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MATHEMATICAL MODELING AND ASSESSMENT OF ECONOMIC STABILITY SCANDIAC HOTELS

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The article builds a mathematical model for the operation of Scandic Hotels based on the Cobb–Douglas production function. The information base of the modeling was the data of the hotel's financial statements for 2017–2021. The model is formalized as a computer program written in Java algorithmic language. The adequacy and reliability of the constructed mathematical model was verified using the coefficient of determination, the high value of which confirms the reliability of the constructed model. Based on the constructed model, an assessment of the economic sustainability of Scandic Hotels was carried out. The practical significance of the work lies in the fact that the author's computer programs for modeling and validating the model are registered by the Federal Intellectual Property Service of Russia in the State Register of Computer Programs, lie in the public domain and can be used in similar studies to develop measures to assess the economic sustainability of enterprises in the hotel industry.

Keywords: mathematical modeling; modeling software; operating activities of the hotel; assessment of the economic sustainability of the hotel.

Introduction

Scandic Hotels Corporation was founded in 1963 and is a hotel chain head-quartered in Stockholm, extending its activities to the Nordic countries. In addition to hotels in Sweden, Norway, Finland and Denmark, the company has hotels in Germany and Poland. The chain's customer base, as in the rest of the Scandinavian market, is mainly Scandinavian or Nordic visitors, with an ever-increasing share of international travelers, mainly from Germany and Russia, followed by customers from the US and the UK. The hotels of the chain operate in the middle segment of the market under the industry-leading Scandic brand [1].

By 1972, the chain had grown to 59 hotels across Europe when Esso sold the non-Scandinavian hotels. The remaining 32 hotels, five of which are in Norway and Denmark, formed the largest hotel chain in Sweden in 1973.

In 1983, the company was sold to a Swedish consortium led by Ratos, and the following year it was renamed to Scandic Hotels. In 1986, the first hotel outside of Scandinavia was opened.

In 1996, the chain acquired Reso Hotels and became a public company listed on the Stockholm Stock Exchange. Two years later, the Arctia Hotels group in Finland was bought, giving Scandic presence in all Scandinavian countries, and in 1999 the group expanded its presence with hotels in Estonia.

In 2001, Scandic was acquired by the London-based Hilton Group. In 2007, it was bought by the Swedish private equity firm EQT for 833 million euros. In 2014, Scandic acquired Rica Hotels, which added 72 properties to its portfolio in Norway and Sweden. In December 2015, Scandic was again listed on the Stockholm Stock Exchange. In June 2016, Scandic Hotels retired the HTL hotel brand in Stockholm and Oslo, its hotels were re-branded to Scandic Hotels after the brand was withdrawn.

In 2017, Scandic announced the purchase of all 43 Restel hotels in Finland for 114.5 million euros. Following the transaction, Scandic became the leading hotel operator in Finland.

Now Scandic is the largest hotel chain in the Nordic countries in terms of the number of rooms [2]. Scandic is the largest Scandinavian hotel operator with a network of about 270 hotels with 55,000 rooms in six countries. Scandic has over 18,000 employees.

Approximately 70 percent of revenue comes from business travel accommodations and conferences, with the remaining 30 percent from conferences and food and beverages. High level of repeat guests is maintained due to Scandic Friends - the largest loyalty program in the Scandinavian hotel sector. The Scandinavian hotel sector is strong primarily due to a stable macro economy. The bulk of tourists arriving in the region come from Scandinavian countries or travel locally. However, the Scandinavian region is becoming increasingly attractive as a tourist destination and meeting place for foreign travelers. Scandic's portfolio, which has the largest geographic coverage in the Nordic countries, includes hotels located in the center of major cities, as well as in business centers and airports, near major highways or in beautiful natural surroundings. Hotels vary in design depending on location and type of hotel, but Scandic's popular standard offerings are the same everywhere.

1. Modeling Algorithm

We used hotel reporting data for 2017–2021 as the initial data for building a mathematical model of the Scandic Hotels economy. The data for modeling are presented in Table 1.

The Cobb-Douglas production function was chosen as the methodological basis for constructing a mathematical model of the economy of a metropolis [3]. The production function describes the dependence of the output indicators of the economic system on the input factors. In the regional economy, the input data for building a production function are production assets and human resources. As an endogenous variable, the gross regional product is considered as an indicator of the volume of the product produced in value form, and exogenous variables are as follows: basic production assets and labor resources. For the integral accounting of heterogeneous labor resources, the indicator of the wage fund was used.

This study is based on the fact that output (CP) can be described by the Cobb–Douglas production function (1).

$$CP = F(FA, FOT), \tag{1}$$

where FA – fixed assets; FOT – wage fund. Regarding the production function, the following is assumed:

1) the continuity and twice differentiability of the function with respect to the arguments CA, FOT;

2) the impossibility of production in the absence of at least one of the factors, i.e. $F(0, FOT) = F(CA, 0) = 0$;

3) the possibility and limitation of substitution between factors; as the cost of one resource increases with constant amounts of others, the marginal efficiency of the use of the first resource does not increase. Thus, the production function, taking into account Hicks-neutral autonomous technical progress, takes the form:

$$CP = A \cdot FOT^{\alpha} \cdot FA^{\beta} \cdot e^{\lambda t}, \tag{2}$$

where A is an empirically determined coefficient that provides conjugation of the sizes of the left and right parts and at the same time acts as a scale conversion factor between all components of formula (2); α, β, γ are indicators of the elasticity of production with respect to labor, fixed assets and technical progress; t is the time adjusted to the base year.

