Re revenue management in railway operations: A study of the Rajdhani Express, Indian Railways

Rohit Bharilla a, Narayan Rangaraj b, *

a Department of Mechanical Engineering, Indian Institute of Technology Bombay, Powai, Mumbai 400 076, India
b Industrial Engineering and Operations Research, Indian Institute of Technology Bombay, Powai, Mumbai 400 076, India

A B S T R A C T

Revenue management is widely practiced in the transport industry, but the bulk of the published literature deals with the airline industry. We consider the case of passenger services in the premium segment of Indian Railways (IR) and illustrate an application of the principles of revenue management. The strategy of overbooking is interpreted in terms of waitlist management by IR and cancellation action of customers. An attempt is made to derive elasticity estimates between key mode choices internal to the railways and finally, revenue management through differential pricing is suggested as a means to increase revenue on average.

Keywords:
Revenue management
Passenger rail services
Overbooking
Differential pricing
Indian railways
Elasticity

1. Introduction

Revenue management (RM), sometimes called Yield management, is a tool widely used with the objective of maximization of the revenue of a firm, that helps to decide how much of inventory (seats in an airplane, rooms in a hotel, or cars in a rental car fleet) to allocate to different types of market segments and at what prices/fares. In the transport sector, the airline industry has been in the forefront of using RM (Donaghy et al., 1995; Kimes, 1989). Industries can follow two types of RM techniques (Talluri and Van Ryzin, 2004): price-based RM (also called retailing) or quantity based RM. Most industries follow a combination of both, with the choice depending on the quantity and price flexibility of the goods/services provided. Retailing is generally preferred over quantity based RM because it not only limits the supply as rationing does, but also increases the revenue. Some industries like the bus industry follow largely quantity based RM.

Our research concerns one of the largest railway networks in the world, Indian Railways (IR). Some features of the various segments of rail passenger travel in India are as follows: Since there is an overall shortage of supply of passenger rail services in India, the pricing of services is largely on a cost-plus basis, with a subsidy element (from freight operations) and a mix of political and social considerations. But of late, it is clear that the premium air-conditioned (AC) segment in rail passenger travel is subject to modern market forces, viz., competition, willingness of customers to pay based on perceived value and service related features of the basic product. Indian Railways gets 20% of its passenger related revenues from its luxury or AC services. IR has responded with some actions, such as reducing fares in the AC I class, and introducing the Tatkal scheme to provide differentiated services for last minute travelers at a modest premium. There might be some reservation of capacity within the railways for internal use and also for the government sector. Since luxury trains
have no pricing concerns arising from social obligations attached to them, the basic concepts of market economics are more directly applicable there. Hence, the train chosen for the illustrative analysis for this study on RM is Mumbai–Delhi Rajdhani express (train no 2951 on IR). This is one of the first trains on Indian Railways where pricing strategies have been experimented with.

2. Survey of competition

Passenger services such as the Rajdhani service of IR face competition not only within IR, but also from the airlines and bus transport, which use dynamic pricing of different kinds: Markdown pricing, Promotions or Discount Pricing. A comparative analysis of RM techniques these industries use follows.

2.1. No-frill airlines

No-frill airlines have created an impact on the whole transport industry (Taneja, 2004). In the US, no-frill airlines have less than 30% capacity but more than two thirds of the market, while in the UK they have less than 15% capacity but more than one third of the market. They follow dynamic pricing with cheaper fares when the booking opens. Table 2.1 presents a typical fare structure.

2.2. Legacy airlines

Another example is from a legacy airline. Such airlines typically do not change the fares of all the seats dynamically, but have a small number of seats in different classes at low fares and some at full fares (generally available on the spot). A typical scheme is an 'easy fares' scheme followed by Indian Airlines (now Air India), where one can get discounts of more than 50% initially. The rules are more complicated with respect to booking, cancellation, re-routing and validity. The number of discounted seats is dynamic (and thus an example of both price and quantity based RM) and an upper level seat becomes available when the lower level gets filled up. A typical fare structure is shown in Table 2.2.

2.3. The bus industry

The bus transport industry offers examples of revenue management, such as National Express in the UK, which offers fun-fares where tickets which are worth 30–40 pounds on the spot can be bought for a price between 1 and 5 pounds a few weeks in advance (Source: http://www.nationalexpress.com/). This is like the easy fare scheme of the IA where also the number of seats is dynamic (but still it is an example of price-based RM as the quality of service provided for each seat is the same for all fares).

