The Use of Optimal Management Tasks for Verification and Adjustment of New Product Release Planning in Discrete Production Systems

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Keywords: Lot-Scheduling Planning, Optimal Management, Discrete Production, Project, Production System, Engineering Company, Forecast, Prediction, Business Plan, Smart Manufacturing

Abstract: The present paper investigates a modern issue of predictive models for optimal management used to enhance the performance of production system management that can be achieved by a joint consideration and synchronization of internal and external processes of an examined system. Volume planning task is considered as a task that helps verify the results of business planning and take into account the interrelation of subsystems of a production system and foreign market impact based on forecasting data. The article draws on the example of release of leading-edge vacuum pumps in an engineering company in order to define the prospects of this market and estimate manufacturing capabilities. The analysis was carried out based on the data of an approximate business plan and statistical data of vacuum pump market. As a result, it suggests production schedule for vacuum pumps that can be taken as a background for making feasibility decisions on the release of new products and adjusting production activities of an enterprise. The obtained business planning data can be used in practice by solving the tasks of production management that help perform preliminary estimates of enterprise potentiality for market needs and improve the objectivity of strategic decision making by enhancing the formalization level of describing processes and preparing objective data. The synchronization of production processes described in the paper is relevant as it is connected with the current trends, i.e. the reduction of time production, the depreciation of human factor in production processes, all that triggers increased requirements to the quality of management in production processes.

1 INTRODUCTION

Currently, we observe a trend when life cycle is reducing and the range of products is increasing. In discrete productions it leads to new problems of search and integration of new products, product line, modification selection. For all that, decision making is affected by external market environment that is not predetermined yet. The task gets more complicated because of the continuity of production process that consists in the peculiarities of a performed operation, such as in-line assembly, stamping operations, casting, pressing, etc. From the other hand, there is a trend for enhancing the versatility of production tools that sets advanced requirements to management decision making and planning as the interchangeability of industrial machinery causes the invariance of part motion and operations' performance.

Finally, production planning task is connected with the management of production resources necessary for utilizing primary products and parts for the production of final products that have best compliance with customer needs.

Planning and management tasks are considered on the tactical and strategical levels.

The target of a tactical level is to identify the most efficient way of utilizing procured resources (materials, stocks, capacities) with the planning horizon from one or several months up to two years in general (depending on the life cycle of released products). Such tasks are solved by working out operation plans for the procurement of primary products and cargo, transport routes, etc.

The tasks of prospect product portfolio are tackled on the strategical level.

The matching of operation plans with the tasks of project portfolio planning and changes connected with the performance of production systems helps increase management efficiency and decrease management and loss expenses that are caused by the non-coordination of managerial decisions.

The economic task of batch planning combines the decisions on the batch size and production planning. It is difficult to find an optimal solution for this task but it helps increase the capacities of a company.

Production planning tasks have been investigated for over 70 years as they have practical significance. Today, we have both precise methods and approximate deterministic and probability models. Along with a vast practical application, this task has scientific potential since production planning requires complex applications of approaches, methods and models.

Many authors talk about a special function of management, the extended formalization of management principles, the increase in «flexibility» within existing approaches or possibilities to develop new comprehensive methods and models.

The significance of complex estimates with high quality is increasing. Hence, accumulated volumes of collected information bring the tasks of monitoring and parameter forecasting; under current conditions, we need to apply tracking systems to control the dynamics of parameter changes and the matching of their values with the planned values [1].

At the same time, we observe shortage of methodological approaches for the formalization of project management tasks in production systems despite the fact that this area has been investigated for a long time. The methods of objective decision making with limited time factor applied for solving planning and management tasks encounter the problem of NP-completeness; therefore, many of these tasks can be solved only with help of approximate methods.

The development of the concept Industry 4.0 and IIoT that enables the collection of information about each equipment unit and operative control over production processes in production systems [2], on the one hand, presents new possibilities for developing methods of industrial engineering, on the other hand, it causes the problem of big data processing.