Table 1

Data for modeling operations Scandic Hotels, thousand US dollars

Year	Quarter	CP	FA	FOT
2017	1	3 743	357	1 267
	2	3 974	338	1 186
	3	3 769	319	1 434
	4	3 097	282	1 085
2018	1	3 791	353	1 151
	2	4 748	402	1 520
	3	4 874	415	1 353
	4	4 595	434	1 398
2019	1	4 066	373	1 410
	2	4 863	404	1 530
	3	5 195	427	1 440
	4	4 831	430	1 490
2020	1	3 343	290	1 302
	2	665	37	294
	3	2 085	172	408
	4	1 377	113	766
2021	1	930	84	688
	2	1 097	138	753
	3	3 778	294	1 019
	4	3 783	322	1 137

The production function (2) is a mathematical model of the economy of a metropolis, reflecting the impact of the resource provision of production on output. The parameters of the production function A, α, β, γ in the most general form are found on the basis of retrospective data on revenue CP, wage fund FOT, non-current assets FA and the corresponding time t, as a solution to the problem of system of equations (3). In the system of equations (3), m is the number of years for which retrospective data were collected ($m > 4$).

$$\begin{cases} \sum_{i=1}^{m} \ln CP_i = m \ln A + \alpha \sum_{i=1}^{m} FOT_i + \beta \sum_{i=1}^{m} \ln FA_i + \lambda \sum_{i=1}^{m} t_i, \\ \sum_{i=1}^{m} (\ln CP_i \cdot \ln FOT_i) = \ln A \sum_{i=1}^{m} \ln FOT_i + \alpha \sum_{i=1}^{m} (\ln FOT_i)^2 + \\ +\beta \sum_{i=1}^{m} (\ln FA_i \cdot \ln FOT_i), \\ \sum_{i=1}^{m} (\ln CP_i \cdot \ln FA_i) = \ln A \sum_{i=1}^{m} \ln FA_i + \alpha \sum_{i=1}^{m} (\ln FA_i \cdot \ln FOT_i) + \\ +\beta \sum_{i=1}^{m} (\ln FA_i)^2 + \lambda \sum_{i=1}^{m} (t_i \cdot \ln FA_i), \\ \sum_{i=1}^{m} (\ln CP_i \cdot t_i) = \ln A \sum_{i=1}^{m} t_i + \alpha \sum_{i=1}^{m} (t_i \cdot \ln FOT_i) + \beta \sum_{i=1}^{m} (t_i \cdot \ln FA_i) + \\ +\lambda \sum_{i=1}^{m} (t_i)^2. \end{cases} \tag{3}$$

The application of the method of power production functions for the analysis of the economics of production is often difficult because the system of equations (3) may not have a solution. This is explained by the fact that there may be a dependence between statistical data, due not so much to their functional connection, as to the proximity in time of sets of exogenous variables, when all quantities change proportionally. In this case, a phenomenon arises, called by Mendershausen the effect of multicollinearity between independent variables. To overcome this barrier, it is necessary to make the following transformations. Let us divide the total differential of function (2) by the function itself. We get the following:

$$\frac{dCP}{CP} = \alpha \cdot \frac{dN}{N} + \beta \cdot \frac{dFA}{FA} + \lambda dt. \tag{4}$$

Let us introduce the notation:

$$\frac{dCP}{CP} = 2 \cdot \frac{CP_{i+1} - CP_i}{CP_{i+1} + CP_i} = z, \quad \frac{dFOT}{FOT} = 2 \cdot \frac{FOT_{i+1} - FOT_i}{FOT_{i+1} + FOT_i} = x,$$

$$\frac{dFA}{FA} = 2 \cdot \frac{FA_{i+1} - FA_i}{FA_{i+1} + FA_i} = y, \quad dt = t_{i+1} - t_i = 1.$$

Then expression (4) is transformed into the equation: $z = \alpha \cdot x + \beta \cdot y + \lambda$. According to the transformed initial data from the system of equations (5), we find the coefficients of elasticity α, β, λ.

$$\begin{cases} \sum_{i=1}^{m} z_i = \lambda \cdot m + \alpha \cdot \sum_{i=1}^{m} x_i + \beta \cdot \sum_{i=1}^{m} y_i, \\ \sum_{i=1}^{m} (x_i \cdot z_i) = \lambda \cdot \sum_{i=1}^{m} x_i + \alpha \cdot \sum_{i=1}^{m} (x_i)^2 + \beta \cdot \sum_{i=1}^{m} (x_i \cdot y_i), \\ \sum_{i=1}^{m} (y_i \cdot z_i) = \lambda \cdot \sum_{i=1}^{m} (t_i \cdot y_i) + \alpha \cdot \sum_{i=1}^{m} (x_i \cdot y_i) + \beta \cdot \sum_{i=1}^{m} (y_i)^2. \end{cases} \tag{5}$$