2.4. The railway industry

Yield in the railways can also be understood as either yield per available seat mile or yield per revenue passenger mile (Donaghy et al., 1995). Demand for IR is variable and not easy to analyze due to:

<table>
<thead>
<tr>
<th>Table 2.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fares for a Mumbai–Delhi flight (Spice Jet) on different days from the journey, as on 15th March 2006</td>
</tr>
<tr>
<td>Day 0</td>
</tr>
<tr>
<td>Fares (Rs.)</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Table 2.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fares (in Rs.) for a Mumbai–Delhi flight (Indian Airlines) in different classes as on 15th March 2006</td>
</tr>
<tr>
<td>Class</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Easy fares (Level-4) ECONOMY</td>
</tr>
<tr>
<td>Easy fares (Level-3) ECONOMY</td>
</tr>
<tr>
<td>Easy fares (Level-2) ECONOMY</td>
</tr>
<tr>
<td>Easy fares (Level-1) ECONOMY</td>
</tr>
<tr>
<td>Promotional fare</td>
</tr>
<tr>
<td>ECONOMY</td>
</tr>
<tr>
<td>EXECUTIVE</td>
</tr>
</tbody>
</table>

• Uncertainty (due to the various players in the travel industry: land, water or air).
• Varying price elasticity (due to various income groups or various reasons to travel).
• Wide regional variations (due to high/low population in different areas or due to the industrial or tourism related importance of different places).
• Seasonal or time variations (off peak and peak).

Yield management in such capital-intensive service industries is quite closely linked with the maximization of revenue itself as the fixed costs of the industry are quite high and the marginal costs of selling another seat or transporting another passenger in it are quite small and can be ignored as compared to the marginal revenue. Some widely used approaches are Discounted fares (price-based RM), overbooking (quantity based RM) and Discretized booking (both quantity and price-based RM). Discounted fares are widely studied, so we will throw some light on overbooking and discretized booking.

A train can be said as overbooked if paid bookings are accepted beyond its capacity. Overbooking in IR is implemented in two categories, namely RAC (reservation against cancellation) and WL (wait list). Wait listed tickets are refunded if not confirmed and RAC tickets offer partial sitting accommodation with the possibility of upgrading depending on en-route occupancy. IR does not offer refunds to no-show passengers who miss a train, as they have limited capability of offering last minute vacant seats to willing customers at the starting point.

Discretized booking is practiced by IR through the ‘Tatkal’ scheme, which is for the last minute customers, on payment of an extra premium and starts a day before the scheduled journey (at 8.00 a.m. when this study was conducted). This facility which was earlier available only in the trains traveling on the major routes, is available for the Sleeper as well as the AC class in more than 100 trains (as of November, 2004) and has since been extended to all mail and express trains. More on this in the following sections:

2.4.1. The Rajdhani Express on Indian Railways
The data that we provide from IR sources is from Western Railway (WR) records. The fare structure for the Rajdhani express is very simple and time independent, except for the Tatkal seats (at the time of this study it was 10% of the number of normal seats and open only 24 h before the journey) for which a premium of Rs. 300 is charged. It has three passenger classes: AC I, II and III, for which the reservations open 60 days before the journey date. Table 2.3 shows the fares of the three classes.

3. Data analysis
We analyze a particular segmentation of the passenger market for rail travel, discuss their preferences for different travel modes available, the booking and cancellation trends in Rajdhani Express and our interpretation of these which would finally lead to quantitative analysis and model building.

3.1. Passenger distribution and competition
We can divide potential passengers on the Rajdhani service into different categories, as in a framework proposed in Brons et al. (2002). In each category, the preferences of mode of travel with respect to their objectives can be considered:

- Business executives, who usually consider flying as first option as they are extremely time sensitive.
- Leisure travelers, who are service sensitive and hence may switch a little less to no-frill airlines.
- Emergency/short-notice travelers, who have time constraints.
- Middle class travelers, who are not too service conscious, but are time-sensitive.

A first cut analysis indicates that leisure/tourist travelers and sometimes short-notice customers use Rajdhani as a mode of transport. In principle one can consider the low cost airlines as competition to the Rajdhani service, as their lowest class fares are comparable and they also have shorter journey durations. It is thus important for Rajdhani to consider a decrease in its fares, at least for some seats or for some duration of booking. Different strategies can be adopted in this regard. We study various elements related to this, beginning with the price elasticity of demand.

Table 2.3
Fare structure at different times, for Mumbai Rajdhani express as of 15th March 2006

<table>
<thead>
<tr>
<th>Class</th>
<th>Fare (Rs.)</th>
<th>Tatkal charges (Rs.)</th>
<th>Cancellation charges (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before more than a day left for journey</td>
<td>Before less than 24 h left for journey</td>
<td>Before less than 4 h left for journey</td>
</tr>
<tr>
<td>AC I</td>
<td>4135</td>
<td>N/A</td>
<td>50</td>
</tr>
<tr>
<td>AC II</td>
<td>2210</td>
<td>300</td>
<td>30</td>
</tr>
<tr>
<td>AC III</td>
<td>1485</td>
<td>300</td>
<td>30</td>
</tr>
</tbody>
</table>

Source: Western Railways.
3.2. Factors influencing demand elasticity

Price elasticity of demand can be defined as percentage change in demand per percentage change of price. To evaluate the elasticity for Rajdhani service, we define three price points in this luxury train for three classes (AC I, II and III) and identify the following aspects:

- It is a luxury train with passengers switching not only amongst its own available classes (AC I, II and III) based on the available fare, but also within different trains. We tend to ignore its impact since there is a large waitlist maintained because of the overbooking strategy of IR, and we view that as a reasonable expression of desired demand. It is feasible for passengers to book on the waitlist and then to move to other modes if rail tickets are not available, since a full refund is available. For the Rajdhani trains, there is no internal competition as there are no comparable luxury trains offering the same levels of service.

