The use of the model apparatus in solving problems of optimization of multimodal transport

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Abstract. On the basis of retrospective analysis of approaches and principles of modeling of business processes of the company, the main parameters of their modernization in the conditions of globalization of modern economy are allocated. Approaches to the integration of methodological tools of mathematical and simulation modeling of business processes with an emphasis on the need to assess the parameters of the internal and external environment of the transport company in order to optimize its functioning in a competitive market are summarized. The mechanism of formation of the model of multimodal transportation with an emphasis on inland waterway transport, taking into account the resource base of the transport company and the restrictions imposed on the technological parameters of multimodal transportation, is considered.

1. Introduction

One of the most important aspects of the formalization of the strategic directions of the company's development is the modeling of its business processes, followed by the specification of the general parameters of the generated system on the basis of market research. In general, modeling is a method of studying objects on their simplified models, which largely reflect the essential features of these objects. Studies have shown that the modeling of business processes of the company is carried out primarily through simulation. In other words, the business process is trying to reproduce with the preservation of its economic and / or technological nature, or use some physical phenomenon similar to the study. It is important to comply with a set of requirements, the use of which can greatly simplify the modeling process and possibly reduce the impact of the subjective nature of management decisions made on its basis.

At the same time, the dynamism of changes taking place in the economic environment, high rates of change in the field of socio-economic processes, a sharp reduction in the life cycle of innovations in globalized business systems impose significant restrictions on the possibility of applying regulatory models of management decision-making. In this situation, decision makers prefer to use descriptive models.

The formalization of the descriptive model is based on empirical observations that contain a limited number of parameters and justify the economic dependencies between them in simplified terms of «bounded rationality». The use of these models is advisable in cases where the use of other models is impossible or economically unprofitable. For example, in situations with unprogrammed solutions or situations with a high degree of uncertainty.
The purpose of this study is to develop a mechanism for determining the optimal trajectory of multimodal transportation, taking into account the restrictions imposed by the consumer of transport services in its cost and quality level, provided that the optimal use of technological and economic potential of each of the participants in the transport process.

2. Method of research
The study is based on dialectical methods of cognition, as well as system-structural analysis, contributing to the assessment of the dialectics of technological and economic, General and private, regional and sectoral. The paper uses General scientific methods of theoretical and empirical knowledge, namely: analysis and synthesis, generalization and detailing, the transition from the abstract to the concrete, analogy, systematic approach, monographic description. The use of mathematical modeling confirmed the hypothesis about the deterministic relationship between the parametric characteristics of the multimodal transport model.

3. Research result
Studies have shown that the modeling process can be applied to both organic and inorganic systems, engineering and technical objects, as well as to physical, chemical and socio-economic processes. The purpose of the modeling process is to identify opportunities to improve the quality characteristics of objects and processes, as well as to optimize the principles of their construction and management methods.

The modeling process makes it possible to provide parameters close to the parameters of the object within a fairly rigidly formalized assumptions and acceptable errors. Models allow to correctly reflect the relationship between the dependent and independent parameters of the impact on the object of study. The independent parameters in the modeling process are most often the parameters of the action, and the dependent variables in this case are the expected variables with a predetermined probability distribution of a particular outcome of the influence of independent variables.

The modeling process involves the implementation of three successive stages:
1) model generation;
2) study the model and get the result;
3) interpretation of the result.

At each of these stages can be solved quite heterogeneous in structure and content of the problem, which involves the use of a sufficiently wide range of theoretical and applied research methods and, accordingly, a significant number of tools and tools to achieve the goals.

When solving control problems, simulation and mathematical modeling are most often used. It should be noted that the sequence and structure of the use of various tools and tools of modeling largely depends on the initial parameters of the object of study, and the priorities placed by decision-makers. [1]

First, there is a need for a clear definition and formulation of the problem, which contributes to the harmonization of the objectives of the study.

