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Role of Information and Communication Technology in Revenue Management Using EMSR: Evidence from Mumbai International Airport

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Abstract

"To be World's leading Airport Developer, Operator and Air Navigation Service Provider". There are 133 airports in India, 23 International Airports, 100 Domestic Airports, 10 Custom Airports. Almost 90 % had taken a commercial flight in their lifetime.

In operation research Inventory management is an important function to any business, marketing, since inadequacies in control can result in serious and important problems. If the inventory not managed properly then it will be problematic in satisfaction of customers or curtailment of working capital will result and production, seat inventory, loss.

The start of Operations Research was done during World War II, when basic necessities of soldiers were required to be managed, like, food, commuting, health, logging etc. Operations Research is an effective combination of mathematical and analytical tools for finding optimum results for decisions in a system of multiple and complex resources (treated as variables). Operations Research not only solves the existing problem but also helps to frame a problem and its solution.

Key words: Overbooking Seats, Customer Satisfaction, Passenger movements, Reduce the travelling cost, profitability, low customer charges.

Introduction

The aviation industry has become highly competitive due to increasing passenger demand, fluctuating fuel prices, and dynamic market conditions. Airports and airlines must adopt innovative strategies to maximize revenue and optimize operational efficiency. Revenue Management (RM) plays a crucial role in achieving this objective by using data analytics and mathematical models to forecast demand and allocate resources effectively.

Information and Communication Technology (ICT) has transformed revenue management by enabling real-time data processing, automated decision-making, and advanced forecasting techniques. Modern airports use cloud computing, big data analytics, and artificial intelligence to manage passenger flows, ticket pricing, and resource allocation efficiently.

One of the most widely used methods in airline revenue management is the Expected Marginal Seat Revenue (EMSR) model, which determines optimal seat allocation among different fare classes to maximize revenue.

Mumbai International Airport, one of the busiest airports in India, handles millions of passengers annually and serves as a major hub for international and domestic flights. In 2022-2023, the airport handled about 44 million passengers and nearly 980 flights daily, reflecting rapid growth in air travel demand. This study analyzes how ICT-enabled EMSR models improve revenue management strategies at Mumbai International Airport.

The Expected Marginal Seat Revenue (EMSR) method is a widely used revenue management technique in the airline and hospitality industries to optimize seat or room allocation across different fare classes. It helps determine the ideal number of seats to reserve for higher-paying passengers while maximizing total revenue. EMSR works by comparing the expected revenue from selling a seat at a lower fare versus holding it for a potential future customer willing to pay a higher fare. The decision is based on probability distributions of demand for each fare class, ensuring that limited inventory (such as airline seats) is allocated efficiently to maximize profits. There are two main versions of EMSR: EMSR-a and EMSR-b. EMSR-a calculates protection levels for each fare class independently, assuming demand follows a normal distribution. However, EMSR-b, a more advanced version, considers demand correlation across different fare classes, leading to better optimization. By applying these methods, airlines can decide how many lower-fare tickets to sell while reserving seats for higher-paying customers, reducing the risk of selling out too early at lower prices. This approach helps airlines strike a balance between load factor (occupancy) and yield (revenue per seat), ensuring optimal profitability.

Objectives:

1. To study of passenger's movement at Mumbai's Chhatrapati Shivaji Maharaj Airport.
2. To study the concept of ICT in aviation revenue management.

3. To examine the EMSR model used in airline seat inventory management.
4. To analyze the role of ICT in improving revenue management at Mumbai International Airport.
5. To evaluate passenger traffic and revenue trends using secondary data.

Data Collection:

Secondary data: Review of related literatures from Google Scholar, Shod Ganga, Science direct, MIAL Sustainability Report- 2024.

Scope

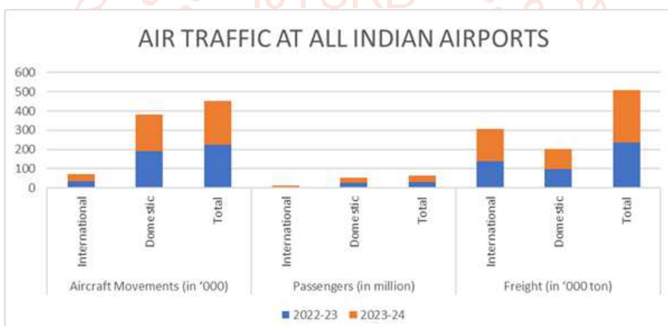
Scope of the study is to find out passenger satisfaction in view of the different services provided by Mumbai International Airport Ltd. (MIAL). The study covers the different aspect of passenger satisfaction. Airport management will get help from this Customer satisfaction survey report.

Research Methodology:

Review of literature, Diagrammatical representation of data.

AIR TRAFFIC REPORT

Category	2023-24	2022-23	Change
Aircraft Movements (in '000)			
International	38.04	33.47	13.7
Domestic	187.66	192.05	-2.3
Total	225.70	225.52	0.1
Passengers (in million)			
International	6.52	5.57	17.0
Domestic	26.21	24.95	5.0
Total	32.73	30.52	7.2
Freight (in '000 ton)			
International	167.05	139.99	19.3
Domestic	106.36	96.69	10.0
Total	273.41	236.68	15.3



Air Traffic in the year 2023-24 increased in the aircraft movement, passengers and freight as compared to year 2022-23.

Data Analysis

Table 1: Passenger Traffic at Mumbai International Airport

Year	Passengers (Million)
2019	48
2020	31
2021	19
2022	36
2023	44

Interpretation

Passenger traffic declined during the pandemic but recovered significantly after 2021, increasing demand for efficient revenue management systems.