- Competition with many airlines is also a factor, as the flights on this small route are comfortable and the service level is generally good in airlines like IA, Sahara, Spice Jet etc. But switching to other modes is ignored as we identify a specific consumer base for Rajdhani trains in Section 3.1.

3.3. Booking/cancellation trends in Rajdhani

We now profile the relevant demand patterns (booking, cancellations, waitlisted passengers and up-gradation). Data from the Indian Railways on the Mumbai Delhi Rajdhani express has been collected and analyzed for 14 days (28th January 2006 through 10th February 2006). The reservation for each journey date starts 60 days prior to it. The 61 days (60 days plus the journey day) have been divided into 9 weeks (the last one having 5 days) and the booking and cancellation data for each week has been tabulated as per the three different classes (AC I, II and III) and is presented in the form of graphs for convenience. For each class, four graphs are presented and explained in the following text. The total capacity for classes AC I, AC II and AC III are 24 (all normal quota), 240 (216 normal quota + 24 Tatkal quota) and 560 (504 normal quota + 56 Tatkal quota) respectively. The total bookings done at any time would typically exceed the total capacity due to overbooking.

For AC I, Fig. 3.1 shows the bookings made every week as a percentage of total bookings made till the end. Fig. 3.2 shows the distribution of the passengers who traveled (or un-cancelled bookings) vs the period when they made their bookings (as a percentage of total no. of passengers who finally traveled). Fig. 3.3 shows the number of bookings cancelled from the respective week’s bookings as a percentage of total cancellations made till the end. Lastly, Fig. 3.4 shows cancellations done from the respective week’s bookings, but as a percentage of total bookings done in that week alone. Similar plots are drawn for the Classes AC II (Figs. 3.5 through 3.8) and AC III (Figs. 3.9 through 3.12).

3.3.1. Class AC I
See Figs. 3.1 through 3.4.

3.3.2. Class AC II
See Figs. 3.5 through 3.8.

3.3.3. Class AC III
See Figs. 3.9 through 3.12.

![Fig. 3.1. Bookings in AC I (% of total bookings). Source: Western Railways.](image-url)
Fig. 3.2. Un-cancelled bookings (% of total un-cancelled bookings). Source: Western Railways.

Fig. 3.3. Bookings cancelled from the respective weeks' bookings (% of total cancellations till the end). Source: Western Railways.

Fig. 3.4. Bookings cancelled from the respective week's bookings (% of bookings made in that week only and not the % of the total cancellations). Source: Western Railways.
Fig. 3.5. Bookings in AC II (% of total bookings). Source: Western Railways.

Fig. 3.6. Un-cancelled bookings (% of total un-cancelled bookings). Source: Western Railways.

Fig. 3.7. Bookings cancelled from the respective weeks’ bookings (% of total cancellations till the end). Source: Western Railways.
Fig. 3.8. Bookings cancelled from the respective week's bookings (% of bookings made in that week only and not the % of the total cancellations). Source: Western Railways.

Fig. 3.9. Bookings in AC III (% of total bookings). Source: Western Railways.

Fig. 3.10. Un-cancelled bookings (% of total un-cancelled bookings). Source: Western Railways.
3.4. Tatkal booking data for Rajdhani Express

Besides the overall booking/cancellation data, we also study the current statistics of the Tatkal Seva scheme to comment on viable options for revenue management. Tables 3.1 and 3.2 refer to this.

3.5. Observations and interpretations

A striking feature seen from Figs. 3.1, 3.2 and 3.3 (and corresponding figures for AC II and AC III) is that a similar trend is shown: a decreasing–increasing trend. The following interpretation can be made from the Sections 3.3 and 3.4.

Table 3.1
Statistics of Tatkal booking scheme in AC II class (total capacity = 24), Rajdhani Express (2951)

<table>
<thead>
<tr>
<th></th>
<th>28-Jan</th>
<th>29-Jan</th>
<th>30-Jan</th>
<th>31-Jan</th>
<th>1-Feb</th>
<th>2-Feb</th>
<th>3-Feb</th>
<th>4-Feb</th>
<th>5-Feb</th>
<th>6-Feb</th>
<th>7-Feb</th>
<th>8-Feb</th>
<th>9-Feb</th>
<th>10-Feb</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booked</td>
<td>25</td>
<td>27</td>
<td>21</td>
<td>18</td>
<td>20</td>
<td>20</td>
<td>18</td>
<td>23</td>
<td>17</td>
<td>14</td>
<td>15</td>
<td>20</td>
<td>22</td>
<td>27</td>
<td>20.5</td>
</tr>
<tr>
<td>Canceled</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Travelled</td>
<td>22</td>
<td>26</td>
<td>21</td>
<td>18</td>
<td>20</td>
<td>20</td>
<td>16</td>
<td>22</td>
<td>16</td>
<td>14</td>
<td>15</td>
<td>18</td>
<td>18</td>
<td>27</td>
<td>19.5</td>
</tr>
<tr>
<td>Waitlisted</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Western Railways.
Table 3.2
Statistics of Tatkal booking scheme in AC III class (total capacity = 56), Rajdhani Express (2951)

