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On revenue management and the use of occupancy forecasting error measures

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ABSTRACT

This study aims to draw the attention of the revenue management academic community to inherent problems in forecasting accuracy measurement, and to initiate a critical discussion about forecast quality assessment in hotels. An exhaustive, literature-based set of seventeen forecasting accuracy measures was applied to hotel daily occupancy forecasting data of 2043 pairs of computer and human forecast/actuals, across multiple forecasting horizons. The empirical analysis demonstrates endemic inconsistencies across the accuracy measures, and a plethora of theoretical and practical challenges with regard to total hotel, as well as customer segment level forecast accuracy assessment. The analysis illustrates the difficulty of interpreting conflicting results, as well as issues like level of data aggregation and multiple forecasting horizons. The paper concludes by briefly discussing a more comprehensive approach to hotel forecasting quality assessment framework and serves to warn hotel revenue management academics, practitioners and solution providers against the unconsidered use of accuracy measures.

1. Introduction

Revenue management practice in the lodging industry has grown significantly in the past three decades, and is now considered an indispensable part of hotels' marketing and operating strategies (Cross et al., 2011). Hotel revenue management policies have been developed with the aim of profitably matching or managing a fluctuating demand, with the hotel's constrained and perishable capacity. This is achieved by employing a range of room pricing and allocation tools, addressing core revenue management concepts such as: the reservation of a portion of the capacity for higher value customers at a later date; efficient price discrimination practices to extract as much of the consumer surplus as possible; overbooking policies to offset no shows; late cancelations; and early departures. A key ingredient for the successful implementation of these core revenue management concepts is making a high quality forecast. As Talluri and Van Ryzin (2004, p. 407, italics added) observe: "A revenue management system requires forecasts of quantities such as demand, price sensitivity, and cancellation probabilities, and its performance depends *critically* on the quality of these forecasts." One estimate suggests that a 20% reduction of forecast error could translate into a 1% increase in revenue generated by the revenue management system (RMS) (Pölt, 1998 cited in Talluri and Van Ryzin, 2004, p. 407). Hence, forecasting is a cornerstone element of revenue management, and the quality of forecasts a crucial characteristic that determines the success of the RMS' capacity to generate higher revenues and profits.

Forecasting is an area in operations research which has grown into a whole discipline of its own with work as early as from the 1960s (Armstrong, 1986) and continuing to draw specialist research attention from a wide range of disciplines (Fildes et al., 2008). A relevant area with a long tradition of high quality research in forecasting is tourism with work as early as Choy (1984) and Fritz et al. (1984), and with seminal contributions by Martin and Witt (1988), Turner and Witt (2001), Li et al. (2006a), Song and Li (2008), Song et al. (2010), and Song et al. (2013). The literature on forecasting in hotels, however, is rather underdeveloped with notable exceptions such as Kimes (1999), Weatherford et al. (2001), Law (2004), El Gayar et al. (2011) and Zakhary et al. (2011). See for a full overview Appendix C.

Enhancing and maintaining the quality of the forecasts is a crucial task for revenue managers, and the automated systems they employ. The forecast quality element that revenue managers are mostly concerned with and address is, unsurprisingly, the forecast accuracy. Within the task domain of achieving the greatest accuracy, hotels select the most accurate forecasting models when

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they start using the RMS, and continually monitor forecast accuracy (Schwartz, 1999). When the accuracy is deemed unsatisfactory, data, forecasting models and/or their parameters, as well as the use of subjective forecasts and the practice of subjective adjustments to the forecasts, are all scrutinized and often modified, as part of the revenue management team's efforts to improve performance. One example of an area of concern where hotels often examine accuracy as part of the monitoring phase of the revenue management cycle has to do with the black-box nature of machine generated forecasts.

Hotels sometimes assess and verify the accuracy of their RMS' computer generated forecasts by contrasting them with "manual" forecasts, that is, predictions made by the hotel's revenue manager or revenue management team. A common dilemma associated with this issue is the extent to which the RMS can be trusted to generate an accurate forecast. Interestingly, when hotels face elevated levels of risk and distress, such as a liquidity challenge, or intensified competition in highly volatile markets, more pressure is placed on the revenue manager to ensure that the forecasts are accurate. In practice it is, therefore, not unusual that those revenue managers override the RMS in an attempt to enhance revenue management performance. The question then arises as to whether these subjective adjustments add value. In other words, do the subjective adjustments by revenue managers improve or diminish the accuracy of the sophisticated computer generated forecasts?

