International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

December 2024 | Issue 61 | Volume 16 | Number 4 | Pages 55-60

OPTIMIZING HOTEL RESERVATION ACCEPTANCE, A CASE STUDY ON REVENUE MANAGEMENT FOR GROUP BOOKINGS USING MATHEMATICAL PROGRAMMING

A. Sinani [1] M. Godolja [2]

1. Department of Mathematics, Faculty of Technical and Natural Sciences, University of Vlora, Vlora, Albania
arjola.sinani@univlora.edu.al
2. Department of Statistics and Applied Informatics, Faculty of Economy, University of Tirana, Tirana, Albania
majlinda.godolja@feut.edu.al

Abstract- This article presents a case study that demonstrates how a mathematical programming model can optimize hotel reservation management, improving the acceptance process for both group and individual bookings. The model utilizes anticipated demand scenarios and integer programming to find optimal solutions. Key components include a demand forecasting model, and an optimization framework specifically designed for group reservations. The model is applied using actual data from a 40-room hotel in Vlora, Albania, which is representative of the average hotel size in the region. Hotel management may respond to fluctuating demand and optimize room allocation by adjusting flexible parameters. While the model does not account for cancellations or no-shows, it offers a solid foundation for maximizing revenue through optimized group booking strategies. This case study demonstrates how the approach may be applied to improve hotel revenue control in real-world scenarios. To enhance its generalizability and usefulness in broader contexts, this model can be extended to hotels of varying sizes and considering additional variables like seasonality and market dynamics.

Keywords: Randomized Models, Large-Scale Integer Programming, Group Reservations, Revenue Management, Optimization.

1. INTRODUCTION

Revenue management in hotels is a crucial part of their strategy, directly impacting the determination of room prices and the number of rooms to be sold. Essentially, this process is like a tool for hotels to enhance profits by adjusting prices according to demand and maximizing profits from the rooms sold. To achieve this, hotels utilize past data and current reservations to forecast future demand and efficiently manage room inventory. The use of machine learning and data mining, can assist in improving this process and increasing hotel revenues [4], [5], [12]. However, the current revenue management systems, still have potential for improvement, which might have a more significant effect on the tourism sector.

Dynamic formulas, which are continuously updated with new estimates, have been shown to produce better results when carefully managed [13]. There are three ways to integrate machine learning into revenue management: using a single machine learning method, combining multiple machine learning algorithms, or blending machine learning techniques with other approaches to improve prediction accuracy and decision-making efficiency [14]. In this study, a hotel revenue management model is being applied, based on data collected from a 40-room hotel in Vlora, a seaside city in Albania. The goal of this model is to provide hotel managers with a more effective tool to increase room revenue. This model includes a method for forecasting demand and an optimization model for group reservations [11]. This combination of strategies aims to sustainably improve the financial performance of the hotel.

In hotels, the same room can be offered to different types of customers, with pricing adjusted based on their budget and preferences. Managers aim to attract customers who are willing to pay higher prices for the same type of room, while also ensuring that rooms are not left empty for less profitable customers. This is why revenue management is essential for determining the right mix of customers to maximize profits. The primary goal of this research is to improve this process, with a particular focus on hotel group reservations. Most research publications in this field do not adequately address this issue. Previous studies on group reservation models have used predefined probability distributions, but this is a significant limitation in real-world applications, as hotel arrival characteristics can dynamically change. To address this challenge, a sophisticated simulator analyzes past reservation data to generate future reservation scenarios. This behavior of room reservations benefits the optimization model, ensuring that hotels make more informed decisions regarding revenue management. This study summarizes this process, applying a model for hotel revenue management and addressing and improving upon expressions from previous models.

