# Towards a new modeling method for developing a balanced hierarchical strategy for heterogeneous organizations: the case of universities

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**Abstract.** The importance of strategic management today is unquestionable. However, when strategizing the organization is often regarded as a single whole, differences in aims and areas of operation of its parts not being considered. This approach works for many organizations, but in the case of a distributed structure its parts may function in the markets which have different requirements, competition intensity and qualification of consumers. Besides, the departments of that organization may have different levels of development. In our present work we do not consider the whole range of distributed organizations, but concentrate on universities, as they have common characteristics with commercial organizations and, at the same time, are very specific in their rules and areas of development. We focus on developing a new modeling method for decision support while designing a balanced hierarchical strategy for distributed universities. This implies beginning from the strategy for the whole organization and moving on to development of individual strategies for its departments. Thus, the proposed method contains two parts: a sub-method to develop departmental strategies and a sub-method to calculate interaction among departments.

This article describes the proposed structure and semantics of the model which can be used in the both of sub-methods.

**Keywords:** distributed organization, distributed university, business process modeling, organizational structure, simulation modeling, DEMO

## 1 Introduction

In today's world the organizations are known to grow rapidly, both in terms of quantity and quality, which often leads to considerable gaps in development between various departments of one organization. This can be explained not only by the difference in market demands but also by internal characteristics of a department. Being

competitive is increasingly a matter of organizational flexibility and timely response to external changes. As a consequence, the system is often being decentralized through delegating considerable authority to the department level. Moreover, when markets where the departments operate and their history are not homogenous, their levels of development and goal-setting principles may vary greatly. It is therefore likely that the described specific dissimilarities at the lower level of management are typical for activities that require expertise, knowledge and talent of the staff as the main resource.

We argue that ensuring organization's competitiveness in such environment necessitates drafting both overall organizational strategy and individual programs for departments. Each individual strategy must comply with the overall course of action, but at the same time consider the specificity of state and goals of separate departments. Due to different individual goals it is particularly important to maintain the unity of the organization. Development programs corresponding to the above- mentioned requirements will be further referred to as balanced hierarchical strategies.

The suggested approach is, in our point of view, especially relevant for large geographically distributed organizations which include structural elements with different levels of development and operate in different segments of product and service markets. Large universities are a good illustration of such heterogeneous organizations.

This paper seeks to propose a model for building balanced hierarchical strategy for universities.

When using the method it is necessary to solve two problems:

1. Define, to what extent the individual development programs for each department must correlate with the overall strategy of the University,
2. Develop methods allowing to consider reciprocal impact of development of different departments within the University.

The model is based on assessment of the initial state and achieved results of university development through several parameters "quality of educational services", "financial state", "level of science and research", "public image" corresponding to the strategic goals of the University.

This work being at the inception stage, we cannot yet report the results either supporting or disproving our approach.

The article presents our approach as follows. Section 1 presents the overview of relevant works on analysis and simulation of interaction among various departments of educational institutions focusing on achievement of strategic goals. Section 2 contains formal requirements to the model of heterogeneous university and description of the suggested model which may be used for development of its strategy. This section describes what has been done at the first stage of our research, namely general task setting, input data, courses of development of algorithms and methods of interdepartmental interactions and development. Section 3 contains our proposals for determining particular values of the model parameters based on the high-level ontological model.

## 2 Context of the research

The university is a complex structure. In the conditions of decreasing public financing, common today for most countries, it should be considered as a commercial organization operating in competitive environment. The issues of developing growth strategies, planning operations, expanding and improving provided services are therefore essential and require a thorough analysis of large amounts of data, development and assessment of various scenarios. The use of decision support systems to analyze university performance has been described in the following works: academic DSS for resource distribution [1-2], measurement of effectiveness [3], planning [4], strategic planning [1], etc. Thus, [5] suggests using a decision-making assistance system which allows to model scenarios and assessment techniques. The system processes data from various sources and outputs the population of important values and their correlations. In [5] the studies of academic process are focused on supply-demand ratio of academic services with faculties as service providers and students as consumers. Teaching staff is the major resource.

