Decision tree as a tool for implementing a scenario approach for multi-level predictive models

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Abstract. The paper presents a decision-making method for a quantitative income estimation depending on the intensity of the future tourist flow, as a complex indicator reflecting the level of the tourist market in a region or in a separate object (a hotel complex, sanatorium, tourist base, etc.). The authors proposed to use a three-level economic and mathematical model as a practical implementation of the hotel complex room stock management process. Each its level corresponds to a specific task. At the first level it is a pre-forecast study, substantiation and selection of forecasting models. At the second it is a forecast model and the quantitative value of the predicted indicator. At the third level it is a model to help a decision maker (DM) with decision making, i.e., a decision tree is applied as a tool. Thus, the authors present a complete system of models and methods of decision support. The results of pre-forecast analysis, development of predictive models, building, adaptation and implementation of top-level economic and mathematical models will help decision makers to make effective management decisions. There by the maneuver material resources, choose sales technologies and search for economic solutions, including in tourism recreational production activities.

1. Introduction

A significant contribution to the forecasting techniques study in the field of tourism is made by research works of D.K. Frachtling, H. Sonck and S.F. Witt, K.F. Wong. Scientists conduct research in the following areas: V. M. Geets develop industry forecasting, Yu. N. Lapygin, V. E. Krylov and A. P. Chernyavsky develop economic forecasting. The works of A. I. Uemov laid the foundations for the development of modern modeling. At the same time, Russian authors, unlike foreign ones, do not single out forecasting in the field of tourism as a separate area for research. So, the topic of this paper considers to be relevant [1].

The tourist flow, or rather its intensity, is the backbone of the tourism economy and the main source of income for the industry. The accuracy of the tourist flow forecasting at a certain point in time (season, off-season) will help managers of hotel complexes to make informed decisions concerning the cooperation with tour operators and specialized sites, i.e., On-line Travel Agency (OTA). This fact determines the relevance of the presented study [2, 3].

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The authors proposed to use a three-level economic and mathematical model as a practical implementation of the hotel complex room management process. A first level model is a decision tree [4, 5, 6]. On the basis of its results a decision maker (a hotel room manager) estimates the number of rooms allocated for the package purchase to travel operators through specialized platforms On-line Travel Agency (OTA). A second level model is a predictive model of the tourist flow [7, 8]. The predicted values, i.e., input data for the top-level model, ensure the implementation of the effective functioning of the hotel complex (a tourist and recreational zone) in changing conditions of both the external and internal environment associated with such diverse factors as weather, environmental (including epidemics and pandemic), market conjuncture, inflation, etc. A model of the first level is pre-forecast modeling [7, 9, 10], i.e., the analysis of the time series of the tourist flow, identification of its quantitative and qualitative pre-forecast characteristics.

2. Research methodology

The predicted values of the intensity of the tourist flow, obtained on the basis of such an artificial intelligence method as a linear cellular automaton [4, 7, 11] and one of the main indicators of the tourism industry, involves these informed decisions methods application, including a decision tree building. A practical example of building a decision tree is given below. We note additionally that the predicted values of the tourist flow used in this example are obtained on the basis of real statistical material.

We will take into account in the problem setting the presence of the sales channel’s variety for the hotel room stock and the choice of strategies for using all the possibilities. The first one is booking a room through specialized platforms On-line Travel Agency (OTA) (Booking.com, Expedia, 101Hotels, Airbnb, HRS, Hotels.com, Your Hotel and some others). The second one is the development and use of the hotel’s personal website through the built-in online booking module, which implies self-selection of a room and its instant reservation. The third one is the sales department of the hotel as a traditional way of direct booking through the manager. The fourth one is agency sales, i.e., package sales of rooms through travel operators or agencies. Moreover, ideally, it is necessary to take into account the influence of such factors as infrastructure, room stock size, location, number of bookings through each channel, cost of sales through channels, control of statistics and demand calendar, market situation and competitors' policies.

Task 1. A manager of the typical resort hotel complex located on the Black Sea coast (a room stock is 200 rooms) [2]) needs to make a decision on the implementation of the room stock for the high season. The size of the room price had to be adjusted even during the season downward to 4000 rubles. Per day taking into account that the intensity of the tourist flow in the season of the past year was restrained by a number of factors (natural, environmental, epidemiological, inflation, etc.). On the basis of the recent years’ experience, a manager understands that, having held the number of rooms during the high season, it may be possible to sell it using the second and third sales channels described above at a more favorable price of 8,000 rubles, than if you put up package sales for purchase by travel agencies at whole sale price per room. Make the following assumption, relying on the long-term statistics of the hotel complex functioning that in demand, the probability of types for the number of rooms in the hotel complex is 0.3, 0.3, 0.4 respectively. What decision should a manager of the hotel complex make (set 100% at the wholesale price for redemption to travel agencies in February, or hold on to the number of rooms and, given the likelihood of demand for rooms, implement it immediately before the start of the high season) to get the highest income?

