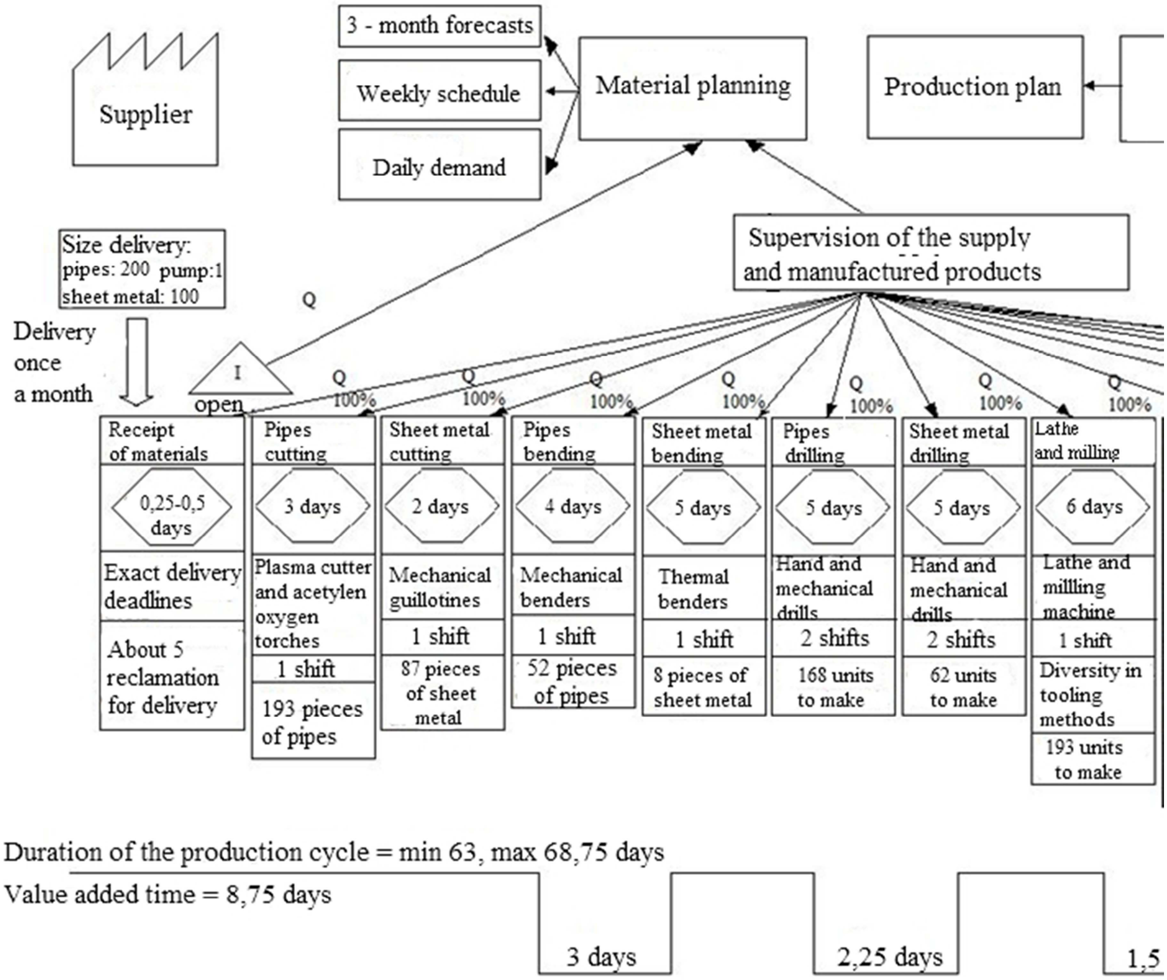

Fig.2. Big Picture

Based on the Big Picture determined that the entire production cycle lasts a minimum of 63 days and a maximum of 68,75 days. Value added time in the cycle was 8,75 days and contained time needed to search and to provide the tools – 3 days, time for employees breaks – 2,25 days, time for instructing employees with work instructions – 1,5 days and time for failure detection – 2 days. As it is seen on Big Picture map, the added value time is considerable, and would be much higher if machine retooling time was counted in.

3. Simulation experiment

For the purpose of verification of the simulation produced changes in the production company, with a view to also determine the possibility of supporting the implementation of Lean techniques using simulation systems, simulation models of production flow in a company were prepared. Models have been created using a simulation system called Enterprise Dynamics. The input data were obtained during the characterization of the subject of research and from Big Picture. Models made for the operating level of production with an accuracy of individual production cells (incl. welders, saws, presses, etc.). For each object in the model introduced relevant parameters, such as work calendar, setup and cycle time, inter-

0resources buffers capacity and information about the control procedures for each manufacturing resource and manufacturing processes. The parameter values can be changed according to the plans of changes developed during the analysis and the results obtained in the previous stages. Fig. 3 is an example of object parameters form and Fig. 4 shows the finished simulation model to conduct the experiments.

