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Challenges in Data-driven Hotel Infrastructure Assignment Decisions

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Abstract High quality short-term Hotel Infrastructure Assignment decisions (*HIADs*) can improve hotel profitability and customer satisfaction. Optimization of *HIAD*s requires addressing two fundamental challenges namely, accurate prediction of customer behaviour and management of interaction complexity and customer reactions. Here, we view the decision environment as a sequence of decisions within the context of customer lifecycles. Each decision is composed of two parts i.e. the hotel´s decision followed by the customer´s decision. We analyze the challenges and conclude that sequential assignment of hotel infrastructure to customers may not be optimal because of limited incorporation of implications of customer reactions in the decision mechanism. Therefore, we need to consider parallel assignment i.e. assignment of hotel infrastructure to the most promising of the likely subsets of potential customers competing for the same time slot. Finally, we discuss a possible data-driven decision support scheme for *HIADs* that is based on the integration of data mining techniques with micro-simulation.

Keywords: Infrastructure Assignment, Decision-making, Parallel Assignments, Data Mining, Micro-simulation

1.1 Introduction and Related Work [2]

The hospitality industry is extremely competitive due to industry factors such as over capacity, perishable hotel rooms, low barriers to entry, supplier fragmentation and long lead times for capacity change. Further, external challenges such as the economic downturn, cost pressures from new forms of intermediation, demanding and discerning customers have increased competitive pressures (Rutherford & O´Fallon, 2007). In addition to high levels of operational

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effectiveness and efficiency, a hotel also needs to customize its products and services on the basis of pro-active anticipation of changing customer requirements (Minghetti, 2003). Design of guest rooms, conference rooms and other customer facilities are typical examples of long-term resource assignment decisions (Rutherford & O´Fallon, 2007). These, involving dedicated long-term resources, are based on long-term demand forecasts (Noone, Kimes & Renahan, 2003; Sigala, Lockwood & Jones, 2001). The fixed hotel infrastructure sets the context that defines the hotel-decision making environment. However, the resultant operational decisions, that involve short-term assignment of fixed hotel infrastructure to individual customers referred to as *Hotel Infrastructure Assignment Decisions* (*HIADs*), is the focus of the current work.

Within the framework of a research project on simulation-based enhancement of hotel decision making, this paper focuses on the design of a framework to support *HIAD*s. Hotels need to optimize their *HIADs* since improvement in their quality would ensure both operational efficiency and customer satisfaction. After discussing a few typical features of *HIAD*s, we identify its two fundamental challenges namely, customer behavior prediction and management of interaction complexity and customer reactions. We can view a customer´s lifecycle as a sequence of related hotel-customer decision dyads. On analysis, we conclude that sequential assignment of hotel infrastructure to customers may not be optimal because of limited incorporation of implications of customer reactions in the decision process. This leads us to propose a parallel infrastructure assignment design i.e. assignment to the most promising of the likely subsets of potential customers competing for identical hotel infrastructure at the same time slot. Finally, we discuss one possible data-driven decision support approach for *HIADs*. This, based on the integration of data mining techniques with micro-simulation, leverages the rich customer data that hotels collect during their routine operations.

1.2 Hotel Infrastructure Assignment Decisions

A hotel has to make many short-term infrastructure assignment decisions while providing services to its customers, e.g. room allocation. Although the impact is limited to the period of the stay, allocation can be made considering other factors like current availability, future demand for the same period, customer value and others. *HIADs* take place within the hotel´s existing infrastructure context that has a fixed capacity in the short-term. For example, the hotel cannot change the number and type of available rooms. In the hotel context, the customer lifecycle is defined as a series of phases that a customer passes through when he/she avails the services of a hotel. Typical phases include information search, enquiry, booking, check-in, stay, check-out and feedback (Natarajan & Duran, 2012). From the customer´s perspective, the hotel´s infrastructure assignment decisions set the context which influences his/her choices. In some cases like room allocation for a

stay, the customer´s request lead to the setting of room rate depending on whether the assignment is likely to maximize the hotel´s efficiency and profitability parameters. Some aspects considered here include the customer´s willingness to pay, probability of repeat stays, likely demand for the room between the booking-time and actual time of stay and others. In other situations like ancillary services, the hotel may offer a choice to the customer with respect to the available services. Customer satisfaction and revenue generation may be maximized if the hotel´s decisions incorporate customers´ likes, dislikes and preferences. Sometimes an initial infrastructure assignment decision can have a cascading effect on the later decisions of the customer. For example, personalization of services may increase the customer´s possibility of engaging other hotel services leading to additional revenue earning opportunities.

