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Particularities of Solving the Problems of Support for Managerial Decision Making in Production and Economic Systems Using the Statistical Data

Leonid A. Mylnikov*

Department of Innovations, Perm National Research Polytechnic University, Russia. *Email: leonid.mylnikov@pstu.ru

ABSTRACT

The subject of this paper is the decision making processes in production and economic systems (PES) conditioned by implementation of goods innovation projects as well as economic and mathematical models and methods of managing the processes. The research object viewed in the paper is the construction of models of goods innovation projects implementation and the ways of implementation thereof based on the mathematical apparatus and statistical data. The paper discusses a method of constructing the models of support for managerial decision making in PES and working with them based on simulation and mathematical programming methods. The task of selecting the PES for implementation of projects as well as of forming the PES portfolios is worded in general. The author also pays attention to the questions of designing and using the information systems based on simulation approaches for supporting the decision making, studying the goods innovation projects at various development stages, and the PES implementing them. A method of forming and transferring data is suggested the implementation of which will allow solving the tasks of support for decision making in PES based on statistical data and criterial methods as well as perform risk assessment and measure the sensitivity of the results obtained to changing characteristics of the projects and the influence of the environment.

Keywords: Decision Making Support, Mathematical Programming, Volume Scheduling, Innovation Project, Production and Economic System, Data Processing, Statistical Data

JEL Classifications: C44, C55, C63, C87

1. INTRODUCTION

At present the single numerical evaluations and decisions play an increasingly smaller part in management and managerial decision making, yet the accelerated growth of significance of qualitative and complex evaluations is observed. An essential role in the process is played by the large volumes of information and data of statistics already accumulated and being accumulated. Being surrounded by the external environment, man accumulates data and then transforms them into experience and knowledge. The same approach is true for the modern managing systems and algorithms too. This is why the methods of working with data, obtaining new knowledge based on the data, working with temporal series are the areas the development of which is most relevant as of today and most promising from the viewpoint of obtaining new knowledge, methods and approaches.

Such an attitude to data becomes possible due to a rapid growth of their volume. However, in order to obtain qualitative evaluations, not only a large volume of data integrated into the historical view is required but also the methods which can work with them efficiently. On the other hand, the quantity of digital data is known to have featured an avalanche-like growth in the recent years, yet that of such data on the time spans more remote in the past is smaller. The analysis of data over large time spans allows getting the qualitative results that exceed the results feasible for a human in their level.

The disadvantage associated with the lack of data and invariance of the environment where the processes take place is compensated by elaboration of methods for forecasting and modeling the possible change and deviations using the models of processes and systems studied.

With regard to this, the systems of information processing and modeling that are able to solve tasks based on the data enjoy an increasing demand. A special role is gained by the data and approaches based on modeling in dealing with the open systems that evolve together with the external environment. The production and economic systems (PES) are an example of such systems: They are purposeful systems incorporated at the same time in several purposeful systems of various levels (a production system where the project is implemented, industry branch system and so on). Meanwhile, its parts can have their own purposes (people who implement the projects; the strategic, production, operating levels of management etc.).

Such systems are distinguished by difficulties associated with management due to the numerous uncertainties related to the uniqueness of the process, interdisciplinary character, multi-factor nature of the processes taking place, hierarchical structure of the factors and elements, a considerable volume of information - both data and their connections, which determines the complexity due to visibility, the existing spatial and temporal relationship between the innovation project elements, and the ability of systems to switch to various behavior types under change of the external conditions (Faizrakhmanov and Mylnikov, 2016).

Meanwhile, when studying a part of parameters in such systems, the lack of data can be sensed that is due to invalid data present or their inconsistent character. Moreover, such systems contain sources of uncertainty that is manifested in different ways - when identifying the purposes and subpurposes, when random factors occur, during the lack of resources. The sources of uncertainty in the system are random factors which on top of that are interrelated and influence indirectly all the parameters of the PES where a project is implemented.

Any attempts to formalize such systems face the necessity to accommodate the description of them within the framework of the general concept that has its particularities of implementation and limitations of the applicability scope.

Initially, the task of products management was studied by Albert Calmes as a problem of accounting and statistics in factory and goods production (Voigt, 2008). The task grew into the development of planning methods (Taylor (1967) and Gantt and Forrer, 2006). Further development of science in this area brought about the improvement of mathematical formalization methods (to which the start was put by works of such authors as Von Neumann and Morgenstern (2007), and Kantorovich (1939)). On the one hand, taking into account as many factors as possible in these methods contributed to it as well, and so did the elaboration of managerial decisions within the entire production spheres (e.g., works of Tirole in industry branch markets management (see for instance, Joskow and Tirole (2007)). On the other hand, the attempt to describe the "physics" of the processes occurring in PES played its part too, which has led to creation of the theory of production functions (Solow, 1957).

When considering the production management task from the side of the project, the approaches based on such phenomenon as innovation diffusion (Gault and Hippel, 2009) are most known, in particular, the implementation and studying of the experience of similar products in different production systems in order to find out the common features. In 1995, it was suggested to use the game theory in describing the backup and improving innovations in order to take into account the interaction and influence of projects on each other (Pepall, 1995). It is this approach that has made it possible to pass to solving the task of change management.

2. METHODOLOGICAL FRAMEWORK

The modern models based on using the data have to allow evaluating the production risks and planning risks, which results in the necessity to perform multiple cyclic calculations. Moreover, at present, the linear idea about products output has given its place to the idea of a cyclic nature of the products life cycle. In it, the quality and consistency of managerial decision making associated with its choice, modification, planning and production organization gain a special importance.

So, the process model for support the decision making will have the appearance given in Figure 1.