Table 2: Average Daily Flight Operations

Year	Average Flights per Day
2019	950
2020	600
2021	500
2022	850
2023	980

This data indicates the need for advanced ICT tools to manage large volumes of flight operations and passenger demand.

EMSR Mumbai to Delhi (Air India)

EMSRa calculation for weekdays Air India Business Class, premium economy and Economy

T-10 EMSRa calculation for weekdays Air India Business Class, premium economy and Economy

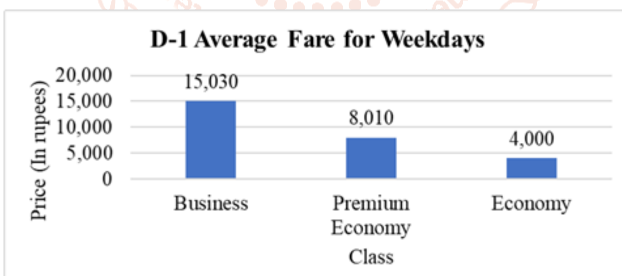
Sr No.	Fair price on Business Class	Demand on Business Class	Fair price on Premium Economy	Demand on Premium Economy	Fair price on Economy	Demand on Economy
1	14900	87%	8100	70%	4100	92%
2	15200	88%	7900	72%	3900	91%
3	15150	85%	8050	74%	4000	94%
4	14950	86%	8000	69%	4050	90%
5	15050	89%	7950	75%	3950	93%
6	14850	90%	8100	68%	4000	95%
7	15075	86%	7850	71%	3900	92%
8	15125	87%	8000	74%	4100	91%
9	14975	85%	8150	73%	3950	90%
10	15025	88%	7900	65%	4050	94%
11	15100	89%	8050	70%	4000	92%
12	15000	85%	8100	67%	3900	90%
13	14925	86%	7950	66%	4100	95%
14	15050	87%	8050	75%	3950	91%
15	15075	90%	8000	72%	4050	93%

We have **three fare classes** with their respective average fares:

T-11 **Three fare classes** with their respective average fares

Class	Average Fare	Average Demand in percentage
Business	15,030	87
Premium Economy	8,010	71
Economy	4,000	92

The data shows that Economy class has the highest average demand at 92%, indicating its popularity among travellers due to affordability, despite having the lowest average fare of ₹4,000. Business class, with the highest fare of ₹15,030, has a lower demand at 87%, suggesting that while some travellers prioritize comfort and premium services, the higher cost limits its reach. Premium Economy, positioned between the two, has an average fare of ₹8,010 and a moderate demand of 71%, indicating that while it offers a balance between cost and comfort, it appeals to a smaller segment of passengers compared to Economy and Business classes.



Step 1: Applying Littlewood's Rule

The probability of protecting seats from a lower fare class is given by:

where:

$P\ (D_k >> y_k^{j+1}) = \frac{r_{j+1}}{r_k}$

- r_k is the fare of the lower class.
- r_{j+1} is the fare of the higher class.

We then find the corresponding Z-score from the normal distribution table to get the protected fraction.

Step 2: Protection Limit for Premium Economy (y_{12})

We protect Premium Economy seats from Economy bookings:

$P\ (D_{Economy} > y_{12}) = \frac{8010}{4000} = 2.0025$

From the normal distribution table:

- **Z-score for 2.0025 ≈ 2.00**
- **Cumulative probability ≈ 97.72%**
- **Probability of rejection = 1 - 0.9772 = 0.0228**

Since Economy demand is 100% (all 140 seats fill up), we compute the protected fraction:

Protected Fraction = 1−0.9772 = 0.0228

Protected Seats=140×0.9772 = 137 seats

So, 137 seats are protected for Economy, leaving only 3 seats for discounted rate**.**

Step 3: Protection Limit for Business (y_{23})

We protect Business seats from Premium Economy bookings:

$P\ (D_{Premium\ Economy} > y_{23}\ ) = \frac{15030}{8010} = 1.876$

From the normal distribution table:

- **Z-score for 1.876 ≈ 1.88**
- **Cumulative probability ≈ 96.94%**
- **Probability of rejection = 1 - 0.9694 = 0.0306**

Since Premium Economy demand is 100% (all 24 seats fill up), we compute the protected fraction:

Protected Fraction = 1−0.9694 = 0.0306

Protected Seats = 24 × 0.9694 = 23.26 ≈ 23

So, **23 seats are protected for** Premium Economy **class**, leaving only **1 seat for Economy**.

Step 4: Total Protection Limit Calculation

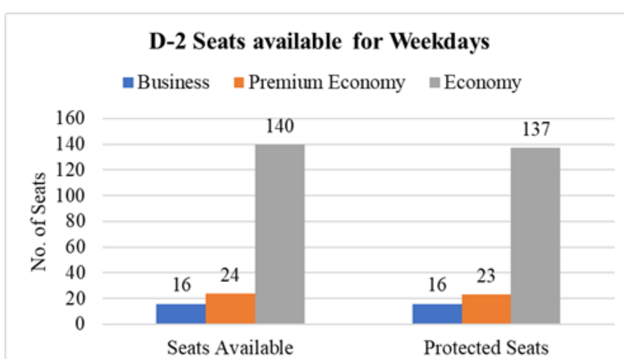
The total protection limits are:

$y_3 = y_{12}+y_{23} = 137 + 23 = 160$

Since the total available seats are **16 (Business) + 24 (Premium Economy) + 140 (Economy) = 180**, we adjust:

Class	Seats Available	Protected Seats	Available for Lower Class
Business	16	16 (fully protected)	0
Premium Economy	24	23	1
Economy	140	137	3

The data indicates that Business class seats are fully protected, meaning all 16 seats are reserved exclusively for Business class passengers, with none available for lower-class upgrades. In Premium Economy, 23 out of 24 seats are protected, leaving just one seat available for Economy class passengers if needed. Economy class has the highest seat count at 140, with 137 protected and 3 available for potential downgrades or adjustments. This setup reflects a strict protection policy for premium seats while allowing minimal flexibility for lower-class passengers to move up if capacity permits.



