Acta Logistica - International Scientific Journal about Logistics
Volume: 4 2017 Issue: 4 Pages: 23-26 ISSN 1339-5629

doi:10.22306/al.v4i4.76
Received: 05 Dec. 2017
Accepted: 29 Dec. 2017

OPTIMIZATION OF MATERIAL FLOW BY SIMULATION METHODS

Adam Drastich
VSB - Technical University of Ostrava, 17. Listopadu 15, 708 33 Ostrava-Poruba, Czech Republic, EU, adam.drastich@vsb.cz

Keywords: simulation, logistics, material flow, KANBAN, loss

Abstract: In the sphere of production area, methods of simulation of production processes and logistic processes are increasingly used. These methods are mainly used in planning, optimization and operational management of production flows and technologies.Material flow simulation methods are closely linked to information technologies and related statistical disciplines. The combination of these disciplines allows the creation of efficient methodologies for generating material flow through simulation models and related algorithms. Logistic dependencies found through these models are then ideally applicable to serial production lines.

1. Introduction

Based on the above-mentioned findings, it is a cyclical process that brings new scientific knowledge and concepts that enable the implementation of a systemic approach to the solution of logistics problems, new technologies and processes in manufacturing area due to emerging automation and management technologies and actually brings with it new challenges in the field of theoretical research. An important contribution in this area is the effort of many companies to gradually create the basics of management on the 4.0 industry platform. At the early stages of preparation for this business management concept, manufacturing processes focus on integrated product development, production planning, logistics concept and production system layout with a view to minimizing waste times in material flow and operations. All these steps must be targeted and matched by the corresponding strategical processes. One of the tools to recognize company processes as a living organism is to use visualization and simulation of strategic company processes with a focus on continuous enterprise data management [1]. Visualization and simulation are recommended to use because of the overall complexity of data, which can not be easily described using a classical mathematical methods. Instead of an analytical approach is used computer technology to create a digital model of a real system. A simplified display of an existing system, including downstream processes, is considered a model. Modeling is used to simulate the behavior of the real system. We are talking about the simulation model. Through the simulation model, we perform simulation experiments to test the response and behavior of the system, depending on the impulses given. Simulation experiments are based on simulation tools that can be combined with artificial intelligence using the Petri nets, neuron-networks, the concept of building elements, etc. The simulation models can also be used for the virtual implementation of production lines, robotic workplaces, handling elements. The aim is to connect all available information (production documentation, orders, inspection certificates) to database in order to achieve synergy with material flows in the enterprise.

2. Principles of Material Flow Modeling

Material flow is understood as the movement of components in a complete manufacturing process from input of raw materials through semifinished products to final product and dispatch to the customer [2]. An integral part of the material flow is a set of activities and data closely related with a material flow. We call the set of these activities a logistic chain. Activities closely tied to material flow can proceed simultaneously with the material flow, they can follow material flow, or even against the material flow. In many cases, the production stream is monitored separately from the material flow. That is why was created the concept of logistics. From the point of view of strategic management, we consider logistics a set of activities leading to the acquisition, manipulation and storage of input materials, semi-finished products and finished products. The aim is to maximize the profitability of individual orders. These activities form a unified system, which is defined as a set of things and relations between them interconnected in one complex enitity. For definition of system, we then use logic schemes, math and natural language (1), therefore:

$$\text{System} = (Q/F/R/P) \quad (1)$$

where:
Q – set of system elements and **F** is a set of functions
Q/F – set of functions of each system element
R – a set of relations and a **P** set of system elements
R/P - a set of relationships between system elements

The system is also defined by inputs and outputs on its interface. In the system then follows to sequence of states depending on the actual state of the system. The sequence of these states is called a process. The set of processes is then defined as behavior [3]. Complex material flow can be observed especially in series production. Reliability of this system is judged on the basis of reliability theory according to level of automation, manual workplaces, complexity of production operations planning in production process. The basic criterion for assessment of material flow is the distribution of material flow from a time view. We distinguish the discrete and continouos flow. As discrete flow, we consider the transfer of individual entities. As continuous material flow is considered distribution of the medium (compressed air, natural gas, etc.). In the material flow simulation, we deal with a discrete material flow, where we evaluate the movement of individual entities over a defined path at defined time intervals. In order to view the material flow thus defined, we use flowcharts that allow to visualize the desired level of differentiation - movement, waiting, branching, connection, etc.