Under this approach, the optimization task becomes the key element. The task depending on the application area can be used for solving such particular tasks as optimizing the production routes of movement of parts and components according to various parameters (time, cost, manual work scope), optimizing the procurement and warehouse activity, evaluating the cost of equipment, parts, employees hiring and the like while bearing in mind the cost of ownership and participation in production processes, the volume scheduling of production for producing several items within a subdivision or an enterprise, selecting technical solutions and forming the products portfolio, etc.

In general terms, the model can be represented as the following tuple (Zelenkov, 2012):

$$\Psi\{U, A, R, \Theta, w(\cdot), v(\cdot), I, \Gamma, \varphi\}=0,$$

Where $U = (U_F, U_B, U_P, U_V, U_C, U_S, U_I)$ is the management vector incorporating the management of financing, production, products, implementation, sales, scientific development, and institutional management; A is a set of actions to achieve purposes; R - A set of results of the actions; Θ - A set of values describing the condition of the environment; $w(\cdot){:}A\times\Theta\rightarrow R$ - The result of activity depending on actions and the environment condition; $v(\cdot)$ - Preferences of the agent set by the utility function; I - The information which the agent has as of decision making point; Γ - Purposes; $\varphi=(\varphi_1, \varphi_2,\ldots,\varphi_n)$ - The vector of models of product innovation projects represented as the tuple:

$$\varphi_i=\{P,T\};$$

With P being a set of values of the management parameters; T - A set of the project's needs of resources; i - The project number.

To construct a model, the task of its identification has to be solved. Due to complexity of the task conditioned by distinctions in subject areas from which the models emerge and insufficient studying of the processes occurring during innovations implementation, it is rather difficult to construct a universal model. Hence its own model is formed individually for each system and for each project.

Making the models more certain generates the problem of selecting the set of methods and models (Mylnikov, 2012; Mylnikov, 2015). For implementing each project in a PES considered, the model represented in general terms as (Ψ_j) is formed by means of expert selection of the known or author's models and methods based on the information about the PES and the innovation project, about the purposes of innovation project implementation and the set of values of the management parameters:

$$\{I, \Gamma, \varphi\} \rightarrow \{M_i(m_{ik})\},$$

Here $M_i(m_{ik})$ are the methods and m_{ik} - parameters of the methods.

The methods can be united around the optimization task. When considering the PES, the task can be worded proceeding from the diagram given in Figure 2.

2.1. Examples of Formalizing the Optimization Tasks for Working with Data

When implementing the projects that have reached the implementation stage, one of the crucial tasks is to evaluate the prospects and implementation method for the project. The task of selecting a market to be developed consists in having to choose the most profitable method of implementing the development. With regard to this, it has to be borne in mind that one and the same project (development implementation method) can go to different markets (for example, to market B2B or B2C) - Figure 3.

So the mathematical setting of this task will take the following form:

$$max_{1 \le j \le m, 1 \le a \le n} R_j(t) C_{ab}(t),$$

Where *j, a* are integers, R_j - Market capacity, *j*, C_{ab} - Profit from production of the project *a* in PES *b*. The market capacity R_j(t) is determined as the difference between asymptote *K* and saturation

Figure 1: The structure of a typical model of production and economic system for making prompt managerial decisions