Registered: 240628 Article Info: 1899 Accepted: 241121
Reserved: 240911 Available: 241231

Furthermore, a case study is provided to demonstrate how effective this new model is in practice. As the number of tourists in Albania has shown a consistent increase in recent years, Vlora, situated between the Adriatic and Ionian Seas, has greatly benefited from this growth. In recent years, Vlora has become a preferred destination for tourists. This has led to an increased demand for accommodations in the hotels of that region. A hotel located in an attractive area, just 200 meters from the sea, provided the necessary information for conducting this case study. This hotel has a capacity of 40 rooms. The paper is structured into sections: the first section provides a literature review that contrasts two distinct revenue management models. The second section discusses the results of applying the model for group reservations, based on data from a specific hotel in Vlora, considering three different price classes. The final section includes a summary of the results, as well as recommendations for further research in this field, suggesting new directions for future studies that could help improve the hotel's financial performance.

2. LITERATURE REVIEW

This article explains two key models: the deterministic model and the revenue management (RM) model. The deterministic model replaces demand with its expected value to optimize room allocation in a hotel, while the RM model includes a demand forecasting model and an optimization model for handling group reservations. These models are designed to assist hoteliers in room management and revenue maximization by considering demand forecasts and room capacity.

2.1. Deterministic Model

In this article, is presented a concise summary of the deterministic model referenced in the literature [2], [1]. This model substitutes actual demand with an estimated value, facilitating optimal room allocation according to the anticipated demand. Consequently, it treats demand as deterministic, aligning it with its expected outcome. To create this model, a hotel stay is defined as (n, S, c) where n_i is the first night, S is the length, and c is the price class.

Let B_s represent the pattern of behaviors that use night s, such that [2]:

$$n = s = n + S - 1 \tag{1}$$

$$B_s = \{(n, S, c) : n = s = n + S - 1\} \tag{2}$$

The deterministic model is then presented in the following way:

$$\text{Maximize}: \sum_{n,S,c} P_{n,S,c} Y_{n,S,c}$$

subject to:

$$\sum_{n,S,c \in B_s} Y_{n,S,c} \le K_s \qquad \forall s \tag{3}$$

$$Y_{n,S,c} \le d_{n,S,c} \qquad \forall n, S, c$$

$$Y_{n,S,c} \ge 0 \qquad \forall n, S, c$$

where, $Y_{n,S,c}$ denotes the room number booked for a stay of category (n, S, c), $P_{n,S,c}$ is the income earned for a stay of category (n, S, c), $d_{n,S,c}$ is the projected number of bookings for a stay of category (n, S, c), the hotel's capacity, or the total number of rooms available, and K_s is for the day s [2].

This method aims to efficiently manage hotel reservations and maximize total revenue, ensuring that the bookings on each night remain within the available capacity. With this approach, a cost-effective experience is created for guests while also optimizing the hotel's financial potential. The method involves the sustainability of rooms, and their allocation based on demand levels, which are replaced by their predictive value in this model. Randomized linear programming is another improved method to address the same problem. Many studies have been conducted regarding revenue management strategies. [11] analyzes the revenue management strategy to determine the implementation analysis of revenue management strategy in increasing revenues for available rooms at a certain hotel. [10] deals with forecasting the demand for various tourism services using statistical methods such as Holt-Winter.

The aim is to develop a model to predict the demand for services like hotel room bookings and tourist guiding services using time series data. This is crucial for managing tourism businesses and ensuring that services are available at reasonable prices for tourists. This approach incorporates stochastic information about demand into its optimization model. Nonetheless, the bid prices obtained through these methods may lead to undesirable outcomes in an associated control policy and are therefore not examined in this research. The randomized model operates the simulator repeatedly. With each iteration, it considers the anticipated demand arrivals and utilizes these predicted figures to create a deterministic model.

After calculating the optimal average room distribution and the average opportunity cost for reservations, an analysis of this data is conducted. This involves evaluating how many rooms are still available and determining the cost of missing out on another opportunity would be if we accepted a certain reservation. When hotel managers decide whether to accept or decline a reservation, they use this information to calculate what the actual benefit or loss would be. The opportunity cost, which is the cost that occurs if we choose one option over another, serves as a reference price. In this way, they can make more informed decisions and maximize profits for their business. [7] overlooks the aspect of group bookings (where reservations for groups must be either fully accepted or completely rejected). The main contribution of this study is the application of the model to data collected from the selected hotel to optimize group reservations. It is important to mention that the model does not include cancellations and no-shows.