<table>
<thead>
<tr>
<th></th>
<th>28-Jan</th>
<th>29-Jan</th>
<th>30-Jan</th>
<th>31-Jan</th>
<th>1-Feb</th>
<th>2-Feb</th>
<th>3-Feb</th>
<th>4-Feb</th>
<th>5-Feb</th>
<th>6-Feb</th>
<th>7-Feb</th>
<th>8-Feb</th>
<th>9-Feb</th>
<th>10-Feb</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booked</td>
<td>58</td>
<td>57</td>
<td>50</td>
<td>59</td>
<td>61</td>
<td>54</td>
<td>53</td>
<td>61</td>
<td>68</td>
<td>57</td>
<td>60</td>
<td>61</td>
<td>64</td>
<td>61</td>
<td>58.8</td>
</tr>
<tr>
<td>Cancelled</td>
<td>7</td>
<td>7</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>9</td>
<td>10</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>9</td>
<td>14</td>
<td>5.2</td>
</tr>
<tr>
<td>Waitlisted</td>
<td>49</td>
<td>47</td>
<td>48</td>
<td>53</td>
<td>60</td>
<td>53</td>
<td>52</td>
<td>47</td>
<td>55</td>
<td>55</td>
<td>59</td>
<td>57</td>
<td>60</td>
<td>61</td>
<td>52.1</td>
</tr>
</tbody>
</table>

Source: Western Railways.

- From Fig. 3.1 (and corresponding figures for AC II and AC III) it can be said that there are always some passengers who play a safe game and book tickets as soon as booking opens for a particular date. These passengers also contribute to a relatively higher number of cancellations (from Figs. 3.3 and 3.4 and corresponding figures for AC II and AC III) than travelers (from Fig. 3.2 and corresponding figures for AC II and AC III) as compared to the following few weeks (till around the fifth or sixth week).
- All the figures till the fourth or fifth week are approximately lower than or equal to the first week figures.
- From Figs. 3.1, 3.2 and 3.3 (and corresponding figures for AC II and AC III) it can be said that a very high percentage or number of bookings/cancellations/travelers corresponds to the last 3 weeks. Eighty percent of cancellations in AC I and 50% in AC II and III are done in the last 3 weeks.
- From Fig. 3.4 (and corresponding figures for AC II and AC III) it can be seen that at least 25–40% of the tickets booked every week are cancelled in AC II and AC III while most of the times more than 40% of tickets are cancelled in AC I.
- There is rarely any waitlist in AC II Tatkal booking and often a very small waitlist in Tatkal AC III.
- All the figures lie between 5% and 20% for AC III class.

Based on the above observations we can suggest the following:

- A scheme having concessional fare tickets for the first 6 weeks with cancellation rules similar to the ones mentioned in Section 2.2 will attract more people towards booking early.
- Along with the above scheme, a better strategy would be to not open all the seats for the first 6 weeks as maximum bookings take place in the last 3 weeks. These seats, like the Tatkal service can have a premium charge attached to the base fares. The value of this premium will depend on the value of the concession given and the current cancellation charges. The extra fare from these last 3 week booked tickets should not only cover the loss in fares due to the concessional fare seats minus the cancellation charges, but should also add a surplus to the revenues as compared to earlier. This would be discussed in detail later in Section 4.
- The Tatkal fares should be adjusted, since in AC II there is hardly any waitlist, indicating a required reduction in the Tatkal premium. Similarly an increase in AC III Tatkal premium is warranted.
- Tatkal can be introduced in AC I, helping in situations when AC I has a waitlist, indicating a higher demand. This is a not a very frequent occurrence but the scheme has no obvious negative points.
- Another alternative is a non-refundable ticket (for a fixed no. of seats) which will have huge discounts (of the order of say more than 50%) if booked in the first few weeks (say 2 weeks), followed by a slightly lower discount (say 20%) for the next 2 weeks. There needs to be a deadline (say 2 h through 1 h before journey, i.e. an hour before the final charting of passengers begins) when the passenger should get his ticket rechecked at the railway ticket window, or might lose his seat to a waitlisted passenger, only to wait for another train with an empty seat of an equal or lower fare. This sort of system is already used in bus transport services in the UK.