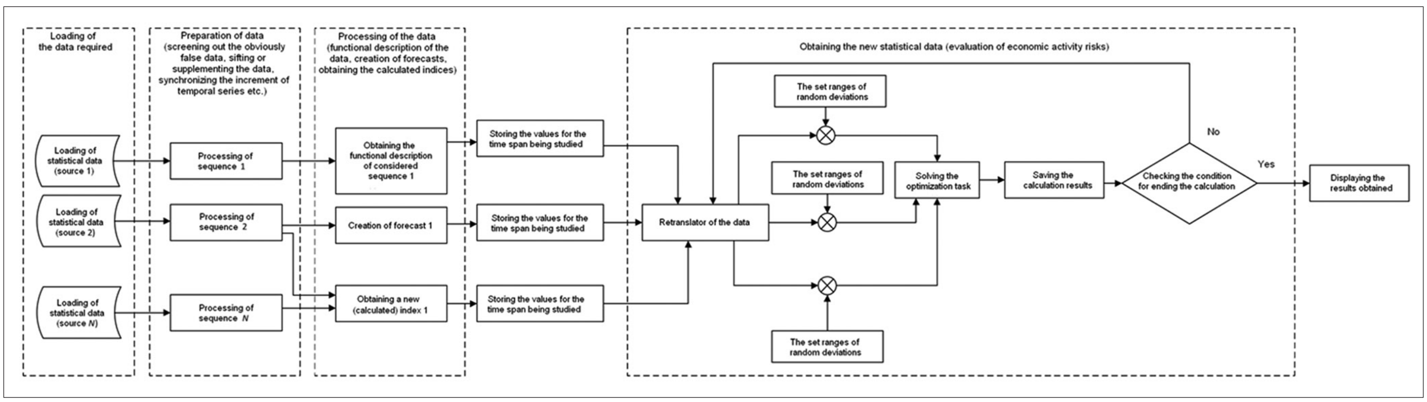

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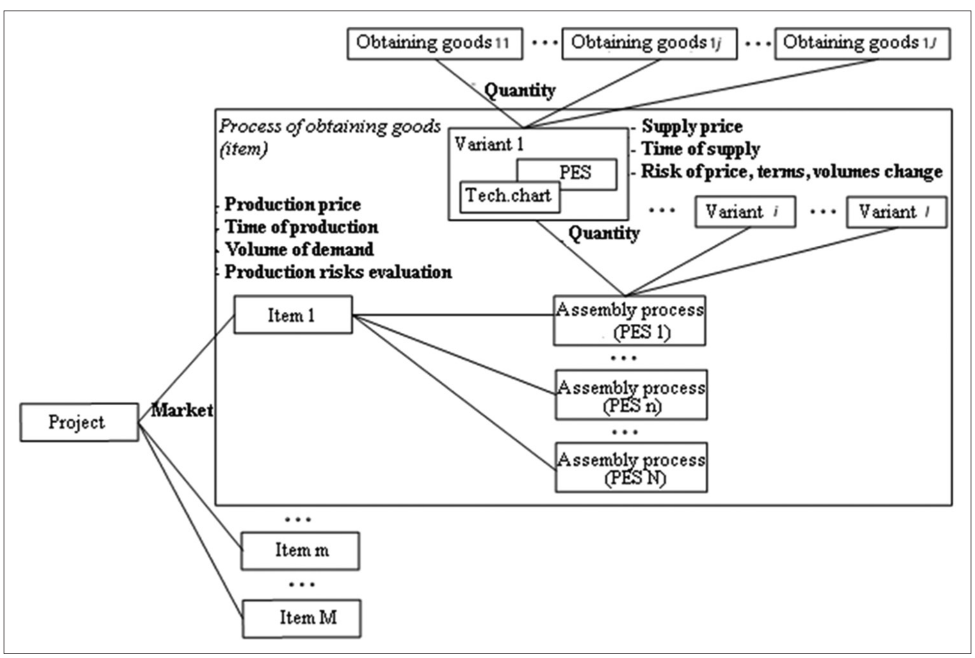
Figure 2: Structural diagram for constructing the task of optimum management in production and economic systems



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of the market $N_j(t)$ which is described by an S-shaped curve: $R_j(t)=K-N_j(t)$, while the profit is determined as the difference between selling price $Q_{ab}(t)$ and the expenses for producing $Z_{ab}(t)$ the goods a: $C_{ab}(t)=Q_{ab}(t)-Z_{ab}(t)$. Then the task of choosing a market will take the form:

$$\max_{1\le j\le m, 1\le a\le n} R_j(t)(Q_{ab}(t)-Z_{ab}(t)).$$

Figure 3: The choice of markets for products that can be sold on the basis of development

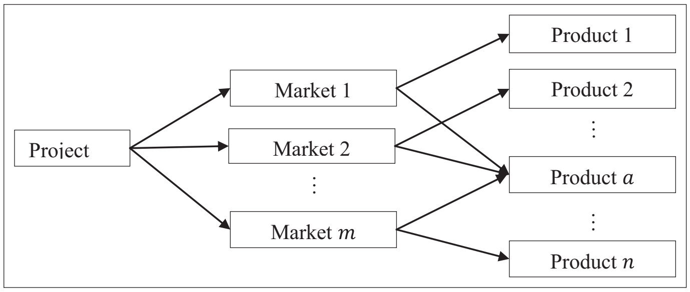

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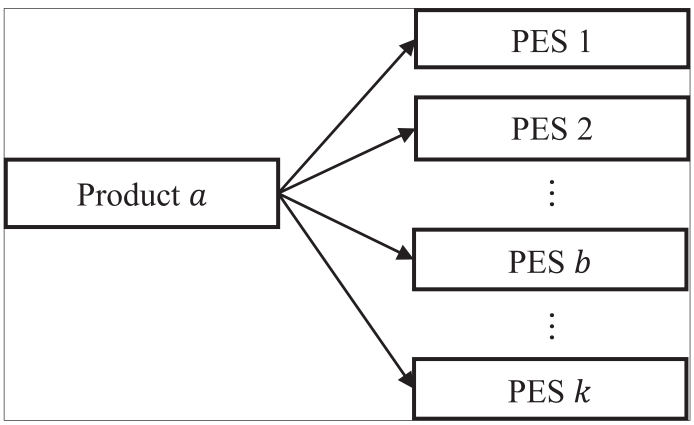
Figure 4: The choice of markets for products that can be sold on the basis of development



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The next step during a project implementation is choosing the PES where this project will be implemented. It can be given for selling to the existing PES or it can be sold independently via the newly created legal entities.

Depending on the task the developers face, they may have to solve either the task of maximizing the profit from the project implementation or the task of bringing the time of production to the minimum. This yields two models.

The first model is one for minimizing the expenses (Figure 4):

$$Z_{ab}(t)=\sum_{g=1}^{l_h} z_{abg}(t)\rightarrow min, b=\overline{1,k}, \qquad (1)$$

Here l_h is the quantity of operations in PES b for producing the goods a and z_{agb}- The expenses for performing the operation g in PES b during production of the goods a.

The second model is one for minimizing the expenses of time. It has to be borne in mind that some operations can be performed simultaneously (Figure 5).

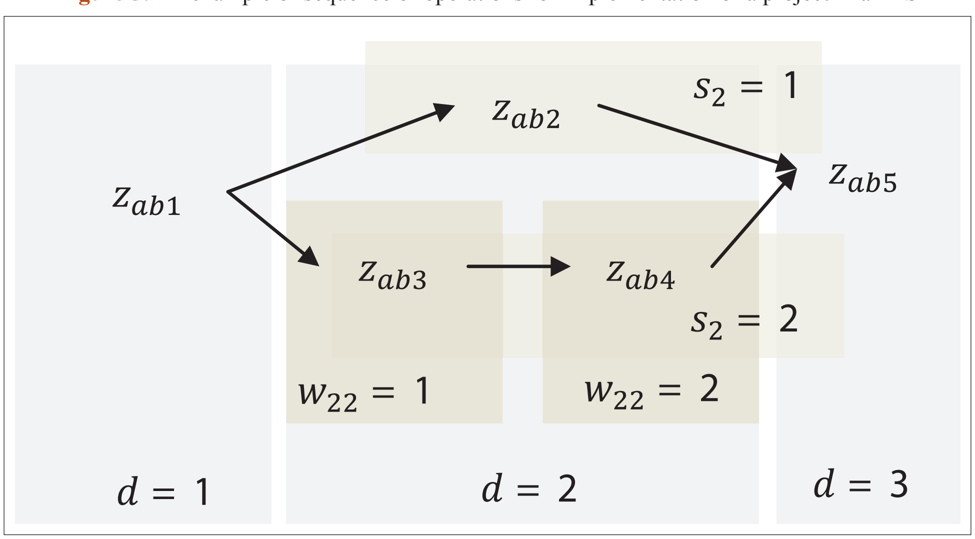
Then the model for minimizing the time expenses will look as follows:

$$\sum_{d=1}^{v}\sum_{s=1}^{s_d}\max\sum_{f=1}^{w_{de}} T_{z_{abdef}} \rightarrow min, \qquad (2)$$