2.2. Revenue Management (RM) Model

The implemented Revenue Management (RM) model [1], [6], [9] consists of two key components. First, there is an advanced model for predicting room demand, which helps identify the number of rooms needed in the future based on trends and customer preferences. Second, there is an optimization model for group reservations, which helps efficiently manage large group bookings, maximizing capacity utilization and reducing costs.

This strategy allows industry professionals, such as hotel managers or marketing experts, to intervene in the forecasting and optimization processes. They can apply their specialized knowledge and practical experience to adjust the model parameters and improve the final outcomes. By combining practical insights with advanced algorithms, they can achieve more effective management and respond better to customer needs. Consequently, it establishes a system that supports decision-making in an efficient and flexible manner for revenue management.

The main functions of this system are:

The creation of a demand forecasting model involves two important aspects: first, examining historical trends in hotel bookings and occupancy rates, and second, analyzing current reservations. This process helps in understanding how demand has evolved and how it can be predicted in the future. Using the forecasts from the forecasting module as input for an optimization module that makes pricing and allocation decisions based on these forecasts.

The main users of the system are hotel revenue managers, who can modify parameters and assess the impact of these changes on the hotel's total revenue. Is helps the managers make decisions about pricing and resource allocation. To create projections for future reservations, the forecasting module obtains reservation data from the hotel database. Following this, the optimization module uses these projections to determine pricing strategies and resource allocations based on the made forecasts. Revenue managers can also monitor the system's results and, in certain cases, intervene to change these results, such as the forecasted demand for rooms. After the manager's intervention, the system is reassessed to incorporate the recent updates and adjust the room reservations accordingly. Below is the definitive version of the revised deterministic model, along with the parameters set in the room distribution system.

$$\text{Maximize}: \sum\nolimits_{n,S,c,g} P_{n,S,c,g} Y_{n,S,c,g}$$

$$\text{subject to}:$$

$$\sum\nolimits_{n,S,c,g \in B_s} g \cdot Y_{n,S,c,g} \le K_s \qquad \forall s \tag{4}$$

$$Y_{n,S,c,g} \le d_{n,S,c,g} \qquad \forall n,S,c,g$$

$$Y_{n,S,c,g} \ge 0 \qquad \forall n,S,c,g$$

where, $Y_{n,S,c,g}$ represents the quantity of rooms allocated to a stay of category (n,S,c,g), $P_{n,S,c,g}$ is the income earned from a stay of category (n,S,c,g), $d_{n,S,c,g}$ is the projected number of bookings for a stay of category (n,S,c,g), K_s is the capacity of the hotel available for the day s [2].

This strategy focuses on maximizing total revenues from bookings while taking into account several important constraints. One such constraint is setting a limit on the number of reservations that can be accepted for a given night in accordance with the hotel's capacity. This means that, to avoid situations where rooms remain empty, it is essential to forecast the demand for stays, which helps determine how many rooms will be reserved for different types of accommodation. Utilizing expectations and demand analyses becomes a key component in this process, as it ensures that reservations align with capacity and maximize the hotel's benefits without causing difficulties in room availability. This careful approach not only enhances the effectiveness of hotel management but also contributes to improving the guest experience by reducing the likelihood of disappointment due to a lack of available rooms during peak demand periods.

To address unforeseen or challenging situations, such as requests for large groups, urgent requests, or requests for many rooms at a specific time, a randomized model found by [8] is used. Utilizing this model allows for calculating an average opportunity cost, which provides a benchmark for making decisions on whether to accept or reject a request. This model holds significant importance in the context of simulations and statistical analyses. It establishes a sophisticated approach in managing requests by focusing on the procedures occurring before and after their approval.