| Scenario | Total expenses for the maintenance of the hotel complex (mln. rubles) | Mathematical expectation of income depending on the channel and the method of selling the room stock (mln. rubles) | Probabilistic estimation of the demand for rooms in the season | Expected income based on a probabilistic estimation of the demand for the room stock (mln. rubles) |
|----------|-------------------------------------------------------------------|---------------------------------------------------------------|----------------------------------------------------------------|-------------------------------------------------|
| Scenario 0 | 90                                                                | 90                                                            | 1                                                               | 90                                             |

Table 1. Scenarios for the of the room stock realization through two channels.
Scenario 0: The hotelier uses a single sales channel (based on the experience of hotels in Turkey) and exposes the entire room stock in January for purchase to agencies (strategy 0) at a wholesale price of 5,000 rubles per day for the entire high season (90 days), and receives a guaranteed income equal to the mathematical expectation of 90 million rubles. Moreover, the received profit will be enough to cover the total costs of maintaining the hotel complex, including the entire list of services for the high season.

Scenario 1: A hotelier realizes rooms, having sold it to agencies at a wholesale price per day for the entire high season (90 days) just before the high season. In this case, the profit is a random value, depending on the price situation depending on the types for the high season (4,000 rubles, 6,000 rubles or 8,000 rubles).

Thus, with the given probability of the conjuncture price estimations, Scenario 1 is the most preferable for the room stock realization with the additional profit. If Scenario 0 is selected, the amount expected to be received will only ensure the breakeven operation of the enterprise during the high season.

The calculation of income from the room stock realization in May-June according to the variants for the price conjuncture are as follows:
1. 200 x 4000 x 90= 72 mln. rubles;
2. 200 x 6000 x 90= 108 mln. rubles;
3. 200 x 8000 x 90=144 mln. rubles.

The mathematical expectation of profit when realizing the room stock in May – June before the high season is as follows:
\[ 0.3 \times 72 + 0.3 \times 108 + 0.4 \times 144 = 21.6 + 32.4 + 57.6 = 111.6 \text{ mln. rubles}. \]

**Problem 2.** A hotelier becomes aware that in the consulting center for a small fee (200 thousand rubles) you can purchase a price forecast for the number of rooms and, accordingly, an estimate of the level of intensity of the tourist flow for the high season. Meanwhile, the accuracy of the forecast of the consulting center has the following characteristics based on statistical data:

| Scenario | Price | Probability |
|----------|-------|-------------|
| 0        | 5,000 | 0.3 (low)   |
| 1        | 4,000 | 0.3 (middle)|
| 2        | 8,000 | 0.4 (high)  |

**Figure 1.** Decision tree for choosing a way for rooms realization through two channels.
• if they predict in February that a level of intensity of the tourist flow will be high during the season, then this forecast is justified with a probability of 70% (low with a probability of 10%, - 20% is average);
• if a consulting center predicts the average level of tourist flow, then the probability of such a forecast will be 70% (15% is low, 15% is high);
• if the consulting center predicts a low level, then the accuracy of the forecast is at the level of 70% and, respectively, - 0.2 is medium and 0.1 is high.

A hotelier has three scenarios for the implementation of the room stock applying the predictive information about the intensity of the tourist flow in the high season:

• Scenario 1: if the forecast of the intensity of the tourist flow during the season is low, then it is profitable to put up 35% of the room stock for redemption and sell it in advance at a low (wholesale 6,000 rubles per room) price and transfer 35% of the room stock for placement in OTA;
• Scenario 2: if the average intensity of the tourist flow in the season is predicted, then 30% of the room stock will be put up for purchase and OTA;
• Scenario 3: if the intensity of the tourist flow is high, 20% of the room stock can be set up for the purchase of 30% to travel agencies and on the OTA sites, 50% can be kept with you in order to obtain a higher profit.

Make the following assumption, relying on the long-term statistics of the hotel complex functioning: the probability of types in demand for the number of rooms in the hotel complex is 0.3, 0.4; 0.3 respectively. What decision should a manager of the hotel complex make (set 100% at the wholesale price for redemption to travel agencies or 70%, 60% or 50% of the room stock to travel agencies and OTA) in order to obtain the highest profit?

Figure 2. Example of possible outcomes in the form of a decision tree (according to the condition of task 2).
Figure 2 presents an example of three options for possible scenarios in the form of a decision tree, i.e., a hotelier makes a choice and makes a decision on the implementation of the room stock for the high season using different options for combining four sales channels. Separately, we note that Figure 1 is a particular, rather simplified case of figure 2.

