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A CONTRIBUTION TO THE DETERMINATION OF CRITERIA AND MEASURES FOR EVALUATING OPERATIONAL PLANNING AND PRODUCTION CONTROL

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Preliminary notes

For the operational planning and production control domain criteria and measures are suggested according to which the successfulness of operational planning and production control can be evaluated and that process assessed in relation to others and a certain reference system by virtue of an adequate coefficient. Three criteria and measures for evaluating operational planning and production control are given and analysed, as well as a synthetic criterion for a consolidated evaluation. The example from the undertaken research in one production system shows the evaluation of operational planning and production control, and by means of an adequate model, an estimate is made of the possibility for the improvement of that process by using the available resources, without making any investments.

Keywords: *meeting the deadlines, operational planning sensitivity, stock management efficiency, successfulness of the operational planning and production control*

Doprinos određivanju kriterija i mjerila za ocjenjivanje operativnog planiranja i praćenja proizvodnje

Prethodno priopćenje

Za područje operativnog planiranja i praćenja proizvodnje daje se prijedlog kriterija i mjerila po kojima se može ocjenjivati uspješnost operativnog planiranja i praćenja proizvodnje te vršiti ocjena tog procesa u odnosu na druge i neki referentni sustav putem odgovarajućeg koeficijenta. Data su i analizirana 3 kriterija i mjerila za ocjenjivanje operativnog planiranja i praćenja proizvodnje te sintetski kriterij za jedinstvenu ocjenu. Na primjeru provedenog istraživanja u jednom proizvodnom sustavu prikazano je ocjenjivanje operativnog planiranja i praćenja proizvodnje a putem odgovarajućeg modela napravljena je procjena mogućnosti unapređenja tog procesa korištenjem raspoloživih resursa, bez ulaganja.

Ključne riječi: *efikasnost upravljanja zalihama, osjetljivost operativnog planiranja, uspješnost operativnog planiranja i praćenja proizvodnje, zadovoljenost rokova*

1
Introduction
Uvod

In the theory and practice of production and its management there is a large number of criteria and measures for the optimization of production programs and plans, and some of them are at the same time also indicators which speak of the efficiency and successfulness of production, that is, there are criteria and measures which individually provide insight into the results of a certain production process or its parts and contents.

However, there are two problems related to operational planning of production:

- the optimum is dominantly treated from the aspect of production itself and it diverges to a certain extent from the current events on the market
- a more precise insight into the influence of the direct operational planning and process control on the production itself, and vice versa, does not exist.

As operational planning and control mostly affect the efficiency and successfulness of the direct production process, it is necessary to consider the criteria and measures according to which the successfulness and the efficiency of that organizational process, and not only of the production and its parts, would be evaluated.

The planning and process control is part of the organizational process in which the linking and coordination of particular organizational processes is carried out in the realization of the objectives set for the whole. Thereat, the process is treated as a set of logically connected and coordinated activities with the pertaining algorithms, input and output data.

The planning and process control also implies the supporting information system as part of its structure.

The planning process is not feasible without the control so they form an integral process.

After the planning, in the realization phase, we perform the control, not only to determine if the planning is being carried out as defined and what the results and indicators of success are, but also in order to timely determine any disorders which might have occurred and which are thereafter aligned with the existing state and objectives, and vice versa.

This means that both the planning and the control are carried out in connection and continuation and so we can refer to that process as the management of the organizational process of a certain system, just as it is most often referred to in science and practice.

As the results of the production process are mostly a consequence of the manner and efficiency of management and realization of the operational planning and process control, the obtained results and assessments of the efficiency of production need to be the evaluations of the successfulness of operational planning and control at the same time.

2
The existing situation in literature and practice
Postojeće stanje u literaturi i praksi

In many works of literature, especially those from the domain of production economics [2], as well as in everyday practice, the business success of production is measured according to the following standard indicators:

- **economy** = a ratio of cash return on capital invested
- **productivity** = a ratio of output of goods and employee hours worked
- **profitability** = a ratio of profit to the capital invested.