The approval process for a request is grounded in a rigorous analysis and the comparison between the expected revenues generated by the request and its average associated costs, which are calculated using a stochastic model. This model assists in identifying situations where economic benefits justify the acceptance of the request. For example, consider a situation where we have a request for accommodation, described by factors (n,S,c,g). When this request is received at a specific time t and generates revenue a, it will be deemed acceptable only if this revenue is equal to or greater than the average cost anticipated by the model.

$$a \ge r_{before} - r_{after} \tag{5}$$

where, r_{before} represents the maximum total revenue that the model can generate at time t, before a request is accepted. On the other hand, r_{after} indicates the maximum total revenue that the model can achieve at the same moment after the request has been accepted. The key difference in the optimization approach pre- and post-request acceptance lies in the capacity vector K_s. When a request is accepted, the capacity vector is reduced by the quantity of available capacity allocated for that request. Thus, the acceptance of the request impacts the availability of resources for generating additional revenue [2].

3. CASE STUDY IMPLEMENTATION AND RESULTS

Based on the data provided, the optimization model for the simulated hotel case study involves determining the best room allocation for various types of stays one year in advance. The model utilizes hotel booking data from the past three years to generate advance booking data for the upcoming month for each day. This research focuses on the process of optimizing guest stay management in hotels, a matter of great importance for the sustainable growth of hotel revenues. The management process includes, above all, several key factors that influence decision-making and specific strategies.

One of the main factors analyzed is the arrival date of the stay, which is important because it helps structure reservations and manage the flow of guests. On the other hand, side, it is important to consider the length of stay; each guest is allowed to stay for a maximum of 7 days, which helps in predicting room availability for other periods. Another important aspect is the price that guests pay, which influences the pricing strategy that the hotel uses to attract the desired clientele. Finally, the number of group members plays a crucial role in the hotel's capacity and the services offered.

The analysis lasts for a period of 31 days, during which the hotel strategically manages room reservations. In this scenario, each guest could book a room for up to 7 days, assisted by clear rules regarding the maximum number of five people per group. With a total capacity of 40 rooms, the hotel starts with an occupancy rate of 60% in the first month. This means that around 24 rooms are occupied, providing a good level of initial occupancy. However, after the first month, the occupancy rate is expected to decrease, with projections predicting a 10% reduction each month. This means that, for example, in the second month, the occupancy rate will drop to 50%, resulting in a reduction in the number of occupied rooms. This trend will continue, creating a challenge for capacity management and maximizing revenue.

To address this challenge, the hotel manager categorizes the clientele into three price levels. Guests in the first tier, paying €200, provide higher revenues, while those in the second and third tiers pay €150 and €100, respectively.

This segmentation helps in better managing demand: the hotel can optimize offers according to customer preferences and maintain competitiveness in the accommodation market.

The optimization model is described as a broad approach to partitioned programming and is implemented through the R software. While considering the demand for rooms, the model applies a "first-come, first-served" (FCFS) approach. This means that if there are multiple requests, the one that is expected to generate the highest revenue for the hotel is prioritized, if there is availability for its accommodation.

For further details and specifics, reference can be made to the work of [1]. The opportunity costs of different scenarios are the differences between the expected revenues and the predicted demand for each scenario. To minimize costs and increase profits, the hotel needs to employ a capacity and pricing management strategy. Costs vary depending on demand, so it's crucial to adapt strategies to reduce losses. By using the FCFS algorithm, the hotel can adjust room arrivals and departures to maximize profit. Owners should monitor demand to develop successful business strategies. The study shows that Holt Winters additive exponential smoothing is the most effective method for predicting demand. The goal is to optimize costs and profits for good financial performance. If costs exceed potential profits from FCFS, the hotel should review its capacity management strategy.

The code in *R* initializes variables and calculates revenue for each combination of check-in date, duration of stay, and group size. The FCFS algorithm is implemented using the provided function, where revenue is calculated based on the incoming and outgoing data. The comparison of results shows that different price classes have a significant impact on the overall profit of the hotel. In cases where room prices are higher, the overall profit is higher, while in cases where prices are lower, the profit is lower. This also results in a decrease in opportunity cost when price classes are lower.