Thus:

- **All Business seats are fully protected.**
- **Only 1 seat of premium economy is left open for Economy Class bookings.**
- **Only 3 seats are left of economy class with discounted rate Economy bookings.**

EMSRa calculation for Weekends Air India Business Class, premium economy and Economy

T-12 **EMSRa calculation for Weekends Air India Business Class, premium economy and Economy**

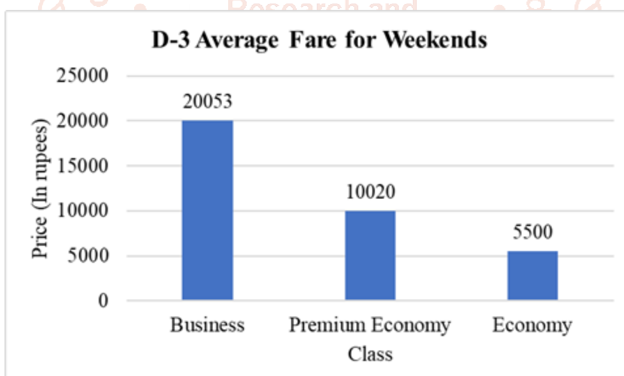
Sr No.	Fair price on Business Class	Demand on Business Class	Fair price on Premium Economy	Demand on Premium Economy	Fair price on Economy	Demand on Economy
1	20500	70%	10200	65%	5400	97%
2	19800	72%	9800	62%	5600	96%
3	20050	74%	10100	66%	5500	98%
4	19900	69%	9950	64%	5450	99%
5	20200	75%	10050	60%	5550	97%
6	19750	68%	10300	67%	5500	100%
7	20100	71%	9900	61%	5600	95%
8	20350	74%	10000	68%	5400	98%
9	20025	73%	10250	69%	5550	97%
10	19850	65%	10150	63%	5450	99%
11	20075	70%	9800	66%	5500	96%
12	19950	67%	10000	62%	5600	100%
13	20150	66%	9950	64%	5400	99%
14	20275	75%	9800	60%	5550	95%
15	19825	72%	10050	65%	5450	98%

We have **three fare classes** with their respective average fares:

T-13 **Three fare classes** with their respective average fares

Class	Average Fare	Average Demand in percentage
Business	20053	71%
Premium Economy	10020	64%
Economy	5500	97%

The data shows that Economy class remains the most in-demand, with a 97% average demand, driven by its affordability at an average fare of ₹5,500. Business class, despite its significantly higher fare of ₹20,053, has a moderate demand of 71%, indicating that while premium travelers value comfort, the high cost limits its reach. Premium Economy, positioned between the two with an average fare of ₹10,020, has the lowest demand at 64%, suggesting that many passengers either opt for the more affordable Economy class or choose to pay a premium for the superior Business class experience.



Step 1: Applying Littlewood's Rule

The probability of protecting seats from a lower fare class is given by:

where:

$P\ (D_k > y_k^{j+1}) = \frac{r_{j+1}}{r_k}$

- ➢ r_k is the fare of the lower class.
- ➢ r_{j+1} is the fare of the higher class.

We then find the corresponding Z-score from the normal distribution table to get the protected fraction.

Step 2: Protection Limit for Premium Economy (y_{12})

We protect Premium Economy seats from Economy bookings:

$P\ (D_{Economy} > y_{12}) = \frac{10020}{5500} = 1.82$

From the normal distribution table:

- ➢ **Z-score for 1.822 ≈ 1.82**

- **Cumulative probability ≈ 96.56%**
- **Probability of rejection = 1 - 0.9656 = 0.0344**

Since Economy demand is 97% (all 140 seats fill up), we compute the protected fraction:

Protected Fraction = 1−0.9656 = 0.0344

Protected Seats=140 × 0.9656 = 135 seats

So, 135 seats are protected for Economy , leaving only 5 seats for discounted rate.

Step 3: Protection Limit for Business (y_{23})

We protect Business seats from Premium Economy bookings:

$P\ (\ D_{Premium\ Economy} > y_{23}\ ) = \frac{20053}{10020} = 2.002$

From the normal distribution table:

- **Z-score for 2.002 ≈ 2.00**
- **Cumulative probability ≈ 97.72 %**
- **Probability of rejection = 1 - 0.9772 = 0.0228**

Since Premium Economy demand is 64% (all 24 seats fill up), we compute the protected fraction:

Protected Fraction = 1−0.9772 = 0.0228

Protected Seats = 24 × 0.9772 = 23.45 ≈ 23

So, **23 seats are protected for Premium Economy Class**, leaving only **1 seat for Economy**.

