MODELLING, SIMULATION AND OPTIMISATION OF PRODUCTION SYSTEMS

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Abstract: *In management of the production run the choice of the most proper solution is connected with the larger number of criterions. The simulation project does not create the possibility for finding the optimum solution, but it is the tool aiding designer's work and enabling quick testing on the computer system of different variants of production process runs. There is presented an example of the application of optimisation (the Yager's method) in the simulation project.*
Key words: *modelling, simulation, production system, optimisation.*

1. ANALYSIS OF THE PRODUCTION PROCESS RUN

Efficient analysis of the production system functioning requires fulfilment of two conditions:

- collecting and disposing of information about the realized production process,
- disposal of theory and technique assuring the obtainment of an optimum state.

At the beginning of any analyses there is necessary to define the input parameters of the analysed system, which would collect, and output parameters, which will be a result of the conducted analyses on the base of which, there will be accomplished an opinion about the analysed system. There can occur two cases. First, in which for the made assumptions of the input parameters there will be conducted a simulation of the system maintenance. Second one, in which different collections of output data exist, where problem of finding of the optimum to produce articles with the best parameters from the point of view of the criteria of opinion exists. It is difficult to find the optimum solution. Proper planning of particular stages of experimental researches, finding possible variants of solutions and, first of all proper settlement of criterions of opinion are necessary.

In case, when while modelling and simulation many variants of proposed solutions, researches of all possible combinations come into being, all possible arrangements of value of the studied factors are very time-consuming. If it is not possible to examine all arrangements, there should be studied only these variants, which are chosen on the base of subjective opinion of the researcher, his intuition and knowledge about the object of researches.

Modelling of production systems is mainly based on statical data base, that is on the registered information in the data processing system of the company. These information e.g. norms of work time, material norms, information about possessed resources, costs of machine-hour, are seldom updated. The changes, which occur nowadays and which will occur in nearest future are not often taken into account. By the use of the modelling and simulation packet we can analyse the effects of changes which are to occur [1,2,5].

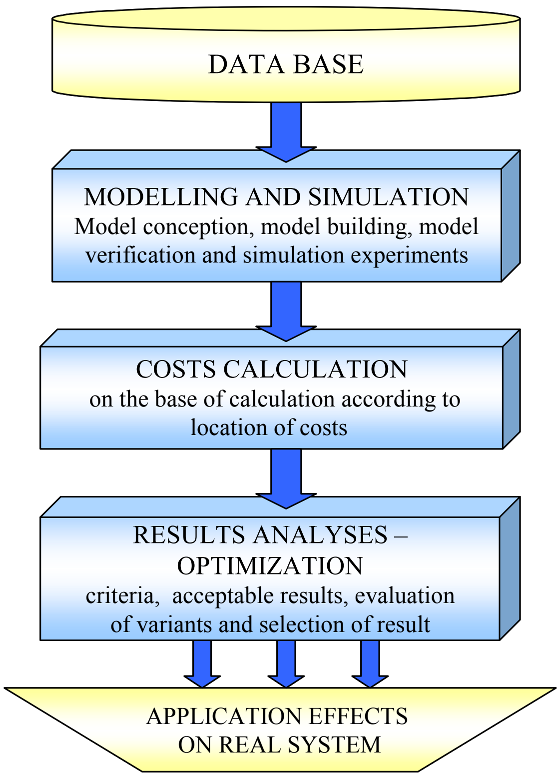

Fig.1 *Management of production aided through modelling and simulation technique*

The estimation and choice of the rational process run it is possible to execute by application of multi-criteria estimation tools using the subjective point criterions or criterions with fuzzy character [8].

2. ESTIMATION AND THE CHOICE OF THE VARIANT OF MANUFACTURING PROCESS RUN FOR REALIZATION

In the introduced below example for estimation and the choice of manufacturing process run structure there was proposed the point-by-point method of assessment according to Yager [6]. Input data of this method are:

- number of criterions m,
- number of variants of manufacturing process run n,
- elements of matrix of individual criterions validity $B = [b_{ij}]$,
- elements of matrix $C = [c_{ij}(e)]$, which are the point estimate if the i-variant according to j-criterion, passed by p-expert.

Each expert is liable for the construction of the validity estimation matrix of criterions with the Saaty's method consisting in comparing of pairs of received criterions [7].

