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THE INFLUENCE OF INFORMATION TECHNOLOGIES ON THE EFFICIENCY OF PRODUCTION CONTROL

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Abstract: The efficiency of production planning and control is increased by the application of contemporary information and communication technologies. The influence of the existence of an information system on the entire functioning of a business system, as well as on the effectiveness of production planning and control, is generally known and does not need to be proven. The paper presents the effectiveness of production control of a particular product with the use of simulation software tools that are integrated with the production information system. The basic space of the condition of the problem which the management of planning and production control should solve in the case of the production of a certain product will be presented tabularly.
Keywords: production efficiency, production control, information system

1. INTRODUCTION

The current trend in the field of business systems control is the integration of management efforts at all levels of the management hierarchy of a business system, in order to achieve the set business goals. Utilising the performances of modern information and communication technologies, with the use of modern management strategies in order to implement the mentioned integration, is one of the current challenges faced today by experts from various scientific disciplines [1,2,3,4]. The notion of integration of the structure and behaviour of a business system is a higher level abstraction, something that is strived for and achieved only in part by the fusion of those aspects of the structure and behaviour of the business system and different management strategies into the control model, i.e. into the information system of the business system. It is considered that the integration should be carried out on two levels: internal - at the level of the business system and external - at the level of communication with the hierarchically superior system, i.e. the market environment [1,4,5,6]. The latest research in the field of modern cybernetics is aimed at the building of a model by which it is possible to establish a communication with the system we want to manage.

In the study of complex systems, evolutionary mechanisms of cyclical nature are noticed, which enable the maintenance of the existing state space, adaptation to new requirements of a hierarchically superior system and self - organization [7]. The mentioned evolution indicates the dynamic nature of real systems and is presented by unpredictable patterns of growth of structural and functional complexity at all hierarchical levels. It is concluded that the behaviour of the system is directed towards some future state, which is not deterministic and predictable from the aspect of the observer. The knowledge on possible future states of a production system, and, by means of that, the increase of the elements of predictability and determinism, is achieved by applying simulation software. In this way, the probability of timely implementation of the set goals is significantly increased, as well as the effectiveness of the management of the production planning and control process. The modelling of a real system with the help of modern information technologies and the designing of an information system and simulation software in order to increase the effectiveness of planning and production control imply the analysis of the structure and behaviour of the observed system, registration of acquired knowledge by using verbal, graphic, mathematical or logical models and translating these models into the code of appropriate software. In all three mentioned phases, which present only the tip of the iceberg, the basic problem is to overcome the complexity.

The basic model of the structure and behaviour of a business system is an appropriate information system that provides management with data on the current state of the system, generates reports necessary for making the control decisions, creates the plans which initiate and direct the behaviour of the business system in the upcoming period and automates certain business processes and activities. It should be noticed that the information system is a static model of the structure and behaviour of the

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business system, which does not provide management with the ability to predict which is necessary to make timely control decisions that lead to optimal system behaviour and full utilisation of its performances. The stated shortcoming of this model is especially visible in the decision-making at the tactical or operational level of production planning and control. In response to the mentioned requirements, it is inevitable to use a dynamic simulation model that will provide management with the necessary information about the structure and behaviour of the system at the tactical level and unambiguously direct their control decisions [1,2,8,9].

2. ANALYSIS OF THE INFLUENCE OF INFORMATION TECHNOLOGIES ON EFFICIENCY

The basic space of the state of the problem that the management of planning and production control should solve in the case of production of a certain product will be presented tabularly. Solving of the given problem follows the following scenario. Twenty work orders have been formed and are awaiting their final termination and launch. The system should process six different types of products with similar characteristics so that the preparatory-ending times are balanced and minimally affect the main time of the flow of parts through the system. According to the given delivery deadlines and other criteria obtained from the top management, each work order is assigned an appropriate priority. The products are delivered to different customers and the basic criterion for defining the size of a batch is the agreed delivery time. Since there is a two-way communication with the process of procurement, transport and sales, the response times of the supplier (procurement time in Table 1) as well as the time of delivery of the product to the customer (delivery time) are available.