Where d is the quantity of operations performed in a series during production of goods a in PES b, s - The quantity of parallel sequences in sequence d, and w_s - The quantity of operations in a sequence. $T_{z_{abdef}}$ is the time required for performing the operation z_{abdef} in PES b during production of goods a. In order to use the above model, a table of correlations between values g in (1) and d, e, f in (2) is required.

From the viewpoint of PES, the task of projects management looks like a task of selecting the products portfolio (Figure 6).

Figure 5: An example of sequence of operations for implementation of a project in a PES



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Mathematical setting of this task takes the following form:

$$\sum_{v=1}^{u} C_v(t)X_v(t) \to max,$$

Where C_v is the profit of implementing the project v, and X_v is the project output volume v. The same can be written down otherwise:

$$\sum_{v=1}^{u} (Q_{vb}(t) - Z_{vb}(t))X_v(t) \to max.$$

If $a=v$, the models of selection of the market and forming the products portfolio can be united, which yields the task of optimum distribution of the projects set between PES.

$$\sum_{a=1}^{n} \max_{1\le j\le m} R_j(t)(Q_{ab}(t) - \sum_{g=1}^{l_{h_a}} z_{abg}(t))\sum_{v=1}^{u}(Q_{vb}(t) - \sum_{g=1}^{l_{h_v}} z_{vbg}(t))X_v(t) \to \min, b=\overline{1,k}, \quad (3)$$

The value of expenses $Z(t)$ can express not only the financial expenses but also ones for materials, component parts etc. except the time (2).

If it is required to take into account these expenses and expenses of time (2), the relevant criteria of form (1) can be added to the task to be considered jointly.

The expenses are determined by the technological charts of production of goods a in PES b. The charts have the form given in Table 1.

In order to take into account the limitations of a certain PES, the criterial function can be supplemented by the following limitations:

$\sum_v\sum_g R_{gv}X_v(t)\le P,$

$\sum_v\sum_t S_{gv}X_v(t)\le T,$

Where P is the general resource in capacities for each equipment type found by calculation of the mean performance for all equipment of this type; T is the volume of key materials available determined on the basis of the data about condition of the warehouse and procurement plan.

Such an approach functions well when one goods project is considered in a PES in which the remaining projects portfolio has already been formed. If a set of projects, goods, markets, PES is viewed comprehensively, the dimension of the task increases multiply. Nevertheless, it is brought down to (3) if for all the projects under consideration the markets are determined and the common list of possible products is formed.

Despite all advantages, the cited task of mathematical programming in general terms cannot be solved (especially in the case of considering a set of criteria). It has already been shown in literature that tasks of this kind are NP-complete (e.g., for the markets selection task see (Van den Heuvel et al., 2012). However, other tasks can be solved.

Model 1: Compiling the volume schedules of production broken down to groups of goods based on forecasting the demand and saturation of markets.

$$\sum_{v=1}^{u} (Q_{vb}(t) - \sum_{g=1}^{l_{h_v}} z_{vbg}(t))X_v(t) \to min,$$

$\sum_v\sum_g R_{gv}X_v(t)\le P,$

$\sum_v\sum_t S_{gv}X_v(t)\le T,$

$X_v(t)\le G_v(t),$

Where G_v is the market limitations for goods v (it is determined proceeding from the sales volume of the goods or its analog).

Model 2: Selecting the methods of implementation and production systems for producing the new innovation projects.

$$\sum_{a=1}^{n} \max_{1\le j\le m} R_j(t)(Q_{ab}(t) - \sum_{g=1}^{l_{h_a}} z_{abg}(t)) \to min, b=\overline{1,k}$$

$\sum_v\sum_g R_{gv}X_v(t)\le P,$

$\sum_v\sum_t S_{gv}X_v(t)\le T.$

Some data for these tasks (such as the sales volume, prices change, market saturation and others) have to be determined based on forecasts. Then the complexity of the task to be solved will increase and the resistance of decisions obtained to fluctuations of parameter values will have to be studied. Not only the production risks will have to be evaluated but planning risks too.

Table 1: The structure of a technological chart

Number of the operation	Name of the operation	Cost of performing the operation	Previous operations	Following operations	Time of performance	Need of component parts	Need of materials	Need of equipment
.								
;								
.								
g	...	z_{vbg}	...	...	T_{zabdef}		S_{gv}	R_{gv}
.								
.								
.								

R_{gv} - Need of capacities of each equipment type per ready product item, S_{gv} - Need of key materials per ready product item

Given essential limitations, there are other formalization methods for this class of tasks as of today. With regard to this, there are a lot of Nobel prize winners among the scientists working with this topics range (Kantorovich, 1939; Solow, 1987; Markowitz, 1994; Stiglitz, 2001; Tirole, 2014). However, a special role of management and significance of a higher extent of formalization of management principles and the applicability sphere within the existing approaches and concepts should be pointed out.

An important stage at selecting a managerial decision is the analysis of results obtained. Many authors make efforts to solve the tasks associated with the analysis of single decisions risk. For instance, Capital-Asset-Pricing-Model suggested by Sharpe (1964), Lintner (1965), Mossin (1966) and relying on Markowitz's (1952; 1970) theory can be used for evaluating the projects portfolio risks. When using the parameters described by functions obtained on the basis of forecast values, the approach described in (Abdullaev et al., 2012) can be applied for risk evaluation.

