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APPLYING THE BASIC LAWS OF PRODUCTIONS LOGISTICS AS A MEANS OF IMPROVING PRODUCTION PROCESSES

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Abstract: *This article contains a description of applying the program "Witness" to depict the dependencies between parameters describing the production system. Process perfecting in production companies typically aims at minimizing the throughput times, optimizing the utilization of machines and equipment, or generally reducing costs related with the production process. The application of the means of modeling material flow in order to foresee the consequences of planned actions and their validity has been proven by employing one of the basic laws of productions logistics.*

Key words: *Basic laws, simulation, witness 13*

1 INTRODUCTION

Presently, undertaking actions aiming at maintaining material flow is becoming a natural part of realizing production processes. The next step should be constant perfecting this flow [1]. Many sources point the idea of Lean Thinking [2] as recipe for achieving the assumed plan. It focuses on identifying and eliminating any wastefulness by transforming it into a value which adds to the product. The popularity of this concept keeps on growing. Despite many undoubtfull advantages however, this method might be questionable when it comes to the costs of implementing or profitability of such an idea in a small or medium company.
An alternative, or a compliment to this approach could be methods focusing on more than just quality analysis, but also a quantitative approach to the subject which can define the dependencies between different parameters of the production process. One of these methods is Logistic Operating Curves [3].

2 LOGISTIC OPERATING CURVES

Description of the method is based on literature [3]. Logistic Operating Curves (LOC) consists in analyzing and utilizing a series of dependencies and diagrams which help identify the cause of deviations from production schedule, and allows for undertaking adequate measures. The basis for these are such models and methods as the Funnel Model, Throughput Diagram or the Queuing theory [4]. The characteristic feature of LOC is that the analyzed parameters are depicted not only as a function of time, but as another crucial value – Work In Process (WIP). A graphic representation of these dependencies allows one to simply and quickly see the dependencies between occurrences.

One of the advantages of applying the aforementioned method is the possibility of a quantitative description of relations, which to this day have only been described quality-wise. The dilemma concerning the choosing of a logistic objective which must be achieved by a company in the process of perfecting, may serve as an excellent example [5]. From the productions` standpoint, achieving the minimum throughput times and rarest changes in production schedule is most profitable, while from the economy's standpoint, maximal utilization of equipment is crucial. Eventually, taking actions in each of these fields leads to an improvement in the continuity of production flow and in the end to a general reduction of costs in realizing the production process. However, these two approaches contradict each other when approached separately. A graphical representation of the system`s parameters in relation to a single value (in this case WIP) and a mathematical description of these dependencies opens an easy way of manipulating certain values, and how will such action influence the remaining parameters and the entire efficiency of the production system.

There are three types of reference processes to which the whole production process can be divided – production, transport and storage. To each of these, LOC may be applied. These are drawn for four parameters which have the greatest impact on the production process: schedule adherence, throughput time, output rate, cost, but may also be used e.g. for utilization. Pic1 shows example curves for the reference process.