4. Quantitative analysis of elasticity and revenue impact

Referring to \( p \) as price and \( q \) as demand, let us consider two states; state ‘\( i \)’ (with demand \( q_i \) and price \( p_i \)) and state ‘\( j \)’ (with demand \( q_j \) and price \( p_j \)). If we go from state ‘\( i \)’ to state ‘\( j \)’, \( \Delta q \) is the change in demand and \( \Delta p \) is the change in price. The Elasticity \( E_{ij} \) can be defined as

\[
E_{ij} = \frac{\Delta q}{q_i} / \frac{\Delta p}{p_i}
\]  

(4.1)

It can be observed that while going from state ‘\( j \)’ to state ‘\( i \)’ (i.e. in the reverse direction) the elasticity value will be different. To avoid any confusion and computational errors and to reduce the complications in any mathematical model, the use of arc elasticity (Eilon, 1983) is more commonly used, where the percentage change is taken with respect to the average price and the average demand (usually presented as absolute numbers, thus negative signs of \( \Delta q \) or \( \Delta p \) are not considered).

\[
E_{arcij} = \frac{\Delta q}{q_{avg}} / \frac{\Delta p}{p_{avg}} = E_{arcji}
\]  

(4.2)

where \( q_{avg} = (q_i + q_j)/2 \) and \( p_{avg} = (p_i + p_j)/2 \).
4.1. Pricing norms on Indian Railways

Discussions with railway personnel reveal that not much experimentation is done to feel the pulse of the competitive market. The major check is only to see if the revenues are higher than the money spent, in any initiative. One parameter considered to analyze the pricing is unsatisfied demand, where IR assumes as a rule of thumb that 50% of the cancellations are due to the unavailable seats (non-confirmed reservation). Thus unsatisfied demand is usually estimated as

Unsatisfied demand = \( W + C/2 \) \hspace{1cm} (4.3)

where \( W \) is the number of waitlisted passengers and \( C \) is the number of tickets cancelled.

We ignore the impact of passenger switching to other modes and to other trains as discussed in Section 3.2. We neglect the fact that there is an overbooking capacity that is arbitrarily decided by IR. The waiting list is allowed to get large whenever it happens, because the railways sometimes use options of providing additional capacity (additional coaches and even special trains). In this sense the waitlist is viewed as an indication of the desired demand.

Therefore, for our quantitative analysis, we consider only the price changes at different time periods (across the 60 day reservation period) to start off with the calculation of elasticity values. As elasticity is a complicated term and can be calculated in various ways, we calculate the cumulative demand for the first 6 weeks for all the three classes to remain consistent with our strategy of formulating a new fare structure with discounted ticketing in the first 6 weeks (as it is a period with very little variation in booking/cancellation trends, see Section 3.5). Tables 4.1 and 4.2 show the demand through booking and cancellations in all the 9 weeks.

4.1.1. Elasticity analysis

It is difficult to estimate pure elasticity with respect to price in a situation where multiple products or services are offered at the same time. In such a situation, customers would choose to enter the market not just on price valuation for a standard commodity, but based on a more detailed price value trade-off for each variant. Earlier studies on elasticity highlight the common fact that with a large number of parameters involved (price, income, preference, class of travel, type of travel; business or leisure etc.) it is difficult to make or validate a perfect model. Each study makes some appropriate approximations and assumptions to present the results/data in a manner which is mathematically interpretable and that can be implemented practically. Some examples are discussed here. Fridström and Larsen (1989) take the average cost and demand values for all travel classes to estimate elasticity. Brons et al. (2002) take two or more parameters for modeling. Greene (2000) defines a bias factor to take into account the overestimation, and Uysal and McLellan (1991) solve the model for two parameters at a time using techniques like SURE.

The booking system followed by IR allows for a substantial waitlist for each class of travel. Although this study, like other studies, also identifies the presence of numerous parameters affecting the evaluation of elasticity for the use of different Rajdhani classes, we conjecture that the total booking for each class is an expression of the true demand for each class. For the Rajdhani service on IR, at least compared to other rail services and road, it would seem that the basic service element of fast, reliable and premium service per se would be the most important factors influencing travelers. Within this, the demand expressed for each class does capture the elasticity with respect to price. This may need to be deflated a bit to account for the fact that the service element in each class is actually differentiated.

Using the same terminology as is used in the beginning of this section, we can write (for a situation where price decreases and demand increases) \( p_{\text{avg}} = (p - \delta p)/2 \) and \( q_{\text{avg}} = (q + \delta q)/2 \); where \( \delta q \) and \( \delta p \) are both positive numbers and 'p' and 'q' are the initial values of price and demand respectively. Now using Eq. (4.2), we get the final equation as

\[
p/\delta p = [E_{\text{arc}} + q/\delta q] + [(E_{\text{arc}} + 1)/2]
\]

\hspace{1cm} (4.4a)

<table>
<thead>
<tr>
<th>Table 4.1</th>
<th>Bookings done every week (average for Journey dates 28th January 2006 through 10th February 2006)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>Week 2</td>
</tr>
<tr>
<td>AC I</td>
<td>9.52</td>
</tr>
<tr>
<td>AC II</td>
<td>22.78</td>
</tr>
<tr>
<td>AC III</td>
<td>94</td>
</tr>
</tbody>
</table>

Source: Western Railways.