The following work [6] analyses the mechanisms of technology transfer (TTM) which enable researchers to assess whether the achieved results match the goals of the university. These are regarded as a medium between the university and society. Research, joint ventures, business-incubators and technological clusters can be considered as TTM complementing conventional methods: HR development schemes, scientific advice, scientific and technological services, recruitment, etc. ANP-based MCDA method is used [7] and AHP [8] to work out the method which allows to measure the compliance of the university goals and its courses of action. Other works present the attempts to calculate the correlation between research and teaching activity. The authors put emphasis on studies of quantitative assessment of correlation between research and educational functions of the academic staff. It is calculated by comparing effectiveness of teaching (basing on students' rating) and academic activities (basing on quantity and value of publications). [9-12].

The following research [13] focuses on methods of funds' distribution taking into account goals, development indicators and other additional parameters. This work's difference from others [14] lies in the fact that the authors suggest allocating the finance according to the performance of individual departments and measuring their productivity with regard to university's priorities.

The work [1] describes a specific simulation game allowing to perform a Vensim Software – based simulation. Having designed and tested the model for relevance, the authors developed on its basis a game which makes possible simulation of long-term strategic goals of management, such as student/teachers training, assessment of quality of teaching and research productivity. The results of the conducted research prove the game useful for purposes of strategic management.

The next paper [10] analyses relation between research and teaching activity of universities. The research confirms the existence of this relation and describes its categories. A similar issue is examined in [15], however it focuses on how students and teachers consider scientific research, emphasizing the difference in their views.

Having analyzed the large body of literature on software and modeling tools for strategic management in universities, the following can be said:

1. The previous studies on building strategies for universities have solved various relevant, however isolated tasks (resource distribution, identifying relations between academic activity and teaching, etc.). Those studies have not dealt with the issue of forming interconnected overall organizational strategy and individual courses of action of its departments which would consider the interests at different management levels and ensure sustainable and effective development.
2. Most studies focus on assessing various quantitatively defined development indicators, including those used to solve tasks on optimization, planning and modeling of behavior.
3. The following widely-used modeling tools can be mentioned:

- Various modifications of neuron nets. The biggest advantage of the methodology is its minor sensitivity to accuracy of separate characteristics' assessments used for modeling. At the same time, collective features of those characteristics are well represented. Neuron nets are often suitable for modeling in the conditions of non-linear correlations when traditional probability methods do not apply [20-22];
- The most widely-used method of analysis is multi-criteria decision analysis (namely ANP [7]), designed to solve the overall task of organizational development when priorities are clearly set.

4. The main limitation of works on strategy development is, however, their theoretical emphasis which is revealed through use of expert information without establishing procedures of its obtaining and verification.

The decision makers really need some consolidation approach which binds the isolated tasks into a consistent strategy. To model the university's business processes and achievement of strategic goals, modern approaches to business process modeling and management can be used. For example, the work [16] describes the use of BPMN methodology [17] to structure the university's business processes. BPMN is a universally recognized tool for business modeling and it is very efficient in various spheres.

However, universities have an important difference from industrial organizations: many processes are based on flexible communication between partly autonomous actors. At large extend strategic development and innovations adoption in the university depend on such bottom-to-up communication processes which may be well described and studied in the framework of language-action perspective, and particularly using J. Habermas' theory [18]. This theory serves as a basis for the DEMO methodology [19] that suggests a coherent set of business-process modeling techniques. The choice and application of DEMO will be thoroughly explained in Section 3.4.

## 3 Suggested method for decision support

We propose a method which is based on the particular formal model. The model is used to simulate the designing of overall development strategy for a large heterogeneous university. Different divisions of a university have different business processes, distribution markets and levels of development. Another purpose of our model is to forecast the consequences of decisions made in relation to the overall and particular strategies. Due to specificities of the target market and the existing level of development, they are considered to have different goals and priorities.

With a certain degree of approximation, it can be suggested that the outcome of implementation of competitive strategy is the sum of the outcomes of various departments. Conversely, knowing the overall organizational development strategy we can estimate individual strategies of departments. It is also taken into consideration that although departments are not usually linked by a single business process, they impact each other. This is caused by exchange of academic services, interdisciplinary research, influence of stakeholders' perception of one departments on the image of others, etc. Thus development of each separate department depends not only on its track record, resources available and chosen strategy but also on the state of other departments. .