The above mentioned indicators assess the business success of production but do not tell us to which extent they are influenced by the acting influence factors of operational planning and control and production itself.

On the other hand, by browsing a large amount of scientific and professional literature and articles, as well as owing to the experience gathered in the practice related to the operational planning and production control domain, it can be ascertained that the chosen criteria and measures are mostly used for production optimization where the following criteria and measures are most often encountered:

a) profit (money) [11, 12]
b) production costs (money) [3, 4, 6, 7, 8]
c) product quantity (number/volume/weight) [6]
d) time spent (hours, days) [8, 9, 10]
e) additional time spent (hours, days) [3]
f) spent material (quantity) [7]
g) labour costs (money) [4]
h) used capacities (time, %) [4, 5, 7, 9]
I) used additional capacities (time, %) [3].

The same criteria and measures are also used for the evaluation of the successfulness of production according to the ratio between the planned and the achieved production results.

As can be determined from the above, the matter at hand is a larger number of criteria and measures which give individual production process success evaluations of which only the "profit" criterium is synthetic. However, it does not show us how the influence factors of production and operational planning and control influence its successfulness.

Besides, the above stated criteria and measures do not provide sufficient insight into the quality and efficiency of the progress of the operational planning and process control and of production too.

The other problem occurs in practice, in almost all the production systems, when due to more or less dynamic changes on the market, there occurs a need for modifying and amending the operational production plans.

From the aspect of the market, meeting the market's demands is preferred, while the production system strives to realize such plans that enable the optimum results according to previously selected criteria and measures.

We can basically conclude that, not only due to a certain number of disorders in the process of realization of production, but also due to the need for meeting the market's demands to the greatest and highest quality extent, in most cases the optimum planned results cannot be expected but only strived for.

It is possible to come near such planned results by improved management of the production system by virtue of an improved operational planning and process control and if the market provides input data that are precise and obtained in due time.

Operational planning and production control is a process that connects the production and the market and that itself is evidence enough of the importance of the process. Not only should it be well organized and managed but also adequately monitored and evaluated.

3
Choosing criteria and measures
Izbor kriterija i mjerila

Depending on the complexity of the problem, there might occur the need for applying several criteria and measures related therewith and, in that case, it is difficult to give a consolidated and integral evaluation of the situation, influence factors or solutions, that is, to choose the actually optimum solution.

That is why it is necessary to create a smaller number of synthetic criteria and measures, or only one, if possible. The measures should preferably be dimensionless to enable comparisons of the concerned solution or research with others.

As the point here is to evaluate operational planning and process control, of production process primarily, and it is described and defined by the QUALITY-DEADLINES-COSTS trinomial, the success of the planning and control process should be determined according to the criteria and measures that would speak about each part of the above stated trinomial.

Therefore, three criteria are suggested here for the evaluation of the success of the operational planning and production control, and these were chosen so that they can be applied in as many segments of life and work as possible and be synthetically connected into consolidated criteria for evaluating success.

1. The level of realization on the market in relation to the operational plans and realization of production – SENSITIVITY OF PLANNING AND CONTROL – U_1
2. Level of meeting the delivery deadlines – MEETING THE DEADLINES – U_2
3. Level of participation of all the stock in relation to the realization on the market and expenditure in the production – STOCK MANAGEMENT EFFICIENCY – U_3.

For all the above criteria, the measures are dimensionless and stated in percentages (%) which ensures that various production processes, that is, organizational systems, can be compared regardless of their size and content of work.

For the overall, synthetic evaluation of the success of operational planning and control, the notion SUCCESS OF PLANNING – U is chosen and it represents a group of individual criteria chosen according to an adequate algorithm.

3.1
Criterion U_1 – sensitivity of planning and control
Kriterij U_1 – osjetljivost planiranja i praćenja

This criterion for the evaluation of the sensitivity of operational planning and production control includes the level of the monthly realization of the product on the market in relation to:

- the annual plan (its twelfth, 1/12)
- the monthly plan of sale realization
- realized monthly production.