Furthermore, the process of achieving target indicators is not a single-stage process, yet it is a series of interdependent states. More than that, target indicators can change in time and can represent a set of differently related values [3].

2 MANAGEMENT TASK SETTING

There are studies of planning the release of new products, i.e. the determination of product costs, target market volume; as a result, business plan with target indicators is obtained. Despite the existing practice to use business planning, it should be noted, that business plans do not consider the task from the standpoint of immediate planning and production planning, procurement and sales, the allocation of production capacities and production plan adjustments in enterprises (in big production systems). Nevertheless, the application of business planning (see Table 1) (institutional management level) in the tasks on the managerial and technical levels of management can help verify the feasibility of proposed plans, sustainability of obtained results and development of alternative implementation variants.

Table 1: An example of business planning results for two types of new products.

Quarter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sales volume (item)																				
Turbomolecular pump	3	5	6	8	8	9	11	11	12	14	15	16	16	16	17	18	19	19	20	20
Cryogenic pump	2	3	5	6	9	11	12	14	15	16	17	19	20	20	20	21	21	21	21	22
Net profit (thou. rub.)																				
Turbomolecular pump	-3892	-2449	-1721	-150	-710	119	1854	1900	84	1687	2812	3281	3375	3559	4584	5653	6767	7029	8218	8513
Cryogenic pump	-2367	-1965	-880	-440	1487	2681	2967	3856	2888	3580	4295	5477	6243	6456	6559	7138	7252	7368	7486	8110

Applying such approach as an approach for the management on the basis of a limited parameter set and building structures of collective decision-making was shown in the works by R. Sah and J. Stiglitz.

In most cases, building a task «from nothing» is based on the application of best practices and analyst expertise.

One of the most wide-spread approaches is the application of optimization tasks.

For the mathematical formalization of optimization task, it is necessary to determine calculation parameters $Z = AX$, where Z – the parameter vector (including computable parameters), A – the incidence matrix, X- the vector of model parameters (including the parameters obtained on the basis of forecasting data with the risk $R(\varepsilon)$ and the precision ε).

$$J\{Z\} \to opt$$
$$f_i(Z) : G_i, i = \overline{1,n},$$

where - : one of the operations $>, <, \geq, \leq, =, \neq$; i – the number of forecast-based parameter imposed restrictions of a model; G_i – the values for restrictions; $f_i(Z)$ – the function with parameters. Formalization examples can be found in the references (for instance, see [4]).

From the standpoint of production system, project management task consists in the task of maximizing profits by selecting a product portfolio. However, not all economically effective goods can be produced at a certain enterprise due to its technological capabilities. In order to consider all these peculiarities, we should select feasible suggestions. Hence, we can consider the task of volume planning. The target of this task is to receive optimal production plan by maximum net profit and minimum costs. Besides, it should be taken into account, that production time depends on the time of parts' production and the time of product assembly, and the number of manufactured products should be placed within the bounds from break-even point up to the number of goods that the market is able to consume. Net profit of sold products depends on revenue and costs of manufacture. Also, it should be noted, that there should be a sufficient amount of parts at the time of manufacturing of products.

In this case, volume planning task with time restricted parameters [5] can be presented as follows:

$$\sum_n (C_n(t) - (Q_m(t) + I_n(t))) \times X_n(t) \to max$$
$$X_n^H(t) \leq X_n(t) \leq X_n^B(t)$$
$$(C_n(t) - (Q_m(t) + I_n(t))) \geq 0$$
$$D_{nm}(t) \geq Z_{nm}$$
$$S_{pc} \geq S_n(t) \geq 0$$

where X_n – the release volume of the product n, $C_n(t)$ – the revenue from the sold products n, Q_m – the costs of parts' manufacture, I_n – the assembly costs of the product n, X_n^H – the number of the products n to meet break-even requirements, X_n^B – the number of the products n that the market is able to consume, n – the type of product, m – the set of parts, t – the time, S_n – the number of available machinery, S_{pc} – the number of machinery, D_{nm}- the matrix of existing parts that can be shown as follows:

A set of parts	1	…	m
The number of parts	D_{n1}		$D_{nm..}$

Z_{nm} - the matrix of parts required for manufacture, that is given as follows:

A set of parts	1	…	m
The number of parts	Z_{n1}	…	$Z_{nm.}$

It should be considered, that the restrictions include also the functions of time. It can be explained by the fact that production system descriptions can alter in time, procurement schedule can change, and the volume of requires allotted for the implementation of a certain projects can also adjust, etc.