Table 1. Basic information about the work order

Priority of work order	Type of product	Batch (pieces)	Delivery deadline (in days)	Procurement time (in days)	Delivery time (in days)
1	4	1350	15	5	7
2	1	980	22	5	10
3	1	2700	18	5	3
4	2	800	23	6	1
5	6	2650	26	6	3
6	6	1500	27	7	4
7	3	1200	28	6	4
8	6	1600	35	5	2
9	3	1000	41	5	7
10	1	1300	38	7	2
11	2	3700	46	5	2
12	4	1450	49	7	4
13	2	2750	49	7	2
14	3	2000	55	5	3
15	4	1600	63	5	7
16	1	1800	71	5	2
17	5	1300	84	6	1
18	4	950	92	5	3
19	2	3500	114	5	1
20	2	1000	124	5	6

Table 2. Results of the first simulation experiment

	Logging in the system (day-hour-minute)			Logging out of the system (day-hour-minute)		
1.	0	0	0	4	0	29
2.	0	0	1	2	7	23
3.	0	0	2	10	4	53
4.	2	1	57	5	6	32
5.	3	0	26	13	3	17
6.	4	3	53	13	7	9
7.	6	3	28	15	6	30
8.	8	2	29	18	0	40
9.	9	4	24	18	2	31
10.	9	4	48	21	2	6
11.	11	6	30	28	7	27
12.	11	7	15	25	0	11
13.	13	1	50	32	4	33
14.	15	4	51	33	2	37
15.	20	0	22	41	6	41
16.	20	4	6	37	1	59
17.	20	4	17	41	7	10
18.	24	4	12	43	2	32
19.	25	9	23	49	3	42
20.	27	1	49	45	5	22

The management of the production planning and control process analyses the data and enters them into the simulation software in order to perform a simulation experiment. Without the existence of the simulation software, production would be launched according to the given priorities of work orders.

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After conducting the simulation experiment, the management received the following data from the simulation software given in Table 2.

The analysis of the obtained results registers the entry and exit from the system of each work order and shows the total completion of all work orders with the exit of the work order with priority 19 from the system in 49 days 3 hours and 22 minutes. The analysis of time reserves provided by the simulation software is accessed in order to register possible delays. After concluding that it is a valid schedule, another simulation experiment is accessed in order to optimize the obtained schedule. After the analysis of the Gantt chart, the priorities of work orders are changed, the priority of the work order with ordinal number 19 is changed to priority 17, as well as the priority with ordinal number 16 to 14. After the entry of the given data, another simulation experiment is accessed, which provides management with the results shown in Table 3.

Table 3. Results of the second simulation experiment

	Logging in the system			Logging out of the system		
1.	0	0	0	4	1	23
2.	0	0	1	3	0	49
3.	0	0	2	10	5	49
4.	2	1	57	5	7	27
5.	3	0	26	13	4	12
6.	4	3	53	14	0	35
7.	6	3	28	15	7	25
8.	8	2	29	18	1	36
9.	9	4	24	18	3	26
10.	9	4	48	21	3	2
11.	11	6	30	29	0	52
12.	11	7	15	25	1	7
13.	13	1	50	32	5	29
14.	15	4	51	33	3	32
15.	20	0	22	36	2	21
16.	20	4	6	37	7	24
17.	20	4	17	39	3	40
18.	23	7	3	40	0	4
19.	24	2	24	45	2	22
20.	25	0	2	43	4	27

The analysis of time reserves is accessed again, in order to register possible delays. After concluding that this is a valid schedule, the next simulation experiment is accessed in order to optimize the obtained schedule and the total completion of all work orders is noticed, with the exit of the work order with priority 19 from the system in 45 days 2 hours and 22 minutes.