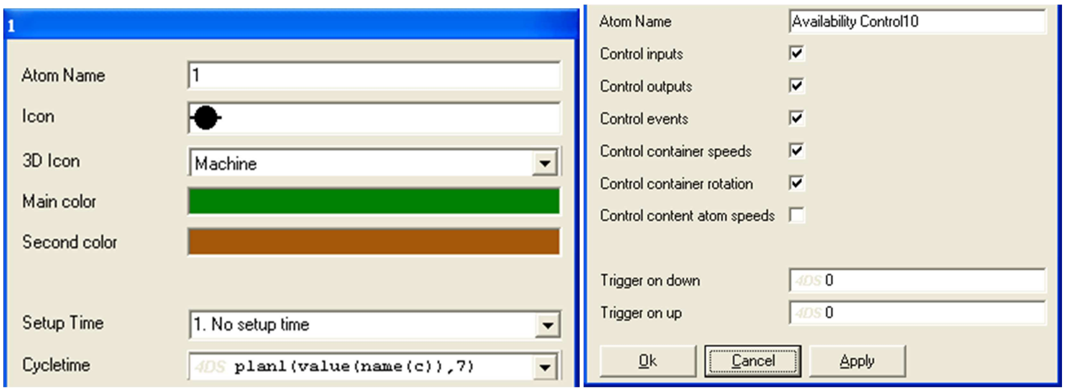

Fig.3. Properties of atom model

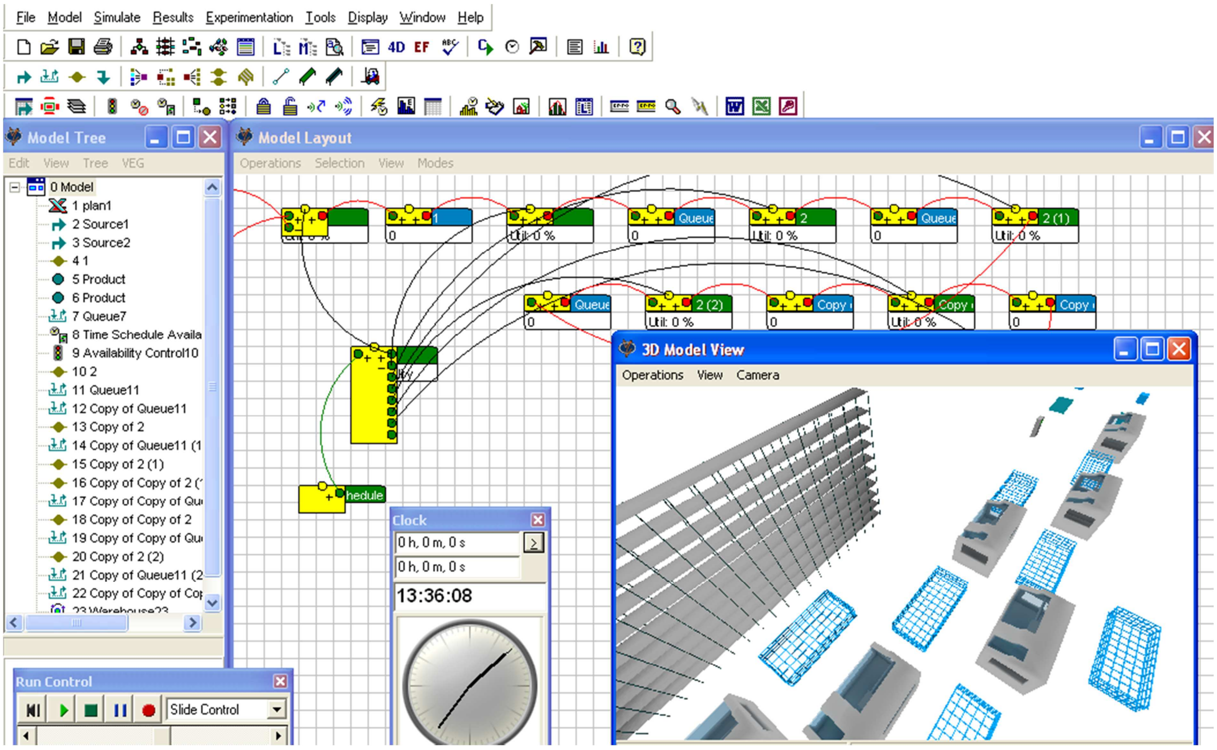

Fig.4. Simulation model

The results of these experiments confirmed the possibility of achieving the expected parameters of the production system and the planned amount of value added time (8,75 days). Support the planning and implementation of Lean Manufacturing techniques through the use of simulation tools, in addition to the possibility of verification possible to achieve results, also gives a visualization of the proposed changes, which helps in parallel to identify other problems and limitations of the production system (for example ergonomic work, possible collisions, the identification of unnecessary stocks, etc.). In addition, the use of computer-aided simulation and visualization enables testing of the alternatives changes in the production organization. This eliminates the need to incur the costs of implementing the various options of changes in the real system before choosing a standard solution.

4. Conclusion

The paper presents an example of implementation of Lean Manufacturing techniques in the enterprise and shows opportunities to support this process by means of simulation and computer visualization. This combination makes it possible (except for the effects mentioned in the previous section) to eliminate the major problems arising in the implementation phase, which include.: lack of support for change on the part of top management, the conviction of the need to maintain a large number of stocks, the reluctance to withdraw from established structures organization or lack of trust in the line workers. The ability to visualize both ways to make changes, implement the amended process or the potential to achieve results, is more effective than dozens of chart analysis results in the traditional form of paper. Another area of use of computer visualization is an area associated with training employees who implement change in their positions, allowing to trace changes prior to production implementation.

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