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A GIS-based decision support system for hotel room rate estimation and temporal price prediction: The hotel brokers' context

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ABSTRACT

The vastly increasing number of online hotel room bookings is not only intensifying the competition in the travel industry as a whole, but also prompts travel intermediates (i.e. e-companies that aggregate information about different travel products from different travel suppliers) into a fierce competition for the best prices of travel products, i.e. hotel rooms. An important factor that affects revenues is the ability to conclude profitable deals with different travel suppliers. However, the profitability of a contract not only depends on the communication skills of a contract manager. It significantly depends on the objective information obtained about a specific travel supplier and his/her products. While the contract manager usually has a broad knowledge of the travel business in general, collecting and processing specific information about travel suppliers is usually a time and cost expensive task. Our goal is to develop a tool that assists the travel intermediate to acquire the missing strategic information about individual hotels in order to leverage profitable deals. We present a GIS-based decision support system that can both, estimate objective hotel room rates using essential hotel and locational characteristics and predict temporal room rate prices. Information about objective hotel room rates allows for an objective comparison and provides the basis for a realistic computation of the contract's profitability. The temporal prediction of room rates can be used for monitoring past hotel room rates and for adjusting the price of the future contract. This paper makes three major contributions. First, we present a GIS-based decision support system, the first of its kind, for hotel brokers. Second, the DSS can be applied to virtually any part of the world, which makes it a very attractive business tool in real-life situations. Third, it integrates a widely used data mining framework that provides access to dozens of ready to run algorithms to be used by a domain expert and it offers the possibility of adding new algorithms once they are developed. The system has been designed and evaluated in close cooperation with a company that develops travel technology solutions, in particular inventory management and pricing solutions for many well-known websites and travel agencies around the world. This company has also provided us with real, large datasets to evaluate the system. We demonstrate the functionality of the DSS using the hotel data in the area of Barcelona, Spain. The results indicate the potential usefulness of the proposed system.

1. Introduction

With the ongoing penetration of the Internet and mobile technologies into all aspects of our lives, the number of online users is growing rapidly. As a result, consumer behavior is changing towards online shopping, which provides such benefits as product and price comparisons, ease of use, speed of purchase transaction, and trust [19,46]. This trend is especially noticeable in the travel domain. More and more online travel websites have been emerging, including hotel advertisements and websites that aggregate information about hotel room rates around the world [29]. The advantage of travel aggregates, which are also referred to as travel intermediates or brokers is that they allow customers to simultaneously gather information about many hotels at their travel destination. Thus, the user can compare prices easily rather than having to search for single information about individual hotels and having to visit each hotel's website.

The competition between travel intermediates is very intense and there are many risk factors that can degrade revenues such as the quality of the website (ease of use, visual attractiveness) [56], the speed of execution, the level of user satisfaction [14], the lack of innovative tools and services, and the level of professionalism of their employees. However, the most important factor is the ability to contract with different travel suppliers. This factor is characterized by two underlying issues: contracting with as many travel suppliers as possible and concluding profitable contracts. While the first issue is mostly organizational, the second issue is related to the personal ability of contract managers to

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conclude contracts and their comprehensive knowledge of the travel business. This knowledge, however, is dependent on the strategic information available about a specific travel supplier and his or her products. In reality, strategic decisions are reached using a limited amount of information due to the inability to acquire and process sufficient information in a sufficiently short time. With this in mind, we aim in this paper to improve the decision-making capability of hotel brokers by introducing a GIS-based decision support system. Our decision support system enables the broker to objectively estimate hotel room rates based on the intrinsic and locational characteristics as well as historic room rates of a given hotel or hotels with similar characteristics.

The analysis of product prices and factors that influence the price has been widely used in finance, economics and real estate property assessments since Rosen [48] formulated the property of price as the weighted sum of the different characteristics composing the product. In the hedonic pricing model (usually analyzed by linear regression) that he proposed, independent variables are the product characteristics relevant for the analysis, while the price serves as a dependent variable. Therefore, by finding the hotels with the same characteristics that affect hotel prices, it will be possible to compare room rates between similar hotels.

For understanding the factors that affect property prices and hotel room rates in particular, the use of the hedonic pricing theory has received much attention (e.g. [8,25,32,33,42,55]). However, the results show that there is no universal solution as to what characteristics should be included and what analytical methods should be applied [6]. Sometimes the results are even contradictory [52]. Among the various reasons for differences in results, we can name such factors as: empirical methods selected for the analysis (linear and non-linear regression estimators, parametric and non-parametric algorithms); data quality and completeness; region of application; and characteristics included in a model.