However, the tasks obtained as mathematical programming ones can only be solved by approximate methods due to their complexity, with the forecast data containing errors. Hence an important analysis stage is studying the sensitivity of the decisions obtained to deviation of parameters (ones characterizing the market and the PES) which can have the Markovian property (a Markovian process) and are modeled by Monte Carlo method.

It is the simulation methods together with block structure of the model that allow conducting such an analysis with a resulting corridor in which the decisions obtained may fluctuate under the interference of various circumstances. In their turn, such data allow engaging experts who will be able to make grounded decisions based on them.

2.2. The Use of Simulation Modeling Approaches for Solving Management Tasks in PES

Simulation models are models of the so-called black box type. This means they ensure yielding the output system parameters if there are input actions on its interacting subsystems. Hence for obtaining the required information or results a "run" (fulfillment, "rehearsal") of models has to be performed but not "solving" of them. Simulation models cannot form their own decisions the way this occurs in analytical models but they can only be a means for analyzing the system's behavior in conditions determined by the experimenter. However, the combination of mathematical models (Batishcheva et al., 2006) and simulators allows combining the advantages of these model types, as the expedience of using the above approach becomes evident with any of the following conditions available:

- The analytical solution methods of the formulated mathematical model have been developed not for all stages of the project implementation;
- There are analytical methods but the mathematical procedures are so complicated and labor-intensive that simulation gives a simpler method of solving the task;
- Alongside with evaluation of certain parameters, it is desirable to observe the process progress for some time using the simulation model.

Despite the described advantages, the use of block simulation models results in emergence of the task of data transfer and interaction, as it is shown in Figures 1 and 2. Blocks can be united by several methods: Serial calculation, layer by layer calculation, and parallel calculation.

2.2.1. Serial calculations method

When serial calculation is used, each model gets a number according to the order of calculation. Using the current values of input data in accordance with the algorithm input into it, the model obtains output values, and so on - until the calculations with all model elements have been performed.

In this case, a model is viewed as an oriented graph. Then the computational task is brought down to that of bypassing the oriented graph (Aho et al., 1983) and performing the algorithms, methods and models of working with the data corresponding to the graph nodes.

2.2.2. Layer by layer calculations method

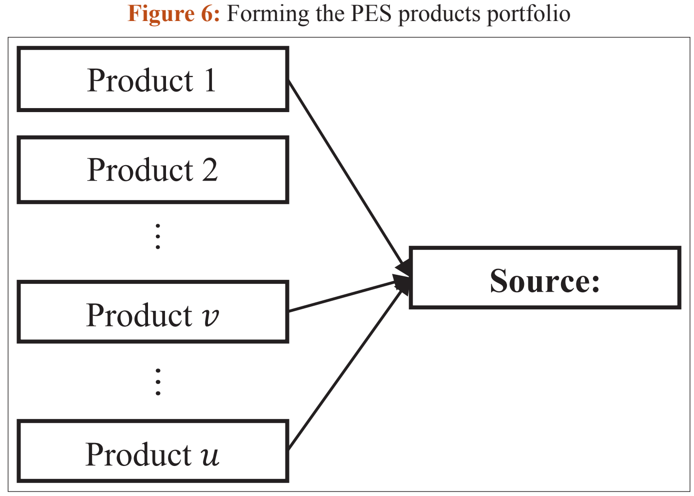
The following model calculation method is layer by layer calculation which is most frequently used when working with neural networks. This is possible if model elements can be broken down into "layers" - blocks the work of which does not depend on the data obtained in the blocks located in the same layer. Thus, the calculation is performed in series by groups of blocks, which allows enhancing the productivity of calculations in computational complexes having several cores.

2.2.3. Parallel calculations method

Parallel calculations can be used in the case when current input data can be used for obtaining the results in each block. Practically, this results in delay of data proliferation and obtaining valid results from input to output, the lag depending on the quantity of serially connected model blocks from its input to its output. However, such an approach allows paralleling the computational process without limitations and raising the calculations speed. Unlike the previous ones, performing the parallel calculations requires the use of mathematical apparatus based on the matrix theory:

$$[\varphi]=-([A][M][A]^T)^{-1}[A][M][E],$$

Figure 6: Forming the PES products portfolio



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Where [φ] is the matrix of value magnitudes at the model blocks output, [*A*] - Matrix of incidence showing the relationships between the model elements, [*M*] - Matrix of magnitudes showing how many times the value of input magnitudes of the model element will be corrected, and [*E*] is the matrix of additional actions and deviations (modeling the random influences of the external environment).

In cases of random or quasi-random actions on the system, an important feature of simulation is the opportunity of repeated calculation and thus obtaining statistical information about the possible deviation ranges for the resulting decisions and probability evaluations of these or those outcomes. In particular, when calculations are planned for the remote future while knowing what statistical information was obtained at what time points, decisions can be obtained with attachment to a future time and the possibility of timely, early or late obtaining of the results can be estimated.

2.3. The Principles of Working with Data when Combining the Approaches of Simulation and Mathematical Programming of PES

The practical implementation of the above models is only possible using the information systems which will have expandable architecture and will perform the required work with the data.

At the level of individual block elements, the following universal elements are essential (Mylnikov and Trusov, 2011):

- First, data reading and forming a synchronized data stream is necessary (Figure 7). For instance, in case different variables have a statistical set of values with various intervals, then either one data set has to be thinned out or the other one has to be supplemented.
- Second, the data have to be prepared depending on their particularities and ones of setting of the task to be solved. If there are spaces or calculations are continued for the intervals for which there are no statistics, they have to be supplemented by data. Functional description and trends revealing can be used in this case to minimize the statistical errors (Bendat and Piersol, 1986) (Figure 8).
- Thirdly, the implementation of the main task solved as a task of mathematical programming (Figure 9). At this stage, the model gets a data stream, processes it and yields certain results for an expert to work with.

