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# Value stream and system dynamics analysis – an automotive case study

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**Abstract**

One way to reduce costs in companies is decreasing inventory levels and improving the value flow. In the present case study a production line where automotive door seals are manufactured was analyzed. First, an analysis with the use of value stream mapping was undertaken in order to identify processes and a material flow. The current state and future state maps were developed. Then, these maps were used to prepare the model of the production system, of which dynamics have been analyzed with the use of Vensim software. As the results, the dynamics of inventory levels along with the manufacturing system were obtained.



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*Keywords:* Value stream mapping; value stream analysis; system dynamics analysis; inventory levels reduction

## 1. Introduction

Costs reduction is nowadays one of the main goals for companies. The companies try to reduce costs in different ways. One way is the inventory levels reduction. In order to reduce the amount of raw materials, work in process (WIP) and inventory level of ready products companies have to identify and eliminate different kinds of problems which are connected to the big amount of inventory. The problems can concern the low quality of products, what causes the necessity of increasing the number of manufactured products in order to ensure that an exact number of good products will be ready to be sent to a client. A high processes variability is another kind of problem. In this situation a company can produce different number of nonconforming products every day, therefore, a company never knows whether it will be prepared to meet the clients' demands. Thus, it keeps a high inventory level just in case. Moreover, machine failures and production downtimes caused by different reasons can force companies to keep high inventory level. At the same time, inadequate manufacturing line organization or improper production control can lead to emergence of excessive inventories. If a week schedule is developed and then each work station works at their own pace, an uncontrolled WIP can appear causing additional costs. Namely, the costs of additional space to keep WIP, costs of additional transportation tasks, costs of unnecessary movements, costs of capital invested in materials, costs of nonconforming products which appeared because of improper WIP protection, etc. For these reasons levels of inventories should be controlled to prevent additional costs. The influence of existing inventory levels on a company lead time (*LT*) can be analyzed with the use of Value Stream Mapping (VSM) and Value Stream Analysis (VSA). Unfortunately, it gives us only a static information about the current situation without the possibility to analyze inventory levels in time. That is why, additional analyses are required to be performed in order to see the dynamics of a manufacturing system (MS) and, particularly, the dynamics of inventory levels. Therefore, it is justified to use a dynamics system analysis.

## 2. Value stream mapping and value stream analysis

Value stream mapping (VSM) and value stream analysis (VSA) are well known methods used in manufacturing processes (MPs) analysis [3, 9, 15, 16]. The main goal of VSM is the presentation of a value flow along with the MP. The data gathered directly from a manufacturing line are


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presented in the form of Current Stream Map (CSMap), which are next analyzed. In order to develop CSMap special symbols are used [14]. The map presents data concerning just one product family. A product family is defined as a group of products that pass through similar manufacturing processes and over common equipment in the downstream processes in the MS [14]. The map is built on the basis of the data concerning a representative of the product family i.e. commonly a product which is manufactured the most often. First of all, in order to build CSMap it is necessary to gather the following data concerning a manufacturing process (among other):

- A sequence of manufacturing processes (MPs),
- Cycle time (*CT*) of the MPs measured in a time study, which gives information about how often one piece of a product leaves a process realized on a workstation,
- Available working time which can be used for MPs,
- Machines or work stations availability for production of this product family,
- Frequency of materials deliveries and the amount of delivered materials,
- Frequency of ready products shipping to a client and a number of products in a shipment.

VSA is made on the basis of CSMap. The main goal of VSA is wastes identification along with the manufacturing line (ML). The results of VSA should give the answer to the question about what should be improved in the ML to eliminate or decrease wastes.

In VSA, among others, the following calculations are made:

- Calculation of processing time (*PT*), which gives us the information about time which is spent for MPs of one piece of a product (Equation 1).
- Calculation of lead time (*LT*), which gives us the information about how much time a product needs to go through the whole production line (Equation 2).

$$PT = \sum_{i=1}^{n} CT_i \tag{1}$$

where: *PT* – processing time [sec], *CT* – cycle time [sec], *n* – number of MPs.

$$LT = PT + \sum_{j=1}^{m} ILTj \tag{2}$$

where: *LT* – lead time [hour], *PT* – processing time [hour], *ILT* – inventory lead time, *m* – number of kinds of inventories.

In VSA we try to answer, among others, the questions how big are inventories and what we can do to decrease *LT*.

On the basis of CSMap and made VSA, using the answers of the presented questions, a future state of value stream map (FSMap) is developed. The map shows the improvements which should be made to obtain ML development. To improve a value flow e.g. SMED or Kaizen can be used [12, 20]. To limit inventories FIFO lanes or Kanban cards with supermarkets can be implemented [19]. A FSMap is only a wish until it is implemented what can take some time.

Unfortunately both, CSMap and FSMap are static and will not give us information about MS dynamics what can be important in the range of inventories level. From CSMap we know what level of inventory we had in a moment when the data were gathered. Next hour, next shift, next day the situation changes. In FSMap, additionally, we have information about what are the minimum or the maximum levels of inventories but we never analyze the dynamics of the inventory levels.

For this reason, to understand better the inventory levels dynamics, it is justified to apply additional system dynamics analysis to understand better the variance of inventories levels.

## 3. The origin of System Dynamics Method and its application to manufacturing systems modelling

System Dynamics allows modelling of the structure of complex systems and processes. System Dynamics was developed as a continuous simulation technique at the Sloan School of Management, Massachusetts Institute of Technology in the late 50s of the twentieth century by Jay W. Forrester and co-workers. The description of the method was published by the author in the article “Industrial Dynamics - A Major Breakthrough for Decision Makers” published in Harvard Business Review in 1958 [6], and in the book “Industrial Dynamics” in 1961 [7]. The book was very important from the point of view of the development of economic systems simulation. The main idea of the method is the perception of a system as a coherent whole in terms of its dynamics. System dynamics approach allows to take into account information feedback existing in the modelled system, as well as it describes the causal dependence of elements of the system under test.

According to Sterman [18] there is no recipe for successful modelling, no procedure one can follow to guarantee a useful model. This is due to the fact that the modelling process is inherently creative, and modelers have different goals and different approaches to their work. However, the correct application of the System Dynamics method requires actions in accordance with the modeling procedure. The first stage of this procedure is to formulate the problem and to determine the goal of creating the model. The next step is to identify the key factors affecting the problem, the main feedbacks and to define the boundaries of the modeled system. The results of these activities allow to perform a verbal description and graphic diagrams depicting the relationship between the elements in the modeled system. In the next stage, a mathematical model of the system is constructed, which is then subjected to simulation. The simulation results (the so-called base course) that show the behavior of the system over time are compared with the available knowledge on the actual system behavior, and they become the basis for the model verification.

The model is verified in order to reach a satisfactory reflection of the behavior of the real system. After the verification process, the simulation of the effects of changes in decision rules can be conducted. Simulation experiments allow to examine the impact of changes in decision rules on