3. Significant material flow characteristics

We assume a discrete material flow between two sites (*A - source location, B - output station*) on the ***l*** path. The number of through-entities is subsequently defined with respect to the possibility of determining average daily production [*ks.hod*$^{-1}$]. Most simulation studies have the following characteristics:

Throughput λ [*ks·s*$^{-1}$] (2) is determined by the intensity of the inputs and the velocities of the material movement ***v***. If we measure the transport of material on a conveyor with a defined free space of two entities ***s***, the throughput will be given by:

$$\lambda = v/s \qquad (2)$$

We can reach the maximum values (3) in the theoretical case when the distance between individual entities is zero.

$$\lambda_{MAX} = v/s_0 \qquad (3)$$

These simple relationships will be used in simulation models, assuming a constant speed of material movement on a given path. The extent to which the maximum (as is apparent from the theoretical results) of the throughput is reached, is defined, in accordance with the above equation (4), by the ratio:

$$\rho = \lambda/\lambda_{MAX} \leq 1 \qquad (4)$$

If time intervals between discrete values get discrete values, it means *v = const*. and *s = const*. the time between passes can be understood as a random value with a defined probability density and distribution function (5):

$$0 \leq f(t) \leq \infty \rightarrow F(t_K) = \int_0^{tk} f(t)dt \qquad (5)$$

Practically, we consider the time between passes (6):

$$E(t) = \int_0^{\infty} f(t) \qquad (6)$$

This methodology can be applied in any logistic chain. In each logistic chain can delays occur when the material does not move. These delays can have divided as followed - planned delays or as unplanned delays and may be caused by necessary technological times between operations, appearance of non-conformity products in production process, machine breakdowns, etc.

Optimization of this downtime is dealt by Applied Mathematics in Queueing Theory, which uses stochastic models working with individual elements in the system at two levels. Analytical level using known model parameters using probability theory tools and simulation level, which is based on the estimated model parameters simulated behavior of the system [4].

4. KANBAN method flow management

The KANBAN circuit can be considered as a self-regulating control circuit based on the defined type and number of KANBAN cards. A typical feature of this circuit is one station between the supply and customer workstations. A simple KANBAN circuit is represented by the following material and information flow (Figure 1).

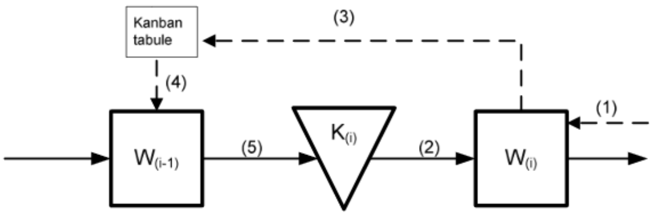

Figure 1 KANBAN circuit, material and information flows

The principle is follows: At the *W(i)* workplace, comes a request from higher-level about the delivery of the product. Components from the KANBAN container *K(i)* are used to meet this requirement, then a card is moved to the workplace *W(i-1)*. This is the impulse for starting the production of the required material in the quantity defined on the KANBAN card. After finishing production on the *W(i-1)* workplace, the card is placed in the KANBAN position *K(i)* and waits for next process at the workplace *W(i)*.

The dual KANBAN circuit (Figure 2) is used in the case of limited storage capacity and increased demand for material flow optimization within the production process and individual operations. The dual KANBAN circuit uses multiple storage space in the supply of individual workplaces to ensure timely optimization of customer supply in the chain and minimization of unused supplies [5]. As part of our material flow simulation, we take advantage of electronic KANBAN with the support of company information system. Electronic KANBAN uses the data and IT infrastructure of the enterprise information system. For information transfer is used the advantages of information technology are utilized to make the classical dual KANBAN combine into one comprehensive electronic KANBAN system, including both the transport and production KANBAN circuits. The advantage of an electronic KANBAN system is the ability to generate requests directly from the corporate IS as shown in the following diagram.

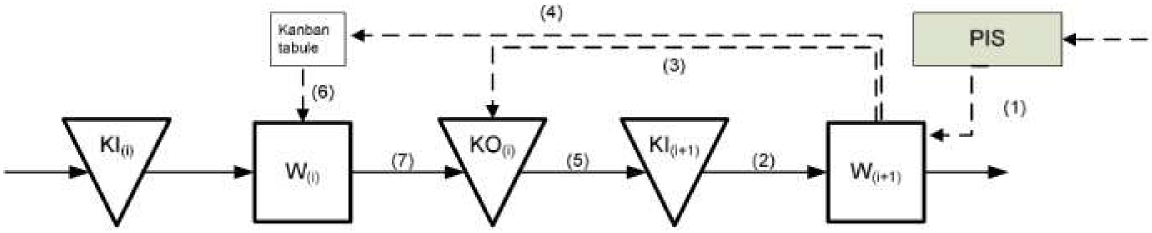

Figure 2 The dual KANBAN circuit

Numbers of KANBAN card for outside circuit is count as follows (7):

$$M = \{DL\ (1+a)\ \} / d \qquad (7)$$

where:

D – Demand for an average consumption of parts per time unit

L - Lead time required to deliver parts from order

a – safety coefficient

d – amoount of pieces for individual KANBAN card.

