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SIMULATION MODELLING OF COMPETITIVENESS OF UKRAINIAN HIGHER EDUCATIONAL INSTITUTION IN ZHEJIANG EDUCATIONAL MARKET

Abstract. *Management decision-making methodology on the basis of simulation modeling is proposed in the work. A competitiveness indicators model for higher education institutions is developed. Experiments scenarios with the model for estimating and predicting competitive advantages are proposed. A number of simple simulation experiments with different values of the input parameters were performed to solve the direct simulation problem. Inverse problem solution variants by means of calibration experiments of the model are presented. The results of experimental calculations of the competitive factors impact on the university's position in the educational services market are obtained. The possibility of making management decisions on the basis of experimental data is also shown.*

Keywords: competitiveness; university; simulation; model; management decision

Introduction

The educational services market is dynamically developing in modern conditions. This is due to the rapid pace of economic and social conditions of the educational institutions changes, the emergence of new technologies in education, the intensification of competition between market participants. Higher education institutions have the opportunity to create new types of activities and services and to introduce innovations in order to obtain competitive advantages. Programs to enter new markets, international joint educational programs are an effective factor in increasing the competitiveness of the university [13].

The task of making timely management decisions that are aimed at improving the competitive position of the organization acquires particular urgency for increasing the competitiveness of the university in the educational services market. Various mathematical models and related methods operations research have a high efficiency during the solution of practical management problems [8].

Linear programming methods use deterministic models. General linear models solved with the help of the simplex-method, transport, network, with several objective functionals, integer, as well as dynamic programming and inventory management are among them [5; 10; 12].

Many management tasks are solved using non-linear models and nonlinear programming algorithms [3; 4].

Probabilistic models and methods of forecasting, game theory and decision-making, simulation and queuing theory are used to make decisions under uncertainty conditions, modeled by random processes [9; 14].

Scientific publications analysis [17; 18] shows that the effectiveness of management decisions depends on many factors: the level of complexity and uncertainty of the problem situation, the choice of the decision-making method, the availability of a sufficient number of alternatives.

The method of simulation is proposed to be used to analyze the competitive position of a higher educational institution, timely decision-making during the external factors change, as well as forecasting the consequences of the chosen solution.

Simulation models were designed and being used for monitoring, analysis, performance evaluation of complex systems and decision-making in conditions of ambiguity of the environment, which makes it difficult to calculate the costs and risks probabilities. A simulation model experiments make it possible to analyze a variety of alternative scenarios and choose a better strategy.

Increasing the effectiveness of decision-making aimed at improving the competitive position of a higher educational institution in the educational services market is the goal of the study.

Analysis of recent research and publications

Experiments with simulation models make it possible to solve various problems arising at management [11]. The results obtained in the implementation of alternative scenarios can serve as the basis for management decisions.

The problems solved by simulation can be divided into two classes [15]:

Direct analysis problems, in the solution of which, the system under study is given by the parameters of its elements and the initial regime parameters, the structure or equations and it is required to determine the system reaction to the acting forces;

Inverse analysis problems that require perturbation which made the system under consideration to come to a given state and given reaction according to the known system reaction.

A direct problem of simulation modeling ("what-if" problems) is solved with the help of a simple experiment. The direct problem of modeling is formulated as follows: the structure of the model is described by a system of equations; all its parameters are considered known. It is required to determine the reaction of the system under the action of certain external forces and given initial conditions.

Direct problems answer the question: what will happen if we choose a particular solution from the set of admissible under given conditions (what will be the criterion of effectiveness, in particular) [16].

The process of direct problem solving can be considered as a mathematical modeling of the cause-effect relationship inherent in the phenomenon [7]. Then the input data characterize the "causes" of the phenomenon, which are set and vary in the process of study, and the output data (the criterion of effectiveness) is a "consequence".

In fact, they do not build a single mathematical model, but some parametric family of models for the mathematical description to be applicable not to a single phenomenon, but to a wide range of phenomena that are close in nature. The choice of a particular model from this family is accomplished by fixing the values of the model parameters.

The solution of the so-called inverse problems consists in determining the input data for a given output data value (the parameters of the model, as in the direct problem, are fixed). The solution of the inverse problem gives an answer to the question of what "causes" led to the well-known "consequence".