There are various ways of selecting indicators of University performance, e.g. [3], [10], [13], [15]. However, realizing the importance of their relatively accurate qualitative assessment both for the University and its departments, we have chosen another approach based on the following assumption. When the organization and its departments behave rationally their competitive strategy corresponds to requirements of their major stakeholders. . Consequently if we consider the market of school-leavers their basic requirement is high quality of educational services and the relevant strategy would be achieving quality leadership. Analyzing such groups of stakeholders as state, society, research and technologies market, it can be observed that in the conditions of technological progress achieving research leadership (which can be compared to the competitive "time leadership") is becoming more and more acute; besides, it ensures leadership in quality of academic services.

Finally, taking into account all internal stakeholders, we suppose that financial state of university is not only the means of achieving strategic goals but a self-contained strategic goal and it defines the "financial leadership" strategy.

The model shall solve the following Universities tasks:

1. Describe the external environment in which the university operates, and the mechanisms of their interactions,
2. Describe distinguishing characteristics of the university's internal environment: organizational structure, interaction of structural elements, degree of strategic development of the whole university and its parts;
3. Identify overall strategy (without considering its internal heterogeneity),
4. Identify strategies of separate departments,
5. Forecast consequences (at both organizational and departmental levels) of various strategic decisions:

- setting the degree of unification for overall and departmental development strategies;
- setting the degree of a department's financial independence when choosing its course of development;

6. Define the development strategy for the university taking into consideration development of its parts.
7. Enable modeling of "what-if" situations for various scenarios of the overall and departmental development considering their interaction.

### 3.1 Input data for modeling

We include to the model the following input parameters which fully characterize modern heterogeneous universities (Table 1).

| Parameter | Description |
|---|---|
| Organizational structure and staff | – number of departments,<br>– number of staff,<br>– internal and external relations of the departments,<br>– current data on departmental development. |
| System of relations, dependencies and rules of interaction | – relations of the whole university and its departments with the outside world,<br>– relations inside the university,<br>– degree of autonomy of the departments (including financial) stipulated by the internal regulations,<br>– how various activities of the whole university and its departments influence the involvement of external resources;<br>– how the efficiency of the whole university and its departments is influenced by the involved financial resources,<br>– how the dynamics of each structural element is influenced by neighbor elements' development<br>– internal pricing in the university |
| System of goals and indicators | – general system of universities goals and their correlation with the characteristics of its progress,<br>– current level of development of the whole university (income, level of scientific development, image, quality of educational services). The sum of figures obtained from the departments must be equal to the overall indicator.<br>– the desired indicator values (income, level of scientific development, image, quality of educational services). The aggregate of each parameter (in some cases considering |

| | |
|---|---|
| | specific coefficients which reflect the size of departments) for all departments must be equal to the aggregate value for the whole university |

**Table 1.** Output data for modeling

We shall examine the basic principles of the suggested approach to define the development strategy for the University.

Having applied DEMO [19], we describe business processes in the organization (in section 3.2 are given the reasons for choosing this methodology) We are able, therefore, to identify the essentials and ontological transactions of university's operations. We base on the DEMO model to calculate the quantitative characteristics of processes upon which depend the indicators, weight numbers, etc.

The DEMO model enables us to define relations among divisions, interaction with the outside world and its density, degree of autonomy of divisions, intensity of transactions, correlation between goals and transactions. (Fig. 1)

Using this input data we model the functioning of the university. The results of modeling are used to build the development strategy. The process is diagrammatized on Fig.

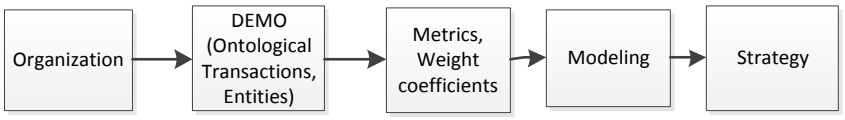


**Fig. 1.**

### 3.2 Tuning and validating parameters of the model of heterogeneous Universities.

For the model we use statistics on the University performance. Section 3.1 generally describes all the necessary output data. Through regression analysis we deduce various weight numbers, e.g. $w_k$ for the size of the nth division and $\omega_{ik}^t$, which sets weighting of the $k$-th division by the $i$-th indicator at the initial stage of simulation, i.e. when $t = 1$ (of section 3). We shall use the DEMO model to calculate weight coefficients.