1.3 Challenges in Hotel Infrastructure Assignment Decision-Making

High quality *HIADs* can have a positive impact on efficiency, effectiveness and ultimately profitability. Many challenges in *HIADs* are related to the dynamic nature of the decision-making environment. The hotel´s environment that consists of series of interactions between the hotel (represented by its employees) and its customers, can be viewed as a series of decisions that each entity makes in response to other´s decision. Consider a scenario during the check-in period where the employee at the reception has to make a decision regarding which of the hotel´s ancillary services should be highlighted to the customer for consideration. The customer decides on the services on the basis of choices communicated by the hotel staff. Once the customer has made his/her decision, the hotel may assign certain infrastructure to fulfill these services. Then, the ancillary services offered to the next customer may differ depending on the new customer´s preferences, availability of required infrastructure and hotel´s updated estimation of likely demand from other customers. In other words, the hotel´s decision sets the context for the customer´s decision. The customer´s decision in turn modifies the environment for the next round of hotel´s decisions and so on. Two fundamental challenges that hotels face are accurate prediction of customer behaviour and management of interaction complexity and customer reactions.

*Customer Behaviour Prediction: HIAD*s set the context and choices for the customer´s decisions. Personalization of hotel services (e.g. room rate quote, prices,…etc.), requires understanding the customer --- likes, dislikes and preferences. The hotel can make a better decision if it has some idea of customer behaviour. However, this data, for the current lifecycle, would be available only after the hotel made its framework setting decisions like offering customers choices, setting room rates, etc. (Duran, Natarajan and Giraldo, 2011). Thus, the first challenge that hotel faces is accurate prediction of customer behaviour to the

choices offered by it. For example, during the check-in period, the hotel employee should highlight only the most relevant ancillary hotel services that have the highest likelihood of being chosen by the customer.

Management of Interaction Complexity and Customer Reactions: The hotel´s offer of services is constrained by its infrastructure capacity. Once a customer has made his/her decision, the hotel would assign infrastructure for the service´s fulfilment constraining the choices available for other customers. Given that a hotel simultaneously serves multiple customers who may interact with each other, a hotel needs to optimize its infrastructure assignment decisions keeping into account not only its own constraints and but also the likely reactions of customers to its decisions. A hotel´s restaurant capacity is limited. Therefore, the process of booking a table for a customer in the restaurant should take into account various factors such as availability of capacity, value of customer, potential reaction of customer if this service is declined / postponed, etc.

