RESEARCH ON THE FLOW OF MATERIAL IN PRODUCTION LOGISTICS

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Abstract   The primary objective of production logistics, in accordance with the laws of 7R, is the supply of the right product, in the right quantity and condition, in the right place, at the right time, to the right customer, at the right price. Specific objectives may, however, be different: they may include improvement of flow continuity (e.g. Womack, Rother) or increased reliability and volume of deliveries (Nyhuis & Wiendhal). In his work, nyhuis, in order to analyse and formalise ongoing flow dependencies, suggests the application of nine laws of production logistics. The article includes a description of these nine critical laws of production logistics and the proposal of the author's own algorithms for use in the quest to improve the continuity of flow.

Paper type: Research Paper

1. INTRODUCTION

A characteristic feature of business management in recent years is the constant search for ways to improve the efficiency of operations. The development of the SCM (Supply Chain Management) concept requires enterprises to transform themselves from function-oriented to process-oriented organisations (Michlowicz, 2013). In addition to the technical sphere, the domain of knowledge which contributes a great deal to improvement in the productivity of manufacturing enterprises is production logistics. In numerous studies on the production logistics of enterprises, most attention is paid to processes related to the procurement, material procurement, purchasing, storage and distribution of products. Meanwhile, in a manufacturing company, the process that involves most of the capital is the manufacture of products. Manufacture makes up the main material stream of the production process flow through the company's individual production cells (positions). This flow depends on many factors, of which the structure of the production system has the most definite effect (Taylor, 2008). The common element that combines different approaches to production logistics is property flows. Hence, new concepts and tasks of production logistics arise. As a way to eliminate waste *(muda)* J. P. Womack and D. T. Jones (Womack & Jones, 2008) recommend the lean approach (*lean thinking*) by creating a stream of values in the enterprise. In the lean approach, one has to go outside the company in order to look at all the actions that make up the process of developing and producing a particular product. According to J. Burton (Burton, 2011), *lean* may be defined most simply as a process of continuous elimination of waste. Access to large spaces leads to the accumulation of large stocks, which leads to the generation of excess manufacturing in the course of WIP (*Work in Process*). In the terms proposed by M. Rother and J. Harris (Rother & Harris, 2007), the most important task in manufacturing systems is the maintainence of continuity in the flow of materials, as well as the constant improvement (*kaizen*) of continuity. In relation to supply chains, P. Nyhuis and H. P. Wiendhal (Nyhius & Windhal, 2009) state that the primary purpose of production logistics can be determined by the ability to increase supply and the reliability of supply at the lowest possible cost of logistics and production. Currently, there are many methods and techniques that can be used in the production-related activities of the enterprise. Hence, proper selection of these (for the enterprise or process) is difficult at times. An extensive array of various tools, techniques, methods assisting the *lean* concept was published by J. Bicheno and M. Holweg in their study *The Lean Toolbox: The Essential Guide to Lean Transformation* (Bicheno & Hollweg, 2008).

It is obvious that from a logistic point of view the appropriate control of the flow of materials within the production system is among the most basic logistical tasks. Here, 'appropriate control' means control that guarantees the continuity of the manufacturing processes in accordance with the 7R rules of logistics (Michlowicz, 2010). In this regard, it is important to properly understand the production process. All customised solutions that contribute to improving the

productivity of manufacturing processes may be of help here. For analysis of the correctness of material flow in production processes, P. Nyhuis and H. P. Wiendhal (Nyhuis & Windhal, 2009) proposed nine basic laws of production logistics (PLP). In contrast, the authors propose their own algorithms to improve production efficiency using, among others, VSM mapping methods and TPM methods of maintaining the efficiency of machines.

2. LAWS OF PRODUCTION LOGISTICS

According to P. Nyhuis and H. P. Wiendhal, the laws of production logistics (PLP) are universal statements that describe the relationships between the various process parameters. Six of these (the first through the sixth) are supported by mathematical descriptions, and the remaining three stem from manufacturing practice.