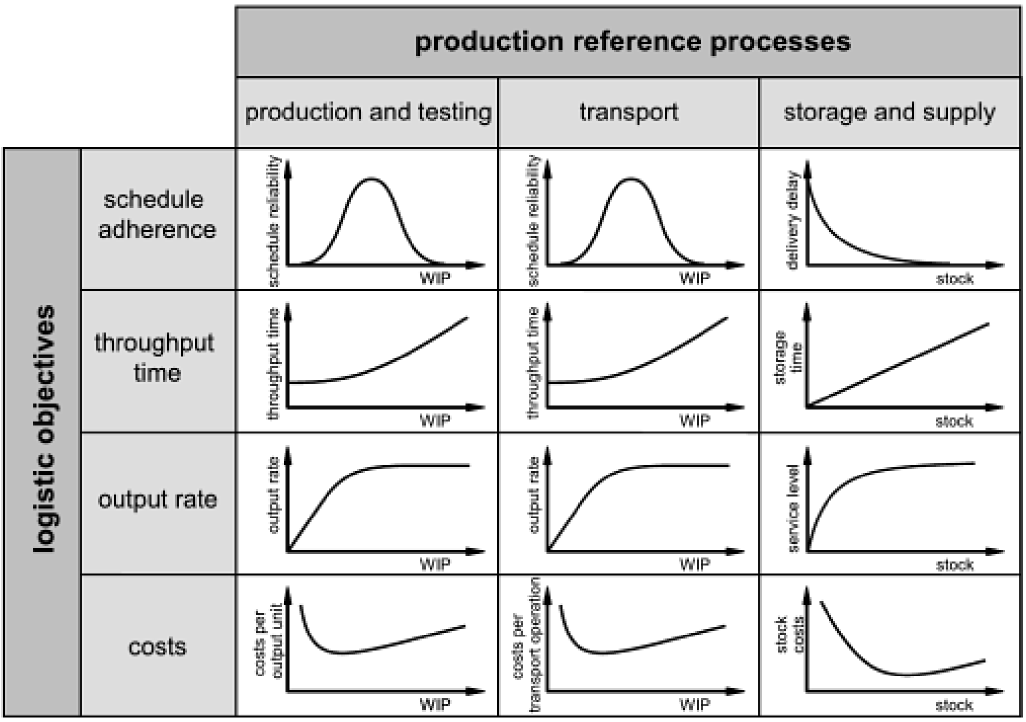

Fig.1 *Logistic Operating Curves for Production Reference Processes. [3]*

It can be noted, that a significant reduction in WIP is possible, to a certain degree, with only a minute loss in output rate. The bell-shaped curve describing Schedule Adherence also shows that reducing WIP level is only profitable to a certain level, below which the value of an analyzed parameter deteriorates drastically. In the case of Throughput time the situation is opposite. It is possible to achieve a WIP level, whose parameter does not change or grows only slightly. Above this point the value of the analyzed quantity grows significantly.

3 BASIC LAWS OF PRODUCTION LOGISTICS

This, among others is the basis on which the Basic Laws of Production Logistics have been formed in literature. It is nine rules describing the basic dependencies between the processes parameters and the ways of influencing their values. Six of them have been proven mathematically, the remaining three depend on actual production practice. The article focuses solely on one of them (Third Basic Law of Production Logistics) describing dependencies between utilization of the workstation, throughput time and WIP.

Throughput time is the time between finishing, which occurs before the observed process, until the end of the observed process. Its components are inter-operation time, which is the time from finishing the previous process, until the start of the observed process and operation time, which is the set up time and the time dedicated to processing, which is the duration of the process itself. If the start of the set up is known, then the operation time may be calculated analogically to the throughput time, but the dependencies between other parameters of the process – the work content and maximal possible output rate. The Inter-operation time is calculated by deducting one value from the other. These definitions derive from the Throughput element in the funnel model definition.

Utilization of a workstation is the ratio of the average and maximum output rate, possible to achieve in the output of the process, expressed in percentage. The value of this parameter may get reduced, e.g. by malfunctions, outages, the process being blocked, or the speed of the process being reduced. As mentioned earlier, from the economic standpoint, it is profitable for this value to be maximal. The full potential of the possessed machinery may be fully used then.

In relation to Utilization it is worth mentioning Output Rate, of which the average value is connected with the sum of Work Content during reference period, which results from the ratio of the output value to the reference period. A graphical interpretation of this value is depicted in the Throughput diagram in Fig.2.