3. RESULTS AND DISCUSSION

In 1942, Schumpeter and in his book (Schumpeter and Swedberg, 2005) turned to the influence of technological change on the economy. He introduced the notion of "creative destruction" thus focusing the attention on the implementation of new technologies requiring the reconstruction of the established technological processes in PES. With regard to this, the gain of enterprises in this scientific and technical race consists in their winning the monopoly at the market for some time. Since this time, efforts have been made to formalize and study the processes occuring during management and projects implementation in PES.

The first models in conditions of limited time with repeated stages that were dealt with within the simulation approach were reduced to the linear approach. Yet even this approach is represented as individual stages with a completed result each.

The first generation of such models is referred to the end of the 1950s - middle of the 1960s. The simplest of them represents a project as a number of stages having a low formalization level: Elaboration and implementation which implies the use and bringing into life of the development (Vinokur and Trusov, 2004).

The linear and serial models with the thrust on the importance of market to the needs of which R&D responses are the second generation models dating back to the late 1960-s - early 1970s (Vinokur and Trusov, 2004). The linear and serial description is also the total of subsequent stages yet supplemented with axes of functional actions of the main production management directions.

The third generation model was put forward in the mid-1980s (Vinokur and Trusov, 2004). This is a coupled model also called the interactive one. To a great extent, this is a combination of the first and the second generation models with the accent placed on technological opportunities and market needs being connected.

The models considered today can be classified as parallel and serial ones. The modeling process in such models is brought down to the use of a set of standardized or author's models for each block composing the general model. When building such models, several approaches can be combined viewing a project as an object having a complex structure which interacts with other projects and for which the production system is the external environment. In its

Figure 7: Data reading and synchronization when preparing them for analysis

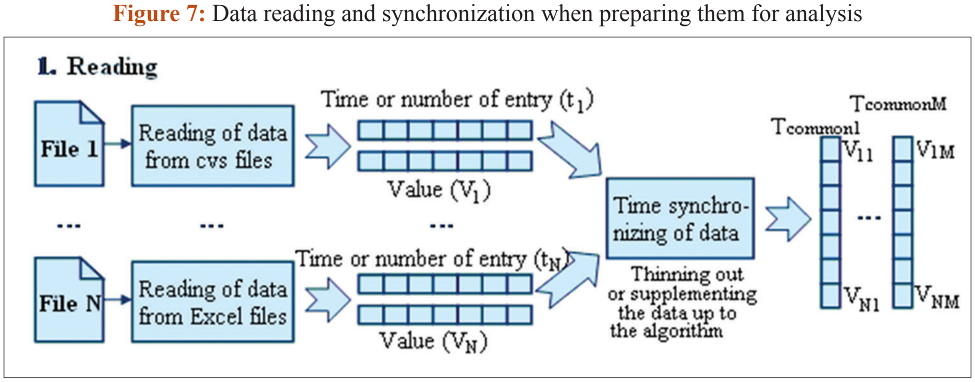

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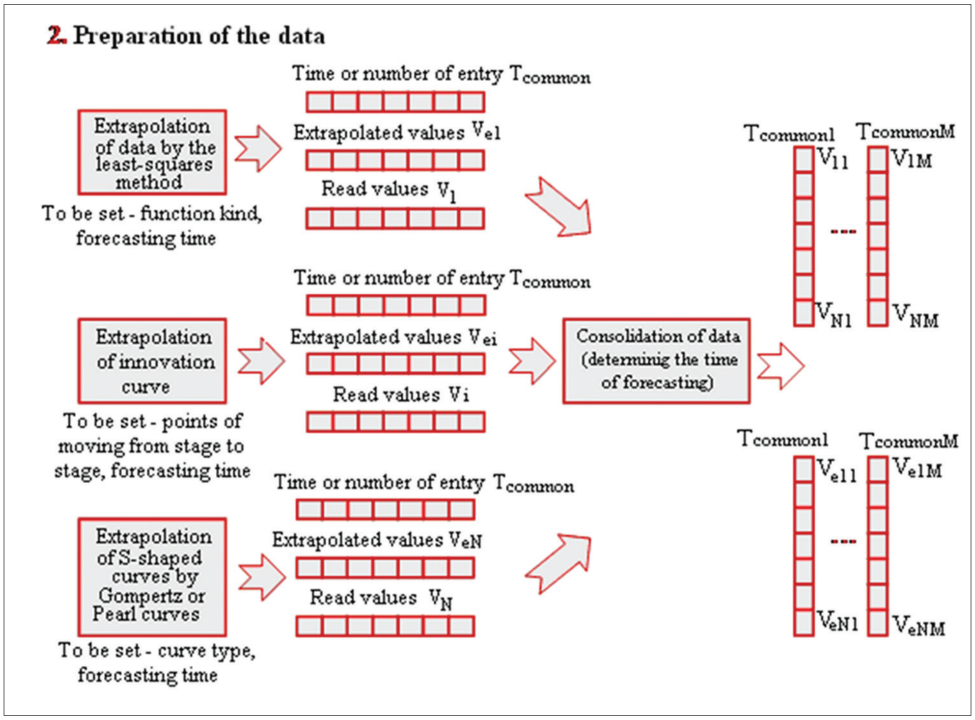
Figure 8: The algorithm of forecasting and preparing the data for solving the decision making support task



turn, the production system will have the market environment for the external one. Meanwhile, each object consists of elements describing the subsystems and resources of the object, and the values of main variables are common and change with mutual influence on each other and further external factors taken into account. Given the opportunity, joint use of numerous approaches will also enhance the objective character of evaluations owing to reducing the entropy value (Gurevich, 2007).