Step 4: Total Protection Limit Calculation

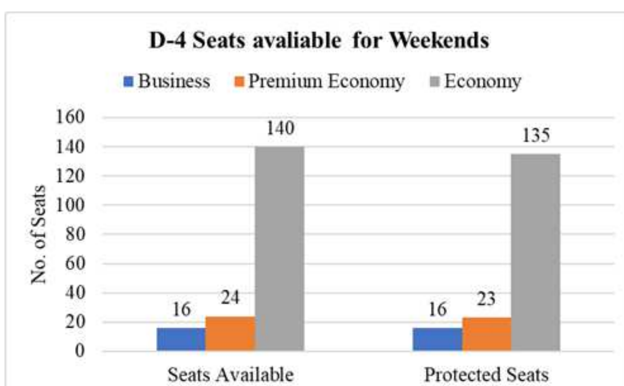
The total protection limits are:

$y_3 = y_{12} + y_{23} = 135 + 23 = 158$

Since the total available seats are **16 (Business) + 24 (Premium Economy) + 140 (Economy) = 180**, we adjust:

Class	Seats Available	Protected Seats	Available for Lower Class
Business	16	16 (fully protected)	0
Premium Economy	24	23	1
Economy	140	135	5

The seat allocation data indicates a strict protection policy for premium seats, with all 16 Business class seats fully protected, meaning none are available for lower-class upgrades. In Premium Economy, 23 out of 24 seats are protected, leaving just one seat available for Economy class passengers if needed. Economy class, with the highest seat count of 140, has 135 protected seats, allowing for some flexibility with 5 seats available for potential downgrades or adjustments. This setup suggests a structured approach to maintaining premium class exclusivity while allowing limited movement for lower-class passengers based on demand and availability.



Thus:

- **All 16 Business Class seats are fully protected**.
- **Only 1 seat of premium economy is left open for Economy Class bookings**.
- **Only 5 seats are available of Economy bookings with discounted rate.**
- **EMSRa ensures revenue maximization** by prioritizing higher-fare passengers, but **may reduce total occupancy** if demand for lower classes is high.

EMSRa calculation for Holidays Air India Business Class, premium economy and Economy

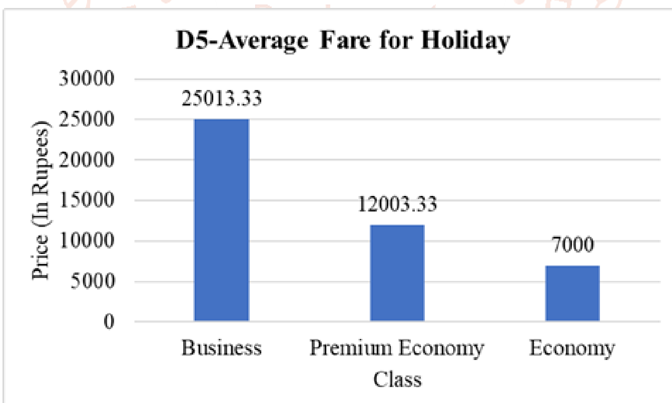
T-14 **EMSRa calculation for Holidays Air India Business Class, premium economy and Economy**

Sr No.	Fair price on Business Class	Demand on Business Class	Fair price on Premium Economy	Demand on Premium Economy	Fair price on Economy	Demand on Economy
1	25200	92%	11850	78%	7100	110%
2	24900	91%	12100	74%	6900	120%
3	24800	94%	11950	76%	7000	100%
4	25100	90%	12200	79%	7050	105%
5	25050	93%	12000	72%	6950	100%
6	24750	95%	11800	80%	7000	120%
7	25025	92%	12050	71%	6900	130%
8	24950	91%	11900	78%	7100	110%
9	25075	90%	12150	75%	6950	100%
10	25150	94%	11850	70%	7050	100%
11	24875	92%	12250	72%	7000	120%
12	25225	90%	12050	78%	6900	100%
13	25000	95%	11950	75%	7100	130%
14	24925	91%	12100	73%	6950	110%
15	25175	93%	11850	77%	7050	100%

We have **three fare classes** with their respective average fares:

Class	Average Fare	Average Demand in percentage
Business	25013.33	92
Premium Economy	12003.33	76
Economy	7000.00	110

The data highlights a significant rise in both fares and demand across all classes, particularly in the Economy class, where demand exceeds full capacity at 110%, likely due to overbooking strategies. With an average fare of ₹7,000, Economy remains the most sought-after option. Business class also shows strong demand at 92%, despite its high fare of ₹25,013.33, indicating a preference for premium travel among high-paying customers. Premium Economy, priced at ₹12,003.33, has a moderate demand of 76%, suggesting that while it offers a balance of affordability and comfort, many travelers either prefer the lower-priced Economy or opt for the fully premium Business experience.



Step 1: Applying Littlewood's Rule

The probability of protecting seats from a lower fare class is given by:

where:

$P\ (D_k > y_k^{j+1}) = \frac{r_{j+1}}{r_k}$

- r_k is the fare of the lower class.
- r_{j+1} is the fare of the higher class.

We then find the corresponding Z-score from the normal distribution table to get the protected fraction.

Step 2: Protection Limit for Premium Economy (y_{12})

We protect Premium Economy seats from Economy bookings:

$P\ (D_{Economy} > y_{12}) = \frac{12003}{7000} = 1.71$

From the normal distribution table:

- **Z-score for 1.71 ≈ 1.71**
- **Cumulative probability ≈ 95.64 %**
- **Probability of rejection = 1 - 0.9564 = 0.0436**

Since Economy demand is 100% (all 140 seats fill up), we compute the protected fraction:

Protected Fraction = 1−0.9564 = 0.0436

Protected Seats=140×0.9564 = 134 seats

So, 134 seats are protected for Economy, leaving only 6 seats for discounted rate.