<table>
<thead>
<tr>
<th>Table 4.2</th>
<th>Cancellations from respective week's bookings (average for Journey dates 28th January 2006 to 10th February 2006)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>Week 2</td>
</tr>
<tr>
<td>AC I</td>
<td>0.42</td>
</tr>
<tr>
<td>AC III</td>
<td>27.14</td>
</tr>
</tbody>
</table>

Source: Western Railways.
Similarly, for a case with increase in price and decrease in demand we get

\[ p/\partial p = [E_{\text{arc}} \ast (q/\partial q)] - [(E_{\text{arc}} + 1)/2] \]  

(4.4b)

where \( q \) is the demand for 6 weeks. If we define \( E_{(\text{II})} = \) Elasticity between two state points – AC I and AC II, from Eq. (4.2) its value now becomes \( = (\partial q_{(\text{II})}/\partial q_{(\text{avg,II})})/(\partial p_{(\text{II})}/\partial p_{(\text{avg,II})}) \). From the data given in Tables 4.1 and 2.3, we can calculate the price elasticity of demand as

\[ E_{(\text{II})} = (123/71.96)/((1925/3172.5) = 2.83 \]

Similarly, we get

\[ E_{(\text{II,III})} = 2.85 \]

As above, analyzing the Tatkal booking data and fares from Tables 3.1, 3.2 and 2.3 we infer

Tatkal elasticity, \( E_{(\text{II,III})} = 2.86 \)

Studies on price elasticity for air travel in the UK and the US are estimated to be between 1 and 2 and sometimes as high as between 2.7 and 3.2 (Brons et al., 2002). Considering the immense competition, the income levels and the bargaining attitude, we should expect the elasticity levels on the premium segment of rail travel in India to be in the higher range. We see that, in fact, the computed elasticity of 2.86 for Rajdhani lies within the range suggested by Brons et al.

4.1.2. Profit analysis

From Tables 4.1 and 4.2 we observe that approximately 36% of the tickets booked in the period of first 6 weeks are eventually cancelled. It points towards a revenue generating possibility for IR by increasing cancellation charges. The following sections will provide three models (for AC II class as an illustration) for an initial strategy of RM based on the Elasticity analysis done earlier. In the first two models we propose the strategy of discounting the fares for the first 6 weeks and increase in fares for the last 3 weeks (this one only in the first model). We will use the following nomenclature (for ease, the given/original quantities have a subscript ‘o’ and the derived ones have a subscript ‘d’):

\[ E = \) price elasticity of demand \]
\[ p_o = \) original ticket price \]
\[ C = \) passenger capacity of the class being examined \]
\[ K = \) current cancellation charges on a ticket \]
\[ A = \) administration cost for a cancellation \]
\[ B = \) proposed additional cancellation charge \]
\[ \lambda_o = \) given proportion of people booking tickets (in the first 6 weeks) who cancel it finally \]
\[ q_o = \) given demand in the first 6 weeks \]
\[ q'_o = \) given demand in the last 3 weeks (excluding the last day, which is for Tatkal) \]
\[ \partial p = \) change (increase in this model) in price of tickets bought in the last 3 weeks \]
\[ \partial d = \) derived proportion of people booking tickets (in the first 6 weeks) who cancel it finally \]
\[ q_d = \) derived demand in the first 6 weeks \]
\[ q'_d = \) derived demand in the last 3 weeks (excluding the last day) \]
\[ \partial p' = \) change (increase in this model) in price of the tickets bought in the last 3 weeks

4.1.2.1. Model I. Overall revenue maximization for both the stages (first 6 weeks and last 3 weeks) together. As we increase or decrease the value of ‘p’ from \( p_o \) by \( \partial p \), the value of ‘q’ also changes by the elasticity law. Although, \( B \) plays a significant role to define the value of ‘\( q \)’ but for the simplicity of the model we assume its affect to be negligible. By using Eqs. (4.4a) and (4.4b) we can find the value of \( \partial q \) for both increase and decrease in price and can say that

\[ q_d = q_o + [(p_o/\partial p) + (E - 1)/2]/[(p_o/\partial p) - (E + 1)/2] \]
\[ q'_d = q'_o + [(p_o/\partial p') - (E - 1)/2]/[(p_o/\partial p') + (E + 1)/2] \]  

(4.5a)  

Also, we know that the number of cancellations is total demand minus the capacity (as the examined classes here always go full and there are rarely any empty seats). Thus, the number of cancellations is \( (q_o + q'_o - C) \) in the original case and is \( (q_d + q'_d - C) \) in the proposed model. Hence we get

\[ q_o + q'_o - C = \lambda_o \ast q_o + \lambda'_o \ast q'_o \]  

or \( (1 - \lambda_o) \ast q_o + (1 - \lambda'_o) \ast q'_o = C \)  

(4.6)