The interrelation with other tasks, such as power supply system management, stock control, HRM, procurement management, sales management, utilization management, management of works sequence and paralleling [6] presumes the use of total resources (production means, parts/ components/ materials, return of goods, reused parts/ components/ materials, etc. see Table 2).

By calculating weakly formalized factors it is necessary to simulate the deviations of parameter values and observe their impact on the performance of system. Such approach allows define most probable development scenarios (we take into account a joint impact of deviations on a series of interrelated tasks and parameters), estimate the probability of scenarios implementation on business planning, and define the way these scenarios are affected by certain parameters.

Table 2: An approximate structure of process chart for the production of pilot turbomolecular vacuum pumps.

№	Operation	Time	Parts and components	Amount	Measurement unit	Machinery	Outcome	Personnel
1	Processing of rotor forging	T_{12}^1	Rotor forging	$Part_{1231}$	unit	Metal-working machinery	Processed rotor forgings	Machine operator
2	Pressing and punching of rotor shaft	T_{21}^1	Cylindrical work	$Part_{2141}$	unit	Metal-forming and punching machinery	Unprocessed rotor shaft	Puncher
3	Thermal processing of shaft	T_{22}^1	Unprocessed rotor shaft	$Part_{2251}$	unit	Furnace for metal normalizing	Normalized shaft	Furnace tender
4	Mechanical processing of shaft	T_{23}^1	Normalized shaft	$Part_{2331}$	unit	Metal-working machinery	Rotor shaft (Z_{12})	Machine operator
5	Processing of stator forgings	T_{12}^1	Stator forgings	$Part_{3231}$	unit	Metal-working machinery	Processed stator forgings	Machine operator
6	Manufacture of ceramic racers	T_{41}^1	Silicon nitride	$Part_{4161}$	unit	Turning machinery	Ceramic racers	Lathe operator
7	Manufacture of ceramic bearing balls	T_{42}^1	Silicon nitride	$Part_{4271}$	unit	Processing machinery	Ceramic bearing balls	Machine operator
8	Punching of pump body	T_{51}^1	Billet	$Part_{5121}$	unit	Metal-forming machinery	Punched pump body	Puncher
9	Processing of pump body	T_{52}^1	Punched pump body	$Part_{5231}$	unit	Metal-working machinery	Pump body (Z_{15})	Machine operator
10	Manufacture of rotor forgings	T_{11}^1	Cast metal ingot	$Part_{1111}$	unit	Metal-cutting machinery	Rotor forging	Machine operator
				$Part_{1121}$		Metal-forming machinery		Puncher
11	Manufacture of blades on rotors	T_{13}^1	Processed rotor forgings	$Part_{1311}$	unit	Metal-cutting machinery	Rotor disks (Z_{11})	Machine operator
				$Part_{1331}$		Metal-working machinery		
12	Manufacture of stator forgings	T_{31}^1	Cast metal ingot	$Part_{3121}$	unit	Metal-forming machinery	Stator forging	Puncher
				$Part_{3111}$		Metal-cutting machinery		Machine operator
13	Manufacture of blades on stators	T_{33}^1	Processed stator forgings	$Part_{3311}$	unit	Metal-cutting machinery	Stator disks (Z_{13})	Machine operator
				$Part_{3331}$		Metal-working machinery		
14	Assembly of ceramic bearings	T_{43}^1	Ceramic bearing races	$Part_{4381}$	unit	Assembly facilities	Ceramic bearings (Z_{14})	Assembly worker
			Ceramic bearing balls					
15	Assembly of cryogenic pump	T_{61}^1	Rotor shaft (Z_{12})	$Part_{6181}$	unit	Assembly facilities	Ceramic bearings (Z_{14})	Assembly worker
			Pump body (Z_{15})					
			Rotor disks (Z_{11})					
			Ceramic bearings (Z_{14})					
			Stator disks (Z_{13})					

3 MANAGEMENT TASK SOLUTION

The task presented in the previous section generally can become a multi-parameter task with nonlinear restrictions when a part of parameters is assigned by the functions of time, and they can be discrete, continuous and stochastic [7].