L - is calculated (8), from the above image, as the sum of the times from ordering the material (sending) from the customer´s KANBAN card

$$L = t5 + t6 + t7 + t4 + t2 \qquad (8)$$

where:

t5 is approaching zero in electronic KANBAN because the transmission of an electronic KANBAN card by the information system is immediate.

t6 is the time to classification a KANBAN card on a KANBAN board from the production of the material at the supplier's workplace.

t4 is the time required to move the material between the delivery station of the supplier's workplace and the customer's input station.

t2 and *t7* are times needed to deliver material from the workstation to the KANBAN station. From information mentioned above:

$$L = t_6 + t_4 \qquad (9)$$

then:

$$M = \{D.(t_6 + t_4)\ .\ (1 + a)\} / d \qquad (10)$$

From the meaning above (9,10) is obvious that the basic requirement of the organization following the implementation of the KANBAN method is to optimize material flow in terms of cost and time waste in the form of surplus stocks. Based on the acquisition of relevant data on the use of KANBAN implementation, it is necessary to measure the performance of this method. Performance parameters are determined by parameters that will be compared to each other. In this case, it is the cost of inventories in circulation, which are a reliable indicator for assessing the material flow economy. Another parameter is the stock turnover. Both of these parameters are directly proportional to the amount of inventory. As inversely proportional to the cost of inventory, we estimate the cost of transporting the material, or the cost of insufficient material within the KANBAN circuit (Figure 3). There is a dependence between both parameters, which can be expressed as the sum of these costs. At the minimum point of this function, we find the optimum amount of inventory, the point where the total cost of inventory is the lowest.

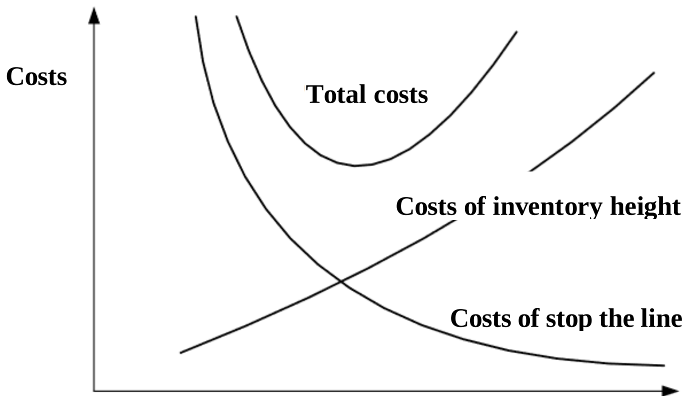

Figure 3 The chart of costs insufficient with the KANBAN circuit

5. Conclusion

From the view of customers and still increasing requirements on quality, delivery dates and final product prices, it is necessary to address the possibilities of optimizing the production process and search weaknesses in this process, in order to complexly increase the efficiency of the company's operation. It has to be done together with the search for weaknesses, which increase the cost of production and negatively affect the production process in terms of cost, quality and overall logistics. Together with the development of automation and artificial intelligence, it is essential for businesses to start analyzing existing processes to further automate and develop these processes. An integral part of this process is the strategy of further development of the company due to the development of our own product and new technologies. This step must be preceded by a perfect mastery and understanding of ongoing business processes. The ability to simulate production processes in an enterprise can provide relevant information about the further development of the process and the optimum material flow. This is supported by company information technology and appropriate technical equipment for data collection. Simulation and subsequent optimization of production processes for companies that want to succeed in global competition must become an integral part of corporate technology, even with regard to the relatively short return on investment associated with a competitive advantage that increases the chances in the global market.

References

[1] PERICA, P.: *Logistický management, Teorie a podniková praxe*, Radix, s.r.o., Prague, 1998. (Original in Czech)
[2] PRECLÍK, V.: *Průmyslová logistika*, Vydavatelství ČVUT, Prague, 2006. (Original in Czech)
[3] KUNCOVÁ, M., MEDONOS, M., DLOUHÝ, M.: *Využití simulačních modelů k analýze výrobního procesu*, Technická univerzita v Liberci, Liberec, 2010. (Original in Czech)
[4] WILSON, L.: *How to implement Lean Manufacturing*, McGrawHill Professional, 2009.
[5] WANG, J.: *Lean Manufacturing: Business Bottom-Line Based*, CRC Press, 2010.

Review process
Single-blind peer review process.