Step 3: Protection Limit for Business (y_{23})

We protect Business seats from Premium Economy bookings:

$P\ (D_{Premium\ Economy} > y_{23}) = \frac{25013}{12003} = 2.08$

From the normal distribution table:

- **Z-score for 2.08 ≈ 2.08**
- **Cumulative probability ≈ 98.13%**
- **Probability of rejection = 1 - 0.9813 = 0.0187**

Since Premium Economy demand is 76% (all 24 seats fill up), we compute the protected fraction:

Protected Fraction = 1−0.9813 = 0.0187

Protected Seats = 24 × 0.9813 = 23.25 ≈ 23

So, **23 seats are protected for Premium Economy**, leaving only **1 seat for Economy**.

Step 4: Total Protection Limit Calculation

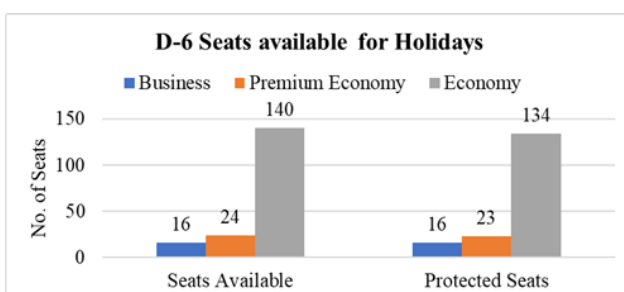
The total protection limits are:

$y_3 = y_{12} + y_{23} = 134 + 23 = 157$

Since the total available seats are **16 (Business) + 24 (Premium Economy) + 140 (Economy) = 180**, we adjust:

Class	Seats Available	Protected Seats	Available for Lower Class
Business	16	16 (fully protected)	0
Premium Economy	24	23	1
Economy	140	134	6

The seat allocation data indicates a firm protection policy for premium seats, ensuring exclusivity for higher-paying passengers. All 16 Business class seats are fully protected, meaning none are available for downgrades. In Premium Economy, 23 out of 24 seats are protected, leaving just one seat available for potential Economy class upgrades. Economy class, with the highest seat count of 140, has 134 protected seats, allowing for some flexibility with six seats available for adjustments. This setup suggests a controlled approach to managing seat availability while maintaining premium class integrity and accommodating slight fluctuations in demand.



Thus:

- **All 16 Business Class seats are fully protected**.
- **Only 1 seat is available for Economy Class bookings**.
- **Only 6 seats are available for Economy bookings** with discounted rate Economy bookings.
- **EMSRa ensures revenue maximization** by prioritizing higher-fare passengers, but **may reduce total occupancy** if demand for lower classes is high.

T-15 Summary Table of Air India Using EMSRa

Weekdays

Class	Seats Available	Protected Seats	Available for Lower Class
Business	16	16 (fully protected)	0
Premium Economy	24	23	1
Economy	140	137	3

Weekends

Class	Seats Available	Protected Seats	Available for Lower Class
Business	16	16 (fully protected)	0
Premium Economy	24	23	1
Economy	140	135	5

Holidays

Class	Seats Available	Protected Seats	Available for Lower Class
Business	16	16 (fully protected)	0
Premium Economy	24	23	1
Economy	140	134	6

4.4.3. EMSR Mumbai to Dubai (Air India)

4.4.3.1 EMSRa calculation for weekdays Air India Business Class, premium economy and Economy

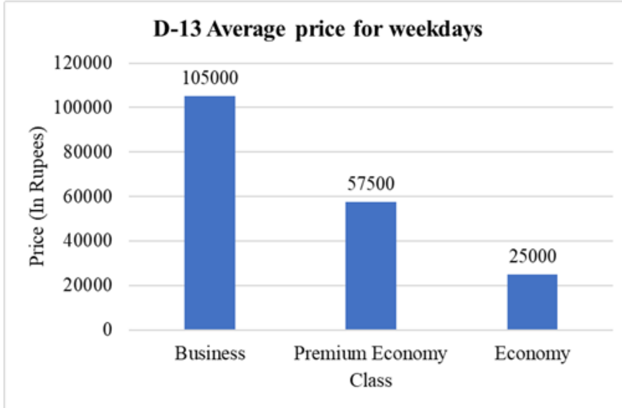
T-20 EMSRa calculation for weekdays Air India Business Class, premium economy and Economy

Sr No.	Fair price on Business Class	Demand on Business Class	Fair price on Premium Economy	Demand on Premium Economy	Fair price on Economy	Demand on Economy
1	1,00,000	80%	55,000	90%	25,000	90%
2	95,000	85%	50,000	92%	22,000	88%
3	1,10,000	78%	60,000	91%	27,000	91%
4	90,000	79%	52,000	89%	20,000	89%
5	1,05,000	82%	65,000	88%	30,000	92%
6	95,000	81%	55,000	90%	23,000	90%
7	1,15,000	80%	60,000	92%	26,000	89%
8	1,00,000	82%	50,000	91%	22,000	91%
9	90,000	78%	63,000	90%	28,000	90%
10	1,10,000	81%	55,000	89%	21,000	88%
11	1,05,000	80%	58,000	91%	24,000	90%
12	1,20,000	79%	50,000	90%	29,000	91%
13	95,000	83%	60,000	92%	20,000	89%
14	1,15,000	80%	52,000	89%	27,000	90%
15	1,00,000	81%	65,000	90%	25,000	92%

We have **three fare classes** with their respective average fares:

Class	Average Fare	Average Demand in percentage
Business	105000	80%
Premium Economy	57500	90%
Economy	25000	90%

The fare and demand data indicate a clear trend where lower-priced classes experience higher demand. Business class has the highest average fare at ₹1,05,000 but a slightly lower demand of 80%, suggesting that premium pricing may limit occupancy. In contrast, Premium Economy and Economy classes, with fares of ₹57,500 and ₹25,000 respectively, both have a higher demand of 90%, reflecting greater affordability and preference among passengers. This pattern highlights the price sensitivity of travelers, with Economy and Premium Economy attracting more passengers due to their relatively lower fares while Business class maintains exclusivity at a higher price point.