In that way we include the evaluation of the operational planning and production control from its beginning to the end and at the same time we obtain insight and adjust to the changes which in that sense temporarily took place in the observed process.

These criteria can be used to determine the sensitivity of planning and control for the current situation, acting of the influence factors on the planning and control sensitivity and the level of planning and control sensitivity according to the chosen solution – production program in the observed period.

U_1 criteria – ***planning and control sensitivity*** are significant because they show the quality of the performance of that process, its influence and connection with the other processes and thereat they encompass all the contents related to the process and cause numerous activities and thus also costs of work.

The measure of the achieved level of sensitivity of the planning and control U_1 will be according to the expression (1) the product of the *variation level* $(1 - \sigma_{\bar{x}}/\bar{x})$ and the *accuracy level* $(1 - \Delta\bar{x})$

$$U_1 = (1 - \sigma_{\bar{x}}/\bar{x}) \cdot (1 - \Delta\bar{x}) \quad (1)$$

where:
$\bar{x}$ - mean value of the ratio between the annual and monthly plan and the realization of production in relation to the realization of the product on the market $\bar{x}$
$\sigma_{\bar{x}}$ - standard mean value deviation of the observed ratio
$\Delta\bar{x}$ - error in the planning ($\Delta\bar{x} = |1 - \Delta\bar{x}|$)
y_{1ij} - 1/12 of the annual plan (GP) of the products group (j), ($i = 1, 2, \ldots, 12; j = 1, 2, \ldots, p$)
y_{2ij} - monthly plan (MP) of the products group (j), ($i = 1, 2, \ldots, 12; j = 1, 2, \ldots, p$)
y_{3ij} - monthly production (PR) of the products group (j), ($i = 1, 2, \ldots, 12; j = 1, 2, \ldots, p$)
y_{4ij} - monthly sales (PD) of the products group (j), ($i = 1,2,\ldots 12; j = 1, 2, \ldots, p$)
x_{1ij} - ratio between the 1/12 of the annual plan (GP) and monthly sales (PD) of the products group (j), ($x_{1ij} = y_{1ij}/y_{4ij}$)
x_{2ij} - ratio between the monthly plan (MP) and monthly sales (PD) of the products group (j), ($x_{2ij} = y_{2ij}/y_{4ij}$)
x_{3ij} - ratio between the monthly production (PR) and the monthly sales (PD) of the products group (j), ($x_{3ij} = y_{3ij}/y_{4ij}$)
x_{kij} ($k = 1, 2, 3; i = 1, 2, \ldots, 12; j = 1, 2, \ldots, p$)
p - number of products groups

where:

$$\bar{x} = \frac{\sum_{ij} x_{1ij} + \sum_{ij} x_{2ij} + \sum_{ij} x_{3ij}}{3 \cdot 12 \cdot p}. \quad (2)$$

The achieved level of sensitivity of the planning and control U_1 is the product of the variation level $(1 - \sigma_{\bar{x}}/\bar{x})$ and the accuracy level $(1 - \Delta\bar{x})$.

Actually, it is also important to determine the dissipation $\sigma_{\bar{x}}$ around the determined arithmetic mean $\bar{x}$ and the deviation of the arithmetic mean $\bar{x}$ from the 100 % accuracy of the plans compared to realization.

As the mean value of the ratio between the plans and the realization $\bar{x}$ can be both over and under 100 %, the error in planning $\Delta\bar{x}$ that is, the accuracy level is assumed in the absolute amount $|1 - \Delta\bar{x}|$.

The level of sensitivity of the planning and control U_1 can assume values within the following ranges:

$$U_{1\max} = 1 \ (\sigma_{\bar{x}} = 0; \ \Delta\bar{x} = 0), \quad (3)$$

$$U_{1\min} = 0 \ (\sigma_{\bar{x}} = \bar{x} \ ; \ \Delta\bar{x} = 1). \quad (4)$$

The value U_1 will be higher if $\bar{x}$ is higher and $\sigma_{\bar{x}}$ and $\Delta\bar{x}$ are lower, while it will assume its maximum value $U_{1\max} = 1$ when $\sigma_{\bar{x}} = 0$ and $\bar{x} = 1$, that is when $\Delta\bar{x} = 0$.