Secondly, the decision-maker should strive to increase the degree of certainty of the system on the basis of obtaining reliable and relevant information about the object of study, which serves as the basis for the subsequent analysis of all permissible options and, consequently, the possible consequences of decisions.

Third, a clear formalization of criteria for evaluating alternatives to management decisions allows the decision-maker to choose the option of management impact, which will be optimal (in some cases – acceptable) for the entire managed system.

Fourth, the decision-maker focuses on a rational approach to assessment of management impacts and setting priorities among control tasks, that is the objective basis of selection of optimal specific conditions for the functioning of the managerial option impact, contributing to the quick resolution of problems.
The first experiments on business process modeling date back to the beginning of the XX century. However, it was not until the mid-1960s that attempts were made to articulate the goal-setting, principles and methods of the modelling process. The founder of the normative (classical) model of management decision-making is considered to be the American economist and sociologist Herbert Alexander Simon. It's G. A. Simon introduced the term «bound rationality» into scientific use and justified the possibility and expediency of implementing the mechanism of «preferred attachment» to assess the distribution of power dependence between the input and output parameters of the business process. In 1978, Simon was awarded the Nobel prize in Economics for his pioneering research into the decision-making process within economic organizations, for his contributions to the study of organization theory, as well as complex systems and computer modeling of business processes.

The principles of business process modeling developed by the author encourage decision-makers to search for rational solutions. The rapid spread and wide popularity of regulatory models is associated primarily with the possibility of active use of quantitative methods of management decision-making based on the use of computer technology. At the same time, quantitative methods are based on the construction of a tree of goals, analysis of break-even points, solving linear programming problems, justification of the forecast of the results of management actions and modeling the parameters of operational and strategic actions.

Modeling of business processes based on regulatory models is justified in situations where information about the parameters of the controlled system is reliable and reliable, which allows you to accurately predict the probability of outcomes of management actions. In fact, it is the normative model that is most adequate to rigidly determined decisions in conditions of limited risk.

G. A. Simon's concept of limited reality with its «administrative person» making the decision on the basis of primitivization of representations about reality and being guided by option of the administrative influence lying in «area of admissible decisions» contradicts Adam Smith's classical model of «the economic person». Indeed, the turbulence of the market environment makes it almost impossible to make an optimal decision in all situations. The need to process a significant amount of information in a limited period of time and the high cost of making the wrong decision in the face of uncertainty and increased risk limits human rationality and becomes a prerequisite that the decisions and actions of individuals becomes a lot of irrational. Developing the idea of the need for significant unification of management procedures, G.A. Simon introduces the concept of programmed and unprogrammed decisions and justifies the conclusion that to improve the efficiency of its functioning, the company should strive to program most management decisions.

In descriptive models, relationships between structural elements are usually formalized using simplified dependencies described mathematically as inequalities or equations. The main disadvantage of these models is that they do not fully reflect the relationship between the elements of the system and the constraints imposed by the parameters of the environment. However, they can serve as a basis for the construction of sophisticated, semi-parametric models. An example of a descriptive model is the model of ideal competition for forecasting the dynamics of demand in the global economy.

Descriptive models have the following undoubted advantage: they are able to display the desired target function parameters of the real production or commercial process. In other words, these models allow to determine rather rigidly both separate operations of business process, and as a whole technology of production of new goods (services, ideas). The use of standard procedures for modeling business processes, taking into account the formalized criteria and specified constraints allows for the selection of the optimal (in some cases – acceptable) solutions. That is why the descriptive model often underlies the construction of the optimization model.

It should be noted that the complexity of business process modeling is determined by the lack of quantitative information used by decision makers. This is the basis of the fact that many complex mathematical models can not have practical applications, because some parameters of the model are not quantifiable. Indeed, it is almost impossible to predict the reaction of competitors, changes in demand trends, the emergence of innovative technological and information and communication
innovations. In fact, these parameters are qualitative indicators. Under these conditions, it is advisable to use invariant models of management decision-making.