2.1. The first law of production logistics: 1PLP

The input rate and output rate of a workstation have to be balanced over the long term (Nyhuis & Windhal, 2009).

The first law of production logistics can be justified simply. Each process is characterised by certain efficiency which, at a given moment, need not be used in its entirety. Efficiency available at a given time is the upper limit of current processing capacity in the process (production capacity). If for a longer period of time the system load at its input exceeds the available efficiency, the output level will be equal to the latter value.

2.2. The second law of production logistics: 2PLP

Tte throughput time and range of a workstation result from the ratio of the WIP and output rate (Nyhuis, Windhal, 2009).
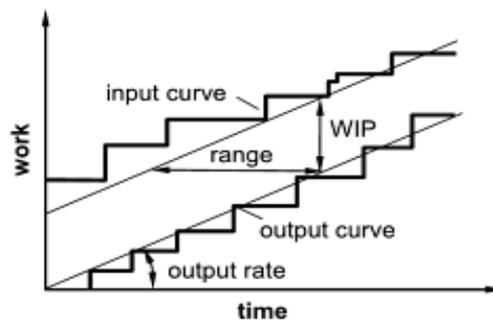

Fig. 1 The second law of production logistics: 2PLP (Nyhuis & Windhal, 2009)

If it is assumed, for the course of the process, that constant values of input and output are maintained, the only way to shorten throughput time is to reduce the level of WIP. The impact of the work in progress and the output level on the occupancy of position results from the definition of this value drawn from the funnel model and Little's laws. The graphic expression of the second law is shown in Fig. 1.

2.3. The third law of production logistics: 3PLP

Decreasing the utilization of a workstation allows the WIP and throughput time to be disproportionately reduced (Nyhuis & Windhal, 2009).

According to the theory of LOC (Logistic Operating Curves), allowance of a minimum loss of use of a position enables a significant reduction in WIP and shortening of throughput time.
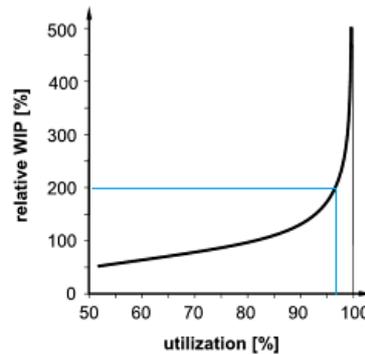

Fig. 2 The third law of production logistics: 3PLP. (Nyhuis & Windhal, 2009)

From analysis of Fig. 2 it follows that to attain 100 percent utilisation of equipment, it is necessary to preserve the value of WIP at five times the stated minimum value of WIP for an ideal curve (WIP_{min} – the amount of work in progress in an ideal process), while reducing the value of the first magnitude by 3.5%, enabling reduction of work in progress of up to 200% of the ideal $WIPI_{min}$.

2.4. The fourth law of production logistics: 4PLP

The variance and mean of the work contetnt determine the logistic potential of the shop (Nyhuis & Windhal, 2009).

Standard deviations in operation-specific work content affect the rate of growth of the output value. For large variations in work content the output function depending on WIP grows slowly. Thus, one can observe the extension of throughput time. This means that for a given efficiency and output level, in order to preserve flow continuity, it is necessary to maintain a higher level of WIP process than at the small work content variation.

2.5. The fifth law of production logistics: 5PLP

The size of the WIP buffor required to ensure the utilization of the workstation is mainly determined by the flexibility of the load and capacity (Nyhuis & Windhal, 2009).