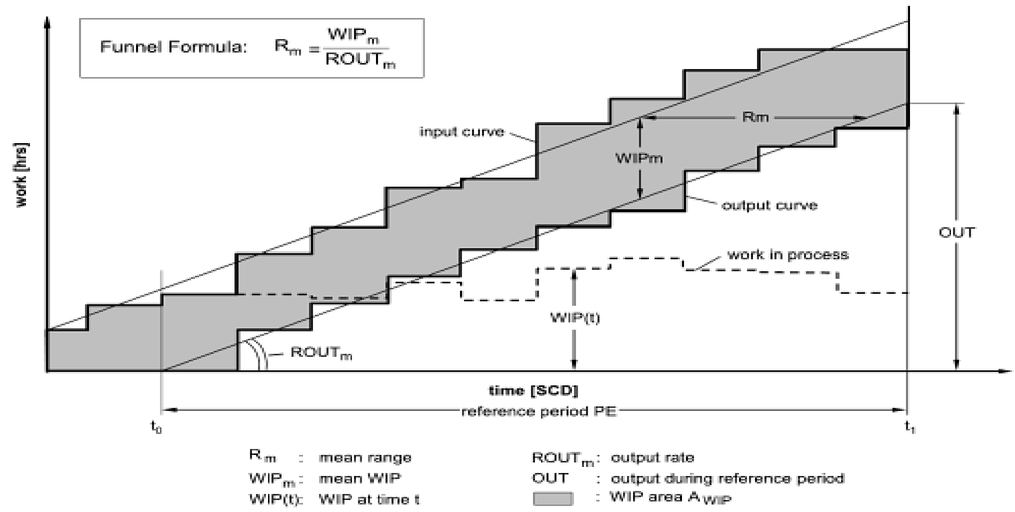

***Fig.2** WIP and Output Range in the Throughput Diagram. [3]*

It must be mentioned, that for the aforementioned dependences to be real, the reference period must be sufficiently long. The achieved results may be influenced by process parameters, which have just began, which is the start of the reference period, but will end while it is still ongoing, as well as those which have begun before the end of the reference period, but will end later. If the workplace`s observation time is too short, then the difference between acquired results and reality may be substantial. With a long enough reference period the influence of these processes is compensated.

The Third Basic Law of Production Logistics states:
„Decreasing the utilization of a Workstation Allows the WIP and Throughput time to be disproportionately reduced." [1]

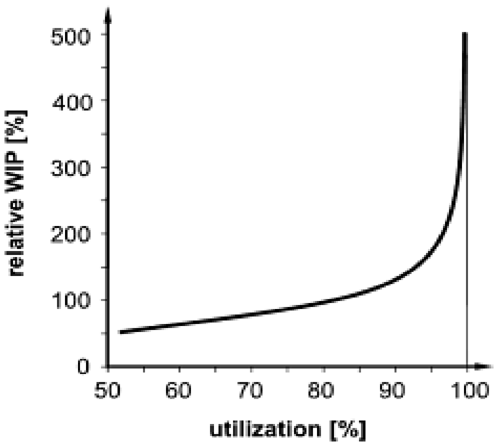

Fig.3 *Third Basic Law of Production Logistics. [3]*

This dependency may be observed while analyzing an exemplary LOC for a production reference process, while assuming output rate as the logistic objective, the parameter directly connected with utilization.

Every process is exposed to a degree changeability of the input value, this cannot be avoided. This can be minimized by applying a buffer at the start of the system, but eliminating this occurrence is impossible. Delays in delivering the processes input material may cause the workstation co cease functioning, while waiting for parts to arrive. Therefore if it is assumed, that declines of utilization values are unacceptable, a high level of WIP must be maintained in order to minimize variables.

Both the Third Basic Law of Production and the shape of the aforementioned Output Rate Operating Curve suggest, that the described dependency between WIP and utilization is not linear and allowing only a minute loss of utilization value allows a significant reduction in WIP value. These deliberations also concern Throughput Time. Achieving a higher level of utilization may be related with a longer processing waiting time in the subsequent operation, or with a prolonged operation time. The shape of the example Throughput Time Operating Curve suggests that reducing WIP (and therefore utilization) may significantly decrease the value of the discussed parameter.

Simulation

Introduction: In order to prove the authenticity of these solutions, the program Witness 13 has been used, which was developed by the Lanner Company. This program is able to simulate even the most complicated production processes. Creating a model of the examined process and conducting a series of simulations of its progress is one of the methods of acquiring data necessary to draw LOC. Only a single parameter should be changed in subsequent tests, and it is best if this parameter is WIP. Choosing this parameter limits the number of simulations necessary to draw all the desired curves.

The program Witness 13 is a highly developed tool which allows creating models and simulating production processes of practically any level of complexity. Applying many logic rules allows building models adequately accurate for the given situation. At the same time it remains an approachable environment, which navigating is rather more intuitive than forced by the program. The program also provides valuable information in the form of data concerning the parameters of the process, calculation of costs, or even the analysis of energy consumption or even the emission of some harmful substances. The aim of process modeling in the program Witness 13 is finding effective ways of perfecting them, often in improving the continuity of flow, without exposing the company to potential loss related with introducing ineffective solutions.[6]

Example: To prove the dependence between the Utilization and WIP, described in the Basic Law of Production Logistics, a simple model will be sufficient. A single type of part has been used in the entry to the system and a single workstation from where parts are being sent to the buffer.