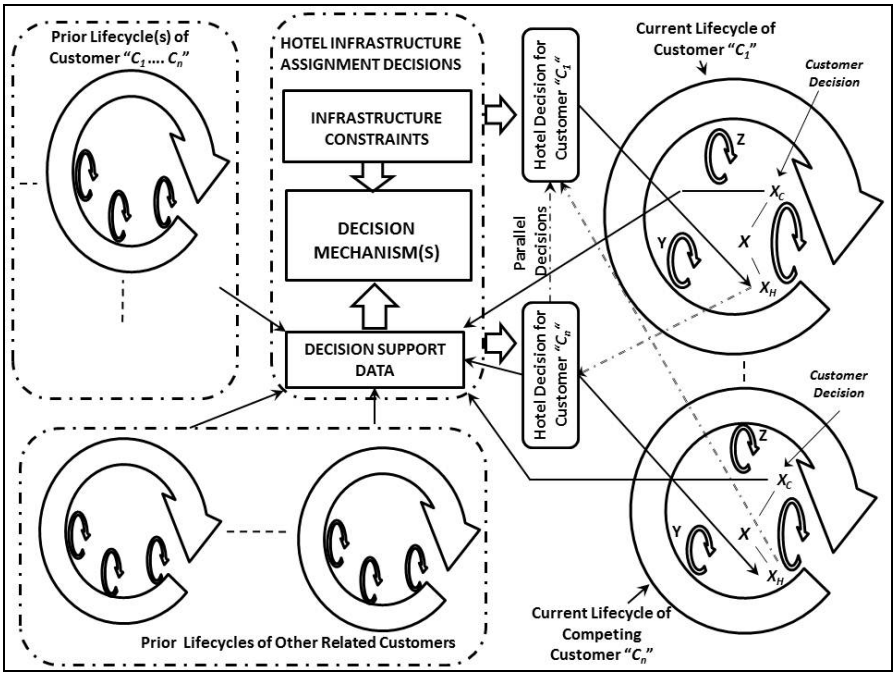

Fig.1.1 Environment for Hotel Infrastructure Assignment Decisions

1.4 From a Single Customer to Sets of Customers

Here, we consider how a hotel can design its decision making processes to address the challenges outlined in the previous section. Figure 1.1 depicts the important elements of a *HIAD*-making environment. The customer lifecycles are depicted using a circular arrow. The lifecycle of a customer, say "C_1" can be viewed as a

sequence of decisions at different points of time. Each decision (e. g. X) point can be viewed as a dyad of related decisions. The first is the initial framework-setting hotel decision (X_H) followed by the customer decision (X_C) (as discussed above), within each customer´s lifecycle. Thus, the series X, Y, Z,… etc. refer to similar decisions within the current lifecycles of all customers C_1, C_2, C_3, .. and others.

The customers´ lifecycles may have commenced at different points of time, may have varying lengths and extents of overlap. Therefore, at any given point of time, a hotel has to serve multiple customers, say $\{C_1,\ldots,C_n\}$ simultaneously. Due to this overlap, different customers can be viewed as potentially competing for the same time slot of a given infrastructure, for example dinner or lunch at the hotel´s restaurant. The hotel cannot serve all its customers due to infrastructure limitations such as limited restaurant tables, staff, etc. A possible solution is to design its service`s framework in a way that maximizes its resource utilization while simultaneously minimizing the potential costs and negative implications of its infrastructure limitations. Figure 1.1 depicts dependencies and interactions between the hotel´s decision and resulting customers´ decision. We assume that all customer behaviour data until the current point of time will be available to the hotel for decision support. This is depicted in Figure 1.1 in the boxes concerning current and prior lifecycles of hotel customers.

One perspective is to view the hotel´s decision-making process as a two-step process. The first step consists of the prediction of customer behaviour using data from the current and past customer stays in the hotel. This process when applied to the current set of customers predicts the hotel services that a particular customer is likely to engage. However, infrastructure assignment using customer behaviour prediction based on past behaviour, as the sole basis, is likely to prove insufficient because of failure to consider the reactions of customers to hotel decisions and interactions between customers. The second step of *HIAD* process assigns its customers to the available hotel infrastructure. As a customer´s life cycle progresses, different types of infrastructure are required for the requested services. Therefore, for a given time slot and a particular assignment decision, the relevant set of customers that have to be considered as competing for the same infrastructure are those whose life cycles are in more or less similar stage of progression. The first step identifies the customers who are likely to request for a particular service. This customer set, further qualified by considering the overlap of their lifecycles, would approximately indicate the customers competing for the same infrastructure. Another important aspect is to incorporate the reactions of the customers into the hotel´s assignment decisions. The final infrastructure assignment would be a subset of the above identified set of customers optimized for maximizing the infrastructure utilization and profitability parameters while simultaneously minimizing the costs of negative customer reactions and missed opportunities. This calls for parallel assignment i.e. choosing among various subsets of potential customer and simultaneous assignment of hotel infrastructure to the most promising customer subset, rather than assigning them in a sequential manner as and when a customer requests a service.