To suppress variation of the input, certain excess WIP is created (relative to the ideal minimum value) in the process. The WIP level can be significantly reduced, provided that it is possible to adjust efficiency to the current load on input, to give up a certain portion of orders, or to redirect them to other positions or to other companies. The process should therefore be characterised by a degree of flexibility. An illustration of the fifth law of production logistics takes the form of dependencies as depicted in the graphs in Fig. 3.
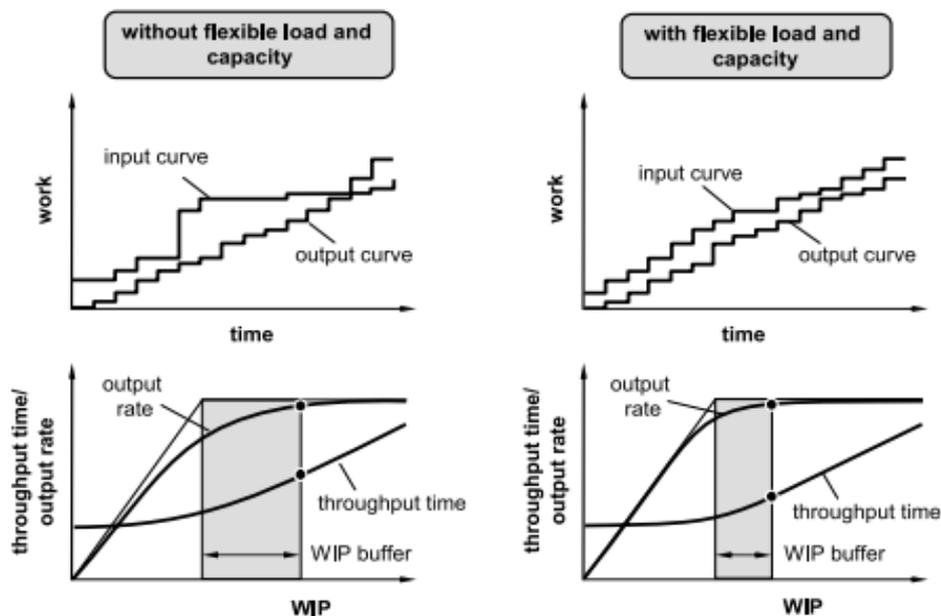

Fig. 3 The fifth law of production logistics: 5PLP (Nyhuis & Windhal, 2009)

2.6. The sixth law of production logistics: 6PLP

When the orders are processed according to the FIFO principle, the inter-operation time is independent of the operation's individual work content (Nyhuis & Windhal, 2009). Should the system utilise a FIFO rule, the work content of the tasks affects only the operation time. The time between operations is, however, dependent on the value of the WIP in the process. This time is not associated with the work content of the operation; thus it can be concluded that this parameter characterises merely the position, not the process itself.

2.7. The seventh law of production logistics: 7PLP

The mean throughput time can be influenced significantly by the applied sequencing rules only when there is a high WIP level and a broadly distributed work content (Nyhuis & Windhal, 2009).

In terms of the entire process, a wide variation in work content affects the average throughput time, whereas this dependency may be different for different sequential rules. Dependencies resulting from the seventh law of production logistics are shown in Fig. 4.
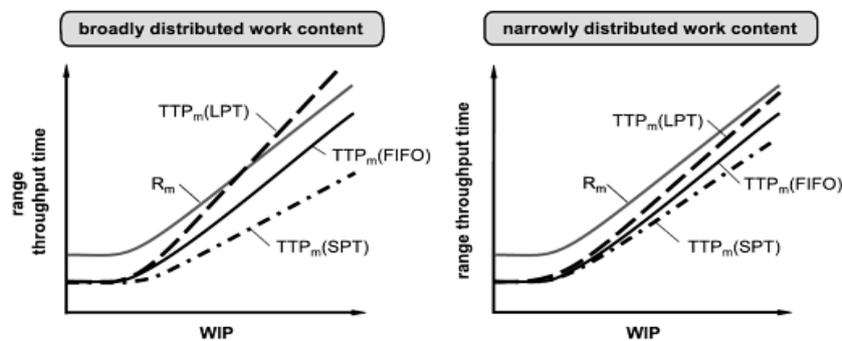

Fig. 4 The seventh law of production logistics: 7PLP (Nyhuis & Windhal, 2009)

2.8. The eight law of production logistics: 8PLP

The throughput time variance is determined by the applied sequencing rule, the WIOP level and the distribution of a work content (Nyhuis & Windhal, 2009).