Step 1: Applying Littlewood's Rule

The probability of protecting seats from a lower fare class is given by:

where:

$P\ (D_k > y_k^{j+1}\ ) = \frac{r_{j+1}}{r_k}$

- r_k is the fare of the lower class.
- r_{j+1} is the fare of the higher class.

We then find the corresponding Z-score from the normal distribution table to get the protected fraction.

Step 2: Protection Limit for Premium Economy (y_{12})

We protect Premium Economy seats from Economy bookings:

$P\ (D_{Economy} > y_{12}\ ) = \frac{57500}{25000} = 2.30$

From the normal distribution table:

- **Z-score for 2.30 ≈ 2.30**
- **Cumulative probability ≈ 98.93%**
- **Probability of rejection = 1 - 0.9893 = 0.0107**

Since Economy demand is 90% (all 175 seats fill up), we compute the protected fraction:

Protected Fraction = 1−0.9893 = 0.0107

Protected Seats=175×0.9893 = 173 seats

So, 173 seats are protected for Economy, leaving only 2 seats for discounted rate.

Step 3: Protection Limit for Business (y_{23})

We protect Business seats from Premium Economy bookings:

$P\ (D_{Premium\ Economy} > y_{23}\ ) = \frac{105000}{57500} = 1.826$

From the normal distribution table:

- **Z-score for 1.826 ≈ 1.83**
- **Cumulative probability ≈ 96.68%**
- **Probability of rejection = 1 - 0.9668 = 0.0332**

Since Premium Economy demand is 90% (all 25 seats fill up), we compute the protected fraction:

Protected Fraction = 1−0.9668 = 0.0332

Protected Seats = 25 × 0.9668 = 24

So, **24 seats are protected for Premium Economy class**, leaving only **1 seat for Economy**.

Step 4: Total Protection Limit Calculation

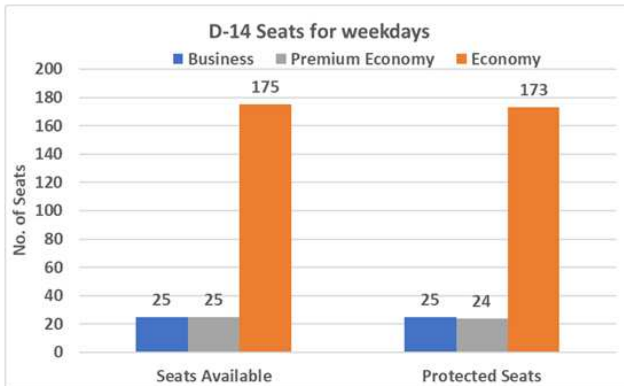
The total protection limits are:

$y_3 = y_{12} + y_{23} = 173 + 24 = 197$

Since the total available seats are **25 (Business) + 25 (Premium Economy) + 175 (Economy) = 225**, we adjust:

Class	Seats Available	Protected Seats	Available for Lower Class
Business	25	25	0
Premium Economy	25	24	1
Economy	175	173	2

The seating allocation shows that in each class—Business, Premium Economy, and Economy—almost all seats are designated as protected, leaving only a minimal number available for passengers from a lower class. In Premium Economy, out of 25 total seats, 24 are protected, leaving just 1 seat open for potential upgrades or reassignments. Similarly, in Economy, 173 out of 175 seats are protected, with only 2 seats available for lower-class passengers. This indicates a highly restricted availability for passengers moving up from a lower class, ensuring that most seats remain reserved for their intended class.



Thus:

- **Business Class seats are fully protected,**
- **24 Premium Economy seats are protected, leaving only 1 for Economy bookings.**
- **Only 2 Economy Class seats are open for bookings.**
- **EMSRa ensures revenue maximization but may reject too many lower-class passengers.**

4.4.3.2 EMSRa calculation for Weekends Air India Business Class, premium economy and Economy

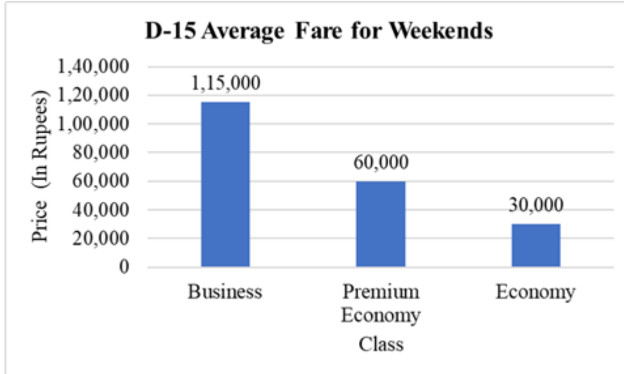
T-21 EMSRa calculation for Weekends Air India Business Class, premium economy and Economy

Sr No.	Fair price on Business Class	Demand on Business Class	Fair price on Premium Economy	Demand on Premium Economy	Fair price on Economy	Demand on Economy
1	1,10,000	90%	60,000	100%	30,000	100%
2	1,25,000	88%	65,000	98%	28,000	98%
3	1,30,000	92%	55,000	99%	33,000	100%
4	1,05,000	89%	70,000	100%	25,000	99%
5	1,15,000	91%	58,000	99%	35,000	101%
6	1,20,000	90%	67,000	100%	29,000	100%
7	1,10,000	89%	55,000	101%	31,000	98%
8	1,05,000	87%	70,000	98%	27,000	100%
9	1,25,000	91%	65,000	100%	34,000	99%
10	1,20,000	92%	60,000	99%	26,000	98%
11	1,10,000	90%	65,000	100%	30,000	100%
12	1,30,000	88%	55,000	100%	33,000	101%
13	1,05,000	89%	70,000	100%	25,000	99%
14	1,25,000	90%	60,000	100%	32,000	100%
15	1,15,000	89%	55,000	99%	29,000	101%

