Optimization of production processes when building a value flow map

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Abstract. The article aims to optimize value flows using the VSM map to increase the efficiency of an enterprise. The article shows that the VSM method is a key method of lean manufacturing. It has already gained popularity. Application of the method is relevant for industrial, transport, educational and many activities. Simulation of production processes reflected as flows for two different industrial activities. This approach allowed for the use of valuation methods to optimize production processes. The approach to assessing the effectiveness of the flow has been changed, and new assessment methods have been proposed.

1. Introduction

The manufacturing is changing. These changes have affected all areas; they are aimed at improving performance at stable production costs. This is possible only using new, high-quality technologies based on lean production.

The term "lean manufacturing" refers to the prevention of losses. This term appeared in Japan. It has been known as a thrifty attitude to everything.

This concept includes a number of areas: the “Andon” system informs company management about problems which allows for the promptest response to any emergency situations or the “5S” system responsible for the rational organization of the working space of the staff.

However, the most interesting system is the VSM (Value Flow Mapping) system involving building of a map on which all production flows are shown. These flows are divided into those that create values and those that do not. Optimization of enterprise flows causes optimization of all its activities which has a positive effect on productivity [4].

Despite the fact that this method originated in the seventies, it was developed only at the end of the twentieth century. Among those who have used this method are P Hines and N Pich [2]. They studied seven types of maps for which they selected tools widely used in other areas, such as logistics, engineering, etc. At the same time, two tools were developed by these researchers.

Chen J C, Shady B D, Li Y [1] built a map for a small US enterprise and were able to reduce reserves for a number of important production sites.

Lu J-C, Yang T, Wang C-Y [3] studied shortcomings of standard procedures for the use of flow maps and proposed their own ones justifying their effectiveness.
In Russia, this method became known after the translation of the book by Rother and Shook "Learn to see business processes: The practice of mapping the value flow" [9]. The book describes the process of map building and all subsequent steps.

D V Kalinin and L V Budchenko [8] developed a flow map for transportation for the Russian Railways. They developed an alternative scenario for constructing a flow map; they selected quality parameters for evaluating production and information operations.

Vasiliev V L, Sedov S A and Ustyuzhina O N [5] studied Russian enterprises using lean manufacturing methods and a flow map (KamAZ, Sollers, AvtoVAZ, Kazan Motor-Building Production Association, Kazanankompressormash, etc.).

Tarasov V N, Ushakova M V, Ushakova Yu A [10] described the process of mapping using specialized software (EVSM). The paper assesses the effectiveness of the system and shows steps to implement the concept of lean manufacturing.

Thus, it the VSM is a powerful tool for visualizing production processes.

In many studies, the issue of efficiency of processes and optimization of value flows is open. In most cases, efficiency is a ratio of time creating the value to the total time spent on production [6]. This approach does not provide any practical tools to optimize the production process. Therefore, an attempt was made to simulate the flow.

2. Materials and methods

The VSM method was the main method of lean production, since it is a key one in analyzing value flows [7].

The flows are reflected using graph models where individual elements select the flows from one production unit to another one, and the graph nodes show equipment operation aimed at increasing the value of a workpiece.

The mathematical interpretation of the value flow is simple, since it operates with additive models. This allows you to perform value flow optimization with simple mathematical tools, without using complex calculations.

3. Results and discussion

Let us consider two variants of the production cycle:
- one type of product is produced by one technological line;
- one type of product is produced by several technological lines;

1 – One type of product is produced by one technological line.

This type is the simplest and most common. The technological process is presented in Figure 1.

![Figure 1. The technological process of production of one type of product by one technological line.](image)

This process can be described as follows:

\[ f(t, e) = t_1 + e_1 + ... + t_n + e_n \rightarrow \text{min}, \]  

where \( t \) – time spent on moving the workpiece using an \( i \)-th machine; \( e \) – time spent on direct processing of the workpiece using an \( i \)-th machine.
To optimize the process, it is necessary to understand its duration. Figure 1 shows that actions can be divided into two groups: direct processing of the workpiece using specific equipment and moving of the workpiece from one machine to another one.

The process that directly adds value is technical processing following rules and regulations. Therefore, it is considered optimized. To improve the characteristics, we need qualitative changes (for example, acquiring more productive equipment). Therefore, this issue is not considered, the process is assumed $e_i = \text{const}$. The sum of constant values will also be a constant value. The optimization function is

$$ f(t) = t_1 + ... + t_n + E \rightarrow \min, $$

where $E=\text{const}$ – total time spent on direct processing of the workpiece.

Thus, movement of the workpiece is optimized.

This process can be optimized by following standards. Each company has to use its own standard.

The calculation principle is as follows. If measure the time of each movement of the workpiece from one machine to another one, one can get a schedule of its movement. Assessing the distance required to move the workpiece at each production site, it is possible to determine those whose movement speed was maximum. Taking this speed as a basis, it is possible to develop a standard for moving the workpiece for each section, taking into account the distance.

In other words, there exist velocity $v$ and distance $s$ at which $t = s / v \rightarrow \min$. If the distance $s$ is a constant value, it is obvious that $t$ reaches its minimum at $v \rightarrow \max$. In this case, there should be a $v_{\max}$ which is maximum. It should be taken as a standard.

Then $t_i$ will always strive for the maximum when the ratio is $t_i = s / v_{\max} = t_{i\max}$.

The effectiveness of each movement ($p$) will be equal to the ratio of the standard to the real time of movement, and the sum of these relations will show the total efficiency of the technological process:

$$ p = \frac{t_{i\text{real}}}{t_{i\text{max}}} \rightarrow 1, $$

$$ P = \sum_{i=1}^{n} p = \frac{\sum_{i=1}^{n} t_{i\text{real}}}{\sum_{i=1}^{n} t_{i\text{max}}} \rightarrow 1, $$

2 – One type of product is produced by several technological lines. This production option is widespread. It is presented in Figure 2.

This process can be described as follows:

$$ f(t, e) = \left\{ \begin{array}{l} t_{i1} + e_{i1} + ... + t_{in} + e_{in} \\ ... + ... + ... + ... \\ t_{m1} + e_{m1} + ... + t_{mn} + e_{mn} \end{array} \right\} \rightarrow \min, $$

This process can be improved by means of standards. There is a variety of machines. It is necessary to determine machines which are located closer. However, some machines are the least efficient, since they are farther away from all others. This will create queues for the most attractive machines and leave the unattractive ones idle.

Given this circumstance, the model needs to be adjusted for the operating time of the equipment required for the immediate processing of the workpiece by the amount of possible waiting time for the end of processing of the previous unit:

$$ t_i = s_i / v_i + (e_i - a_i), $$

where $a_i$ – time spend on the processing of a workpiece using an $i$-th machine.
4. Conclusion
The VSM method is widely used in various fields. It is a promising method which is based on the visualization of production processes. However, the method is not perfect, especially in improving production processes. The regulatory method can improve the efficiency of enterprises. Due to the characteristics of each specific industry and each specific enterprise, there is no method for assessing the efficiency and optimizing processes. Its development is a difficult but promising task.

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