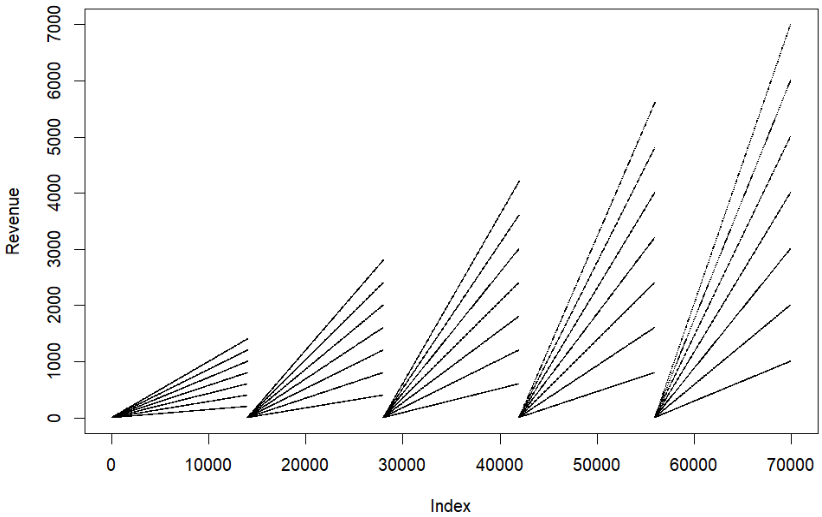


Figure 1. Revenue Matrix Analysis Graph - The First-Class Prices (200€) - FCFS Profit: 464,310,000, Opportunity Cost: 84,160,643

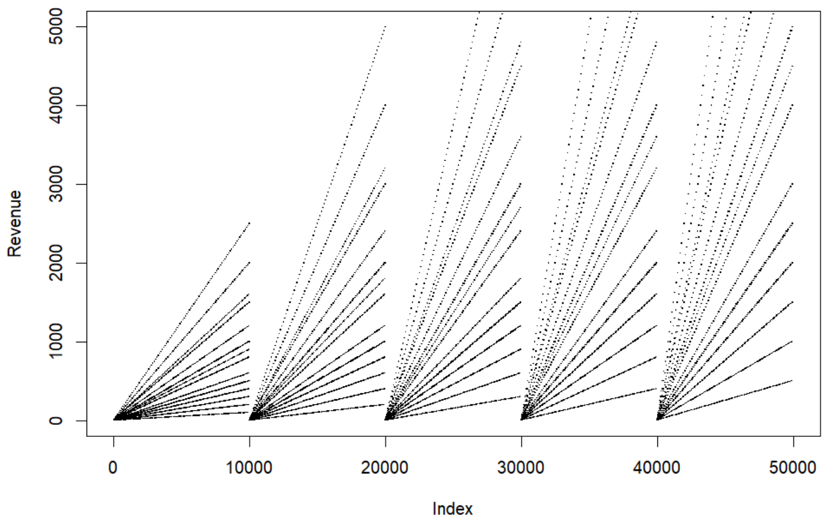


Figure 2. Revenue Matrix Analysis Graph - The Second-Class Prices (150€) - FCFS Profit: 261,607,500, Opportunity Cost: 47,370,532

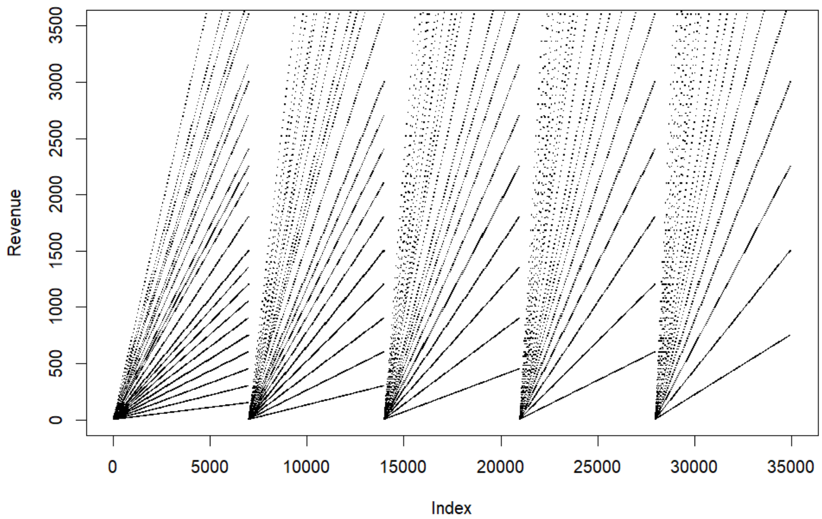


Figure 3. Revenue Matrix Analysis Graph - The Third-Class Prices (100€) - FCFS Profit: 116,655,000, Opportunity Cost: 21,080,421