We have **three fare classes** with their respective average fares:

Class	Average Fare	Average Demand in percentage
Business	1,15,000	90%
Premium Economy	60,000	100%
Economy	30,000	100%

The updated fare and demand data indicate strong demand across all classes, with Premium Economy and Economy reaching full occupancy at 100% despite their relatively lower fares of ₹60,000 and ₹30,000, respectively. Business class, while priced significantly higher at ₹1,15,000, also sees a high demand of 90%, suggesting that premium travelers still value comfort and exclusivity despite the cost. The trend highlights that while affordability drives full occupancy in lower classes, even high-priced Business class maintains strong demand, possibly due to corporate or luxury travel preferences.



Step 1: Applying Littlewood's Rule

The probability of protecting seats from a lower fare class is given by:

where:

$P\ (D_k > y_k^{j+1}) = \frac{r_{j+1}}{r_k}$

- r_k is the fare of the lower class.
- r_{j+1} is the fare of the higher class.

We then find the corresponding Z-score from the normal distribution table to get the protected fraction.

Step 2: Protection Limit for Premium Economy (y_{12})

We protect Premium Economy seats from Economy bookings:

$P\ (D_{Economy} > y_{12}) = \frac{60000}{30000} = 2.00$

From the normal distribution table:

- **Z-score for 2.00 ≈ 2.00**
- **Cumulative probability ≈ 97.72%**
- **Probability of rejection = 1 - 0.9772 = 0.0228**

Since Economy demand is 100% (all 180 seats fill up), we compute the protected fraction:

Protected Fraction = 1−0.9772 = 0.0228

Protected Seats=180 × 0.9772 = 176 seats

So, 176 seats are protected for Economy, leaving only 4 seats for Economy with discounted rate.

Step 3: Protection Limit for Business (y_{23})

We protect Business seats from Premium Economy bookings:

$P\ (D_{Premium\ Economy} > y_{23}) = \frac{115000}{60000} = 1.917$

From the normal distribution table:

- **Z-score for 1.917 ≈ 1.92**
- **Cumulative probability ≈ 97.26 %**
- **Probability of rejection = 1 - 0.9726 = 0.0274**

Since Premium Economy demand is 64% (all 24 seats fill up), we compute the protected fraction:

Protected Fraction = 1−0.9726 = 0.0274

Protected Seats = 30 × 0.9726 = 29.18 ≈ 29

So, **29 seats are protected for Premium Economy class**, leaving only **1 seat for Economy**.

Step 4: Total Protection Limit Calculation

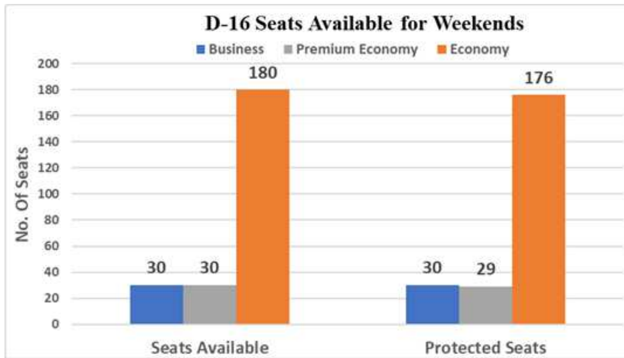
The total protection limits are:

$y_3 = y_{12} + y_{23}$ = 176 + 29 = 205

Since the total available seats are **30 (Business) + 30 (Premium Economy) + 180 (Economy) = 240**, we adjust:

Class	Seats Available	Protected Seats	Available for Lower Class
Business	30	30	0
Premium Economy	30	29	1
Economy	180	176	4

The seating allocation indicates that nearly all seats in each class are protected, leaving very few available for passengers from a lower class. In Premium Economy, out of 30 total seats, 29 are protected, allowing just 1 seat for potential upgrades or reassignments. Similarly, in Economy, 176 out of 180 seats are protected, leaving only 4 seats available for lower-class passengers. This setup ensures that the majority of seats remain reserved for their designated class while allowing limited flexibility for adjustments or upgrades.



Thus:

- **All Business seats are fully protected.**
- **Only 1 seat is available for Economy bookings.**
- **Only 4 seats are available for Economy class with discounted rate Economy bookings**.
- **EMSRa ensures revenue maximization** by prioritizing higher-fare passengers, but **may reduce total occupancy** if demand for lower classes is high.