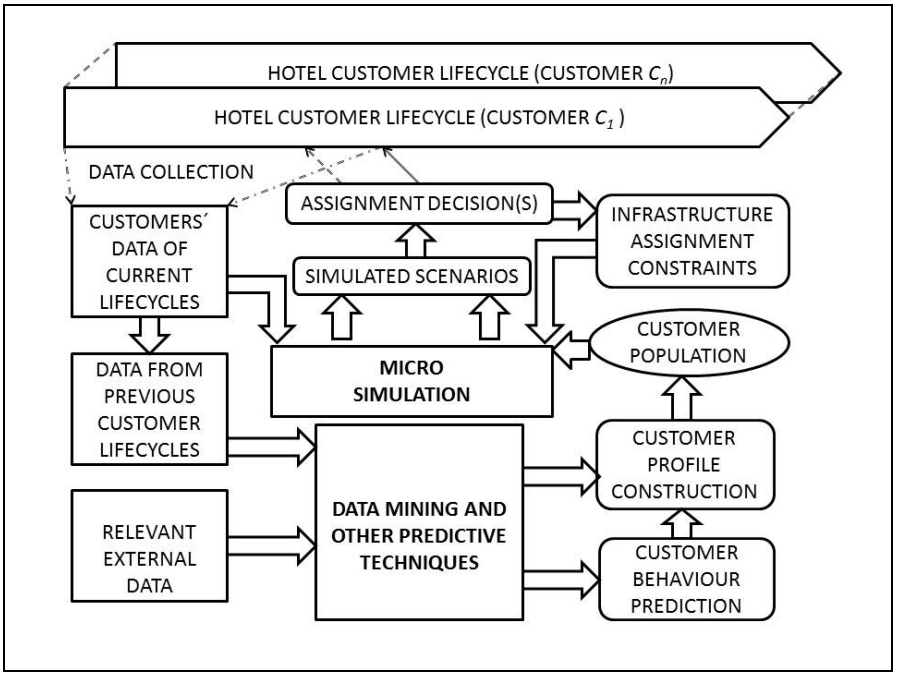

Fig. 1.2 A possible approach to support hotel infrastructure decision-making

We can consider two possible situations in the case of parallel assignment decisions. In the first situation, the hotel sets the framework that influences customer choices. It assigns the total infrastructure for the set of customers by considering each one as identical to the other. For example, in the case of a "Special Menu Offer" published on the notice board, the hotel sets the framework for customer decisions by simultaneously considering the available infrastructure (kitchen capacity, supplies, etc.) and the menu that is likely to be preferred by most of the current set of hotel customers. In the second situation, the hotel can fine-tune its assignment decisions. Consider the process of room booking where the hotel can fine-tune its room rates dynamically (i.e. can modify the offer it makes to a customer based on the outcome of the interaction with the previous one) so as to maximize revenue and profitability while minimizing missed opportunities.

1.5 Supporting *HIADs* with Data Mining and Micro-Simulation

As discussed, high quality *HIADs* need a deep understanding of customers and prediction of their reactions to hotel´s decisions. Further, the dynamic environment presents hotels with a limited time-window opportunity to modify/reverse their decisions. The relevance and importance of any *HIAD* support mechanism would be determined by the accuracy and timeliness of its

behaviour predictions and tolerance of uncertainty with respect to customer reactions. Figure 1.2 presents one possible approach towards supporting the hotel infrastructure assignment decisions by combining data mining with micro-simulation. Micro-simulation involves simulating the behaviour of the hotel customer population using specific representative individual customers as the primary building blocks.

Table 1.1 Data Mining Component of Hotel Infrastructure Assignment Decision Support

Sub-Challenges Addressed	Input/Required Data	Applicable Data Mining Tools/Techniques	Input for Micro-Simulation
Customer Profile Construction	Customer demographics from current and past lifecycles	Clustering and Classification techniques using Decision Trees, Neural Networks, etc.	Traits/Parameters of Customer Population
Customer Preferences and Behaviour Prediction	Specific behavioural data from current and past lifecycles, preference data of generic customer classes	Classification, clustering, regression, Association Rules	Behavioural and relationship parameters of customers
Customer Reaction Prediction	Specific behavioural data from current and past lifecycles expressed as a sequence of hotel and customer decisions.	Sequence Rules	Modeling rules for customer state transitions.
Cost Implications of Customer Reactions	Hotel cost data, customer lifecycle value, Customer Behavioural Data	Regression, Neural Networks	Modeling total cost for an assignment decision.