In next step there is formed one summary matrix of the criterions validity. For the summary matrix there is searched eigenvector *Y*, fulfilling the following matrix equation:

$$B\,Y = \lambda_{\max}\,Y \tag{1}$$

where:

B - the summary validity matrix of criterions,

Y - eigenvector,

$\lambda_{\max}$ - the maximum eigenvalue of matrix *B*.

Eigenvector has as much coordinates as there were accepted criterions, and these coordinates have to fulfil the following condition:

$$\sum_{j=1}^{m} y_j = m \tag{2}$$

where:

y_j - the *j*-coordinate of eigenvector *Y*.

Coordinates of the eigenvector, called weights, express the validity of the answering them criterions (with larger value of weight, there is larger value of criterion). Applying the involution method there is determined the eigenvalue and her eigenvector. In this task was used the numeric procedure written in Pascal language [3].

Later, there is formed the total estimations, which are normalized by averaging of estimations opinions given by particular experts.

$$c_{ij} = \frac{1}{p}\sum_{e=1}^{p} c_{ij}(e) \qquad (3)$$

where: p – number of experts.

The more far conduct depends on creation of the normalised decisions by involution of each component of next normalised estimations to even power the suitable weight.

$$d_j = \sum_{j=1}^{m} c_{ij}^{\ y_j} / w_i \qquad (4)$$

After writing out of the formula it accepts he following figure:

$$\begin{aligned} d_1 &= c_{11}^{y_1} / w_1 + c_{21}^{y_1} / w_2 + \ldots + c_{n1}^{y_1} / w_n \\ d_2 &= c_{12}^{y_2} / w_1 + c_{22}^{y_2} / w_2 + \ldots + c_{n2}^{y_2} / w_n \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ d_m &= c_{1m}^{y_m} / w_1 + c_{2m}^{y_m} / w_2 + \ldots + c_{nm}^{y_m} / w_n \end{aligned} \qquad (5)$$

In result there is created the optimum decision, on the ground of which there is chosen the rational run of manufacturing process which the best fulfils all received to estimation criterions.

$$D = D_1 + D_2 + \ldots + D_n \qquad (6)$$

In assumed method the optimum decision is the decision of type of minimum. As the *i*-component of optimum decision, answering to the *i*-variant, it takes the smallest *i*-component from particular decisions $d_1, d_2, \ldots, d_m$.

$$D_i = \min_j c_{ij}^{y_j} \qquad (7)$$

The best variant of the production process run, under the assumed criterions, is the variant with the largest component in optimum decision.

$$D_{rac} = \max_i D_i \qquad (8)$$

The use of the point-by-point method of assessment according to Yager permits in simple and effective way to choose the rational manufacturing process run. Thanks to validity estimation of individual criterions and taking into account their weights in farther conduct, it is possible to estimate the particular variants of the process run and to rank it in order from the best to the worst. These workings will be helpful in planning the simulation experiments and in the continuous improvement of the production systems.

3. AN EXAMPLE OF MODELLING AND SIMULATION OF THE PRODUCTION PROCESS RUN

In the analysed system there is produced office furniture: the two-partial office wardrobe with shifted doors and the desk with a cabinet on castors [4].

The necessary materials for producing of mentioned articles were divided into three groups: elements of wardrobes, desks and common ones. These materials are ordered together without defining theirs destination.

At the end of manufacturing stage we get installed and packed furniture, which is sent directly to shops and wholesalers.

The aim of the realized analyses was the test of present system functioning and testing different possibilities of development.

There were made the following assumptions:

- times of realization of production operations were determined,
- the planned size of production was determined,
- the demand of particular materials was defined,
- distances between suppliers and the firm were specified as well as the distance between firm and recipients (wholesalers and shops),
- the way of transport, times of transport and the unit cost (per km),
- potential firms were situated, with which would be cooperated (preparation of materials and assembly),
- parameters of simulation were defined (time of cycle e.g. week or month and quantity of cycles).

The current production process was analysed on the first stage. The duty of available resources analyse was done and on the base of test data the calculation of costs was accomplished.

For example in following simulation models chosen operations (cutting of panels, assembly) were realized in cooperation. We achieved the shorter lead time. In the next stage there were analysed supply and sale processes taking earlier proposed changes into account. In table 1 there is introduced the description of the following variants of simulation models.