Its value decreases when $\bar{x}$ decreases and $\sigma_{\bar{x}}$ and $\Delta\bar{x}$ increase, and it assumes its maximum value $U_{1\min} = 0$ when $\sigma_{\bar{x}} = \bar{x}$ and $\Delta\bar{x} = 1$.

However, $\Delta\bar{x} = 1$ if $\bar{x} = 0$ which is practically impossible, that is, pointless, because it is the case when there are no plans or realization in production so we can say that $U_{1\min} = 0$ for the systems which are out of function.

We can conclude that the level of sensitivity of the planning and control U_1 gravitates towards $U_{1\max} = 1$ which is actually the logical objective of each system.

Because of their generality and the dimensionless measures, these criteria are also suitable for the comparison of the sensitivity of the planning and control in various systems, regardless of the type and character of the system, its product-service, size, etc., and one or more ratios between plans and realization can be taken into consideration thereat.

The planning and control sensitivity coefficient, K_{U1} according to the expression (5), can be used as an indicator of changes in a certain system or as a comparative indicator of the sensitivity of the planning and control for a certain system in relation to others or a reference system.

$$K_{U1} = U_{1i}/U_{1j} \qquad K_{U1} \geq \leq 1, \quad (5)$$

where:
U_{1i} - the compared level of sensitivity of planning and control
U_{1j} - the reference level of sensitivity of planning and control.

3.2
Criterion U_2 – meeting the deadlines
Kriterij U_2 – zadovoljenost rokova

Meeting the set deadlines is an aim and an obligation of every system in its functioning and thereat each system strives to meet as many deadlines as possible, and in case of a delay, to make it as short as possible so that the consequences of the delay are not too expensive.

Therefore, we can say that the measure of the achieved level of deadlines met U_2 will be according to the expression (6) a product of the *share of deadlines met* $(R - R_z)/R)$ and *the level of delay* $(1 - \bar{x}_z/\bar{x}_{DI})$

$$U_2 = ((R - R_z)/R) \cdot (1 - \bar{x}_z/\bar{x}_{DI}) \quad (6)$$

where:
R - total annual number of set deadlines (days for deliveries)
R_z - the annual number of unmet delivery deadlines (with a delay)
$\bar{x}_z$ - average number of days of delay
$\bar{x}_{DI}$ - average number of days set as a delivery deadline

where:

$$\bar{x}_z = \sum f_i \cdot \bar{x}_{zi}, \quad (7)$$

where:
f_i - number of deliveries with certain days of delay
$\bar{x}_{zi}$ - days of delay
$\Sigma f_i = R$ - total number of deliveries with a delay.

The level of deadlines met U_2 is a product of the share of deadlines met and the level of the delay because it is both important to have as small a number of unmet deadlines and, if delays do occur, that they are as short as possible.

These criteria are also important for the evaluation both of the process of operational planning and control and of the production process itself.

The level of deadlines met U_2 assumes values within the following ranges:

$$U_{2\max} = 1 \quad (\bar{x}_z = 0; R_z = 0), \tag{8}$$

$$U_{2\min} = 0 \quad (\bar{x}_z = \bar{x}_{DI}; R_z = R). \tag{9}$$

Thereat, the values U_2 will be higher if $\bar{x}_z$ and R_z are lower, and vice versa, and the value U_2 gravitates towards $U_{2\max} = 1$ which is also logical for any system.

Theoretically, the value U_2 can also be negative, that is, lower than 0, in case of $\bar{x}_z > \bar{x}_{DI}$; however, that can practically rarely happen because it is probable that any system will increase $\bar{x}_{DI}$ if it is more often subjected to $\bar{x}_z > \bar{x}_{DI}$ which is disadvantageous for any system in its environment and signifies the possibility of or actual breakdown of the system.