As a rule, inverse problems are more difficult to solve than direct ones, because they have a number of features. First, they are nonlinear, namely, an unknown function or an unknown parameter enters into an operator or functional equation in a nonlinear way. Second, the solution of inverse problems is usually not unique. It is often necessary to require redundancy of experimental information to ensure uniqueness. Third, the inverse problems relate to the type of incorrectly posed problems for which the conditions for the solution existence, the solution uniqueness, and its stability are violated. The meaning of the first (the existence of a solution) is that among the initial data there are no conflicting conditions that exclude the possibility of solving the problem. The second condition (uniqueness) means that the data is sufficient to uniquely determine the solution of the problem. The third condition (stability) means that small changes in the initial data lead to small changes in the solution.

Inverse modeling problems answer the question of which solution maximizes the system efficiency index from the domain of admissible solutions [6].To solve the inverse problem, the direct problem is solved many times. In the case when the number of possible solutions is small, the solution of the inverse problem is reduced to a simple search of all possible solutions. You can find the optimal solution by comparing them among themselves.

If you can’t go through all the variants of solutions, methods of directed enumeration using heuristics are used. At the same time, the optimum or close to optimal solution is after repeated execution of consecutive steps (solutions of the direct problem and finding the model vector of the resulting indicators for each set of input parameters). Correctly selected heuristics brings the experiment closer to an optimal solution at each step.

The model calibration consists of a set of model’s consecutive runs with different parameter values. The parameters values at which the simulation results most accurately correspond to the given data can be found by means of experiments.

Due to the complexity and nonlinearity of the dependencies between the indicators, the use of any optimization models is not possible. In practice, it is usually limited to analyzing a small number of basic scenarios. Automation of this process is possible by conducting experiments based on simulation.

Results

1. Consider an imitation model of the mutual influence of the competitiveness factors of the university (Fig.1) [1] for the development of which the AnyLogic system was used [2].

$$\begin{cases} CE_{i+1} = CE\_{i}; \quad RU_{i+1} = RU\_{i}; \quad QL_{i+1} = QL\_{i}; \\ NS_{i+1} = NS\_{i}; SM_{i+1} = SM\_{i}; RLS_{i+1} = RLS\_{i} \\ CP_{i+1} = \varphi_1(CP_i, CE_i, CE_{i+1}, Q_i, Q_{i+1}, R\mathrm{U}_i, R\mathrm{U}_{i+1}) \\ PS_{i+1} = \varphi_2(CP_{i+1}, MCP_0)_i \\ Q_{i+1} = \varphi_3(Q_i, QL_i, Q\mathrm{L}_{i+1}, RL_i, RL_{i+1}, NS_i, NS_{i+1}) \\ RL_{i+1} = \varphi_4(RL_i, SM_i, SM_{i+1}, RLS_i, RLS_{i+1}) \end{cases} \tag{1}$$

The state of the simulated system at a time t0 is determined by the initial values of the parameters set:

$$x_0 = \begin{Bmatrix} MCP_0, CP_0, PS_0, Q_0, RL_0, CE_0, RU_0, QL_0, NS_0, SM_0, \\ RLS_0, CE\_{0}, RU\_{0}, QL\_{0}, NS\_{0}, SM\_{0}, RLS\_{0} \end{Bmatrix}$$

The parameter values are given in Table 1 for experiments with a model. The market share data and the number of potential students of the Petro Mohyla Black Sea National University (PMBSNU) in Zhejiang (China) data are presented in the table.