Depending on the task received, several approaches can be used, that help obtain both a precise and an approximate solution (see [8]). A universal solution of such tasks is the application of heuristic methods that do not impose limits on target function; this solution enables perform multiple calculations by using statistical methods for simulating deviations and discrete time (the latter one is simulated in accordance with the principle Δt or by allocating special states – completion of certain works and commencement of other works [9]). Evolutionary programming is one of the most wide-spread methods (for example, genetic algorithm). A significant advantage of these methods is a possibility to assign calculation time that can be allotted for calculation performance. It becomes especially important by the necessity of conducting multiple calculations when time for decision making is limited. That is why, industrial engineering task is solved with help of the library rgenoud for the language R (see Listing 1).

Listing1: The function that implements optimization task solutions in the language R.

```
opt<-function(v1_, v2_, pump1, pump2,
ss, niz1, niz2, verh1, verh2, n1, n2){
  n2<-1
  n1<-1
  niz1<-floor(rnorm(1, mean = 8, sd=1))
  niz2<-floor(rnorm(1, mean = 9, sd=1))
  verh1<-floor(rnorm(1, mean = 20,
sd=8))
  verh2<-floor(rnorm(1, mean = 18,
sd=7))
  y<-NA
  if (v1_*n2>v2_*n1) {f<-
genoud(function(y) v1_*y[1]+v2_*y[2],
nvars=2, max.generations = 10,
wait.generations = 10, Domains =
matrix(c(min(niz1,min(verh1, pump1,
ss))-0.1, min(verh1, pump1, ss),
min(niz2,min(verh2, pump2, ss-
min(verh1, pump1, ss)))-0.1, min(verh2,
pump2, ss-min(verh1, pump1, ss))),
ncol=2, byrow=TRUE), max = TRUE,
data.type.int = TRUE)}
  else {f<-genoud(function(y)
v1_*y[1]+v2_*y[2], nvars=2,
max.generations = 10, wait.generations
= 10, Domains =
matrix(c(min(niz1,min(verh1, pump1, ss-
min(verh2, pump2, ss)))-0.1, min(verh1,
pump1, ss-min(verh2, pump2, ss)),
min(niz2,min(verh2, pump2, ss))-0.1,
min(verh2, pump2, ss)), ncol=2,
byrow=TRUE), max = TRUE, data.type.int
= TRUE)}
  return(f)
}
```

In the examined case business planning data can alter depending on the unfolding situation. That is why, we need to consider for planning data possible deviations of their values within confidence interval (if we assume, that planning data are valid (true), the deviations will obey the normal distribution law); hence, the algorithm for task solution will be as presented in the Fig. 1.