Because it is dimensionless and general, these criteria are also suitable for comparing the meeting of the deadlines in various systems.

Thereat, it can be assumed that in the systems with long realization cycles $\bar{x}_{DI}$, higher $\bar{x}_{zi}$ values can be expected, that is, that there is a correlation in the positive direction.

That also means that the character and the type, the product, the product cycle and size of the system do not themselves yield any initial differences between them and that they can be compared.

Meeting the deadlines coefficient K_{U2}, according to the expression (10), can be used as an indicator of changes in a certain system or as a comparative indicator of meeting the deadlines for a certain system in relation to others or a reference system.

$$K_{U2} = U_{2i} / U_{2j} \quad K_{U2} \geq \leq 1, \tag{10}$$

where:
U_{2i} - the compared level of meeting the deadlines
U_{2j} - the reference level of meeting the deadlines.

3.3
Criterion U_3 – stock management efficiency
Kriterij U_3 – efikasnost upravljanja zalihama

Choosing the criteria which might be the most prominent and sufficiently realistic in showing the efficiency of the planning and control, in this case of the considered production system, it has been assessed that this should be efficient stock management.

Namely, the costs arising on account of the stock are the greatest costs directly related to the production planning and control process, they are significantly higher than the direct costs of planning and control and they are also higher than the costs caused by delayed deliveries.

This means that even in case of a great increase of the direct costs of planning and control (work, accessories, power, etc.), these costs will be significantly lower than it will be in the case of only a small increase of the costs of stock.

That is why the *ratio* O_s *between the stock and raw material use* in production and the *ratio between the stock of finished products and delivered products* O_p has been taken here as a standard of efficiency, particularly, of the stock management efficiency U_3 as defined by the following expression

$$U_3 = \frac{1}{\frac{1}{2} \cdot (O_p + O_s)}, \tag{11}$$

where:

$$O_p = \frac{\sum\sum \left(\frac{\bar{z}_p}{\bar{x}_{us}} \right)_{ij}}{12 \cdot s}, \tag{12}$$

$$O_s = \frac{\sum\sum \left(\frac{\bar{z}_s}{\bar{x}_{us}} \right)_{ij}}{12 \cdot s}, \tag{13}$$

where:
$(\bar{z}_p)_{ij}$ - average daily state of products stock (j) in a certain month (i) ($i = 1, 2, 3, \ldots, 12$; $j = 1, 2, 3, \ldots, p$)
$(\bar{x}_p)_{ij}$ - quantity of the delivered products (j) in a certain month (i) ($i = 1, 2, 3, \ldots, 12$; $j = 1, 2, 3, \ldots, p$)
$(\bar{z}_s)_{ij}$ - average daily state of raw materials stock (j) in a certain month (i) ($i = 1, 2, 3, \ldots, 12$; $j = 1, 2, 3, \ldots, s$)
$(\bar{x}_{us})_{ij}$ - quantity of the used raw materials (j) in a certain month (i) ($i = 1, 2, 3, \ldots, 12$; $j = 1, 2, 3, \ldots, s$).

In the expression (11), the value of each ratio is added up with half of the value in order to treat each of them equally and also because in case of multiplication of those ratios, it would be $U_3 = 0$ if only one of the stock assumed the value 0 so the image of the stock management would be false.

The level of stock management efficiency U_3 can also assume the values within the following ranges:

$$U_{3\max} = \infty \quad (\bar{z}_p = 0; \bar{z}_s = 0), \tag{14}$$

$$U_{3\min} = 0 \quad (\bar{z}_p = 0; \bar{x}_{us} = 0). \tag{15}$$

The value U_3 will be higher if, in relation to the stock, the sale and production realization, that is, raw material use also grows; so, in the case when the production theoretically progresses without any stock, the value U_3 assumes the maximum value $U_{3\max} = \infty$.

The value U_3 will be minimum and will be $U_{3\max} = \infty$ in case when there is no using of raw material in production and when there are no deliveries of products, that is, when $\bar{x}_p = 0$ and $\bar{x}_{us} = 0$ and that means the system is not functioning.