Universal as it may be, the direction associated with PES modeling long followed the path of creating specialized methods due to the joint use of methods being a complicated task and making it necessary to conduct multiple model experiments. This, in its turn, necessitates specialized information systems for the purpose.

However, despite all the difficulties, approaches are known at present using which attempts are made to solve the outlined task.

One of these approaches is the research direction in the area of production functions use. This approach specializes in support for managerial decision making in systems having the non-linear cost and systems having a combinatorial structure. The majority of studies in the sphere deal with tasks of bringing the costs to the minimum or demand forecasting. An important problem when considering such tasks is the joint consideration of price formation, volume production planning, and procurement management tasks. Solving the tasks raises the problem of selecting the market and the internal structural organization of the PES and so it can face the NP-completeness. Consideration of the task in such relationship has been called the problem of Wagner-Whitin (Wagner and Whitin, 1958). Moreover, within this approach, difficulties emerge if comprehensive modeling of random actions is necessary.

Pepall suggested using the game theory (Pepall, 1995) for accounting the interaction of the projects and their influence on each other. The development of this approach in projects management is currently associated with agent modeling and the use of forecasts. As applied to PES, this approach is known as multi-agent systems (Jennings, 2000) which allow taking into account such factors as autonomy, dependence on the external factors, flexibility, proactivity, a social factor, the factor of intellectual management in the system (Dignum, 2006). Within this approach, the most difficult is to coordinate interaction between the parts of PES (Kaihara and Fujii, 2008), which is a subject of an individual study. Despite all advantages of the multi-agent modeling, this approach does not allow finding the optimum and quasi-optimum managerial decisions as it does not imply the evaluation of variants obtained.

The approach to management of PES often relies on the diagram of event-based breakdown of the process designed (Jordan's modeling method, Gaine's logical modeling). Their disadvantage is the necessity to have a generated possible decisions list.

A separate major direction in PES management is the grouped methods based on various management types. So, in literature such management types as management of financing, organizational projects management, institutional management (management under limitations), information management are widely described. Within such approaches, a lot of models have been developed that describe the organization of financing, decision making by certain subjects, behavior models and institutions management. The achievements of Stiglitz (Shapiro-Stiglitz model) and active systems models cannot but be pointed out.

The methods of mathematical regression and a number of other functions extrapolation methods, formalization of innovation curves

(Mylnikov and Alkdirou, 2009) and S-shaped curves (Dignum, 2006; Alkdirou and Mylnikov, 2010) formalization approaches, Monte Carlo methods for modeling the random actions, the optimization tasks solving methods, SlopeOne family algorithms, production risks and planning risks evaluation methods (Abdullaev, 2012) and others are widely used for solving the particular tasks.

Although there are quite a lot of methods solving individual tasks and approaches considering individual entire tasks, they are not suitable for solving the described class of tasks. Yet they can be integrated in a complex model of the PES under study based on the approach described in the paper. So they will allow enhancing the preciseness of describing the studied object and the quality of managerial decisions generated.

The above tasks and methods of formalizing thereof cannot be resolved as of today due to limitation of the instrumental means existing. Thus, it can be concluded that instrumental means capable of solving the tasks arising have to be implemented.

For performing the calculations, an information system has to be used that would allow solving the tasks of innovation projects management based on expandable architecture. Taking into account the tasks considered during innovation projects management in PES, the calculations have to be fulfilled in several stages (Mylnikov, 2012).

For implementing the above principles, programming language R is quite suitable. The language has been specially developed for working with statistical data. However, just like the specialized programs of statistical data processing, it is good for serial/linear data processing but it is not intended for organizing the multiple cyclic calculations as well as for separating the work logics into individual blocks.

Due to this, the author supposes as a result of his research that in order to solve the task of managing the PES a special description can be necessary. It is suggested to use the JSON language as such a special description one for serializing the blocks of the model and describing the connections between them, as well as the R language for describing the logics of operation of individual blocks and models. As it has been shown, the relationship between blocks is organized based on the data exchange.

Such a combination has allowed successfully solving the above tasks using the simulation methods, for which a prototype of information system has been developed (Figure 10 for the example of interface and the resulting combination of the JSON language and R-code).

4. CONCLUSION AND RECOMMENDATIONS

Having constructed a model, a researcher can forecast the object's properties and behavior both inside the area for which the model is constructed and (if applied reasonably) beyond it (the forecasting role of the model), control the object selecting the best actions by testing them out on the model (the managing role), study the phenomenon or object the model of which has been constructed (the cognitive role of the model). He can also obtain skills of the object management by using the model as a simulator or game (the teaching role) or even improve the object by changing the model and testing it out (the design role).

As for the practical activity of projects and PES management, the representation of management tasks in PES described in the paper allows constructing the simulation models for certain tasks without having to face the NP-completeness problem (e.g., the problem of Wagner-Whitin). The use of points of stage to stage transition of parameters forecast or points associated with production cycles as described in (Faizrakhmanov and Mylnikov, 2016) as the decision making points allows avoiding the endless

Figure 9: The approach of working with a model for accumulating the statistics when for solving the decision making support task