It is possible to create next variants of the analysed production system comparing and estimating the results from the conducted simulation.

table 1. Variants of simulation models

Variant	Descriptions
1	The whole process is realized in the firm - all materials are compiled and processed in the company. Assembled wardrobes and desks are sent to wholesaler and shops.
2	Furniture panels and fibreboards will be bought after cutting them into suitable dimensions, directly from the supplier.
3	Cooperation was made with the company which veneers edges of furniture' panels.
4	Workplaces of assembly were liquidated and prepared elements were assembled directly at customers.
5	Cooperation was made with the company which assemblies desks and wardrobes.
6	The production process was improved – increase of production efficiency was accepted at about 10% level for checking the possibility of distribution net of finished articles.

Results from the simulation made comparing different variants of proposed changes in the analysed production system possible. They were compared from point of view of three criterions: utilization degree of possessed resources, production costs and quantity of produced furniture. To the choice of the best solution there was used was the Yager's method.

table 2. Results from simulation

Criterion of estimation	Variants:	1	2	3	4	5	6
The average duty of production workplaces connected with manufacturing [%]	Desks	23,1	22,0	21,9	24,4	25,4	28,8
	Wardrobes	39,0	38,5	38,5	43,5	44,1	47,0
Production costs [PLN]	Desks	543,41	524,00	525,50	521,05	510,20	500,54
	Wardrobes	701,10	695,00	692,30	685,25	680,34	675,16
Quantity of produced furniture [pieces]	Desks	225	235	237	235	230	256
	Wardrobes	260	275	280	284	280	300

Expert 1

	k1	k2	k3
k1	1	1	2
k2	1	1	2
k3	0,5	0,5	1

Expert 2

	k1	k2	k3
k1	1	0,5	0,25
k2	2	1	0,5
k3	4	2	1

Expert 3

	k1	k2	k3
k1	1	4	0,333
k2	0,25	1	3
k3	3	0,3333	1

The summary matrix of the criterions validity

	k1	k2	k3
k1	1	1,8333	0,8611
k2	0,5455	1	1,8333
k3	1,1613	0,5455	1

Fig.2 *The defined by particular experts estimation of criterions validity*

The estimation of criterions and variants of production processes run of desks and wardrobes was entrusted to three experts: worker of the production section, worker of the production planning section and the cost-analysis section.

table 3. The multi-criterion estimation of variants in case of production of desks

The co-ordinates of eigenvector:	$Y = \begin{bmatrix} 1,1554 \\ 0,9924 \\ 0,8523 \end{bmatrix}$
The function of optimum decision:	$D = 0,0917/w_1 + 0,0469/w_2 + 0,0469/w_3 + 0,1173/w_4 + 0,1530/w_5 + 0,2522/w_6$
Preferred solution:	Variant 6 with the largest value in optimum decision: **0,2522**

table 4. The multi-criterion estimation of variants in case of production of wardrobes

The co-ordinates of eigenvector:	$Y = \begin{bmatrix} 1,1554 \\ 0,9924 \\ 0,8523 \end{bmatrix}$
The function of optimum decision:	$D = 0,0929/w_1 + 0,0731/w_2 + 0,0729/w_3 + 0,1463/w_4 + 0,1566/w_5 + 0,2129/w_6$
Preferred solution:	Variant 6 with the largest value in optimum decision: **0,2129**

The best results were achieved in variant 6. Owned production resources make possible production enlargement about 10% without necessity of additional financial expenditures. However there is necessary to realize the part of works in cooperation (the cutting and veneering of panels and assembly of furniture pieces).

4. CONCLUSIONS

Thanks to simulation:

- there were checked production abilities of the present system,

- there was estimated influence of the proposed changes on production ability of the company, costs of materials, manufacturing, transportation and cooperation,
- there were compared different directions of the company development in area of supply and sale,
- there was estimated variants from point of view of three criteria – the duty of production workplaces, production costs and quantity of produced furniture.

Large labour-consuming is a disadvantage of modelling of such complex production systems. It is easily to make different changes later in simulation model - to create different variants of analysed production system. Checking of different variants and choice proper can bring significant advantages for firm.

The introduced example and mentioned above advantages from her use testify about large usefulness of the modelling and simulation method in dissolving of problems connected with managing of production processes.

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