We have already mentioned that business processes can be described with the help of different tools and notations, The most commonly used approach is BPMN [17], which provides not only modeling tools but also business processes' management instruments. We, however, suggest using DEMO to solve this task and support our choice with the arguments given below.

In universities, many processes are initiated by the staff. A large number of employees are involved in academic activity (e.g. research) which is introduced by themselves. To advance in their research the staff publish articles, participate in conferences, involve students, interact with other faculties as these studies often become interdisciplinary. The university provides them with financial and organizational

support since they influence its development and, in the long run, the achievement of business goals. Yet it is the staff who generate ideas and create processes. The major distinguishing characteristic of these processes is that they are verbal arrangements not secured by contracts (especially during development) , i.e. based on communication. A famous researcher of communication and the founder of the theory of communicative action is J. Habermas [18]. This theory provides a very transparent explanation of how communication works. At the core of the theory lies the assumption that people strive towards consensus when they have to accomplish things together. In DEMO Habermas' theory serves as the basis for explaining how communication enables coordination [19]. A very important point in conditions of verbal communicative actions is the mechanism of transaction rollback, which was also shown through DEMO basing on Habermas' theory. Thus, the principles of the university operation comply with the theory of communicative action.

Another important statement in favor of DEMO is that, unlike other methodologies, it accurately determines levels of transactions: ontological, infological, datalogical. A competent and experienced researcher will certainly define the level of abstraction regardless of methodology and notations, but in our case we decided upon the methodology which contains formal rules to distinguish transactions. DEMO helps minimize risks of obtaining inadequate result if an unexperienced analyst deals with the task. Furthermore, we do not need a business process management system.

Several parameters and coefficients can be deduced using DEMO [19].

DEMO is a methodology for the design, engineering, and implementation of organizations and networks of organizations. The entering into and complying with commitments is the operational principle for each organization. These commitments are established in the communication between social individuals, i.e. human beings. [23].

In DEMO the basic pattern of a business transaction is composed of the following three phases [24]:

- An actagenic phase during which a client requests a fact form the supplier agent.
- The action execution which will generate the required fact
- A factagenic phase, which leads the client to accept the results reported

The DEMO methodology gives the analyst an understanding of the business processes of the university, as well as the agents involved, but is less clear about pragmatics aspects of the transaction, such as the conversation structure and the intentions generated in each agents mind [24].

Besides, we have to extract only the data which affects the processes; this task can also be solved by DEMO. Fig.2.shows the ATD-diagram of the major processes in the University.

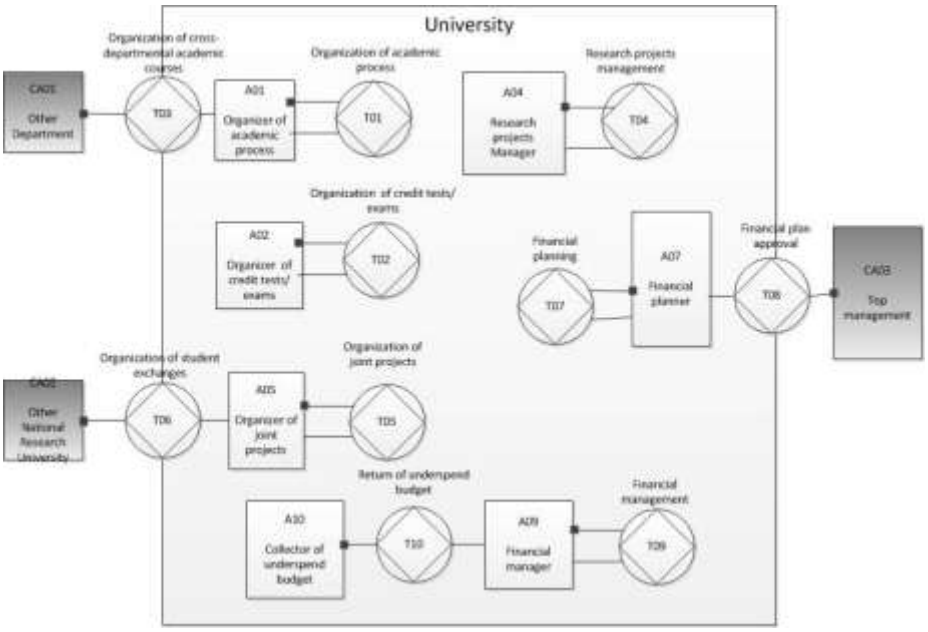


**Fig. 2.** ATD Diagram

The Construction Model (CM) establishes the organizational construction according to operational axiom. This is the highest level of organization and the most concise DEMO model. CM contains:

This diagram shows the major actors and transactions. This is an upper level diagram; it can be particularized by each Actor:

A01 – curriculum development, academic programme development and agreement, ratings' generation.

A04 – analysis of courses of development, search for grant opportunities for research, design and engineering, setting up laboratories, design and training groups.

A05 – analysis of courses of development in other NRUs, working out joint projects, collaboration (student exchange, scientific projects).

A07 – Budgeting (public and commercial), allocating funds to faculties, general expenses of University).

Other Actors - advertising, admission, educating, recruitment, external projects, academic work, ratings' calculation.

Further are described (not given in the article):

Process Model (PM) – defines patterns for each transaction in CM. It also shows causal and conditional relations among transactions, thus presenting state and space of transactions in the "coordination environment" of the organization. PM is shown by the Process Structure Diagram (PSD).

Action Model (AM) – specifies the rules for actions according to which Actors' roles are performed in order to achieve the goals, Similar to CM and PM , AM contains information about actors' roles and transactions among them, casual and conditional relations..

State Model (SM) – specifies the state-space of "productive environment" of the organization. The model contains the following components: class objects, types of facts and output, existing order. These elements can be visualized through Object Fact Diagram (OFD) and Object Property List (OPL) provided by the State Model..

Interstriction Model (ISM) is the second part of CM. It identifies relations among actor roles in the organization and information banks used by them. ISM introduces Actor Bank Diagram (ABD) and Bank Contents Table (BCT). When ATD and ABD are integrated, we have the Organization Construction diagram (OCD).

The thorough development of mechanism to obtain quantitative characteristics using DEMO is underway. But our principal idea is to describe quantitative characteristics and correlation among transactions, objects and facts.

### 3.3 Calculating development indicators: methodology

We assess performance indicators of the whole university by comparing them with the value of similar indicators in other universities. Main indicators are:
$I_1$ – finance, $I_2$– quality of educational services, $I_3$– science and research, $I_4$ – public image
$I_i^{S_u}, i = \overline{1,4}$ – indicator $I_i$ per salaried teachers in university
$S_u$ – the total number of salaried teachers in university.
$I_i^{NRU}, i = \overline{1,4}$ - indicator $I_i$ per salaried teachers in other universities,
$S_d$ – the total number of salaried teachers in the division,
$I_i^{S_d}, i = \overline{1,4}$ - indicator $I_i$ per one salaried teacher in the division.

The method of calculating each indicator is given below:

**Finance.**

For the whole university this component is assessed by comparing University consolidated budget allocated to one member of teaching staff with the amounts assigned in other universities.

The consolidated budget is all the funds annually allotted to university regardless of the source (public or commercial), type of service (educational, scientific, consulting) and organizational level (to the whole university or to its separate departments).

How to calculate:

$$I_1^{S_u} = \frac{W_1}{S_u} \tag{1}$$

$W_1$ – annual budget of university.

$$I_1 = \frac{I_1^{S_u}}{\max(I_1^{NRU})} * 100 \quad (2)$$

The maximum rate is deduced from the set of similar indicators in other Russian universities having the status of National Research University.

The current financial state of each department is calculated in a like manner, but for normalization we use the maximum value of this indicator among all departments of university.

How to calculate:

$$I_1^{S_d} = \frac{W_1^{\mathrm{D}}}{S_d} \quad (3)$$

$W_1^{\mathrm{D}}$ - annual budget of the division

$$I_1^{D} = \frac{I_1^{S_d}}{\max(I_1^{S_d})} * 100 \quad (4)$$

The most important factors affecting financial development of divisions are represented by the rules which:

1. Define how the overall budget is divided between the needs of the whole university and separate departments;
2. Define how the overall divisional budget is distributed among the parts of the university:

- In equal parts (formally),
- In equal parts, but considering the number of staff, goals set for the division, divergence between those goals and current achievements in proportion to their "status" (their financial well-being compared to others); and in proportion to their financial "weakness".