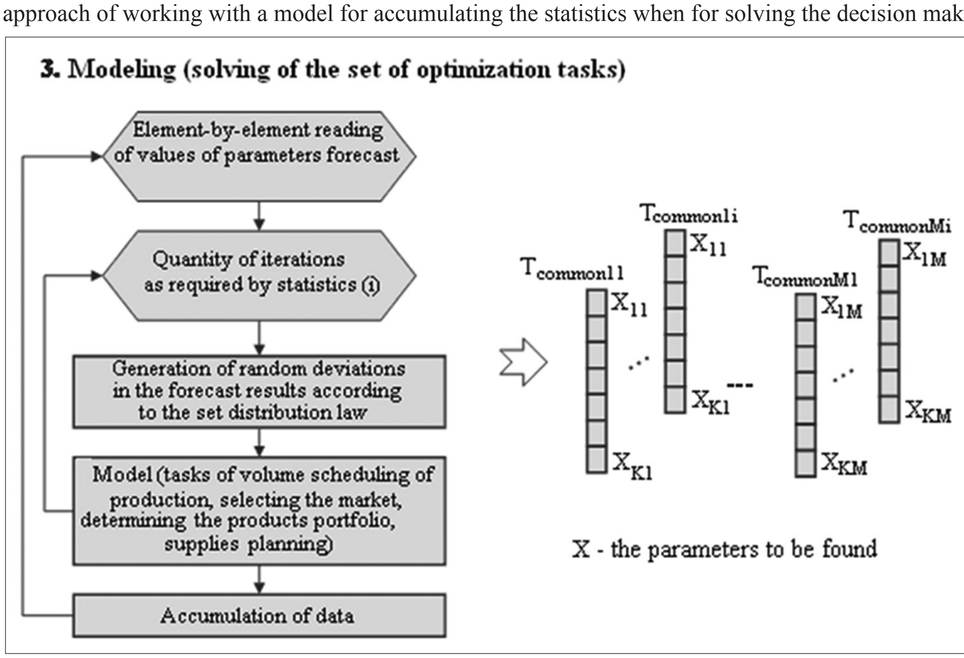
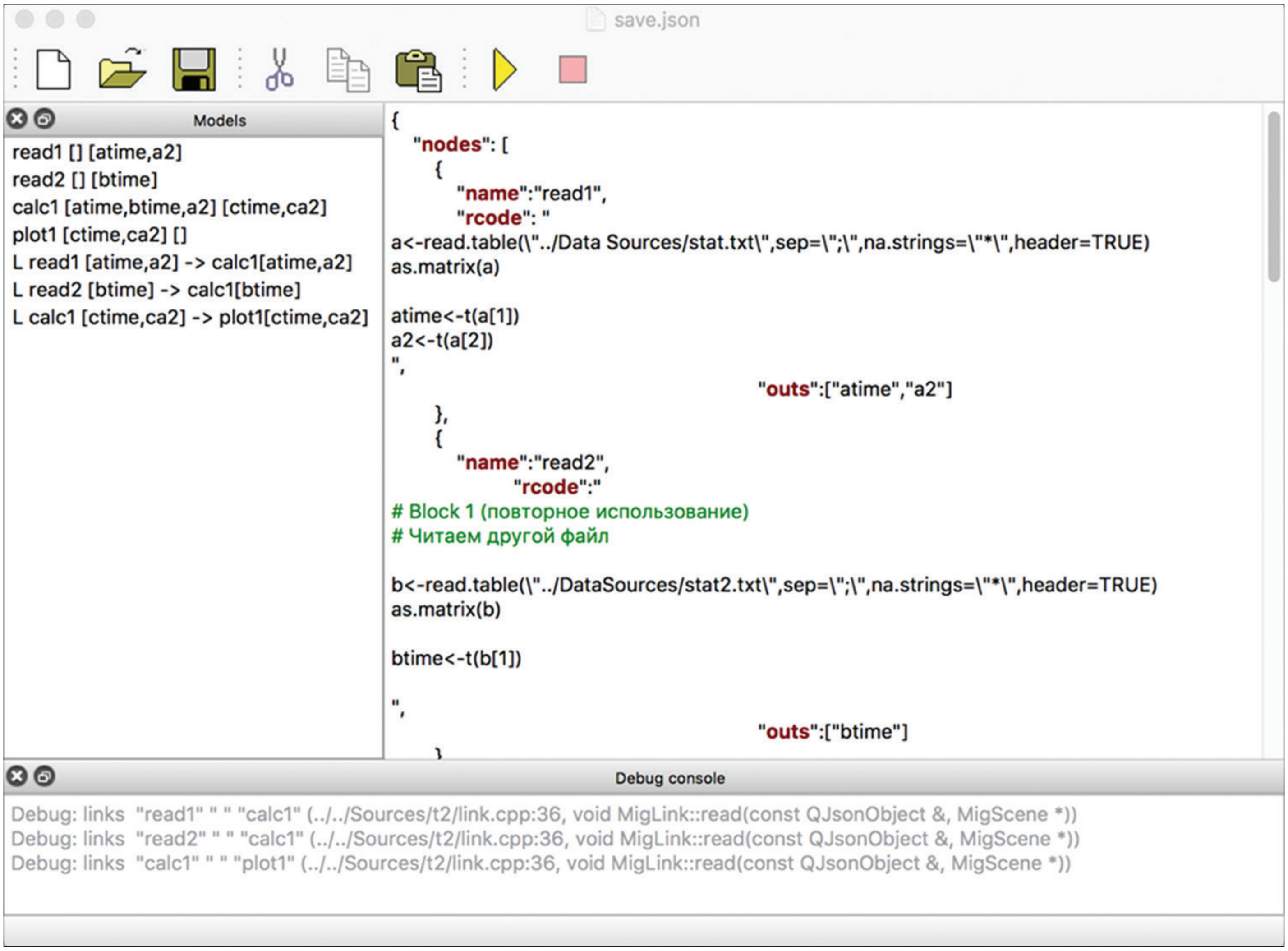


Figure 10: A screenshot of the system being designed with an example of description of the model



horizon problem (Paprotny and Thess, 2013) and eliminating the emergence of such phenomenon in PES as the innovation regress described by Novikov and Tsvetkov (2001), corresponding member of the RAS.

The approach to modeling the decision making support processes described in the paper allows viewing the processes occurring in PES at virtually any detailing level. Meanwhile, in the model, almost any algorithm of managerial activity or behavior of the system can be simulated.

The paper will be useful for researchers in management and support for decision making whose research object is the PES and information systems used for that purpose, as well as for the professionals in design of information systems intended for data preparation, analysis and processing.

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