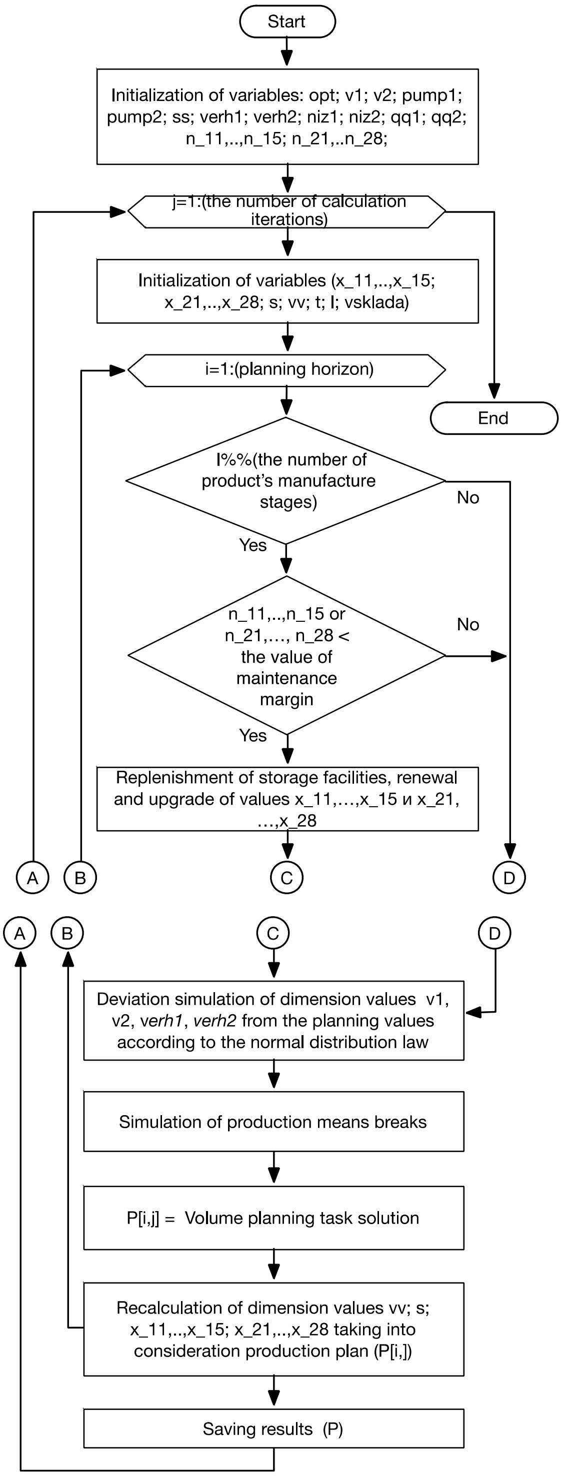

Figure 1: The algorithm of volume planning task solution taking into account possible deviations of parameter values (*v1*, *v2* – the values of net profit from the products 1 and 2; *pump1*, *pump2* – the number of the products 1 and 2, that can be manufactured from the procured number of parts/

components/ materials; *ss* – the number of available production means; *verh1*, *verh2* – the restriction value for market capacity for the products 1 and 2; *niz1*, *niz2* – the value of break-even point for the products 1 and 2; *qq1*, *qq2* – the pump production time of the products 1 and 2; n_11,…,n_15 – the number of different parts/ components/ materials required for the manufacture of the product 1; x_11,…,x_15 – the number of different procured parts/ components/ materials for the manufacture of the product 1; x_21,…,x_28 – the number of different procured parts/ components/ materials for the manufacture of the product 2; s – the matrix of available production means; vv – the matrix of production means that become available on the next stage; vsklada – the size of storage facilities. n_21,…,n_28 – the number of parts required for the manufacture of the pump 2).

4 THE ANALYSIS OF OBTAINED RESULTS

By solving optimal management tasks taking into consideration time factor and a certain discrete time step, the solution will present a tabular function. According to Bayesian theorem, the probability of an effective transition into a new state (to a new solution) will depend on the previous state (the state that we are placed in). At the same time, the simulation of parameter deviations will help obtain a set of solutions for each step (taking the total probability of transition to the next step by 1 taking into account iterations of possible solutions); hence, occurrence probabilities of each of possible states $s_1, s_2, \cdots, s_n$ – are equal to:

$$\begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1m} \\ p_{12} & p_{22} & \cdots & p_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nm} \end{pmatrix},$$

where n – the maximum amount of states on the steps m.

In this case, management task adds up to the selection of a desired state from the set of possible states and to path determination (a series of intermediate states) for its achievement. As a result, we can define the probabilities for obtaining solutions. Therefore, a solution represents a set of project development paths (decision tree) (see Fig. 2) that can be considered as a Bayesian network, that can be used for selecting most probable development path on the basis of the method of dynamic programming (Bellman's method) and matched with planning results for their verification or disproof.