Distribution of the scope of work specifies a certain minimum level of variance in throughput time which cannot be exceeded. The choice of the sequence (SPT, LPT, FIFO) also has an effect on the variability of variance; the wider the distribution of work content, the clearer this choice is. WIP variability affects throughput time variance in cases where LPT and SPT rules are applied.

2.9. The ninht law of production logistics: 9PLP

The logistic process reliability is determined by the mean value and distribution of the throughput time (Nyhuis & Windhal, 2009).

In order to successfully plan the production process, it is necessary to create conditions under which throughput times as short as possible, but generally uniform, will be achieved. The smallest variation in this parameter causes uncertainty in the production schedule. To ensure the safety of the flow stream, thrpughput times greater than those assumed are adopted. This enables the creation of a time buffer and ensures the continuity of the flow of material.

3. FLOW TESTING ALGORITHMS

Production system in SCs supply chain

The production system can be variously defined. Using the simplest definition of the system *in terms of the theory of systems* it can be stated that the production system (functional, technological) is a structured set of elements and relationships between them (Durlik, 2005) (Lodding, 2013):

$$SP = < \{ X, Y \}, R >,$$

where:

$X = \{X_1, X_2, ... X_i, ... X_M\}$; for $i = 1, ... M$ − set of external magnitudes describing the input elements (materials and parts, equipment, personnel, information, capital, energy);

$Y = \{Y_1, Y_2, ... Y_j, ... Y_N\}$; for $j = 1, ... N$ − a set of external magnitudes describing output elements (finished goods, services, production waste, information);

$R = (R_X \times R_Y \times R_T \times R_Z)$ − material, information feedback (relationships) between elements (X, Y, T, Z) of the SP system.

Fig. 5 shows the general form of the production system, indicating sample elements and interrelationships.

The experience of the authors enables the conclusion that the task of introducing the improvement of continuity can be described in several stages. At the first stage, a very precise identification of all processes associated with production and logistics is required. After identifying and determining the actual purpose of improving production efficiency, the proper choice of methods and tools to achieve these goals should be initiated. Thus, the initial activities include two stages:

Stage I – identification of the process – activity: 1, 2, 3, 4
1. Selection of the process for analysis.
2. Drawing up an accurate diagram of the technological process.
3. Collection of data on the process, including orders, deliveries, inventories, etc.
4. Determination of basic parameters and values describing the process, execution of the necessary timekeeping for the timing of operations.

Stage II – The choice of methods and improvement tools (e.g. VSM, TPM) – actions: 5, 6
1. Description of losses and waste in the process (e.g. 7 *muda*, 6 big losses).
2. Tool selection.

Figure 6 shows the first two stages of an algorithm for improving efficiency in the production system

The consecutive steps necessary to achieve the desired improvement of the functionality (effectiveness) of the operation, as well as to ensure the continuity of the flow of materials, depend on the choice of method (tool).

If the VSM (Value Stream Mapping) mapping method is chosen, the algorithm is described by the successive stages III, IV and V.

Stage III – elaboration of the map of the existing state – actions: 7, 8, 9, 10
1. Development of icons for the process.

2. Preparation of a map of the existing state (readable and in an appropriate format, such as A2).
3. Determination and collection of information about possible proposals for changes to the existing system.
4. Plotting the proposed changes on the value stream map.