The obtained results indicate that the flow time of all work orders has been reduced by 4 days 1 hour and 20 minutes. After additional analysis, the work orders are launched according to an optimized schedule. The next task is to communicate with the sales and procurement processes, which use the results obtained from the simulation software to schedule the procurement, schedule the delivery of products to the customer and receive the new orders from the customers.

3. BENEFIT ANALYSIS

Similarly to the way in which the production delays cause a domino effect of work order delays, the presented unburdening of the workshop also enables many benefits and thus increases the effectiveness of production planning and control.

In the given example, there is a batch production with a horizon of operational planning of about two months, so that the saving of four working days entails many positive consequences.

The first and obvious is the unburdening of the workshop capacity and the possibility of accepting new orders, which affects the increase of productivity, i.e. of the profit as a strategic goal.

If we take into account that there are the products with similar characteristics and that the initial plan was to produce 35,130 parts for the same time interval and that it is now possible to produce another 2,330 pieces in the same interval, there is a 6.6 percent increase of the plan. Since the system follows the basics of Lean production and produces only for a known customer, these are sold products.

In the above example, the increased turnover of stocks on an annual basis is obvious. The simulation software connects sales and procurement, sales engages production indirectly through sales plans which are translated into production plans, while procurement plans are generated on the basis on production plans. The simulation software directly affects the scheduling of procurement and sales by creating the production schedules and by generating the forecasts for the implementation of work orders.

The example also indicates very clearly the reduction of time from the launch of the work order to the implementation of the finished product ready for delivery, which is also a measure of the effectiveness of the production planning and control process.

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The simulation software creates the time reserves in relation to the delivery time of products to customers, recognizes when they are negative and, in that case, performs the retermination of production. Also, the cooperation with the procurement, from which the supplier responds are obtained, on the basis of which it warns the procurement to order semi-finished products in a timely manner, enables the reduction or elimination of delays caused by the shortage of raw materials.
In that way, there is an obvious influence of the simulation software on the increase of the percentage of timely deliveries of products to customers as well as on the decrease of the percentage of work orders that have been implemented later (modified - divided) due to lack of materials.
For the same reason, if the production goes according to plan, there are no delays, unfinished production and delivery delays due to lack of raw materials, it is possible to optimize the deliveries and reduce the number of suppliers of finished products to customers. If one order is partially implemented, it implies multiple delivery, and that increases the operating costs of the system.
The simulation software gives the flexibility to the entire system which allows a quick response to unplanned events in the system, changes in the rhythm of production as well as the introduction of the new and improvement of the existing products.
The next benefit is a more efficient use of employees. The simulation further offers the possibility of predicting the workload of workers in a given period and balancing their workload by reallocating tasks in order to increase productivity. This fact has also been used to reduce the unplanned overtime.
The analysis of the obtained Gantt charts and other output results clearly shows the bottlenecks in production, and, in this example, those are the welding machines. By the procurement of another such machine, the production would be greatly unburdened and the average flow time of work orders through the system would be reduced by up to 40%.
The last criterion for assessing the effectiveness of the production planning and control process is the cost of production per unit of a product. In the text that follows, there is an analysis of the influence of the obtained simulation results on production costs, which are significant from the aspect of increasing the effectiveness of the production planning and control process.