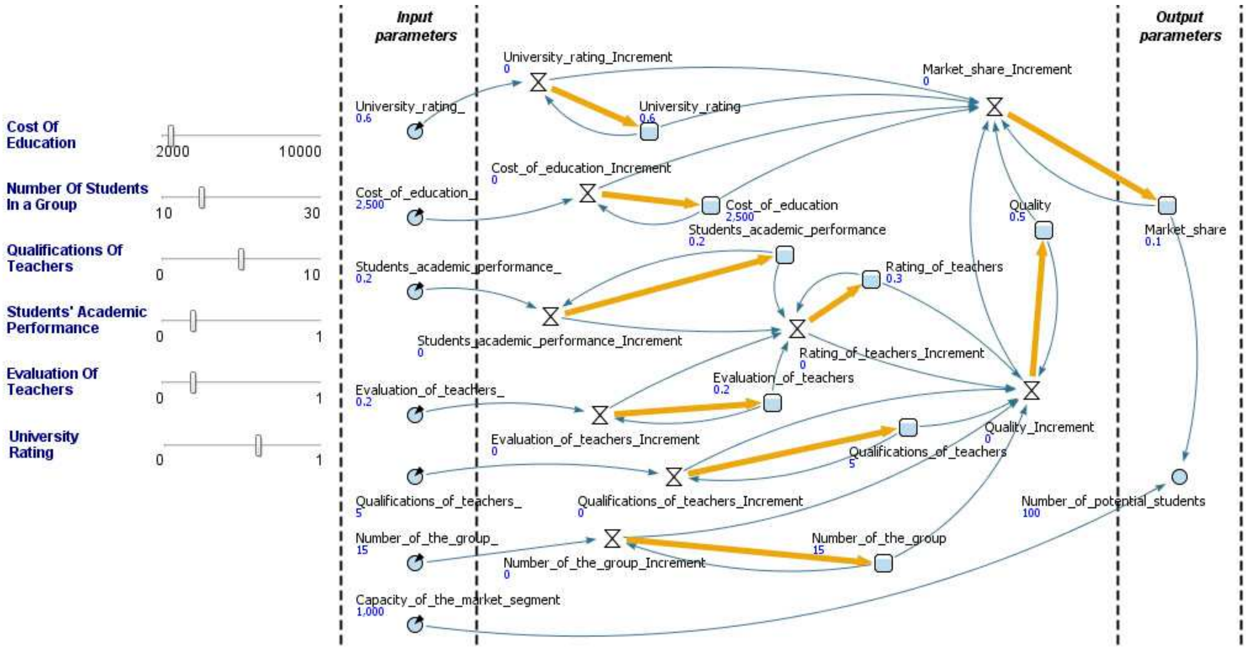

Figure 1 – The model of the influence of factors of competitiveness on the market share of the university
The model is described by a system of equations (1)

Table 1 – ***Parameter values***

	Model parameter	Parameter value	
		Zhejiang, China	Zhoushan, China
Input parameters	Capacity_of_the_market_segment (per.) – MCP	1 000	2 500
	Cost_of_education (RMB/year) – CE	2 500	3 200
	University_rating (points) – RU	0,6	0,5
	Qualifications_of_teachers (points) – QL	5	4
	Number_of_the_group (per.) – NS	15	15
	Students_academic_performance (points) – SM	0,2	0,2
	Evaluation_of_teachers (points) – RLS	0,2	0,2
Dependent parameters	Rating_of_teachers (points) – RL	0,3	0,25
	Quality (points) – Q	0,5	0,45
Output parameters	Market_share (%) – CP	0,1	0,01
	Number_of_potential_students (per.) – PS	100	25

The model parameters can be divided into the following groups:

input parameters – "Capacity_of_the_market_segment", "Cost_of_education", "University_rating", "Qualifications_of_teachers", "Number_of_the_group", "Students_academic_performance", "Evaluation_of_teachers";

dependent parameters – "Rating_of_teachers", "Quality";

output parameters – "Market_share", "Number_of_potential_students".

The input variables values CE, RU, QL, NS, SM, RL Scan be changed by specifying the values of the corresponding target parameters CE_, RU_, QL_, NS_, SM_, RLS_ using the sliders during the experiments of scenario analysis with the simulation model.

It is possible to obtain the dependent and output variables values of the model in simple experiments with the model of mutual university competitiveness factors (simulation) at different variants of the input data changes during the solution of the direct modeling problem.

For example, it is possible to estimate the educational services market share of the Petro Mohyla Black Sea National University in Zhejiang (China) with increasing cost of education per student from 2500 RMB / year up to 2800 RMB / year. The experiments results, which are illustrated by Fig. 2, *a*, *b*, show the variants of decisions in which the training cost change will not only be compensated, but also the market share and, as a consequence, the number of potential students, will increase.

The decision-maker has the strategy choice depending on internal and external factors during the analysis of alternative scenarios (Table 2).