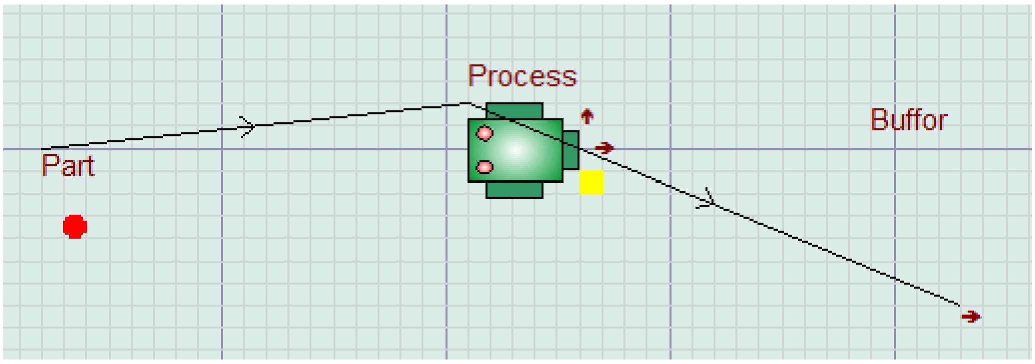

Fig.4 *Model of analyzed process (Witness 13)*

The capacity of the buffer has been set to the level of 10000 parts. Generally speaking this number does not make any difference in terms of the conducted analysis. It is only relevant that the process is not interrupted by reaching the full capacity of storage space.

The parts introduced to the system are idle, which means they are taken with the use of the PULL system. Parameters of the process related with processing, transport and inter-operational storage have been modeled as one element- Process. It is a machine-type of element. Its cycle-time is simulated with the use of the beta schedule with the following parameters: α=7 and β=3. This schedule is used to describe the time of tasks (namely, the time it takes to complete a task). The diversity of time is necessary due to the assumed simplification, namely, as mentioned earlier, that this amount consists not only of operations time, but also transport time and the time it takes to enter the process. These values summed, point the Inter-operation time. Moreover, the diversity of the entering value has been taken into account.

In order to draw the Throughput Time Operation Curve, as mentioned above, a series of simulations advised in which only the WIP parameter should be changed. In the discussed instance however, it is easier to assume an opposite approach, i.e. assuming WIP as the utilization function. This means that the second mentioned parameter will be modulated manually. In the model, this is done by manipulating the frequency of malfunctions and the time of repair. Generally speaking, the tnorm function should be applied in this case, since it depicts these parameters in a faithful and realistic way, as far as the conducted analysis is concerned however, the possibility of precise and controlled changes in utilization is more important.

The value of WIP Parameter can be seen in the Part statistics, while utilization (directing via malfunctions) is depicted in the Process statistics.

After conducting 74 simulations, each one lasting 10000 minutes (minutes are a default unit used by Witness 13) a set of data has been obtained. Basing on this data a curve has been drawn, describing the dependency from the Third Basic Law of Production Logistics. It can be seen in Fig 6.

Name	No. Entered	No. Shipped	No. Scrapped	No. Assembled	No. Rejected	W.I.P.	Avg W.I.P.	Avg Time	Sigma Rating
Casing	47	0	0	43	20	4	4.18	59.80	4.15

Name	% Idle	% Busy	% Filling	% Emptying	% Blocked	% Cycle Wait Labor	% Setup	% Setup Wait Labor	% Broken Down	% Repair Wait Labor	No. Of Operations	% Off-Shift
Assembly	3.50	54.1	0.00	0.00	14.36	15.00	10.00	0.00	3.00	0.00	54	0.00