**Science and Research.**

The scientific development of the university is calculated from the average number of academic publications.

How to calculate:

$$I_2^{S_u} = \frac{W_2}{S_u} \quad (5)$$

$W_2$ –number of academic publications of university staff.

$$I_2 = \frac{I_2^{S_u}}{\max(I_2^{NRU})} * 100 \quad (6)$$

For departments, the scientific activity is calculated from the average number of academic publications of their staff.

How to calculate:

$$I_2^{S_d} = \frac{W_2^{\mathrm{D}}}{S_d} \quad (7)$$

$W_2^{\mathrm{D}}$ - number of academic publications per department.

$$I_2^D = \frac{I_2^{S_d}}{\max(I_2^{S_d})} * 100 \quad (8)$$

**Public Image.**

For the whole university this indicator is the ratio of the number of mentions in the Internet to the overall number of mentions of all National Research Universities.

How to calculate:

$$I_3^{S_u} = \frac{W_3}{S_u} \quad (9)$$

$W_3$ - number of mentions about university in the Internet.

$$I_3 = \frac{I_3^{S_u}}{\max(I_3^{NRU})} * 100 \quad (10)$$

The maximum is deduced from the set of similar indicators in other Russian universities having the status of National Research University.

The image of each division is estimated as competition for admission:

How to calculate:

$$I_3^D = \frac{W_3^{\mathrm{D}}}{\max(W_3^{\mathrm{NRU}})} * 100 \quad (11)$$

$W_2^{\mathrm{D}}$ – competition for admission in university,

$W_3^{\mathrm{NRU}}$ - competition for admission in other universities.

**Quality of educational services.**

The quality is based on independent ratings.

How to calculate:

$$I_4^{S_u} = \frac{W_4}{S_u} \quad (12)$$

$W_4$ - independent rating of university.

For each division this indicator is also based on independent ratings.

How to calculate:

$$I_4^D = \frac{\sum_{i=1}^{S_d} R_i}{S_d} \quad (13)$$

$R_i$– internal ratings of teachers.

The indicators (Science and Research, Quality of educational services, Public Image, Finance) must correlate with the strategic goals of university.

### 3.4 Behavior and interaction of divisions.

The organizational structure of the University can be conveniently represented by a tree, where nodes are the structural elements of the organization and lines show information, financial or resource flows among the elements. . The hierarchical principle enables us to single out those departments where strategizing is one of the goals of the system development, and to introduce the notion of hierarchy. In Fig.1 the lowest level represents employees, the second – departments, the next – faculties, etc. Departments, faculties and branches are divisions of different types, their composition is explicitly defined by the hierarchical structure. Fig 3. shows only hierarchical relations - subordination, not cooperation. In our model we assume that horizontal relations exist among faculties and campuses. Since a faculty is a cost center and all its departments and employees strive for the common goal, direct interaction is possible only among cost centers. We do not consider informal communication as it can not be viewed as business goals, but any contacts within the university are authorized by faculties - cost centers.

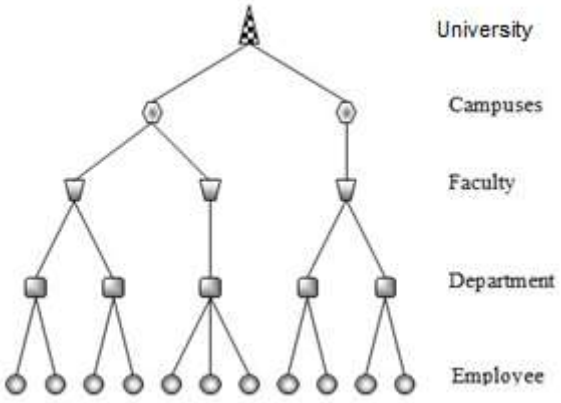


**Fig. 3.Tree model of organizational structure**

**Modeling of dynamic processes in the University.**

To model dynamic processes we use the notion “the state of the system” (University) at the point in time $t$:

$$S^t =< I_i, i = \overline{1,4} > t = \overline{1,T} \tag{14}$$

Where $i$ – development indicator index, $I_1$ – finance, $I_2$– quality of educational services, $I_3$– science and research, $I_4$ – public image. These characteristics are described in section 3.2.

