Digitalization as the basis for advancing educational services

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Abstract. The development of the educational services market takes place in the whole world under the influence of innovation technological and organizational solutions. The use of online technology provides a wide space for developing cooperation between educational institutions not only when mastering current disciplines. This is possible thanks to the modern concept of education being aimed at the possibility of students to choose a number of disciplines of various types based on their own preferences. The application of standard methods does not provide the necessary information for predicting which subjects will be of interest to each specific student. In this case, it is necessary to use digital technologies to process information provided by aggregator sites and search engines. This information reflects statistical data on the level of interest of a student applicant in one area or another of professional training. Based on these probabilistic features, it becomes possible to build a matrix of consumer preferences, viewing the student as a consumer of educational services. These problems can only be solved using digital technologies and by applying methods of stochastic optimization, the mathematical theory for finding solutions during uncertainty, and computer modeling.

1. Introduction

One of the most important tasks of education is the formation of an effective system for identifying, supporting and developing the abilities and talents of children and youth, based on the principles of justice, universality and aimed at self-determination and professional orientation of all students [1]. At the same time, the modern system of training qualified personnel is aimed at creating the unity of the educational space in the country. Universities in the provision of services in the field of education in the areas of training bachelors, specialists and masters should optimize the structure of the main educational programs, the conditions for their implementation and the results of development. The adoption of managerial decisions [2] in the provision of services in the field of education should be carried out taking into account the balance of multidirectional indicators in the framework of the current legislation. The transformation of the system of relations in the market of educational services is primarily due to digitalization and the growing competition of universities. An analysis of the market situation in the field of educational services is crucial for assessing the prospects of attracting applicants to an educational institution in the face of uncertainty [3] of environmental factors. Currently, the main factors...
affecting the activities of higher education institutions are the general decrease in the number of applicants due to demographics, the competitive environment, and the volatility of demand for educational services. Traditional modeling [4] of management work in conditions of incomplete information consists in the formation of a mathematical description, as a rule, based on linear functions [5]. Such a method, possessing sufficient simplicity and clarity [6], cannot ultimately yield results acceptable for practical purposes [7]. It is necessary to develop and introduce methods for predicting [8] the market for educational services based on digital technologies [9], the results of which can be used to develop the structure of the main educational programs offered by the university, in accordance with the requirements and standards in terms [10] of the educational process formed by participants.

2. The main formalisms

Issues of risk analysis of decision making under uncertainty are solved by the methods of the theory of operations research [11]. Since modern youth focuses on Internet resources [12], to solve the problem posed in this article, it is necessary to attract the possibilities of digital information exchange. In general, the preliminary information \( W_i \) received from such large-scale search engines as Google looks like a set of vectors: 

\[
W_i = \{ p_i, D_1, D_2, ..., D_N \}, \quad p_i \text{ is the share of the potential pool of applicants, } i = 1, 2, ..., M, \quad \sum_i p_i = 1, \quad M - \text{ is the number of groups studied, } D_k \text{ for } k = 1, 2, ..., N \text{ the name (type) of a discipline or group of disciplines [13] proposed for study, } N - \text{ the number of subjects in which educational activity is allowed. Next, you can create a matrix reflecting the statistics of preferences for the selection of the desired professional competencies } P = \{ p_{ij} \} \text{ where } i, j = 1, 2, ..., N, \text{ the elements of which show the proportion of preferences when choosing the } i\text{-th subject before the } j\text{-th. The solution to the problem can be divided [14] into three options:}

1. Offer a set of subjects for which the university has a staff and conducts its educational activities. At the same time, funds are not spent on promoting new disciplines or on researching the work of competitors. The choice of this approach allows you to concentrate on your own competencies without spending money and time resources. At the same time, there is a risk of possible losses due to the uncertainty of demand for educational services.

2. To conduct a study of the current and future educational activities of other competing educational institutions in order to determine their policies in the field of attracting applicants as consumers of educational services. This method requires additional costs.

3. A mixed strategy is to continue the activities of the first option while assessing the work of competing [15] educational institutions in order to determine the most advantageous offer for the next academic year. Evaluation of the three options presented in terms of economic benefits will allow us to plan the activities of higher education institutions for the next planning period in an optimal way.

