Capacity Partitioning and Resource Allocation Framework for Appointment Allocation in Rehabilitation Outpatient Clinics

R. Yedehalli

Department of Industrial and Manufacturing Engineering, Wichita State University, Wichita, Kansas 67260, USA

1. Introduction

Rehabilitation (rehab) outpatient clinics help patients overcome physical disabilities through various rehabilitation services. Patients requiring rehabilitation services usually need to visit the rehab facility regularly for further care. Patients usually have to make appointments for their visits in advance. Traditional healthcare appointment systems aim at improving resource utilization and reducing patient waiting times [2]. However, these appointment allocation systems do not consider the profit/revenue generated by any given appointment into account. Rehab clinics generate revenue by selling services of a fixed duration. They usually do not receive payments directly from patients but rather from patients' third-party insurers. Different insurances pay a different price for the same service. In this paper, we propose a revenue management framework for scheduling appointments in rehab outpatient clinics in such a way the revenue is maximized and new customer fill rate is increased.

1.1 Revenue Management

Pak and Piersma [5] define revenue management as the art of maximizing the revenue generated from a limited capacity of a product by selling each product to the right customer at the right time for the right price. Revenue management involves segmenting customers, setting prices and controlling a fixed capacity to maximize revenue [6]. Revenue management is applicable in areas where the capacity is constrained and the product is highly perishable in nature. Traditionally applied to the travel and hospitality industries, revenue management is being employed across a growing range of industries. A major application of revenue management is in the airline industry, hotels and restaurants, and car-rentals. Lieberman [4] suggests that the application of revenue management can be extended to healthcare as well. The effect of revenue management depends on three main areas, namely, customer segmentation, demand forecast and booking policy.

Based on the insurance, the customers in rehab clinics can be segmented into high, medium and low revenue generating classes. In addition to these segments, customers can also be classified as new or return patient [2]. In this paper, we consider four different customer segments: new patients, high-revenue class, medium-revenue class, and low-revenue class. Usually in revenue management, either a bottom-up or a top-down forecasting approach is adopted. In a bottom-up approach, the demand for different customer segments is forecasted for each period. In a top-down approach, an aggregate forecast is made and then the anticipated demand is broken down into forecast for different customer segments by means of probability distributions [7]. In this study, the aggregate daily forecasted demand is segmented into different customer groups' forecast by means of discrete probability distributions (i.e., a top-down forecasting approach is utilized). Airlines and hotels usually follow nested booking policy for reserving seats and rooms, respectively. Nested policy reserves a fixed capacity to different customer segments and the segment that produce higher revenue are allowed to use the capacity reserved for any less-profitable segment [3]. In this paper, we adopt the nested booking policy for allocating appointments.

2. Capacity Partitioning and Resource Allocation Framework

We propose a capacity partitioning and resource allocation framework (CPRAP) for reserving capacity to different customers segments and allocating appointments. Barut and Sridharan [1] have proposed a similar capacity apportionment framework for the made-to-order manufacturing industry. We measure the

capacity of a rehab clinic in terms of available appointment slots of 15 minutes.

In lines with the nesting policy used by airlines and hotels, a fixed capacity is reserved for each customer segment and higher revenue classes will have access to the reserved capacity of the lower revenue classes. Once the capacity that is available for each segment is determined, every appointment request is checked against the available capacity. If the existing resources are not sufficient to accommodate requests from return customers, part-time therapists are used to satisfy the demand. However, we assume that new patients can not be treated by a part-time therapist.

Operating factors that are considered in the simulation study are demand, resource availability, and revenue attractiveness. Demand represents the forecasted daily demand. This factor is varied at three different levels, 50, 75, and 100 customer requests per day. Resource availability is a function of the number of salaried therapists in the system. If four salaried therapists are present in the system and each therapist works for seven hours a day, then the total resource available in a day is determined by 4*7*60 = 1680 minutes. This factor is varied at three levels: 4, 6, and 8 salaried therapists. The revenue attractiveness factor is similar to the profit attractiveness factor used by Barut and Sridharan [1]. This factor indicates the rate of change of revenue generated by two successive customer classes. If R_i is the revenue generated by customer class i, then revenue attractiveness is given by R_{i+1} / R_i. When R_i is equal to one, there is no difference in the revenue generated by different classes. In this study, the revenue attractiveness factor is varied at four levels: 0.5, 0.7, 0.9, and 1.0. The CPRAP is tested for these operating factors using simulation analysis. The simulation is run on Arena simulation software (Version 7.01, Rockwell Software Inc.).

The performance of CPRAP is evaluated and compared with the FCFS policy. Metrics that are used for comparison of the two policies include percentage increase in the revenue (PIR) generated with the existing resources, percentage increase in profit (PIP), and increase in the new customer fill rate (PIF).

The simulation results revealed that tighter the capacity, greater the percentage increase in revenue. The percentage increase in revenue generated from the existing resources ranged from -2.82% to 20.92%, with an average increase of 2.94%. The percentage increase in profit ranged between 0% and 17.25%, with an average increase of 6%. This shows that the profit generated under CPRAP is always greater than or equal to the profit generated under FCFS. In addition to the financial metrics, fill rate for new customers is an important measure that is analyzed. The percentage increase in fill rate as a result of adopting CPRAP recorded low and high values of 0% and 100%, respectively, with the average increase being 46.98%. The simulation results are summarized in Table 1.

Table 1: Simulation Results

Metric	Minimum	Maximum	Average
PIR	-2.82	20.92	2.94
PIP	0.00	17.25	6.00
PIF	0.00	100.00	46.98

3. Conclusion

Revenue management is an important tool in customer acceptance and resource allocation policy when there are different customer classes generating different levels of revenue and when the capacity is scarce. In this study, a new approach to the appointment allocation procedure in rehabilitation outpatient clinics has been introduced. We observe that when CPRAP is utilized, total revenue and as a result the total profit increases. Furthermore, the fill rate of new customers improves.

References

[1] Barut, M., and Sridharan, V. (May 2004), "Design and evaluation of a dynamic capacity apportionment procedure," *European Journal of Operations Research, 155(1)*, pp. 112-133.

[2] Cayirli, T. (2002), "Scheduling outpatient appointments using patient classification: A simulation study," *Proceedings - Annual Meeting of the Decision Sciences Institute*, pp. 2195-2195.

[3] Goldman, P., Freling, R., Pak, K., and Piersma, N. (Oct 2002), "Models and techniques for hotel revenue management using rolling horizon," *Journal of Pricing and Revenue Management, 1(3)*, pp. 207-219.

[4] Lieberman, W. H. (2002), "Future of revenue management: What lies ahead," *Journal of Revenue and Pricing Management, 1(2)*, pp. 189-195.

[5] Pak, K., and Piersma, N. (2002), "Airline revenue management: An overview of OR techniques 1982-2001," *Economic Instituted Report EI 2002-03*, pp. 1-23.

[6] Vulcano, G., van Ryzin, G., and Maglaras, C. (2002), "Optimal dynamic auctions for revenue management," *Management Science, 48(11)*, pp 1388-1407.

[7] Weatherford, L. R., Kimes, S. E., and Scott, D. A. (Aug 2001), "Forecasting for hotel revenue management: Testing aggregation and disaggregation," *Cornell Hotel and Restaurant Administration Quarterly, 42*, pp. 53-64.