Decision tree nodes in the Fig. 2 (for the task of volume production planning) match to the combinations of release volumes of products (for example, for 20 time steps and 100 calculations in each time station for a joint release of two types of products see Table 3).

The obtained values will have a different number of iterations (in the examined examples from 3 up to 38), which means, that the probabilities of different states will be also different. As shown in Table 4, in several cases invariant states are encountered. Besides, if we match most probable states with business plan dates (Table 4), they most likely do not match; this observation is demonstrated by the results of multiple calculations, which proves that business planning does not consider production system peculiarities, that show up in planning tasks as optimization tasks in their restrictions.

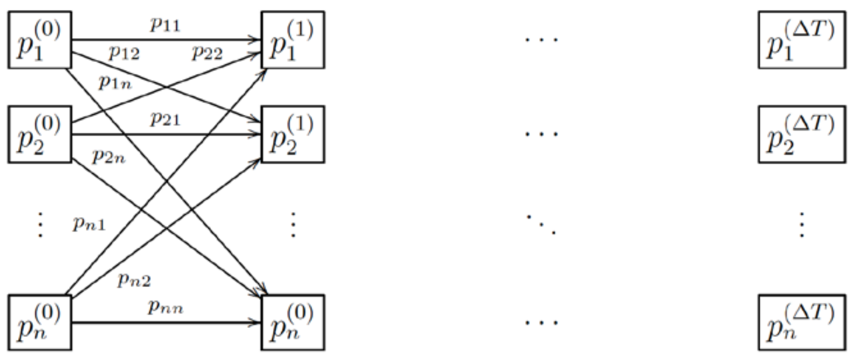

Figure 2: The decision tree for selecting the development path of production system or project implementation.

Table 3: Production volume plan for two products taking into account restriction deviations in market size and net profit by step-by-step increase of allotted production funds according to the business plan.

Calculation number	Time (number of planning month)								
	1		**2**		**3**		**…**	**20**	
1	5	0	5	3	4	5	0	5	3
2	5	0	5	3	8	5	0	5	3
3	5	0	5	3	8	5	0	5	3
4	5	0	5	3	8	5	0	5	3
5	5	0	5	3	8	5	0	5	3
6	5	0	5	3	8	5	0	5	3
7	5	0	0	5	6	5	0	0	5
8	5	0	5	3	8	5	0	5	3
…	…	…	…	…	…	…	…	…	…
100	5	0	8	0	11	5	0	8	0

The calculation results can lead to phenomena when upon removing restrictions on production funds the release of production units changes (for example, first only one type of goods is released and afterwards we start the release of another type of goods), and by the combination of restrictions the release of only one type of goods is deemed optimal.

Such phenomenon justifies the significance of a proper implementation of an adjustment process and market entry taking into account not only state of market, but also the processes that run inside production system. Finally, such verification can indicate the possibility of a backward approach – draw a plan for market entry based on the volume planning task, perform market studies on its basis and set a task.

Table 4: The matrix of state probabilities for time steps without taking into account their interdependence in time (most probable states are marked dark grey, the results received by business planning are marked light grey) with production funds restraint according to the plan of production volume growth that was obtained as a result of business planning.