An example of such a model is the model C. Henry Mintzberg suggests its use to justify unprogrammed management decisions. At the same time, it is necessary to focus primarily on the algorithmization of the sequence of actions within a single business process from the stage of determining the problem to the final stage of its solution. The conceptual solution consists of a set of local elections, which are carried out by the company. In this case, the formalization of the optimal solution is faced with organizational and technological barriers that G. Mintzberg called «interruptions of the decision process». Each barrier implies the need for the company to return to previous decisions, and, if necessary, repeat the cycle, based on alternative business process modeling options.

Finding alternatives is a very important step in modeling. It is based on market research of internal and external environment of the company to provide the management process with reliable and relevant information. Then the register of possible alternative solutions to solve the problem of management is justified. Not only are the alternatives required to be cost-effective and rational, the proposed alternative must be achievable, taking into account formalized assumptions and a system of resource constraints.

The transformation of the theory of business process modeling is closely connected with the active introduction of computer technologies and automated means of information processing into the business environment. The beginning of the first stage dates back to the 20s of the last century, which is associated with the landmark work of Frederick Taylor «Principles of scientific management», published 6 years after the author's death in 1921. Based on the fundamental principles of «the ratio of time and tasks» and «remuneration for the final result, not for the activities», the first stage justifies the need to study business processes, documenting the processes and results, focus on the documented parameters of business processes.

In the economic literature, the question of the periodization of the first stage is debatable, however, the period 1920-1970-ies is most often mentioned. At this stage, the description of business processes is carried out in text or graphical form. At the same time, the graphical view of the description of business processes becomes largely formalized. First of all, block diagrams, oriented graphs (digraphs), mathematical models are used to represent the structure of the system in order to analyze the dynamics of its functioning in terms of «condition-event» (Petri nets). Since the late 1960s, the methodologies «Structured Analysis and Design Technique», «Integrated DFINition» and «Data Flow Diagrams» have been actively implemented to solve the problems of modeling complex systems.

The beginning of the second stage is associated with the publication of the book on changes «reengineering of the Corporation: Manifesto of the revolution in business» in 1993. Authors Michael hammer and James Champy justified the inevitability of changes at the macro-and microeconomic levels, and the need to modernize the company's business processes in order to radically reorganize them, which they gave the name of reengineering. Globalization of commercial and information and communication space has predetermined the revision of the methodology of business process modeling. It is necessary to move «from how it is» to «how it should be», and then implement this model in the company.

As an example of automation of business processes at the turn of XX-XXI centuries most often called methodology and replicated software product ARIS (ARchitecture of Integrated Information Systems) and software company SAP – SAP R/3. Figure 3 indicates that the product is designed to model the company's business process in a three-tier architecture: «client» – «application server» - «database management system».

The basis for the formation of the third stage in business process modeling is the book «business process Management: the third wave» published in 2003 by Howard Smith and Peter Fingar. The «radical» reengineering is proposed to be modified to the systematic and orderly management of business processes BPM (Business Process Management), which makes it possible, based on the changing market conditions and the company's capabilities, to promptly adjust the business process model. In addition, this model does not require the use of additional software products. It is the
modification of the business process that becomes the main incentive for the use of computer technology as the main reserve for ensuring the competitive advantages of the company.

The characteristics of the three "waves" of the development of the theory of business process modeling in correlation with the stages of improvement of information technologies are presented in the table.