4. COST ANALYSIS

The production costs of a unit of product according to the proposed methodology consist of: processing costs, energy costs, premises costs, costs of refrigerants and lubricants, steam, water and air costs and costs related to separation and contribution.
Processing costs consist of costs related to the worker (R), the tool (A) and the machine (M).

$$V_o = R + A + M = n \cdot k_1 \cdot t_k + \left(n \cdot k_1 \cdot t_1 + k_2 \cdot t_2 + \frac{C_a}{i+1} \right) \cdot \frac{t_g}{T} + \frac{C_m \cdot p}{\sum_{i=1}^{l} \left(q \cdot t_k \right)_i} \tag{1}$$

Thus the costs related to workers are equal to:

$$R = n \cdot k_1 \cdot t_k = \left(1 + \frac{k_3}{k_1} \cdot \frac{N_1}{N_2} \right) \cdot k_1 \cdot t_k \tag{2}$$

In equation (2), the values k_1 and k_3 are the gross personal incomes of a production and professional worker, N_1 and N_2 represent the number of machines serviced by the production and professional worker, and t_k is the duration of all production operations, i.e. the production time.
From the structure of this type of costs and for the stated workshop configuration, we can conclude that the increasing of the level of efficiency does not affect this type of cost, i.e. the costs will remain at the same level despite the increase in production and sales. On the other hand, if more is produced and sold in the same period (about 45 working days, or two months), it is obvious that the total costs per unit of the product are reduced.
The costs associated with the tool are:

$$A = \left(n \cdot k_1 \cdot t_1 + k_2 \cdot t_2 + \frac{C_a}{i+1} \right) \cdot \frac{t_g}{T} \tag{3}$$

In form (3), k_2 represents the gross personal income of a sharpener, C_a the value of the cutting tool, t_1 the tool replacement time, t_2 the tool sharpening time, t_g the effective cutting time, T the tool stability, i the number of possible tool sharpenings.

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These costs will be slightly increased due to the increased consumption of the tool in the observed interval, because in the same interval a larger number of workpieces is processed, so that the production volume is increased. It can be assumed that they are proportional to the growth of production volume and do not affect the costs per unit of the product.

The costs related to the machines are:

$$M = \frac{C_m \cdot p}{\sum_{i=1}^{l}(q \cdot t_k)_i} \tag{4}$$

In form (4):

- C_m - represents the value of a machine in $[BAM]$,
- p - is the depreciation rate,
- $\sum_{i=1}^{l}(q \cdot t_k)_i$ - the total performance of one operation during a year and
- l - the number of different production operations that are performed on machine during the year.

With this type of cost, it is clear that with the increase in the number of performed operations, this type of cost decreases, which indicates that it has a positive effect on reducing the costs per unit of the product. In addition, the return on investment in the purchase of the machine is decreased.

The basic data for the stated model of costs and in accordance to the stated notation are shown in Table 4.

Table 4. Input data of the model of costs

k_1	k_2	k_3	N_1	N_2
0,076	0,076	0,085	1	4
t_k	t_1	t_2	t_g	T
15	25	18	3.75	1400
C_a	and	C_m	p	t_{kgod}
1800	12	15000	0.05	4000

Table 5. Values of processing costs before and after the optimization of the schedule

	R	A	M
First schedule	1.4551	0.3810	0.0469
Optimized schedule	1.3533	0.3810	0.0436

Table 5 shows the values of processing costs before and after the optimization of the schedule.

5. RESULTS AND DISCUSSION

By analysing the obtained results, it can be concluded that the obtained costs are in accordance with the type of production (batch), types of machines and workshop configuration.

Other costs from the structure of processing costs can be considered as constant costs if we take into account the impact of changes in the number of pieces made in the appropriate time interval.

Batch-related production costs include additional costs of the pre-adjustment of the tool, preparation costs, control costs, and machine preparation costs.

The labour costs of the worker engaged in the pre-adjustment of the tool are:

$$V_{dpa} = \frac{V_o}{V_{osr}} \cdot \sum_{i=1}^{l}\left(t_{pa} \cdot LD_{pa}\right)_i \tag{5}$$

where:

- $\sum_{i=1}^{l}\left(LD_{pa}\right)_i \, [BAM]$ - gross personal income of workers on the pre-adjustment of the tool
- $t_{pa}\,[\min]$ - time of the pre-adjustment of the tool for the complete production