Time (number of a planning month)																			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
The probability of system to enter the examined state s_i																			
0,54	0,41	0,50	0,52	0,41	0,40	0,46	0,02	0,47	0,43	0,01	0,43	0,01	0,38	0,29	0,37	0,01	0,29	0,01	0,03
0,45	0,48	0,48	0,48	0,01	0,49	0,41	0,34	0,01	0,01	0,44	0,27	0,01	0,25	0,42	0,21	0,28	0,01	0,26	0,02
0,01	0,01	0,01	-	0,47	0,01	0,01	0,43	0,42	0,31	0,01	0,01	0,32	0,02	0,02	0,01	0,28	0,01	0,02	0,04
-	0,02	0,01	-	0,02	0,01	0,01	0,03	0,01	0,01	0,31	0,01	0,01	0,05	0,02	0,01	0,02	0,26	0,25	0,22
-	0,02	-	-	0,01	0,01	0,02	0,01	0,01	0,01	0,02	0,02	0,01	0,02	0,01	0,01	0,04	0,01	0,01	0,22
-	0,01	-	-	0,01	0,01	0,01	0,02	0,02	0,01	0,02	0,03	0,01	0,02	0,02	0,01	0,02	0,01	0,02	0,01
-	0,01	-	-	0,02	0,01	0,01	0,03	0,01	0,01	0,02	0,02	0,27	0,01	0,01	0,01	0,03	0,01	0,01	0,02
-	0,01	-	-	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,01	0,01	0,01	0,03	0,02	0,02
-	0,01	-	-	0,03	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,03	0,01	0,01
-	0,01	-	-	0,01	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,02	0,02	0,01	0,02	0,02	0,03	0,02
-	0,01	-	-	-	0,01	0,01	0,01	0,01	0,03	0,01	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,01
-	-	-	-	-	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,03	0,02	0,02	0,01	0,02	0,01	0,02	0,01
-	-	-	-	-	-	0,01	0,01	-	0,02	0,01	0,02	0,02	0,01	0,01	0,03	0,02	0,01	0,03	0,01
-	-	-	-	-	-	0,01	0,02	-	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,02	0,02	0,01	0,01
-	-	-	-	-	-	-	0,01	-	0,01	0,01	0,01	0,03	0,01	0,01	0,02	0,01	0,01	0,02	0,02
-	-	-	-	-	-	-	0,01	-	0,01	0,01	0,02	0,01	0,01	0,02	0,01	0,01	0,02	0,01	0,02
-	-	-	-	-	-	-	0,01	-	0,01	0,01	0,02	0,02	0,01	0,01	0,01	0,02	0,02	0,02	0,04
-	-	-	-	-	-	-	0,01	-	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02
-	-	-	-	-	-	-	-	-	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,03	0,01	0,03	0,01

-	-	-	-	-	-	-	-	-	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
-	-	-	-	-	-	-	-	-	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,02	0,01	0,04
-	-	-	-	-	-	-	-	-	0,01	0,01	0,01	0,03	0,01	0,01	0,01	0,01	0,01	0,01	0,01
-	-	-	-	-	-	-	-	-	0,01	0,01	0,01	0,02	0,02	0,01	0,01	0,01	0,01	0,02	0,02
-	-	-	-	-	-	-	-	-	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,01	0,01	0,01	0,01
-	-	-	-	-	-	-	-	-	-	-	-	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
-	-	-	-	-	-	-	-	-	-	-	-	0,02	0,01	-	0,01	0,01	0,01	0,01	0,01
-	-	-	-	-	-	-	-	-	-	-	-	0,01	0,01	-	0,01	0,01	0,01	0,01	0,02
-	-	-	-	-	-	-	-	-	-	-	-	0,01	0,01	-	0,02	0,01	0,01	0,01	0,01
-	-	-	-	-	-	-	-	-	-	-	-	0,01	-	-	0,02	0,02	0,01	0,01	0,01
-	-	-	-	-	-	-	-	-	-	-	-	0,01	-	-	0,01	0,01	0,01	0,01	0,01
-	-	-	-	-	-	-	-	-	-	-	-	0,01	-	-	0,01	-	0,02	0,01	0,01
-	-	-	-	-	-	-	-	-	-	-	-	0,01	-	-	0,01	-	0,01	0,02	0,01
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,01	-	0,01	0,01	0,01
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,01	-	0,01	0,01	0,01
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,01	-	0,01	0,02	0,01
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,01	-	0,01	-	0,01
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,01	-	0,01	-	0,01
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,01
The number of possible states n on the step m																			
3	11	4	2	10	12	14	18	12	24	24	24	32	28	25	37	30	37	35	38