4. CONCLUSIONS

Revenue management is crucial for hotels, directly influencing room prices and occupancy levels. Revenue management strategies are essential for improving profitability by adjusting prices according to demand and optimizing room availability. Given that traditional methods mainly rely on past data and current reservations, the use of more advanced models is necessary to accurately predict future demand and increase revenue, especially in a market with changing conditions. Group reservations present a unique challenge for hotels and require special treatment due to their impact on availability and room prices. In this study, a specific optimization mechanism for group reservations was applied in the revenue management model.

The model used provides flexibility for experts to intervene and update parameters and results according to the specific needs of the hotel and market conditions. In revenue analysis, we draw several conclusions: Room prices significantly impact the hotel's total profit. Higher prices result in higher profits, while lower prices lead to lower profits; The first class, priced at 200€, generates higher profits compared to other classes, suggesting customer preference for this class; However, the first class also incurs higher opportunity costs, indicating that despite higher profits, there's greater opportunity loss; The third class, priced at 100€, yields lower profits but also lower opportunity costs. This makes the third class more viable considering opportunity costs; To maximize total profit, the hotel can adjust room prices based on customer preferences and optimize opportunity costs.

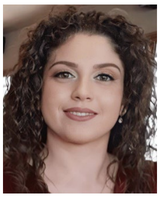
Balancing price and opportunity cost is crucial for developing an effective pricing strategy; Future research needs to be expanded by considering other models for demand prediction and implementing revenue management models, taking into account group reservations in a hotel with a larger number of rooms. The study focuses on a hotel with 40 rooms, which is a typical example of a medium-sized hotel in the Vlora region. However, the methods and conclusions of the study can also be applied to other hotels, regardless of their size or location. This model is flexible and useful for individual bookings, but it also helps in managing group reservations, which are often more challenging. It is important to note that this study does not address certain factors such as cancellations and no-shows, which are critical in practice and should be included in future versions of the model. By incorporating these factors, the system would become more accurate and better equipped to handle the unpredictability of hotel bookings.

In future researches, there is an opportunity to include additional crucial elements that influence consumer behavior, such as seasonality and pricing policies. By adding these components, the model could become more appropriate and reliable. Additionally, hoteliers may anticipate changes and modify their plans in real-time by utilizing artificial intelligence systems for demand forecasting. In conclusion, this study maximizes hotel income and enhances group booking management. By incorporating additional hotel types and examining factors such as market conditions and cancellations, the model can be further improved and made even more beneficial. As the hospitality industry continues to change, models like this will be essential for staying competitive and making smarter revenue management decisions