The transfer function for the dynamic system is thus:

$$S^{t+1} = F(S^t, O^t, \varepsilon) \tag{15}$$

where $O^t$ represents the structure of the university at the point of time $t$ :

$$O^t = \begin{matrix} \\ i \end{matrix} \begin{matrix} \begin{matrix} j \end{matrix} \\ \begin{bmatrix} - & \begin{matrix} | \\ p_{ij} \\ | \end{matrix} & - \end{bmatrix} \end{matrix}, \; i,j = \overline{1,N} \tag{16}$$

$N$– number of structural divisions in the university,

$p_{ij} \in [0,1]$ – division-to-division correlation ratio,

$\varepsilon$ sets external influences

To forecast the organizational structure therefore means to stabilize the dynamic system

$$S^{t+1} = S^t \tag{17}$$

With the specified limitations for its states:

$$l_{I_i} \leq S_i^t \leq L_{I_i}, i = \overline{1,4} \tag{18}$$

where $l_{I_i}$ and $L_{I_i}$are minimum and maximum values of $i$-th indicator characterizing an interval in which the total university value of this indictor at the point of time $t$ should be included.

The state of the university can be represented as the superposition of states of its divisions:

$$s^t = < I_i, i = \overline{1,4} > , t = \overline{1,T} \tag{19}$$

where we can show each state as a dynamic subsystem with its own transfer function

$$s^{t+1} = f(s^t, o^t, \varepsilon) \tag{20}$$

$o^t$ stands for the division structure at the point of time $t$.

The state of the university by the $i$-th indicator at $t$ can be shown as the combined value for all departments with regard to the weight coefficient $w_k$, depicting sizes of divisions

$$S_i^t = \sum_{k=1}^{N} w_k \cdot s_{ik}^t \tag{21}$$

Where $s_{ik}^t$ – the state of division by the $i$-th indicator at the point of time $t$ can be described by the following function

$$s_{ik}^t = \omega_{ik}^t \cdot I_{ik}^t \tag{22}$$

Where $\omega_{ik}^t$ – sets weighting of the $k$-th division by the $i$-th indicator at $t$, $I_{ik}^t$– value of the $i$-th indicator of the $k$-th division at $t$. The ways to measure $w_k$and $\omega_{ik}^t$ are described in the section 3.2

The system complicates if we assume that development indicators are not static and vary in time in the following way:

$$I_{ik}^{t+1} = f_k(I_{ik}^t, I_1^t, I_2^t, I_3^t, I_4^t), i = \overline{1,4}, k = \overline{1,N} \quad (23)$$

where $I_i^t$ – vector of values of $i$-th indicators for all departments at $t$. This law of alteration of development indicators' values allows to consider cross-dependence among the analyzed parameters.

If we allow cross-dependence within the system at the point of time $t$, then the state of the $k$ –th division by the $i$ -th indicator at $t$ can be described with the function:

$$s_{ik}^t = \omega_{ik}^t \cdot I_{ik}^t + \sum_{\substack{m \in M^k{}_{ij} \\ j=1,4 \\ j \neq i}} p_{mk} \cdot \omega_{im}^t \cdot I_{im}^t \quad (24)$$

Where $M_{ij}^k$ – the set of divisions providing resources by the $i$-th indicator to the $k$-th division in exchange for resources by the $j$–th indicator from the $k$–th division. For example, if $i = 1, j = 3, k = 1$ then $M_{13}^1$ defines the set of divisions providing scientific services to the division #1 in exchange for finance from this department. Thereby the values "level of development" for each indicator aggregates not only the value of each indicator derived resources produced by the division, but also the value derived from resources received from other divisions for internal contracts.