3. Calculation

We demonstrate the order and algorithm of the solution. In the process of recruiting applicants conducted a survey. Applicants were asked to determine the degree of attractiveness of the areas of professional training. The obtained statistical data will be formally presented in the form of correspondence \( D_k \) (Discipline) for \( k = 1, 2, 3, 4 \). We write the values of the vectors \( W_i \). Their components are indicators of applicants’ interest in descending order of preference. Since in modern conditions [16] the penetration of digital technologies [17], the data necessary for the calculation can be obtained online, the calculations are carried out in real time, which will allow us to go to the modern system of leading indicators at the planning stage. As a result, the following distribution is obtained:

\[
W_1 = \{ 6.5\%, D_1, D_2, D_3, D_4 \}; \quad W_2 = \{ 18.5\%, D_1, D_3, D_4, D_4 \}; \quad W_3 = \{ 32\%, D_2, D_1, D_4, D_3 \}; \quad W_4 = \{ 43\%, D_4, D_1, D_3, D_4 \}.
\]
We note that the condition \([18]\) for the completeness of the group of events (the sum is \(p_{ij}\) equal to unity for \(M = 4\)) is satisfied. Computer processing allows you to build \([19]\) an already complete preference matrix \(P\) in the following form:

\[
\begin{array}{cccc}
* & 1 - p_{21} & 1 - p_{31} & 1 - p_{41} \\
p_{21} & * & 1 - p_{32} & 1 - p_{42} \\
p_{31} & p_{32} & * & 1 - p_{43} \\
p_{41} & p_{42} & p_{43} & *
\end{array}
\]

\[
P = \begin{pmatrix}
D_1 & D_2 & D_3 & D_4 \\
D_1 & * & 43\% & 75\% & 93.5\% \\
D_2 & 57\% & * & 32\% & 50.5\% \\
D_3 & 25\% & 68\% & * & 18.5\% \\
D_4 & 6.5\% & 49.5\% & 81.5\% & *
\end{pmatrix}
\]

where \(p_{ij}\) is the degree of preference for discipline \(D_i\) over \(D_j\), \(i, j = 1, 2, 3, 4\). Finally, we got the numerical values of the matrix \([20]\) according to the survey \([21]\).

4. Mathematical model

Consider the case of competition between two universities \(U_1\) and \(U_2\). Let it be able to concentrate activity on directions \(D_1, D_2\), and in turn, the sphere of interests \(U_1\) lies in directions \(D_2, D_4\). In the first version of the work, we can construct the following representation of the problem (table 1).

| Option | \(U_1\) | \(U_2\) |
|--------|--------|--------|
| \(D_2\) | 43\% | 93.5\% |
| \(D_3\) | 68\% | 18.5\% |

The matrix is used to solve the dual linear programming \([22]\) problem. We introduce the following notation: \(\alpha\) - the proportion of discipline \(D_1\) in the curriculum \(U_1\), \(\beta\) - the proportion \([23]\) of discipline \(D_2\) in the curriculum \(U_1\). Then from the equation

\[
S = \beta [43\% \alpha + 68\% (1 - \alpha)] + (1 - \beta) [93.5\% \alpha + 18.5\% (1 - \alpha)]
\]

we find a solution \(\alpha^*, \beta^*\) from the condition:

\[
\frac{\partial S}{\partial \alpha} = 0; \quad \frac{\partial S}{\partial \beta} = 0.
\]

We get: \(\alpha^* = 0.495, \beta^* = 0.75\) and define \(H_1^\prime\) - the university \(U_1\) share of the total number of applicants and \(H_2^\prime\) - the university \(U_2\) share:

\[
H_1^\prime = 43\% \times 0.495 + 68\% \times 0.505 \approx 55.63\%; \quad H_2^\prime = 100\% - 68\% \times 0.75 - 18.5\% \times 0.25 \approx 44.37\%.
\]

This will allow you to plan \([24]\) work based on the distribution \([25]\) of the flow of incoming between universities \(U_1\) and \(U_2\).