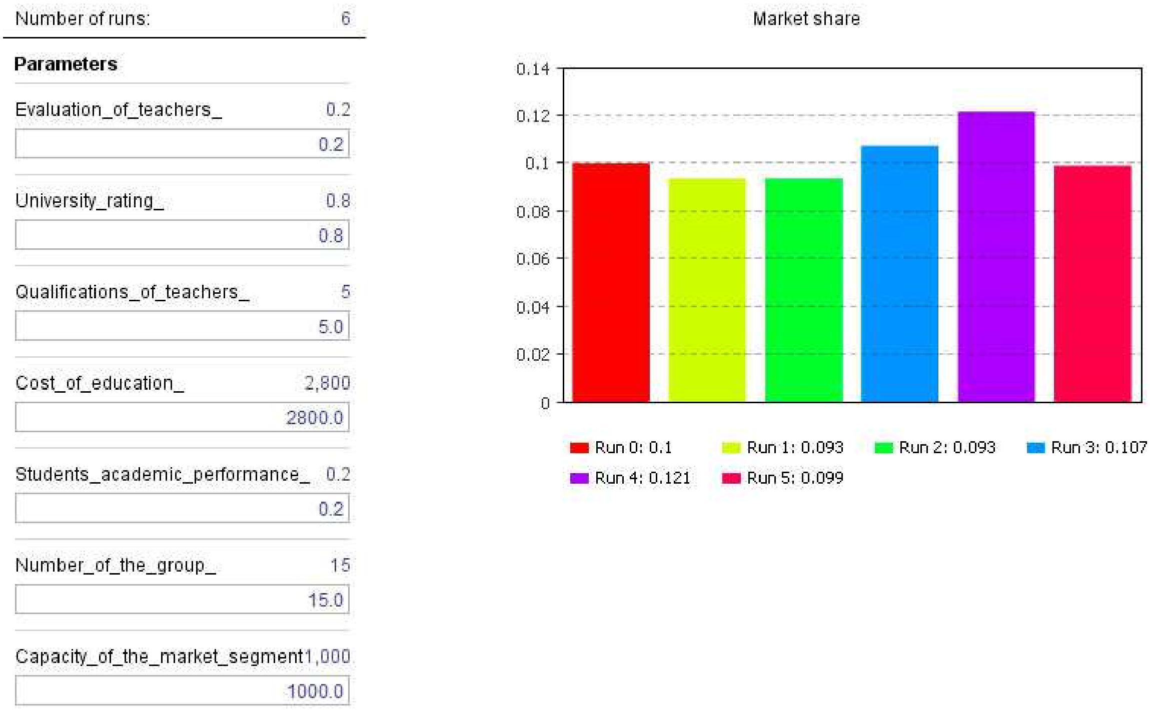

Figure 2 – Results of the CompareRuns experiment

*Table 2 – **Model parameters for alternative scenarios***

Model parameter	Parameter value					
	Run 0	Run 1	Run 2	Run 3	Run 4	Run 5
Evaluation_of_teachers_	0.2	0.2	0.2	0.2	0.2	0.2
University_rating_	0.6	0.6	0.6	0.6	0.6	0.8
Qualifications_of_teachers_	5.0	5.0	5.5	6.0	5.0	5.0
Cost_of_education_	2500.0	2800.0	2800.0	2800.0	2800.0	2800.0
Students_academic_performance_	0.2	0.2	0.2	0.2	0.2	0.2
Number_of_the_group_	15.0	15.0	15.0	15.0	12.0	15.0
Capacity_of_the_market_segment_	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0
Market_share	0.1	0.093	0.093	0.107	0.121	0.099

The table shows six runs of the model with different data:

Run 0 –the initial values of the vector elements of input parameters are not changed;

Run 1 – the cost of education has increased ("Cost_of_education_" parameter value has increased), and consequently, the "Market_share" parameter value and the number of potential students in Zhejiang decreases;

Run 2, 3, 4, 5 – alternative compensation scenarios for increasing "Cost_of_education_" parameter value. Suppose that the PMBSNU will train 120 students from Zhejiang. We will perform the model calibration for the inverse problem solution for the decision making on the cost of training: find the"Cost_of_education_", "Qualifications_of_teachers_" parameters values for a pre-defined the "Number_of_potential_students_" output parameter value (Fig. 3).

The "Cost_of_education_" parameter values ranged [2300 – 2800], "Qualifications_of_teachers_" ranged [4 – 7]during the experiment. The values of the other parameters are shown in Table 1.

The number of model runs = 500. The following values were obtained as a result of the experiment:

"Cost_of_education_" = 2,328.308;

"Qualifications_of_teachers_" = 6.

Conclusions

1. Scenario studies were conducted on a simulation model of the mutual influence of university competitiveness factors on the example of the educational services market share assessment of the Petro Mohyla Black Sea National University in Zhejiang (China).

2. It is shown that the results of a large number of "what-if" experiments make it possible to conduct a comprehensive analysis of a large number of alternatives and to select the management decisions variants which correspond to specified criteria.

3. Results shows the Calibration experiments for Zhejiang (China). The target values of the output parameters were set and the corresponding values of the input parameters were obtained in each experiment.