Fig.5 *Statistics of Part and Machine elements (Witness 13)*

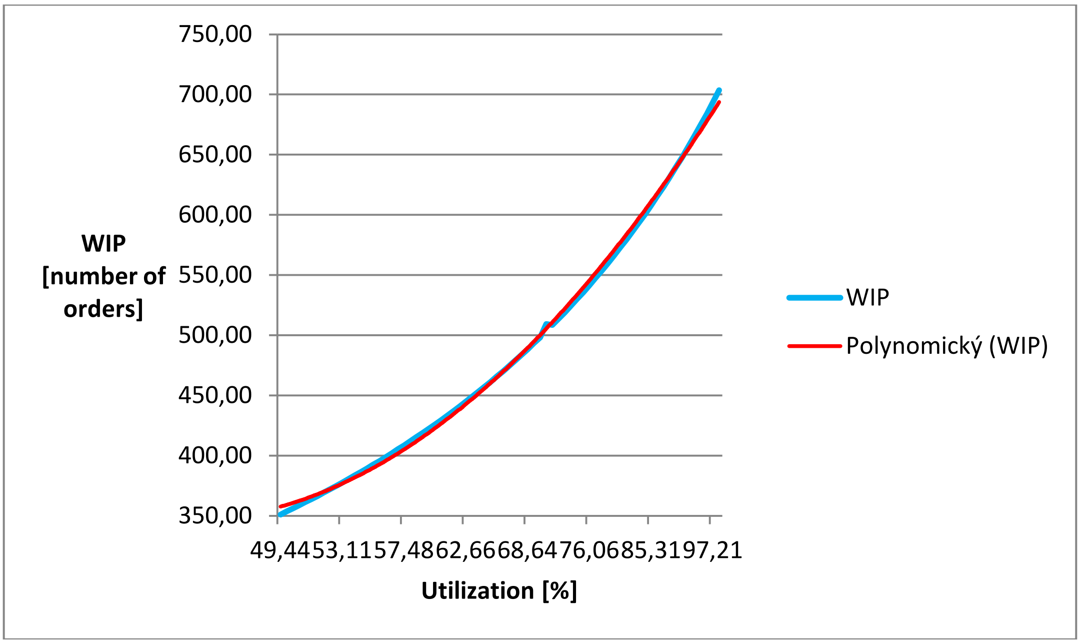

Fig.6 *Results of the simulations*

The shape of the curve drawn basing on the simulation data differs from the one describing the Third Basic Law of Production Logistics. The first mentioned dependency is much closer to being linear. The principal difference between them is that literature mentions relative WIP [%], which means the value of WIP in the analyzed process was assumed basing on the ideal minimum WIP, which is the value derived for a perfect process. Results of the simulation represent values concerning the process, which were given directly by the Witness 13 program.

Despite this divergence, the tendency described by the discussed law has been kept. Results of the simulation given in the diagram have been marked with the color blue, red represents the trend. This is easiest to prove by analyzing the numerical data which served to create the chart. The initial differences between consecutively read values of WIP for large values of utilization equal 10, while the mentioned differences for utilization at 50% only equal about 2,5. Some of this data is shown in chart presented on Fig 6.

Tab. 1 *Some of the results of conducted simulations*

Utilization [%]	100,00	98,58	97,21		70,74	70,00	69,39		50,16	49,80	49,44
WIP [number of orders]	713,65	703,48	693,60		509,25	498,21	493,27		356,11	353,60	351,12

6 CONCLUSIONS

Results of the conducted analysis confirm that the Third Basic Law of Production Logistics may be introduced to actual production processes. The differences between acquired results and theory results mainly from the assumed simplifications, described earlier in the article.

With 100% of utilization, the average WIP equals 713,65. Reducing utilization by a more 1,5% allows achieving a WIP value of 703,48. This means that allowing for a minor loss in utilization, the process may contain 10 parts less than in the case of full utilization of machines, and the continuity of the flow will be retained. Reducing the level of utilization by 5% allows lowering the WIP value by approximately 30 parts. These values may seem small, but in practice, such changes provide certain savings.

Keeping the level of utilization constantly low is not profitable, as it does not allow to fully make use of the potential of the process. Moreover, both theory and simulation results indicate, that lowering WIP by reducing utilization is pointless beyond a certain point. If the value of the second mentioned parameter equals about 75%, reducing it by a further 1% will change WIP only to a level of approximately 5,5 parts, which is half the amount of the utilization of nearly 100%.

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