Table 1. Stages of development of business process modeling methods.

| Stage    | Period          | Characteristics of the stage                                                                 | Applied computer technologies                                           |
|----------|-----------------|---------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Stage I  | 1920s-1980s     | • Research of ways to perform operations;                                                    | ➢ Database management system;                                            |
|          |                 | • Rationalization of production and commercial operations;                                  | ➢ Operational information processing                                      |
|          |                 | • Modeling business processes «manually»;                                                    |                                                                          |
|          |                 | • Low level of automation of business process modeling                                       |                                                                          |
|          |                 | • Software for building a business process model;                                             |                                                                          |
|          |                 | • Study of individual business processes;                                                    | ➢ Distributed computing;                                                  |
|          |                 | • Business process modeling as needed;                                                       | ➢ Integrated use of individual functions of the business process          |
| Stage II | 1990s-2000s     | • Business process-oriented software;                                                        | ➢ Business process management systems;                                   |
|          |                 | • Standardization and unification of business process modeling procedures;                   | ➢ Integrated use of business processes                                    |
|          |                 | • Business process simulation and performance analysis                                        |                                                                          |
| Stage III| 2000s to present|                                                                                             |                                                                          |
|          |                 |                                                                                             |                                                                          |

In the context of globalization of the information space, the speed of data collection from external sources, the use of on-line resources, interaction with other systems, including data reconciliation and transfer, is increasing. In such conditions, work on the adjustment of existing internal business processes should be carried out in a continuous mode. It seems that the improvement of software products for business process modeling will take place in the direction of robotization of process work for the collection and aggregation of data from internal and external sources and the development of optimal solutions for operational and strategic tasks. [2]

One of the most important aspects of formalization of strategic directions of optimization of transport process is application of tools of mathematical modeling with the subsequent specification of the General parameters of the generated system on the basis of the carried out conjuncture researches. [3,4]

The purpose of the process of economic and mathematical modeling is to identify opportunities to improve the quality characteristics of objects and processes, as well as to optimize the principles of their construction and management methods. The modeling process makes it possible to provide parameters close to the parameters of the object within a fairly rigidly formalized assumptions and acceptable errors. Models allow to correctly reflect the relationship between the dependent and independent parameters of the impact on the object of study. The independent parameters in the modeling process are most often the parameters of the action, and the dependent variables in this case are the expected variables with a predetermined probability distribution of a particular outcome of the influence of independent variables.

The use of mathematical modeling in the planning and implementation of the interaction of different modes of transport in the organization of multimodal transport may be considered appropriate. Under multimodal transport should be understood transport and technological system of organization of transport, combining in a single chain of different modes of transport, combined in various combinations, in which the goods are transported in the same container under the
responsibility of one carrier under a single document using the principles of «door-to-door» and «just in time». [5-8]

One of the most effective tools for the formation of an optimal model of multimodal transport is the use of a methodological apparatus that allows taking into account the types of transport and the current market situation, as well as criteria for the requirements of shippers to the quality of the transportation process. [9,10]

It can be proposed the following mechanism for the formation of the model of multimodal transportation.

1. Determination of the set of ways to organize the shipment of cargo from the shipper to the river port: $A = \{a_i\}, i = 1, \ldots, n_1, n_1$ – the number of options for the organization of cargo delivery to the river port.

2. Determination of the set of methods of delivery of cargo by river transport to the point of transshipment: $B = \{b_j\}, i = 1, \ldots, n_2, n_2$ – the number of options for the organization of cargo delivery from the river port to the transshipment point.

3. Definition of multiple methods of delivery from the transshipment point to the consignee: $D = \{d_k\}, i = 1, \ldots, n_3, n_3$ – the number of options for the organization of cargo delivery from the transshipment point to the consignee.

4. Definition of a set of variants of cargo delivery from the consignor to the consignee:

$$V = \{V_{ijk}\, = \,(a_i, b_j, d_k) | a_i \in A, b_j \in B, d_k \in D\}.$$  

The set $V$ is the direct product of the sets $A$, $B$, $D$, that is $V = A \times B \times D$. The number of variants of cargo delivery from the shipper to the consignee is equal to $n = n_1 \cdot n_2 \cdot n_3$. It is necessary to create a model of multimodal transportation, which would best meet the requirements of the shipper (consignee) to the level of quality of the transportation process.