Varying the values of the "Market_share", "Number_of_potential_students" parameters, the decision maker has the opportunity to choose the optimal strategy to increase the competitiveness of the university.

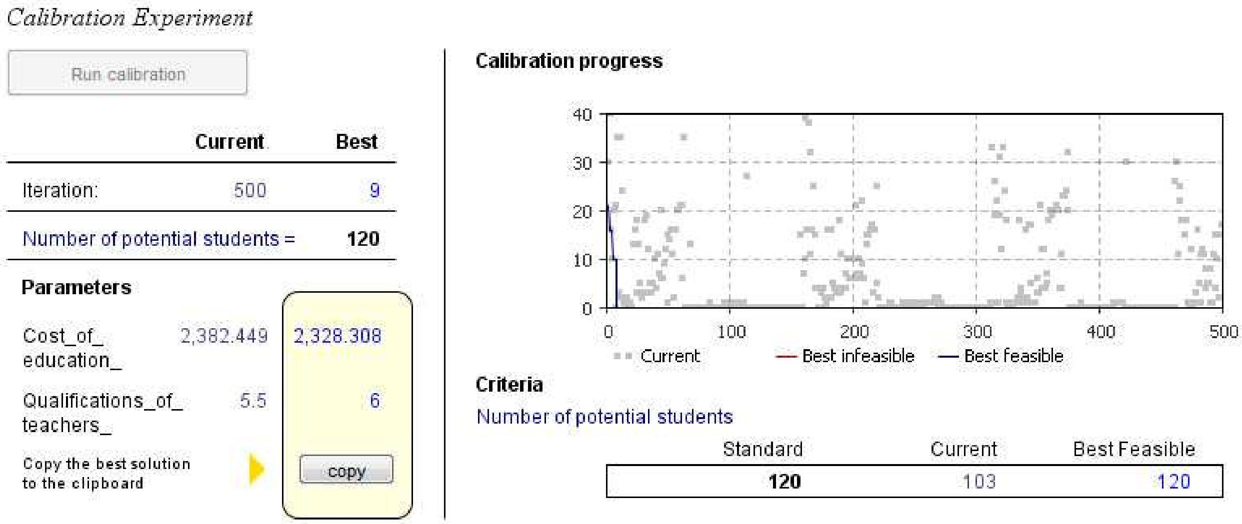

Figure 3 – Results of the Calibration experiment for Zhejiang

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СИМУЛЯЦІЙНЕ МОДЕЛЮВАННЯ КОНКУРЕНТОСПРОМОЖНОСТІ ЗАКЛАДУ ВИЩОЇ ОСВІТИ УКРАЇНИ НА ЧЖЕЦЗЯНСЬКОМУ РИНКУ ОСВІТИ

Анотація. *Запропоновано методику прийняття управлінських рішень на основі імітаційного моделювання. Розроблено модель показників конкурентоспроможності для закладів вищої освіти. Запропоновано сценарії експериментів з моделлю для оцінювання і прогнозування конкурентних переваг. Для вирішення завдання прямого моделювання проведено ряд простих імітаційних експериментів з різними значеннями вхідних параметрів. Представлено варіанти розв'язання оберненої задачі за допомогою калібрувальних експериментів моделі. Отримано результати експериментальних розрахунків впливу конкурентних факторів на позицію університету на ринку освітніх послуг. Також показана можливість прийняття управлінських рішень на основі експериментальних даних. Через складність і нелінійність залежностей між показниками використання будь-яких оптимізаційних моделей неможливе. На практиці це, як правило, обмежується аналізом невеликої кількості базових сценаріїв. Автоматизація цього процесу можлива шляхом проведення експериментів на основі моделювання. Дослідження сценарію проведено на імітаційній моделі взаємного впливу факторів конкурентоспроможності університету на прикладі оцінки частини ринку освітніх послуг Чорноморського національного університету ім. Петра Могили. Засвідчено, що результати великої кількості експериментів «що-якщо» дають можливість проводити комплексний аналіз великої кількості альтернатив і вибирати варіанти управлінських рішень, які відповідають визначеним критеріям. Результати показують експерименти калібрування для Чжецзян (Китай). Встановлено цільові значення вихідних параметрів і отримано відповідні значення вхідних параметрів у кожному експерименті. Змінюючи значення параметрів "Market_share", "Number_of_potential_students", особа, яка приймає рішення, має можливість вибрати оптимальну стратегію.*

Ключові слова: конкурентоспроможність; університет; імітація; модель; управлінське рішення

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