We can conclude that the level of efficiency of stock management U_3 strives towards the highest possible value and in a well-organized and automatic production system it can assume values even greater than 10.

Since being general and dimensionless, the described criteria are suitable for comparing the efficiency of stock management in various systems and are also suitable for determining changes in a certain system or comparing a certain system with the reference system by virtue of the

efficiency coefficient K_{U3}, according to the expression (16)

$$K_{U3} = \frac{U_{3i}}{U_{3j}} \qquad K_{U3} \leq \geq 1 \tag{16}$$

where:
U_{3i} - the compared level of the efficiency of stock management
U_{3j} - the reference level of the efficiency of stock management.

3.4
Synthetic criterion U – planning and control success
Sintetski kriterij U – uspješnost planiranja i praćenja

From the aspect of the overall evaluation of planning and control of a certain process, it is necessary that it is successful according to several criteria, that is, all the chosen criteria, which in this case means that there should be a high level of sensitivity and deadlines met with the efficiency of stock management as great as possible.

According to expression (17), the evaluation of the planning and control of the observed process in the chosen system can be done according to the synthetic criterion U – *successfulness of planning and control.*

$$U = U_1 \cdot U_2 \cdot U_3. \tag{17}$$

Possible weighting of individual criteria within the synthetic criterion was not separately considered; it has been estimated that, due to a wider range, the criteria of efficiency of stock management U_3 will have greater significance within the synthetic criterion of successfulness of the planning and control; moreover, this is correct from that criterion's value aspect.

The expression (17) for the synthetic criterion of successfulness is logic because individual criteria supplement each other from the aspect of evaluation in the sense of as integral as possible evaluation of the successfulness of planning and control and these are also logically connected by their activities.

The level of the successfulness of the planning and control U assumes values in the following ranges:

$$U_{\max} = \infty \ \ (U_{1\max} = 1; U_{2\max} = 1; U_{3\max} = \infty) \tag{18}$$

$$U_{\min} = 0 \ \ (U_{1\min} = 0; U_{2\min} = 0; U_{3\min} = 0). \tag{19}$$

According to the expression (19) the level of successfulness will have the minimum value $U_{\min} = 0$ if only one of the individual criteria assumes the value 0 and it will have the maximum value $U_{\max} = \infty$ if the individual criterion U_3 assumes its maximum value ∞.

Since being general and dimensionless, these synthetic criteria are also suitable for comparing the successfulness of the planning and control in various systems and are also suitable for determining changes in a certain system or comparing a certain system with the reference system by virtue of the *efficiency coefficient* K_U, according to the expression (20)

$$K_U = U_i / U_j \qquad K_U \geq \leq 1, \tag{20}$$

where:
U_i - the compared level of the successfulness of planning and control
U_j - the reference level of the successfulness of planning and control.

4
Example of a study
Primjer istraživanja

Within the framework of the project of improvement of operational planning and control of a production system, during the recording and analysis of the existing state, as the 1st level for evaluation, characteristics and evaluations were obtained of the existing manner of work according to the above stated criteria and measures as shown in Tab. 1.

The above stated characteristics of the existing manner of the operational planning and control were obtained by processing data for the period of the last 5 years from which then, by means of the expression (1), (6) and (11) evaluations U_1, U_2, U_3 and U were reached.

The obtained evaluations of the existing manner of operational planning and control belong to the group of inferior evaluations of successfulness so, by performing research, possibilities for improvement were determined according to the chosen influence factors.