In the second embodiment, the mathematical representation of the problem has the form in table 2.

| Option 2 | \(U_1\) |
|----------|--------|
| \(D_1 - D_2\) | \(D_1 - D_2\) | \(D_1 - D_4\) | \(D_1 - D_4\) |
| \(D_3 - D_2\) | \(D_3 - D_4\) | \(D_3 - D_2\) | \(D_3 - D_4\) |
| \(U_2\) | \(D_1\) | 43\% | 43\% | 93.5\% | 93.5\% |
| | \(D_3\) | 68\% | 18.5\% | 68\% | 18.5\% |

In the second variant, by the Nash theorem \([26]\) for a university \(U_1\), we get: \(\min \max = 43\%\), for a university \(U_2\), we get: \(\max \min = 43\%\). Thus there is a pure equilibrium. In these conditions, the
university $U_2$ pays maximum attention to the development of academic disciplines $D_1$. Then the university $U_1$, having received information about the areas of study of another university, will direct the maximum efforts to the development of educational disciplines $D_2$.

In the third option, for the first period (as a rule for the academic year), part of the applicants $r$ will be interested in other offers from $U_2$. For the university $U_1$, these applicants will be lost. The mathematical description of the third version of the problem can be reduced to compact table 3.

**Table 3. Option 3.**

| Option 3 | U1       | D2      | D4      | D2 | D4  |
|----------|----------|---------|---------|----|-----|
|          |          | $r + 43(1 - r)$ | $r + 93.5(1 - r)$ | $43\%$ | $93.5\%$ |
|          | U2       | $r + 68(1 - r)$ | $r + 18.5(1 - r)$ | $68\%$ | $18.5\%$ |

We determine for calculating the loss $r = 20\%$ (you can take any other value), after applying mathematical modeling, we get from the six strategies presented only two necessary. To calculate the Nash equilibrium, we solve the equation: $0.544\alpha + 0.348(1 - \alpha) = 0.43\alpha + 0.68(1 - \alpha)$. Searched value: $\alpha^* \approx 0.744$. The obtained results allows us to determine the value $H_1^*$ of the share of the university $U_1: H_1^* = 0.544 \cdot 0.744 + 0.348 \cdot (1 - 0.744) \approx 49.38\%$. From here you can calculate: $H_2^* \approx 50.62\%$. The results of using methods for forecasting the market [27] for educational services based on digital technologies are summarized in table 4.

**Table 4. Comparison of three calculation options.**

| University | Var. 1 | Var. 2 | Var. 3 |
|------------|--------|--------|--------|
| U1         | 55.63% | 43%    | 49.38% |
| U2         | 44.37% | 57%    | 50.62% |

Thus, the presented methodology allows one to rigorously mathematically [28-30] evaluate various options for planning university activities. The advantage of the mathematical model is the use of statistical data obtained on the basis of digital technologies. The university management uses the obtained forecast results for further economic calculations. First of all, the costs of training, the study of the situation in a competitive environment and the planned profit are taken into account.

5. Conclusions

When choosing an institute of higher education, the modern applicant prefers internet resources as the main source of information on the educational services market. At the same time, the possibilities of web networks give extensive feedback material, allowing statistics on the preferences of future students to be collected and segmented according to a number of features, such as geography, age, high school graduation date, areas of interest, and other information, which allows university management to flexibly transform their educational programs and maintain a balance between the basic and variable parts. Similar feedback systems are carried out by leading universities, including EQIS accreditation. The trend towards digitalization, including the use of mathematical models and AI systems, allows for management solutions which are optimal from an economic point of view to be used when planning the work of educational institutions, and for activities to be planned according to market demands. Based on the use of digital technologies when forecasting the educational services market, universities can plan their activities several years in advance, primarily by determining the best choice of educational disciplines in the part formed by the participants of the educational process, as well as the personnel,
financial, and logistical resources, while taking into account the requirements of educational standards. Thus, the use of methods of forecasting the educational services market based on digital technology, first and foremost, gives universities the opportunity to develop an optimal structure of the main educational programs, satisfying not only the requirements of current legislation but also the demands of the market.

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