The selection of a certain solution should be based on path choice by the consideration of probabilities of their implementation (see Table 4 and Fig. 3). The probability of each solution achievement is defined by chain rule: $P(s_1, s_2, \dots, s_n) = \prod_{j=1}^{n} P(s_j | s_{j-1}, \dots, s_1)$ (for most probable sequence of states from Table 5 we receive the following probability values - 0,54; 0,2592; 0,1296; 0,0674; 0,0317; 0,0155; 0,0071; 0,0031; 0,0014; 0,0006; 0,0003; 0,00012; 0,00004; 0,000014; 0,000006; 0,0000022; 0,00000062; 0,00000018; 0,00000005; 0,00000001). Obtained values will be smaller than those obtained in Table 4. Small values show, that project implementation involves a set of factors that are not considered.

The table given above demonstrates that the data obtained by solution selection differ from those of economic planning. It is connected with the optimization processes and the matching of processes in each production system. At the same time, in optimal planning tasks we need to consider a minimum quantity of goods of each type to be produced; such tasks involve a group of other tasks to be tackled, i.e. management, social function, production peculiarities, break-even for each type of goods, etc.

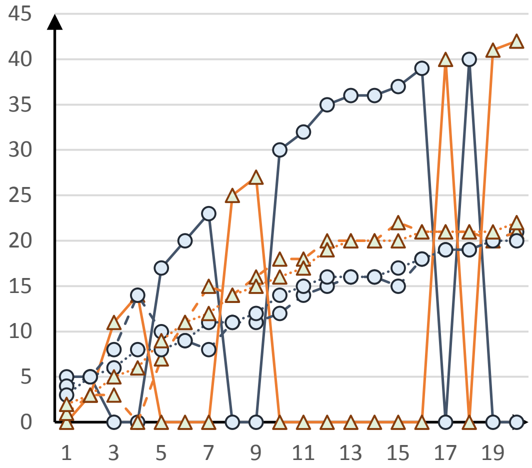

Figure 3: Alternative volume plans for two products (orange line – first product, blue line – second product; solid line - results of lot-scheduling planning; dotted line - results from business planning; dashed line - result from the pool of lot-scheduling planning results which near business planning result).

5 CONCLUSIONS

The application of forecast data in the tasks of optimal management and information systems, based on data and models, creates new possibilities to investigate processes that run in production systems. In particular, we can consider probabilistic nature of processes that run outside the examined production system, estimate the risks of planning and production activities, time factor [11].

Obtained solutions are approximate solutions; the task applies also planning data. Therefore, the task has statistical setting, but the model itself can superpose different formalization types that leads to the combination of different simulation types.

By the consideration of time factor, we examine system performance as a string of states. These states can take place and cannot take place (the system will take an alternative path then), that is why, calculation and evaluation of a state should be iterated on each time step.

Despite the possibility to perform multiple calculations, the decision is eventually made by a person; however, the processing of subjective data and their workable representation increases the objectivity of made decisions which is crucial in the situations when most promising markets are the markets of innovation goods; on such markets we cannot talk about the stability of production processes due to the short life cycle of such goods, big amount of modifications and components, increased power and resource intensity of goods.

Corresponding libraries and modules can be integrated into information systems of production and business process management, i.e.: ERP, MRP, CSRP.

Production systems where management tasks are solved are considered inertial objects of management. They cannot momentary adjust running processes; besides, the adjustment of technological processes requires the use of additional resources, i.e. time, financial resources, staff expertise, organization resources. The studies of such issues and the consideration of their impact on production system development paths can become the subject of further investigations; the data of the analytical agency Gartner verify the necessity of such research directions («Road map of production information systems» dating from March 28th, 2017).

ACKNOWLEDGMENTS

The author thanks the government of Perm Krai for the support of the project for “Development of software and economic and mathematical models for supporting innovation project management processes in production systems”, which is being implemented in accordance with decree №166-п of 06.04.2011.

The reported study was partially supported by the Government of Perm Krai, research project No. C-26/058.

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