**Hierarchical principle: correlation at the same level and among levels.**

If we use the hierarchical principle, i.e. choose the function $I_{ik}^{tl}$ $I_{ik}^{tl}$, where $l$ – the number of hierarchy level, then the number of divisions will be the function of the number of the level $N = N(l)$ and $k = k_l = \overline{1, N(l)}$

Then (23) is the function of the alteration of development indicators for each division at the same level of hierarchy and the equation

$$I_{ik_{l+1}}^{t(l+1)} = g_l\ (I_{ik_l}^{tl}), i = \overline{1,4}, k_l = \overline{1, N(l)}, k_{l+1} = \overline{1, N(l+1)} \quad (25)$$

is the function of the level and defines how the dynamics of indicators at the $l$ level affects the level $l+1$, establishing the system of interactions inside the university (section 3). (25) sets the ascending motion through the levels of the hierarchy.

The law of alteration of development indicators including relations at the same level (23), and among levels (25) is

$$I_{ik_{l+1}}^{(t+1)(l+1)} = \underbrace{f_{k_{l+1}}^{(l+1)}\ (I_{ik_{l+1}}^t, I_1^t, I_2^t, I_3^t, I_4^t)}_{Intralevel\ dependendenses} + \underbrace{g_l(I_{ik_l}^{tl})}_{interlevel\ dependences}, \quad (26)$$

$$i = \overline{1,4}, k_l = \overline{1, N(l)}, k_{l+1} = \overline{1, N(l+1)}$$

## 4 Conclusion

In this work we offered a model for developing a balanced hierarchical strategy of a modern heterogeneous university, which meets the requirements from different management levels and large parts of organization. Building the overall strategy is a hierarchical and iterative process: both “top to bottom” (from overall to individual strategies) and “bottom to top” approaches were considered. The model takes into account the requirement to maintain the organizational integrity while giving departments more rights for achieving their goals.

The model contains a concise set of metrics for evaluating the current state of the university and correspondence of its activities to the strategic goals. Also the offered model describes the details of organizational structure of the university at a reasonable level of granularity. Furthermore, not only do we use business process modeling to analyze the processes within the university, but also combine it with analytical metrics. We propose to use such model as a base for a new method of decision support when developing a balanced hierarchical strategy. The metrics of the model facilitate evaluation of tangible and intangible outcomes in the case of application of different scenarios.

In comparison with other known approaches our research brings on the table several new advantages. The distinguishing characteristics of the suggested approach are:

- Departmental strategies are based on the overall logic of organizational development but their status and interests are also taken into account. The overall strategy results from implementation of individual strategies. The resulting vector of development is the sum of multidirectional vectors of individual strategies limited by the basic principles of the overall strategy.
- The state of the university and each of its departments is described through the set of characteristics («Quality of educational services», «Financial state», «Level of science and research» and «Public Image»). The choice of characteristics and calculation methods for them were defined by the most relevant demands of various groups of stakeholders and the opportunity to obtain relatively accurate information at university and departmental levels. The combination of their values defines the overall universities strategy and individual strategies of departments and their input in implementation of the overall development program.
- Departmental development strategies can be defined individually (according to the overall development program).
- Universities characteristics («Quality of educational services», «Financial state», «Level of science and research» and «Public image») are calculated considering similar characteristics of the best Russian universities.
- To receive objective results of modeling , the university is regarded as an open management system; it manifests through dependency of the amount of obtained external resources on its development and through relative values of the set of characteristics. For their normalization were used maximum values of the similar characteristics throughout the country.

- Changes in characteristics at management levels in a defined period of time are interpreted as quantitative expression of chosen strategy.
- Performance of each division depends not only on its history and available resources, but also on the state of other departments. This approach enables the management to harmonize interests of various departments.
- Rules of state-to-state change for the university and its departments (depending on history and available resources) shall be defined on the basis of the previous years' statistics.

Our research opens a perspective to constructing a method of decision support, which may be implemented in the form of clear and user-friendly systems. To achieve this goal we see the following important issues for further elaborating and research:

- To refine and verify the mathematical model using the statistical data on the university performance,
- To calculate quantitative characteristics of the university performance using DEMO,
- To design decision-support systems in order to build overall and individual strategies for large university and their divisions whose business processes, markets and levels of development are heterogeneous.

The model under development can be used for decision support while building strategies for large complex organizations where departments act and (relatively) autonomously develop in market segments with different features.

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