Table 1 *Characteristics and evaluations of the operative planning and control*
Tablica 1. *Obilježja i ocjene operativnog planiranja i praćenja*

Characteristics and standards	Values	
	1st level	2nd level
1. Mean value of the ratio between the annual and the monthly plans and the realization of production in relation to placement $\bar{x}$	0,990	0,972
2. Standard deviation of the arithmetic mean of the ratios between the plans and realizations of production in relation to placement $\sigma_{\bar{x}}$	0,191	0,164
3. Error in the planning $\Delta\bar{x}$	0,011	0,028
3. Total annual number of set delivery deadlines R	1322	1220
4. Annual number of unmet delivery deadlines, with a delay R_z	185	85
5. Average requested number of days requested for delivery $\bar{x}_{DI}$	25	23
6. Average number of days of delay in deliveries $\bar{x}_z$	2,14	2,52
7. Average ratio between the state of the monthly stock and delivered products O_p	1,02	0,664
8. Average ratio between the state of the monthly stock and use draw material O_s	1,07	0,904
9. Planning and control sensitivity U_1	0,798	0,808
10. Deadlines met U_2	0,787	0,828
11. Stock management efficiency U_3	0,957	1,275
12. Successfulness of the planning and control U	0,601	0,853

Thus it was determined that it is possible to significantly improve and raise 3 influence factors to the second, higher level relatively simply and quickly:

A - intensity of gathering input data necessary for operational planning and control

A_1- 1st factor level, existing state with collecting data from sales and production 2 times a week

A_2- 2nd factor level, collecting data from sales and production 5 times a week

B - mode of product placement according to the acquaintance with the buyers

B_1 - 1st factor level, existing state with sales from the stock and production for the stock

B_2- 2nd factor level, 50 % of sales and production for the known buyer, the rest from the stock

C - manner of operational planning and control

C_1- 1st factor level, existing state with monthly planning and control statistically, once

C_2- 2nd factor level, sliding monthly planning and control with the alignment of the monthly plan once every week in the period of one month.

The approach to treating influence factors is similar in some of its parts to the approach described by some other authors as well [20, 21].

By means of a simple model, simulation of the process of operational planning and control and the production itself was carried out so that the phenomena and regularities of the simulated activities were raised from the 1st level of the stated influence factors to the 2nd level described herein above.

The obtained results were processed and studied by the factors experiment plan 2^3 with 6 repetitions so in that manner characteristics and evaluations were obtained of the suggested, improved operational planning and control according to the chosen criteria and measures, given in Tab. 1 as well.

It is evident that the obtained results are better which means that, with only lesser changes in the manner of operation, without any investments, the considered production system can achieve greater success in operational planning and production control and thus more significantly decrease the costs of production.

If we additionally compare the successfulness of the planning and control U^{2nd} for the suggested solution with the influence factors on the 2nd level with the successfulness of planning and control on the 2nd level with the successfulness of the planning and control U^{1st} for the existing state with influence factors on the 1st level as the reference level, we obtain the *efficiency coefficient* $K_{U2nd} = 1{,}42$ according to the expression (20).

It can be concluded that there is an obvious difference between the success of operational planning and control according to the suggested solution in relation to the existing one for the observed production system.

5
Conclusion
Zaključak

Evaluating the success of the planning and control U in the production systems can be established in a very short period and relatively simple manner because all the necessary input data are used even today, more or less, as elements of the algorithm for the individual criteria U_1, U_2 and U_3 in various reviews and reports on the results of the state and efficiency of production.

Since in most cases the use of the computer was introduced for the above stated purposes, the monitored input data, with the use of simple software, can be transformed into a form suitable for evaluation by means of the suggested algorithms for each individual and synthetic evaluation criterion.

Moreover, it is possible to simply and quickly establish comparative evaluation of a certain production system with equal or similar systems which represents very useful information for knowing where the observed production system stands in relation to those most developed and to develop and improve it by adequate analyses and solutions.

One issue remains for consideration and that is the determination of the share of the significance of each individual criterion to the overall, synthetic criterion.

Actually, it is to be expected in practice that the production systems will most often be encountered with evaluations according to individual criteria within the following ranges:

$$U_1(0{,}70 \cdots 0{,}95),$$
$$U_2(0{,}70 \cdots 0{,}95),$$
$$U_3(2{,}00 \cdots 5{,}00).$$

Although from the monetary aspect the criterion U_3 presumably has the greatest individual influence on the synthetic criterion U, it is possible that sometimes inferior results, according to the criterion U_2, have a big influence in view of the damages arising for the production system, far more than the share of that criterion in the overall, synthetic criterion.