Costs related to the labour of a control worker are:

$$V_{dk} = \frac{V_o}{V_{osr}} \cdot \sum_{k=1}^{l1}\left(t_{kon} \cdot LD_{kon}\right)_k \tag{6}$$

where:

- $\sum_{k=1}^{l1}\left(LD_{kon}\right)_k \, [BAM/\min]$ - gross personal income of a control worker
- $t_{kon}\,[\min]$ - total control time

Costs related to the work of a preparation worker are:

$$V_{dpr} = \frac{V_o}{V_{osr}} \cdot \sum_{i=1}^{l2}\left(t_{pr} \cdot LD_{pr}\right)_i \tag{7}$$

where:

- $\sum_{i=1}^{12}\left(LD_{pr}\right)_i \left[BAM/\min\right]$ - gross personal income of a preparation worker
- $t_{pr}\left[\min\right]$ - preparation time

For the values of gross personal income of workers on pre-adjustment, control and preparation of BAM 0.085 per unit time (minute) and pre-adjustment times of batch (35 min per the batch), control (7 min per the batch) and preparation (25 min), production costs related to the batch are BAM 0.017 per unit of the product. The third part of the production costs, which refers to the complete volume of production, includes the purchase price of the simulation software.

Depending on the system configuration and other characteristics, the price of simulation software varies in relatively narrow limits and can be calculated with the amount of BAM 10,000. In that way, for an annual production volume of 200,000 units of the product, the procurement of simulation software burdens the price of a unit of the product with BAM 0.05.

6. CONCLUSION

The role and importance of designing quality software solutions, that is, in the final context of this paper, of the simulation software as a dynamic model of production planning and control, can be clearly seen in the global view of the functioning of the entire social system.

The organization of the contemporary social community, i.e. the state, is based on production as the basic human activity in it. It is clear that the level of development of s social system, as well as the level of quality of life of the people who live and work in it, is directly dependent on the level of development of the economic system. The most obvious measure of the efficiency of the functioning of any business system is the economic criterion which justifies its existence, as well as the realised profit (or profit).

In order for a business system to be effectively controlled, that is, for the system to implement successfully the appropriate processes and activities, it is necessary for the management to have the appropriate information at all times. This information must be accurate, available in a timely manner, in the required format and current, i.e. to describe the actual condition of the system. This information provides the management with a control model, and the control model is an appropriate software solution or set of software solutions that make up the information system of a business system.

References

[1] Arsovski, S., Arsovski, Z., Mirović, Z., The Integrating Role of Simulation in Modern Manufacturing Planning and Scheduling, Strojniški vestnik - Journal of Mechanical Engineering, vol. 55., 2009.
[2] Bergman, B., Klefsio, B., Quality from Customer Needs to Customer Satisfaction, McGraw Hill Book Company, London, 1984.
[3] Husby, C. P., Swartwood, D., Fix Your Supply Chain - How to Create a Sustainable Lean Improvement Roadmap, Taylor & Francis Group, New York.
[4] Jugulum, R., Samuel, P., Design for Lean Six Sigma: A Holistic Approach to Design and Innovation, John Wiley & Sons, 2009.
[5] Mann D., Creating a Lean Culture, Productivity Press New York, 2005.
[6] Pohlman, R., Gardiner, G., Value Driven Management: How to Create and Maximize Value Over Time for Organizational Success, McGrow Hill, New York, 2000.
[7] De Marco, T., Controlling Software Projects, Yourdon Press, Prentice Hall, Inc, Englewood Cliffs, New Jersey, 1989.
[8] Bums, J., Morgeson D., An Object – Oriented World - View for Iteligent Discrete, Next-Event Simulation, *Management Science,* Vol. 34, No 12, 1988.
[9] Currie, W., Hlupic, V., Change Management Panaceas and the Supporting Role of Simulation Modelling, Proceedings of the WSC'2000 (Winter Simulation Conference 2000), pp. 2022-2028, Orlando, USA, 2000.

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