Obviously, this is where the forecast quality monitoring procedures have a place, as the question is best answered using a well-designed, systematic, and appropriately implemented, forecasting quality assessment procedure. In this research paper, we use both machine and manual forecasts to bring to the fore some fundamental practical issues associated with the challenge of hotels forecasting accuracy assessments within their practice of revenue management. Specifically, the paper illustrates how, when applied to real-life hotel data, this supposedly straightforward question of machine vs. manual forecasting accuracy can result in some unexpected and somewhat disturbing contradictory answers. Given the importance of monitoring and assessing hotel forecasting accuracy, and given that the issue of the measures' adequacy has been neglected by the hospitality academic community, this short illustration serves to underscore the complexity of the task ahead, and the urgent need for research in this domain of hotels' revenue management forecasting accuracy measures and procedures.

2. Forecast accuracy measures

A multitude of forecasting accuracy measures have been proposed and extensively discussed in the generic (i.e. non-hospitality management specific) forecasting literature (Ahlburg, 1992; Armstrong and Collopy, 1992; Chatfield, 1992; Collopy and Armstrong, 1992; Fildes, 1992; Makridakis, 1993). Aiming to provide forecasting accuracy guidelines based on reliability, validity, outliers, sensitivity, and interpretability, Armstrong and Collopy (1992) facilitated this discussion by conducting an empirical study. This early deliberation, however, did not produce any conclusive evidence, and no agreement was reached. Instead, it merely revealed the nuances of the various proposed and tested accuracy assessment methods. New measurements developed later to address some of the issues described in their paper also failed to generate consensus as to which forecasting accuracy measure is "the best".

Whilst failing to identify the ideal solution, these research efforts generated a plethora of forecasting accuracy measures. For example, in the latest 'Makridakis competition', i.e., the seminal large scale M3-competition (Makridakis, 2000), forecasting methods were evaluated using the following five different accuracy measures: (1) symmetric Mean Average Percentage Error (sMAPE), (2) average ranking, (3) percentage better, (4) Median Absolute Percentage Error (MdAPE), and (5) Median Relative Absolute Error (MdRAE). Interestingly, a key outcome of this competition was that the answer to which forecasting *method* is best *varies* with the accuracy *measure* that is chosen for evaluation.

In their review of published studies on tourism demand modeling and forecasting Song and Li (2008, p. 213) challenge the field as 'forecast performance has mostly been evaluated by non-statistical measures such as mean absolute percentage error (MAPE) and means square percentage error (RSPE)' and conclude that 'without the support of statistical testing it would be difficult whether one model is significantly better than others'. The studies, however, generally do not justify the use of accuracy measures (e.g. Li et al., 2006a, 2006b; Song et al., 2010).

A number of accuracy measures are also mentioned in the hospitality forecasting literature. For example, Schwartz and Hiemstra (1997) used Mean Absolute Percentage Error (MAPE) and Mean Absolute Deviation (MAD), Schwartz (1998) used Absolute Percentage Error (APE), Yuksel (2007) used MAPE, MAD and Mean Squared Deviation (MSD), and in a recent project Lim and Chan (2011) used Root Mean Square Error (RMSE). However, the fundamental question of which accuracy measure should be used in different hospitality forecasting tasks and circumstances, has not been fully addressed in these publications. A preliminary effort to explore this question (Schwartz, 1999) has not been followed up by hospitality forecasting researchers in recent years. This topic is of utmost importance because any evaluation of a forecasting method requires proper selection of an accuracy measurement. For example, as Armstrong and Collopy (1992) and Fildes (1992) demonstrated, MAPE puts a heavier penalty on forecasts that exceed the actual, than on forecasts that are less. In addition, these studies showed that RSME is a scale-dependent measure, only applicable to data sets that have the same data scales.

Although the hospitality forecasting literature is not necessarily different from the general literature in its failure to develop a better understanding of the topic, there is a need to justify the choice of error measures used (Ahlburg, 1992). This is an area of concern as the lodging industry has quickly moved to heavily rely on accurate forecasts in their revenue management systems. Accordingly, in recent years, considerable effort has been directed to collecting more data, creating and testing new forecasting methods, and designing and implementing forecasting support systems that are integral part of computerized revenue management systems. Insufficient attention has been paid to how the outcomes of all these forecasting related efforts should be evaluated, and the cost of this "ignorance" could be very high. This is because, as demonstrated in the rest of this paper, which error measure used might determine which, and by how much, a forecasting method is deemed more accurate. Sub-optimal levels of performance of these tests are bound to impair the performance of the hotels' efforts to optimize revenue.

The following sections illustrate some of the challenges associated with the adequate use of forecasting accuracy measures, underscoring the need for hospitality researchers to engage in a systematic long term effort to assess the different accuracy measures, and to justify their appropriateness for hospitality forecasting conditions and circumstances.

3. Method

3.1. Data

This study aims to demonstrate that the effectiveness of revenue management systems might be seriously limited due to