REFERENCES

[1] H.A. Aziz, N. El Gayar, M. Saleh, H. El Shishiny, "A Randomized Model for Group Reservations in a Hotel's Revenue Management System", INFOS2008, March 27-29, 2008.
[2] N.F. El Gayar, M. Saleh, A. Atiya, H. El Shishiny, "An Integrated Framework for Advanced Hotel Revenue Management", International Journal of Contemporary Hospitality Management, Vol. 23, No. 1, pp. 84-98, February 2011.
[3] H.A. Aziz, M. Saleh, M.H. Rasmy, H. ElShishiny, "Dynamic Room Pricing Model for Hotel Revenue Management Systems", Egyptian Informatics Journal, Vol. 12, No. 3, pp. 177-183, 2011.
[4] T.Y. Choi, V. Cho, "Towards a Knowledge Discovery Framework for Yield Management in the Hong Kong Hotel Industry", International Journal of Hospitality Management, Vol. 19, No. 1, pp. 17-31, 2000.
[5] D. Contessi, L. Viverit, L.N. Pereira, C.Y. Heo, "Decoding the Future: Proposing an Interpretable Machine Learning Model for Hotel Occupancy Forecasting Using Principal Component Analysis", International Journal of Hospitality Management, Vol. 121, pp. 103-802, 2024.
[6] N. El Gayar, A. Zakhary, H.A. Aziz, M. Saleh, A. Atiya, H. El Shishiny, "A New Approach for Hotel Room Revenue Maximization Using Advanced Forecasting and Optimization Methods", Conference: Proceedings of the Euro CHRIE, January 2008.
[7] M. Ignaccolo, G. Inturri, "A Fuzzy Approach to Overbooking in Air Transportation", Journal of Air Transportation World Wide, Vol. 5, No. 2, 2000.
[8] K.K. Lai, W.L. Ng, "A Stochastic Approach to Hotel Revenue Optimization", Computers and Operations Research, Vol. 32, Issue 5, pp. 1059-1072, May 2005.
[9] C.P. Rosy, R. Ponnusamy, "Intelligent System to Support Judgmental Business Forecasting: The Case of Hotel Room Demand in Hotel Revenue Management System", IOSR Journal of Computer Engineering, Vol. 16, No. 6, pp. 50-56, January 2014.
[10] C.P. Rosy, R. Ponnusamy, "Tourism Forecasting of Various Services Selection in Time Series Data Using Holt-Winter and Statistical Methods", International Journal of Computer Science and Information Security (IJCSIS), Vol. 15, No. 7, July 2017.
[11] T.D. Sulistiyo, R. Fitriana, R. Angraini, "Analysis of the Implementation of Revenue Management Strategies to Increase Revenue Per Available Room at Harris Hotel Sentul Bogor", Journal Scientia, Vol. 13, No. 01, pp. 558-566, 2024.
[12] D. Zhang, B. Niu, "Leveraging Online Reviews for Hotel Demand Forecasting: A Deep Learning Approach", Information Processing and Management, Vol. 61, No. 1, pp. 103-527, 2024.
[13] R. Effatnejad, M. Hedayati, K. Choopani, F. Koneshloo, M. Effatnejad, A. Effatnejad, "Avanced Theory Methods Based on Optimization", International Journal on Technical and Physical Problems of Engineering, Issue 52, Vol. 14, No. 3, pp. 121-132, September 2022.
[14] N. El Koufi, A. Belangour, M. Sadiq, "A Systematic Literature Review of Machine Learning Applied to Precision Marketing", International Journal on Technical and Physical Problems of Engineering, Issue 52, Vol. 14, No. 3, pp. 185-192, September 2022.

BIOGRAPHIES



Name: **Arjola**
Surname: **Sinani**
Birthday: 26.09.1990
Birthplace: Fier, Albania
Bachelor: Mathematics, Department of Mathematics, Faculty of Technical Science, University of Vlora, Vlora, Albania, 2012
Master: M.Sc. in Mathematics, Department of Mathematics, Faculty of Technical Science, University of Vlora, Vlora, Albania, 2014
The Last Scientific Position: PhD. Student, Department of Statistics and Applied Informatics, Faculty of Economy, University of Tirana, Tirana, Albania, 2021
Research Interests: Statistics and Applied Mathematics in Economics
Scientific Publications: 2 Papers

Name: **Majlinda**
Surname: **Godolja**
Birthday: 03.05.1971
Birthplace: Diber, Albania
Bachelor: Mathematics, Faculty of Natural Sciences, University of Tirana, Tirana, Albania, 1994
Master: MBA, University of Nebraska, Lincoln, USA, 2000
Doctorate: Economy, Department of Applied Mathematics, Statistics and Informatics, Faculty of Economy, University of Tirana, Tirana, Albania, 2006
The Last Scientific Position: Assoc. Prof., Department of Applied Statistics and Informatics, Faculty of Economy, University of Tirana, Tirana, Albania, Since 2015
Research Interests: Game Theory, Modelling and Simulation, Economics Dynamics
Scientific Publications: 15 Papers, 1 Book, 2 Projects, 1 Theses
Scientific Memberships: Editorial Board SNE, ALBSIM Albanian Simulation Society