To charge or not to charge an extra cancellation fees ‘\( B \)’ depends on whether the prices have increased or not. For an increase in fare (as in the first stage of this model) it makes little sense to also increase the cancellation fee and still expect the demand to increase. Thus, the revenue generated in the original case \( (R_o) \), the proposed model \( (R_d) \) and the overall change in profit/revenues \( L \) is given by
\[ R_0 = C \cdot p_0 + (q_o + q'_o - C) \cdot (K - A) \]  
\[ R_d = [\lambda_d \cdot q_d \cdot (B + K - A) + \lambda'_d \cdot q'_d \cdot (K - A)] + [(1 - \lambda_d) \cdot q_d \cdot (p_o - \bar{c}p) + (1 - \lambda'_d) \cdot q'_d \cdot (p_o + \bar{c}p')] \]  
\[ L = R_d - R_0 \]  
(4.7a)  
(4.7b)  
(4.8)

For a combination of \( \bar{c}p \) and \( \bar{c}p' \), one can assume a practical value (with reasonable factor of safety) of \( \lambda_d \) (which automatically gives \( \lambda'_d \) from Eq. (4.6)) and see if \( L \) has increased significantly or not. Some of the \( L \) values for various values of \( 'B' \) and the following parameters are shown in Table 4.3, where \( p_o = 2210 \) (Table 2.3); \( E = 2.8 \) (Calculated); \( K = 30 \) (Table 2.3); \( q_o = 134 \) (Table 4.1); \( \lambda_o = 0.36 \) (Section 4.1.2); \( C = 216 \) (Section 3.3); \( q'_o = 190 \) (Tables 4.1 and 3.1); \( A = 0 \); \( \bar{c}p = 300 \); \( \bar{c}p' = 200 \).

We can see that for \( B = 0 \) (a very general scheme where we only decrease the prices) for all feasible values of \( \lambda_d \), \( L \) is negative. As we increase the value of \( 'B' \), these values become large. Because of positive values of \( 'B' \) in the first 6 weeks, the demand \( q_o \) will not increase as much as we just calculated. At the same time, the increase in price in the later 3 weeks pushes the demand in the first 6 weeks higher than calculated. Similarly, due to this kind of a scheme (with cheaper tickets in the first 6 weeks), the demand in the later 3 weeks decreases a lot more than calculated, but also, due to the presence of positive \( 'B' \) values, it pushes the demand higher again. As these effects cannot be estimated very precisely without implementing the scheme itself and studying the real-time data, we can use the term \( z \cdot q_o \) in place of \( q_o \) and \( x \cdot q'_o \) in place of \( q'_o \) in the above model and evaluate them once such a scheme is implemented. These large values of calculated profits do suggest that prima facie, such schemes are attractive in their potential for revenue increase.

4.1.2.2. Model II. Revenue maximization for individual stages. In the previous model, we directly calculated \( R_d - R_0 \) to see if there is overall benefit or not. When a new scheme is implemented in stages, it is desirable if there are profits at every stage. We give an example of such a calculation, where only the profit at the first stage (first 6 weeks) is calculated; using the previously defined notation, we have \( R_0, R_d \) and \( L \) as

\[ R_d = q_o \cdot (1 - \lambda_o) \cdot p_o + (K - A) \cdot \lambda_o + q_o \]  
(4.9a)

\[ R_d = (q + \bar{c}q) \cdot (1 - \lambda_d) \cdot (p_o - \bar{c}p) + (K + B - A) \cdot \lambda_d \cdot (q + \bar{c}q) \]  
\[ = q_d \cdot (1 - \lambda_d) \cdot (p_o - \bar{c}p) + (K + B - A) \cdot \lambda_d \cdot q_d \]  
(4.9b)

\[ L = q_d \cdot (1 - \lambda_d) \cdot (p_o - \bar{c}p) - q_o \cdot (1 - \lambda_o) \cdot p_o + (K + B - A) \cdot \lambda_d \cdot q_d - (K - A) \cdot \lambda_o \cdot q_o \]  
(4.10)

In a similar way, individual stages can be set for positive change in revenues. In fact the later stage (the last 3 weeks) can be sub-divided into more stages with different schemes altogether, may be also having a decrease in price (lower than the first 6 weeks) but with a lower or zero \( 'B' \) value. Many such combinations are possible, but the basic idea is to calculate the change in revenues at each stage. A few \( 'L' \) values are calculated by this approach with \( p_o = 2210 \), \( E = 2.8 \), \( K = 30 \), \( q_o = 134 \), \( \lambda_o = 0.36 \), \( C = 216 \), \( A = 0 \), \( \bar{c}p = 300 \) and various \( 'B' \) values and are given in Table 4.4.

Similar to the previous model, \( L \) becomes more and more profitable with an increase in \( 'B' \) value. It seems quite justified to assume that for \( B = \bar{c}p = 300 \), the calculated change in demand will be quite close to the real-time values due to a typical customer's psychology (as the cancellation penalty is the same as the decrease in price). Also the \( \lambda_d \) values could be quite close to the \( \lambda_o \) values. Here, it is interesting to note that for both the above models, when \( B = \bar{c}p = 300 \), the \( 'L' \) values are significantly positive for most of the \( \lambda_d \) values close to \( \lambda_o \).