To make figure 2 clear, assume that a manager of the hotel complex decides to order a forecast on the price situation for the room stock for the high season and, accordingly, the level of intensity of the expected tourist flow. In this case, the decision tree demonstrates the complexity of the decision-making choice facing the hotelier, depending on the forecast results:

**Scenario 1.** If a consulting center provides information on a possible low level of tourist flow intensity and, accordingly, low demand for rooms during the high season, then the hotelier is most profitable to conclude a buyout agreement with travel agencies and sell the whole room stock according to the zero strategy in January of the current year. It secures a guaranteed profit and a break-even operation of the hotel complex for the high season in the amount of 90 million rubles. This solution demonstrates a comparison of the sale results of the room stock according to Scenario 0 (Task 1). The volume of the received profit compensates for the costs of ordering a forecast in a consulting center, taking into account the probabilistic assessment of the accuracy of the forecast value. Thus, abandoning Scenario 1 and choosing Scenario 0 provides the hotelier with a margin equal to 90-0.2-83.024 = 6.776 million rubles.

**Scenario 2.** With the forecast of the average value of the intensity of the tourist flow and the corresponding structure of the distribution of the room stock by sales channels (strategy 2, figure 2), the hotelier will receive a margin equal to 97.74-0.2-90 = 7.54 million rubles, where 0.2 million rubles is the cost of the forecast, 90 million rubles the guaranteed profit (scenario 0) at the room stock transferring for the high season period for redemption to agencies in January.

**Scenario 3.** With the forecast of high demand for room stock, the margin of a hotel complex manager in comparison with the mathematical expectation of the guaranteed income under Scenario 0 (Task 1), will be 113.832-0.2-90 = 23.632 million rubles.

Thus, it can be concluded that ordering and buying a forecast is advisable. Moreover, this will provide a hotelier the profit in the interval [6.776; 23.632] million rubles, taking into account the probabilistic evaluation of the accuracy of the provided forecast.

The analysis of the presented decisions based on the decision tree tool helps to conclude that any information about the price situation and the intensity of the tourist flow is very useful in making efficient economic decisions. Today, it is important to be able to use the obtained forecast information qualitatively in the conditions of stochastics and uncertainty [12, 13]. The results of pre-forecast analysis, development of predictive models, building, adaptation and implementation of first-level economic and mathematical models will enable decision makers to make efficient management decisions. Thereby it can be possible to maneuver material resources, choosing sales technologies and searching for economic solutions, including in tourism and recreational production activities [14]. The latter becomes a particularly important fact in the context of the development of domestic tourism in the current framework of the epidemiological situation.

**Acknowledgments**

The study was carried out with the financial support of the Russian Foundation for Basic Research within the framework of scientific project No. 19-010-00134 A.

**References**

[1] Generalova N 2014 Forecasting in the field of tourism: classification and analysis of methods Journal of international law and international relations 4 57-63
[2] Frolova T A 2011 Economics and Management in the Sphere of Social and Cultural Service and Tourism. Lecture notes (Taganrog: Publishing house of TIT SFedU) http://www.aup.ru/books/m19/ (date of access 04.16.2021)
[3] Yakimenko M V and Zhertovskaya E V 2020 Methodological approach to assessing the potential and scenario forecasting of the development of tourist and recreational clusters Tourism: law and economy 3 24-32

[4] Popova E V, Kumratova A M and Chikatueva L A 2013 Sustainability of development of the agrarian sector: a complex of mathematical methods and models Polythematic network electronic scientific journal of KubSAU (Scientific journal of KubSAU) 06(090) 953-68

[5] Kurtsev I V and Zadkov A P 2003 Adaptive systems of agriculture Risk Management 4 41-8

[6] Eddows M and Stansfield R 1997 Methods of decision making (M: Audit, UNITT) p 590

[7] Popova E V, Kumratova A M et al 2008 Tourist and recreational activity: methods, models, forecast (Krasnodar) p 194

[8] Kumratova A, Popova E, Piterayskaya L, Tretyakova N and Chikatueva L 2021 Application of nonlinear dynamics methods for predictive testing the economic time series data Indo American journal of pharmaceutical sciences 6(3) 5598-602

[9] Kumratova A, Popova E, Shaposhnikova O, Skiter N and Klintsevich R 2021 Socio-Economic Nonlinear Dynamics Processes for Forecast and Pre-Forecast Information Based on Time Series International transaction journal of engineering management & Applied sciences & technologies 12(2) 1-10

[10] Kumratova A, Popova E, Khudyakova E, Vasilenko I and Saykinov V 2021 Statistics Application of the Dynamics Socio-Economic Processes: A Case of Russian Insurance Data International transaction journal of engineering management & Applied sciences & Technologies 12(3) 1-9

[11] Krichevsky M L 2005 Intellectual methods in management (SPb: Peter) p 305

[12] Peters E 2004 Fractal Analysis of Financial Markets: Application of Chaos Theory in Investments and Economics (M: Internet trading) p 304

[13] Sviridova N D and Negoda A A 2020 Investment activity as a form of regional tourism development Scientific result.Bizness and service technologies 6(1) 22-9

[14] Matyunina M V, Timirgaleeva R R et al 2020 Chapter 6. Theoretical and methodological aspects of regional planning of tourism development. Development of tourist destinations: models, methods, tools. (Maykop: LLC "EIT") pp 196-273