Stage IV – introduction of changes – actions: 11, 12
1. Preparation of arrangements and deadlines for possible changes.
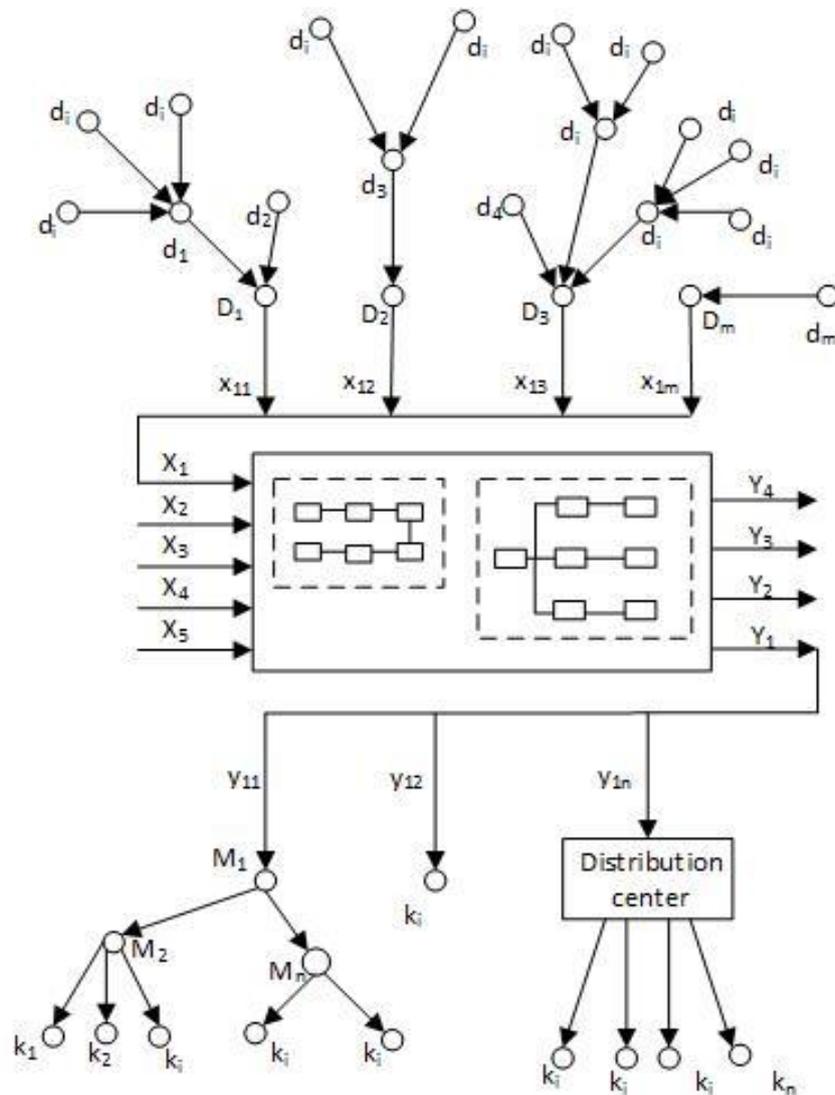2. Introduction of changes.

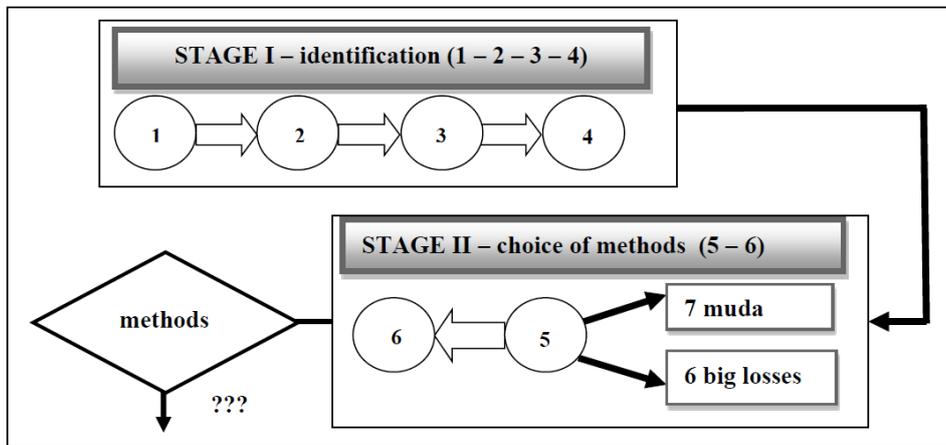**Fig. 5** The production system within the supply chain