It is also possible that by direct or indirect influence of the manner and efficiency of work, there would occur a poor and harmful result according to the criterion U_1 in the operational planning and control.

It is therefore suggested to consider and study whether it might be necessary to take the evaluations according to criterion U_1 and criterion U_2 with the square of their values or to take the evaluations according to the criterion $U_3$with the root of their values.

However, in any case, the application of the suggested criteria and measures will yield a more objective image both of the comparative value of the efficiency and the success of the operational planning and control of the production systems, and of the other organizational systems as well.

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References
Literatura

[1] Vila, A.; Štajdl, B.; Čala, I.; Karabaić, I. Modeli planiranja proizvodnje u industriji, Informator, Zagreb, 1982.

[2] Žaja, M. Ekonomika proizvodnje, Narodne novine, Zagreb, 1975.

[3] Voss, S.; Woodruff, D. L. Introduction to Computational Optimization Models for Production Planning in a Supply Chain, Springer, New York, 2002.

[4] Tork, R. M.; Cordon, P. J. Operational Profitability, John Wiley&Sons, New York, 2002.

[5] Caramia, M.; Dell' Olmo, P. Effective Resource Management in Manufacturing Systems: Optimization Algorithms for

Production Planning, Springer, New York, 2006.
[6] Hackman, S. T. Production Economics, Krieger Publishing Co., Melbourne, Florida/US, 2007.
[7] Halevi, G. Industrial Competitiveness: Costs Reduction, Springer, New York, 2006.
[8] Pinedo, M. L. Planning and Scheduling in Manufacturing and Services, Springer, New York, 2004.
[9] Argonato, P. & Coautors. Production Planning in Production Networks: Models for Medium and Short-term Planning, Springer, New York, 2008.
[10] Miller, T. C. Hierarchical Operations and Supply Chain Planning, Springer, New York, 2002.
[11] Vollman, T. E.; Berry, W.L.; Whybark, D. C. Manufacturing Planning And Control System, Lavoisier, Paris, 1998.
[12] Coelli, T. J.; Prasada Rao, D. S.; Battese, G. E. An Introduction to Efficiency and Productivity Analysis, Kluwer, New York, 1999.
[13] Soman, C. A.; Van Donk; D. P.; Gaalman, G. J. C. Capacitated Planning and Scheduling for Combined Make-to-order and Make-to-stock Production in Food Industry, International Journal of Production Economics, Vol. 108, pages 191-199, 2007.
[14] Hendry, L.C.; Kingsman, B.G. Production Planning System and their Applicability to Make-to-order Companies, European Journal of Operational Research, Vol. 40, pages 1-15, 1989.
[15] Zapfel, G.; Missbaner, H. New Concepts for Production Planning and Control, European Journal of Operational Research, 67, (1993), 297-320.
[16] Buxey, G. Production Scheduling: Practice and Theory, European Journal of Operational Research, 39, (1989), 17-31.
[17] Solot, P. Concept for Planning and Scheduling in an FMS, European Journal of Operational Research, 45, (1990), 85-95.
[18] Olhanger, J.; Rudberg, M.; Vikner, J. Long-term Capacity Management: Linking the Perspectives for Manufacturing Strategy and Sales and Operations Planning, International Journal of Production Economics, 69, (2001), 215-225.
[19] Hong-Sen Yan. Hierarchical Stochastic Production Planning for Flexible Automation Workshops, Computer & Industrial Engineering, 38, (2009), 435-455.
[20] Štefanić, N.; Gjeldim, N.; Mikac, T. Primjena Lean koncepta u proizvodnoj djelatnosti, Tehnički vjesnik, 17, 3(2010), 353-356.
[21] Lujić, R.; Šarić, T.; Šimunović, G. Primjena ekspertnog sustava pri određivanju klase prioriteta radnog naloga u pojedinačnoj proizvodnji, Tehnički vjesnik, 14, 1,2(2007), 65-75.

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