As criteria of preferences of the consignor (consignee) can be offered:

- delivery time, $K_1$ – qualitative and quantitative safety of cargo, $K_2$ – cost of delivery. Build sets $V_1, V_2, V_3$.

Form a set

$$V_1 = \{v_{ijk} = (a_i, b_j, d_k) \in V | t(a_i) + t(b_j) + t(d_k) \leq K_1\},$$

$t(a_i)$ – time (in days) of cargo transportation from the point of departure in the organization of its transportation by road, rail or air to the river port using $a_i$ mode of transportation; $t(b_j)$ – time (in days) of transportation by river transport to the transshipment point using $b_j$ delivery method; $t(d_k)$ – time (in days) of transportation by road, rail or air from the transshipment point to the destination using the $d_k$ method.

The condition specifies that the sum of the time of delivery of the goods from the shipper to the consignee along the trajectory $(a_i, b_j, d_k)$ must be less than or equal to the time of delivery set by the cargo owner.

Form a set $V_2$, consisting of those elements of the set $V_1$, that satisfy the criterion $K_2$, that is

$$V_2 = \{v_{ijk} = (a_i, b_j, d_k) \in V_1 | N(\{v_{ijk}\}) \leq K_2\},$$

$N(\{v_{ijk}\})$ – possible costs of qualitative and quantitative losses during transportation of cargo along the trajectory $(a_i, b_j, d_k)$.

Condition $N(\{v_{ijk}\}) \leq K_2$ determines that the costs of possible qualitative and quantitative losses during transport of cargo along the trajectory $(a_i, b_j, d_k)$, may not exceed the maximum allowed by consignor (consignee) the level of $K_2$.

Form a set $V_3$, consisting of those elements of the set of $V_2$, that satisfy the criterion $K_3$, that is

$$V_3 = \{v_{ijk} = (a_i, b_j, d_k) \in V_2 | C(\{v_{ijk}\}) \leq K_3\}.$$
\( C(a_{ij}) \) – cost (in rubles) of cargo transportation operations from the point of departure by road, rail or air to the river port using the \( a_{ij} \) method of transportation;; \( C(b_{jk}) \) – cost (in rubles) of cargo transportation operations by river transport to the transshipment point using \( b_{jk} \) delivery method; \( C(d_{kl}) \) – the cost (in rubles) of performing operations for the transportation of goods by road, rail or air transport from the point of transshipment to the destination using the \( d_{kl} \) method.

Condition \( C_{ij,k_{ls}} = [C(a_{ij}) + C(b_{jk}) + C(d_{kl})] \leq k_{5} \) defines, that cumulative the cost of delivery cargo from shipper until consignee on trajectory \( (a_{ij}, b_{jk}, d_{kl}) \) must be less or equal value of that ready pay shipper (consignee) \(- k_{5} \).

If the results of the implementation of all iterations, there are several variants of the trajectory of transportation of goods eligible \( k_{1}, k_{2}, k_{5} \), then amplified using the criterion of \( k_{5} \), that is \( C_{ij,k_{5}} = \min C_{ij,k_{5}} \) (the minimum value of the cost of cargo transportation by trajectory \( (a_{ij}, b_{jk}, d_{kl}) \), the optimal variant of transportation of cargo from shipper to consignee.

4. Discussion of results

The use of optimization models is most effective in determining the General parameters of the cargo transportation system. Such models can greatly simplify the reality and may not take into account turbulent changes in the operating conditions of multimodal transport participants (for example, climatic or landscape). In addition, it is useful to complicate the model by including alternative modes of transport (e.g. pipelines). At the same time, the use of optimization models is of undoubted practical importance, since it helps to identify the fundamental relationships between goals and management tools. The optimization model can serve as a starting point for constructing a simulation model of decision - making, which fully meets the research problems and the limitations imposed on it.

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