Dynamic Pricing and Timing of Upgrades

Upgrading – offering a premium product to recall and replace a reserved but unused regular product – has been widely adopted in practice by travel companies. Different from classic upgrades offered either at the check-in time (e.g., car rental industry) or at the booking time (e.g., hotel industry), this paper studies a new upgrade strategy where upgrades are dynamically offered between the booking time and the check-in time.

Our research question is motivated by a Dallas-based hotel’s upgrading process. The hotel hosts several conferences every year and offers two types of rooms: the premium room and the regular room. Room prices are predetermined for each conference, and the price of the premium room is naturally higher. The revenue manager uses an email upgrading method. If the number of leftover premium rooms is high, the manager sends emails to regular room purchasers several days before the check-in date and asks whether they want to upgrade to premium rooms for a small upgrade fee. Currently, the hotel’s upgrade process is manually done. The hotel is exploring the possibility of using an automated system to jointly optimize the timing, quantity, and pricing of upgrades. Firms that are similar to the Dallas-based hotel can also benefit from upgrades offered via emails. In fact, such upgrade capabilities have recently been incorporated into some existing automated revenue management systems (e.g., Rentalcar.com and Malaysia Airlines). These recent industry practices further attest to the timeliness and importance of studying dynamic upgrades offered between the booking and the check-in times.

The trade-offs in the dynamic upgrade process are subtle. When the number of leftover premium products is large, it is possible that some of them remain unsold by the check-in time. Moreover, when the leftover regular products are few in numbers, they might be fully booked, and the firm
loses the chance to capture regular customers with low reservation prices. These two outcomes can both be mitigated by upgrading. The firm also needs to maintain enough premium capacity for forthcoming premium customers. When selling a premium product through an upgrade, the firm loses the opportunity of selling it at the full price but frees up a regular product capacity for a possible future sale. The firm needs to analyze the trade-offs between the upgrade fee and the opportunity gain/loss of replacing a leftover premium product by a regular one.

In this paper, we focus on a firm selling two types of products, premium and regular, over a sales season that naturally ends after the check-in date. No replenishment of products is considered. Customers for each product arrive over time. Depending on the leftover capacities of both products at a particular time, the firm can incite regular product purchasers to buy premium products by sending them upgrade notifications that contain upgrade links. After receiving an upgrade link, a regular product purchaser becomes an upgradeable customer. After clicking the link, the upgradeable customer is directed to the firm's upgrade website where she sees an upgrade fee. The upgrade process generates another customer arrival stream in addition to the direct arrivals for premium and regular products. This additional stream of demand depends on previous regular customer arrivals as well as how the firm manages the upgrade process. The firm has the ability to deactivate some or all upgrade links, if upgrading is no longer profitable. Deactivation of the link received by an upgradeable customer cuts off the connection to the upgrade website and shuts down the upgrade demand potentially coming from this customer. Upgrades are time-limited, and the firm controls their durations by sending and deactivating upgrade links. The upgrade notifications sent to customers contains no pricing information. At the arrival of an upgradeable customer to the upgrade website (when an upgradeable customer clicks the link), an upgrade fee is instantaneously generated. The upgrade fee depends on the
cost-benefit analysis of replacing a premium product by a regular one, which is in turn driven by current leftover capacities as well as the future demand expectations. Hence, postponing the upgrade fee until the arrival of an upgradeable customer gives the firm the most up-to-date information in determining an optimal fee.

Our main contributions include the description of the dynamic upgrade process and the optimization of this process to provide insights. The firm's revenue maximization problem is formulated as a dynamic program, and we show that the optimal upgrade policy is of a pulsing type; the firm either maintains zero or the maximum number of upgrade links. Both the optimal number of active links and the optimal upgrade fee are monotone with respect to the leftover capacities. When there are more regular (resp., premium) products leftover, it is optimal for the firm to maintain fewer (resp., more) active upgrade links and to offer a higher (resp., lower) upgrade fee. To obtain these results analytically, we introduce new properties of DH-modularity and DV-modularity for a function and prove these properties for the optimal expected revenue function. Using a systematic numerical study, we compare the industry-standard check-in fixed-price upgrade and the dynamic upgrade and quantify the potential revenue improvement by switching from the static strategy to the dynamic one. We determine when the revenue improvement is significant and how different market environment parameters affect it. For example, we show that a firm can improve its revenue by as much as 49% (in a market with a high premium product capacity level, a low regular product capacity level, a low premium demand, a high regular demand, a high premium price, a low regular price, and a high click rate) when it switches from a static check-in upgrade policy to a dynamic upgrade policy. Finally, our model takes notification spamming into consideration and leads to a detailed guidance on industry implementations.