Customer demographic and behavioural data collected during current and previous visits to the hotel form the input to Data Mining and related predictive techniques. Attitudinal and behavioural components of customer profiles are constructed with the help of customer´s past behaviour, external data and specific customer demographic and psychographic information (Table 1.1). For example, the likelihood of a customer using a particular hotel service like gymnasium services can be predicted using Data Mining techniques that include decision trees, neural networks, regression and association rules (Magnini, Honeycutt & Hodge, 2003). Demographic component of a customer´s profile can be constructed using data collected in the previous visits or extrapolated from more representative profiles of the group to which the customer belongs using classification and clustering techniques. Finally, properties that control the interaction between customers and their transitions between various lifecycle stages can be mined from the past lifecycle data. Customer trait parameters and interaction information unearthed by Data Mining methods can be used to construct individual members of the customer population and transition rules for the micro-simulation bench. The simulated scenarios indicate the best set of assignment decisions considering customer preferences, likely behaviour, customer reactions to hotel decisions and

hotel´s cost implications as customer lifecycles progress. This information can guide the hotel optimize its assignment decisions. Further, real time feedback from actual customer behaviour and changes in infrastructure constraints when incorporated into micro-simulation reflects the actual environment evolution. This increases relevance of the supported *HIAD*s.

1.6 Conclusions

The environment of *HIADs* can be viewed as consisting of successive decision dyads -- the hotel´s context-setting decision followed by the customer´s decision, all within the context of the customer lifecycle. Optimization of *HIAD*s requires tackling two fundamental challenges namely, accurate prediction of customer behaviour and management of interaction complexity and customer reactions. Sequential assignment of hotel infrastructure to customers does not incorporate customer reactions and its cost in the decision process. Therefore, parallel assignment, i.e. assignment of hotel infrastructure to the most promising of the likely subsets of potential customers competing for the same time slot may be a more relevant approach for optimizing *HIADs*. One possible decision support scheme is based on the integration of data mining techniques with micro-simulation. This data-driven scheme integrates the customer reactions and the interaction complexity in the decision mechanism. As a part of future research, we propose to model the interaction complexity and customer reactions using insight provided by mining dynamic customer data.

1.7 References

Duran A, Natarajan R, Giraldo E (2011) Sincronización de los ciclos de información y de gestión de infraestructuras de servicios hoteleros. Dirección y Organización 45 (diciembre 2011): 38-45.

Magnini VP, Honeycutt Jr. ED, Hodge SK, (2003) Data Mining for Hotel Firms: Use and Limitations. Cornell Hotel and Restaraunt Administration Quarterly, 44(2):99-105

Minghetti, V. (2003) Building Customer Value in the Hospitality Industry: Towards the definition of a Customer-centric Information System. Information Technology & Tourism, 6:141-152.

Natarajan R., Duran A. (2012) Aligning Hotel Data Management for Customer-Related Resource Assignment Decisions, In: Industrial Engineering: Innovative Networks, Eds: Sethi, SP, Bogataj M, Ros-McDonnell L Springer, London 157-164.

Noone MB, Kimes ES, Renahan LM (2003) Integrating customer relationship management and revenue management: A hotel perspective. Journal of Revenue and Pricing Management, 2(1):7–21

Rutherford, DG, O´Fallon, MJ (ed) (2007) Hotel Management and Operations. 4th edn. John Wiley and Sons, Inc.New Jersey.

Sigala M, Lockwood A, Jones P. (2001) Strategic implementation and IT: gaining competitive advantage from the hotel reservations process. International Journal of Contemporary Hospitality Management. 13(7):363-371.