The coefficient A is found from the found numerical values of the coefficients of elasticity (6).

$$A = \frac{\sum_{i=1}^{m} z_i \cdot x_i^{\alpha} \cdot y_i^{\beta} \cdot w_i^{\gamma} \cdot e^{\lambda t}}{\sum_{i=1}^{m} (x_i^{\alpha} \cdot y_i^{\beta} \cdot w_i^{\gamma} \cdot e^{\lambda t})^2}. \tag{6}$$

2. Building and Studying the Mathematical Model of the Hotel Economy

The described modeling algorithm is formalized as a computer program written in Java and registered by the Federal Service for Intellectual Property in the State Register of Computer Programs [4]. The results of computer simulation are shown in Table 2.

Table 2

Results of computer simulation of the Scandic Hotels economy

File Help		
Input data		
Set row/column numbers for calculations		
Rows Columns	from **3** from **3**	to **22** to **5**
Simulation results		
$\ln A$	3.47458	
Alfa ($\ln FOT$)	-0.12632	
Betta ($\ln FA$)	0.97922	
Lambda (T)	-0.00341	
Coefficient A	32.2843	**Run a calculation**
$CP = 32.2843 \cdot FOT^{-0.12632} \cdot FA^{0.97922} \cdot e^{-0.00341 \cdot t}$		

The quality of the constructed model was assessed using the determination coefficient:

$$R^2 = 1 - \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{\sum_{i=1}^{n} (y_i - \bar{y}_i)^2},$$

where y_i, $\hat{y}_i$ are actual and calculated values of the variable being explained (in our case CP); $\bar{y}$ is the arithmetic mean of the variable being explained. The coefficient of determination takes values in the range from 0 to 1, and the closer the value of the coefficient is to 1, the better the constructed model describes the initial data. For the constructed model, the value of the coefficient of determination was 0.96, which corresponds to its high accuracy. In 96% of cases the change in Scandic Hotels revenue values is associated with changes in the size of fixed assets and wages. The significance of the coefficient of determination R^2 was checked using the Fisher F-criterion, the calculated value of which is found by the formula:

$$F_{calc} = \frac{R^2}{1-R^2} \cdot \frac{n-m-1}{m} = \frac{0.96}{1-0.96} \cdot \frac{22-2-1}{2} = 228,$$

where R is a multiple correlation coefficient; n is the number of observations; m is the number of variables. According to the table $F_{tabul}(\alpha, \nu_1, \nu_2)$ is determined at significance level $\nu_1 = m$ and degrees of freedom $\nu_2 = n - m - 1$. $F_{tabul}(0.05, 2, 22) = 3.44$.

Since the $F_{calc} \gg F_{tabul}$, then the constructed mathematical model is adequate and reliable. The indicator calculated in the course of modeling $h = \alpha + \beta + \lambda = 0.84949$; characterizes the elasticity of production, i.e. how the scale of production affects the output. It should be noted that the activity of Scandic Hotels in Russia is not yet giving the proper result, because the return of resources used in operating activities by 15% does not compensate for investments.

The author's approach was used to assess the economic sustainability of Scandic Hotels [5, p. 66], according to which the dynamics of the indicator h reflects the economic stability of the enterprise. When $\partial h/\partial t > 0$, at $t = \overline{1, T}$, the economic stability of the enterprise is obvious, otherwise it decreases. Since 2019, the economic sustainability of Scandic Hotels in Russia has been declining.

Conclusions

Since 2019, the dynamics of the indicator h has been negative, i.e. Scandic Hotels in Russia is not economically sustainable. The lack of an economic analysis of the company's operating activities and the failure of the hotel management to adopt the set of measures to change the strategy can lead to bankruptcy and liquidation of the hotel's activities in Russia.

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МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ И ОЦЕНКА ЭКОНОМИЧЕСКОЙ УСТОЙЧИВОСТИ SCANDIAC HOTELS

В. Г. Мохов, Т. С. Демьяненко, Л. С. Лапина

В статье построена математическая модель операционной деятельности Scandic Hotels на основе производственной функции Кобба – Дугласа. Информационной базой моделирования послужили данные бухгалтерской отчетности отеля за 2017–2021 годы. Модель формализована в виде компьютерной программы, написанной на алгоритмическом языке Java. Адекватность и надежность построенной математической модели проверена с помощью коэффициента детерминации, высокое значение которого подтверждает достоверность построенной модели. На основе построенной модели проведена оценка экономической устойчивости Scandic Hotels. Практическое значение работы состоит в том, что авторские компьютерные программы моделирования и проверки достоверности модели зарегистрированы Федеральной службой интеллектуальной собственности России в государственном Реестре программ для ЭВМ, находятся в открытом доступе и могут быть использованы в аналогичных исследованиях для разработки мероприятий по оценке экономической устойчивости предприятий гостиничной индустрии.

Ключевые слова: математическое моделирование; программное обеспечение моделирования; операционная деятельность отеля; оценка экономической устойчивости гостиницы.

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