Fig. 6 Algorithm: choice of methods for improvement

Stage V – analysis of results and improvement – actions: 13,14
3. Analysis of the effects after introducing the changes.
4. Insistent implementation of the principles of *kaizen*!
Figure 7 illustrates the stages of an algorithm utilising the VSM mapping method.
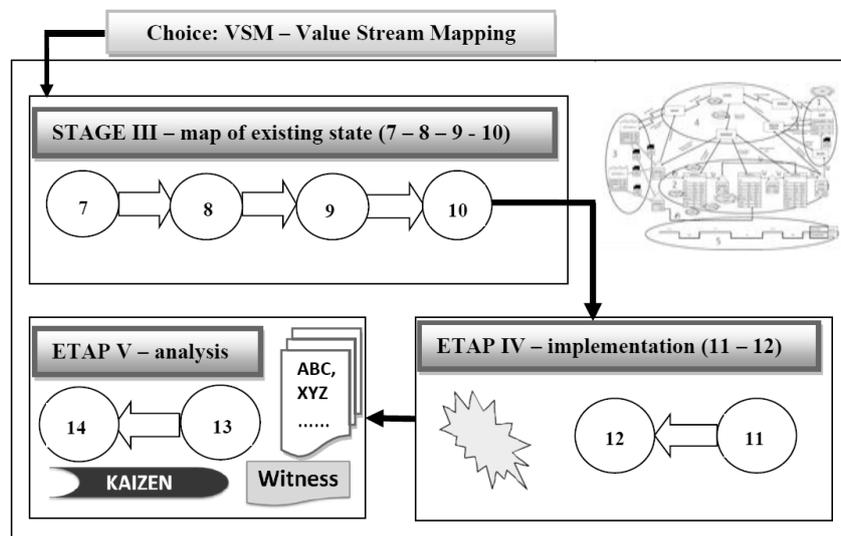

Fig. 7 Algorithm: improvement via the VSM method

As was true of the TPM method, the algorithm takes stages III to VI into consideration.

Stage III – identification of the functioning of machinery – actions: 7, 8, 9
7. Identification of failures and downtime.
8. Plotting of Pareto diagram – causes of failure. Selection of the reasons for improvement.
9. Determination of objectives – limit values of MTTR and MTBF.

Stage IV – determining the OEE efficiency ratio – actions: 10, 11, 12
10. Determination of the availability indicator for the lines (available time net, working time).
11. Determination of the process efficiency ratio (achieved efficiency, nominal efficiency).
12. Determination of the quality indicator (achieved quality, desired quality).

Stage V – introduction of changes – actions: 13, 14
13. Development of time schedule for implementing changes in the area of reducing the number of machine failures.
14. Introduction of changes aimed at improving the indicators of availability, efficiency and quality (of machines involved in the process).

Stage VI – analysis of results and improvement – actions: 15, 16.
15. Analysis of the effects after introducing the changes.
16. Insistent implementation of the principles of *kaizen*!

These two exemplary methods are very often used in manufacturing companies. The experiences of companies that strive for continuous improvement of productivity show that the onset of improvement should be the implementation of the principles of '5S' (5 Pillars of Workplace Visualisation).

4. CONCLUSION

In modern enterprises, the competencies of production logistics and production engineering increasingly overlap, and the area of these competencies is expanding. Production management, in the broadest sense, currently offers many different methods and techniques for improving the functioning of production systems. Some of these methods have been developed within the framework of *Lean Management*. Widely known systems are related to the organisation and control of property flows, among others: The five pillars of visualisation 5S, 7 *Muda* (wastage), SMED (quick changeover), 5W+1H (why and how), JiT (just in time), *Kanban* (control via charts) and integrated IT systems of MRP and ERP range. Production logistics also faces these challenges. Improving value streams through the use of VSM mapping methods and maintaining the machines in high efficiency in terms of TPM are techniques increasingly utilised in manufacturing companies. In many areas, a very helpful tool takes the form of the laws of production logistics (PLP), as well as original algorithms of flow analyze.

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