4.1.2.3. Model III. Adjustments to Tatkal fares. It is seen that the average occupancy of AC II Tatkal is 19.5 for the 22 seats available. This clearly shows that there is a need to decrease the AC II Tatkal fares by a small amount so that the railways can get increased occupancy to offset the loss due to the reduction in fares.

### Table 4.3

<table>
<thead>
<tr>
<th>( \lambda_d )</th>
<th>0.25</th>
<th>0.30</th>
<th>0.35</th>
<th>0.40</th>
<th>0.45</th>
<th>0.50</th>
<th>0.55</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \lambda'_d )</td>
<td>0.57</td>
<td>0.50</td>
<td>0.43</td>
<td>0.36</td>
<td>0.29</td>
<td>0.22</td>
<td>0.16</td>
</tr>
<tr>
<td>( \lambda_o )</td>
<td>0.36</td>
<td>0.36</td>
<td>0.36</td>
<td>0.36</td>
<td>0.29</td>
<td>0.22</td>
<td>0.16</td>
</tr>
<tr>
<td>( L (B = 0) )</td>
<td>−31,961</td>
<td>−26,895</td>
<td>−21,830</td>
<td>−16,764</td>
<td>−11,698</td>
<td>−6632</td>
<td>−1566</td>
</tr>
<tr>
<td>( L (B = 300) )</td>
<td>−16,764</td>
<td>−8658</td>
<td>−553</td>
<td>7552</td>
<td>15,658</td>
<td>23,763</td>
<td>31,869</td>
</tr>
<tr>
<td>( L (B = 500) )</td>
<td>−6632</td>
<td>3500</td>
<td>13,631</td>
<td>23,763</td>
<td>33,895</td>
<td>44,027</td>
<td>54,158</td>
</tr>
</tbody>
</table>

Source: Western Railways.

### Table 4.4

<table>
<thead>
<tr>
<th>( \lambda_d )</th>
<th>0.20</th>
<th>0.30</th>
<th>0.40</th>
<th>0.50</th>
<th>0.60</th>
<th>0.70</th>
<th>0.80</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L (B = 0) )</td>
<td>119,864</td>
<td>81,769</td>
<td>43,674</td>
<td>5,578</td>
<td>−32,517</td>
<td>−70,612</td>
<td>−108,707</td>
</tr>
<tr>
<td>( L (B = 300) )</td>
<td>132,022</td>
<td>100,006</td>
<td>67,990</td>
<td>35,973</td>
<td>3,957</td>
<td>−28,059</td>
<td>−60,075</td>
</tr>
<tr>
<td>( L (B = 500) )</td>
<td>140,127</td>
<td>112,164</td>
<td>84,200</td>
<td>56,237</td>
<td>28,273</td>
<td>310</td>
<td>−27,654</td>
</tr>
</tbody>
</table>
As evaluated in Section 4.1.1, the elasticity value for Tatkal booking is 2.86. Using the methodology used in the last few sections one can easily calculate that if the fares get reduced by Rs. 190 (of course still including the Tatkal premium) the demand increases to 22 and there is also a definite profit, thus suggesting a simple rise/fall in fares of any class without any complicated differential pricing.

5. Conclusions

The fare structure of Rajdhani express is fairly simple as compared to the competition. The customer booking and cancellation trends, as well as the elasticity values are found to be fairly consistent for the considered period and it proves that modeling for trains like these for a given period (Rush/Lean/Peak) is quite feasible and is expected to give positive results. Given the information base and the integrated nature of operations on Indian Railways, and the price elasticity as high as 2.85, we expect a lot more activity in data analytics and research front by IR to come up with differential and dynamic pricing models, as in the case of many of the Air/Bus/Rail industries in the world. More competitive pricing strategies with fare restructuring (as has been suggested in the sections above) is recommended. Any of the above models or a combination of these can be used with an appropriate factor of safety. Indian Railways can be optimistic about such strategies as there is evidence that they work in a number of settings. Some examples in the literature are markdown strategies in various industries, as quoted in Talluri and Van Ryzin (2004), or the airline industry where there have been similar reservation trends as quoted in Teodorovic (1988), or the study to determine the net profit (Suzuki, 2006) from gross profit data considering the effect of ticket sell-ups and overbooking. Indian Railways are indeed experimenting with various aspects of revenue management as follows. The time at which Tatkal booking can be done has changed from one day before day of travel, to two days before day of travel and now to five days before day of travel (as of January 2008). Also, in some trains, a percentage of Tatkal seats is available for immediate booking as soon as the waitlist operates, in essence providing a pure, price differentiated offering for the first time. This offers many more avenues in the area of revenue management in the days to come.

Acknowledgements

We acknowledge the valuable help provided by Mr. A.K. Nigam, Mrs. Rekha Yadav, Mr. R. Gopalakrishnan and Mr. S.T. Sharma, all of Indian Railways, along with Prof. N. Hemachandra of IIT Bombay, for discussion and data support. However, the views expressed here are of the authors alone.

References