The various studies in property valuation, including the hotel domain, showed the importance of considering such locational characteristics as the relative distance of a property to a city center or the distance to business centers in the models. Moreover, hotels have their distinguishing properties, such as the proximity to the waterfront. However, including locational characteristic into the model is very difficult for several reasons. First, the definition of locational properties is usually an ill-structured problem since it is difficult to agree on the definite spatial resolution (distance, areas, and spatial density), which may or may not influence the results. It is easier to answer the question about non-spatial characteristics like *Is there a hairdryer in the room*? than answering the question *How many points of interest are there around the hotel*? since *around* is not precisely defined in terms of distance. Second, the precision and availability of the spatial data limit its use in the analysis.

For these reasons, a completely automated solution process [33] is not feasible since the guidance of an expert is paramount in the case of ill-structured problems and the task at hand. Clearly, there is a need for an interactive decision support system (DSS) [2,28,51] that would help the analyst in testing different hypotheses regarding price factors for selected hotels. In this system, the analyst will be able to select the region of investigation by accessing all the necessary data from his/her corporate database. It would allow him/her to add additional data that he/she thinks is important in the analysis. Such data, for example, could be points of interest around hotels, transportation availability, historical places or information about the proximity of a hotel to the waterfront, etc. Enabling the analyst to build different models and apply various algorithms, the system will help the analyst decide about the desirability of a hotel and the objective room rate.

Geographic Information System (GIS) technology has proven to be useful for businesses. Its addition to a business decision-making environment improves the performance of the decision-maker [9]. Moreover, the importance of GIS in property valuation has been discussed in numerous works (e.g. [7,12,16,18,27,37,40,43,47,49,54,58]). However, the usage of GIS in these instances was mostly limited, either to utilizing spatial queries and distance measures or it was limited to one location only. A few works discuss the implementation requirements of a GIS. In any case, these were not robust due to the lack of appropriate technology, incompatibility in programming interfaces, or were implemented by integrating different components by data import and export facilities, which Denzer [11] called *null integration*. At the same time, no work, to the best of our knowledge, presented a robust and easy-to-use GIS-based solution that can be used in real life scenarios.

In contrast to past attempts, we provide a flexible and highly interactive GIS-based decision support system with rich functionality. Our system is integrated with a real GIS that provides support in order to input and layer spatial data; to represent complex spatial relations; to analyze spatial data; and to output spatial data in the form of maps [10]. The problem of spatial data acquisition, a crucial factor in past research, has been solved by utilizing OpenStreetMap crowdsourcing data [22], which comprises contributions from thousands of individuals around the world. Although, some features like the proximity of a hotel to the seafront are not available in OpenStreetMap, the analyst can use simple user interface to decide about this feature and to note that the hotel is being examined further with regard to this information. The integrated data mining package provides the domain expert with access to dozens of available, ready to run algorithms.

The contribution of the paper can be summarized as follows:

1. The decision support system that we developed meets the real world business requirements of hotel brokerage companies for estimating a hotel's objective room rates.
2. Due to the integration of the OpenStreetMap public data, the proposed DSS can be applied to different parts of the world and is not constrained to analyzing a specific region, as is usually the case in instances cited in the academic literature.
3. The provision of attributes that are usually difficult if not impossible to acquire or determine, e.g. proximity to the waterfront or attributes that are based on spatial characteristics (radius and distance), is facilitated by an interface that allows the domain expert to provide the desired information.
4. The framework is not limited to a predefined hotel characteristic and a single regression estimator but can use a variety of linear and non-linear estimators available in the data mining package that is embedded into the framework along with the capability of selecting the characteristics the domain expert believes to be important in a particular situation. This feature is particularly important since economic theory does not provide guidance about selecting characteristics and determining how these characteristics relate functionally to their product price and what are the best algorithms to apply [6,39].

2. Related work

In this section we review works related to the field of property valuation and the characteristics that influence the hotel room prices. The methods, which are used in both fields, are very common and are based on hedonic pricing models.

There are two main approaches inherent in the hedonic model. The first seeks to estimate how individual characteristics influence the overall price of a property or a room (Section 1). The second approach deals with generating and evaluating a model that can be used in the price prediction (Section 2) that is close to the goal of our paper. Finally, we show related works in which hedonic pricing models are integrated with a GIS (Section 3).

2.1. Determinants of room rates

The influence of a hotel location on room rates and the price contribution of a specific attribute were investigated in [5]. Initially, Bull included five independent variables in the hedonic model (hotel star