4.4.3.3 EMSRa calculation for Holidays Air India Business Class, premium economy and Economy

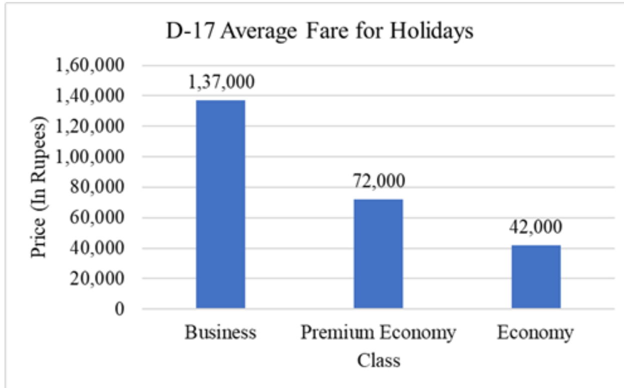
T-22 EMSRa calculation for Holidays Air India Business Class, premium economy and Economy

Sr No.	Fair price on Business Class	Demand on Business Class	Fair price on Premium Economy	Demand on Premium Economy	Fair price on Economy	Demand on Economy
1	1,30,000	100%	70,000	120%	40,000	130%
2	1,45,000	98%	75,000	118%	38,000	128%
3	1,50,000	100%	65,000	120%	45,000	132%
4	1,25,000	99%	78,000	121%	35,000	129%
5	1,40,000	101%	68,000	122%	50,000	135%
6	1,35,000	100%	73,000	120%	42,000	130%
7	1,30,000	102%	66,000	119%	46,000	128%
8	1,20,000	99%	80,000	121%	37,000	132%
9	1,45,000	97%	75,000	120%	48,000	130%
10	1,50,000	100%	70,000	118%	36,000	128%
11	1,35,000	100%	78,000	119%	44,000	130%
12	1,50,000	101%	65,000	120%	47,000	132%
13	1,20,000	100%	80,000	121%	35,000	129%
14	1,45,000	100%	72,000	120%	45,000	130%
15	1,35,000	100%	68,000	118%	42,000	133%

We have **three fare classes** with their respective average fares:

Class	Average Fare	Average Demand in percentage
Business	1,37,000	100%
Premium Economy	72,000	120%
Economy	42,000	130%

The updated fare and demand data show a sharp increase in both pricing and demand across all classes. Business class, now priced at ₹1,37,000, has reached full occupancy at 100%, indicating strong demand despite the high fare. Premium Economy, with a fare of ₹72,000, exceeds capacity at 120% demand, suggesting oversubscription and a need for either capacity expansion or fare adjustments. Similarly, Economy class, priced at ₹42,000, has the highest demand at 130%, highlighting significant excess demand, possibly leading to waitlists or price hikes. This trend suggests a strong market for air travel, with potential opportunities for revenue maximization through dynamic pricing or capacity adjustments.



Step 1: Applying Littlewood's Rule

The probability of protecting seats from a lower fare class is given by:

where:

$P\ (D_k > y_k^{j+1}) = \frac{r_{j+1}}{r_k}$

- r_k is the fare of the lower class.
- r_{j+1} is the fare of the higher class.

We then find the corresponding Z-score from the normal distribution table to get the protected fraction.

Step 2: Protection Limit for Premium Economy (y_{12})

We protect Premium Economy seats from Economy bookings:

$P\ (D_{Economy} > y_{12}) = \frac{72000}{42000} = 1.714$

From the normal distribution table:

- **Z-score for 1.714 ≈ 1.71**
- **Cumulative probability ≈ 95.63 %**
- **Probability of rejection = 1 - 0.9563 = 0.0437**

Since Economy demand is 100% (all 170 seats fill up), we compute the protected fraction:

Protected Fraction = 1−0.9563 = 0.0437

Protected Seats=170×0.9563 = 162 seats

So, 162 seats are protected for Economy, leaving only 8 seats for discounted rate.

Step 3: Protection Limit for Business (y_{23})

We protect Business seats from Premium Economy bookings:

$P\ (D_{Premium\ Economy} > y_{23}) = \frac{137000}{72000} = 1.903$

From the normal distribution table:

- **Z-score for 1.903 ≈ 1.90**
- **Cumulative probability ≈ 97.14%**
- **Probability of rejection = 1 - 0.9714 = 0.0286**

Since Premium Economy demand is 120% (all 30 seats fill up), we compute the protected fraction:

Protected Fraction = 1−0.9714 = 0.0286

Protected Seats = 30 × 0.9714 = 29.14 ≈ 29

So, **29 seats are protected for Premium Economy class**, leaving only **1 seat for Economy**.

Step 4: Total Protection Limit Calculation

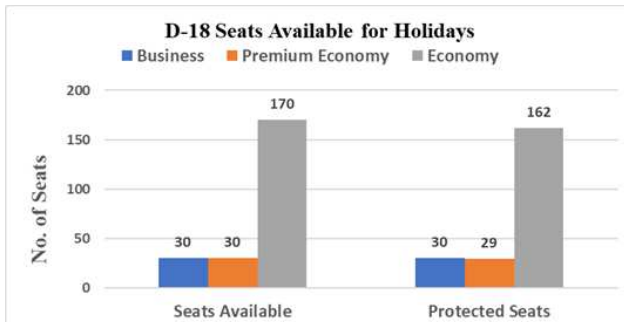
The total protection limits are:

$y_3 = y_{12}+y_{23} = 162 + 29 = 191$

Since the total available seats are **30 (Business) + 30 (Premium Economy) + 170 (Economy) = 230**, we adjust:

Class	Seats Available	Protected Seats	Available for Lower Class
Business	30	30	0
Premium Economy	30	29	1
Economy	170	162	8

The seating distribution shows that most seats in each class are protected, with limited availability for lower-class upgrades or adjustments. Business class has 30 seats, with 29 protected and only 1 available for downgrades or adjustments. Premium Economy offers slightly more flexibility, with 2 out of 30 seats available for lower-class passengers. Economy class, being the largest, has 170 seats, with 162 protected and 8 available for adjustments. This configuration prioritizes protecting reservations while allowing minimal room for accommodating lower-class passengers if needed.



Thus:

- **Business Class seats are fully protected.**
- **Only 1 seat is available for Economy bookings**.
- **Only 8 seats are available for Economy bookings with discounted rate Economy bookings**.
- **EMSRa ensures revenue maximization** by prioritizing higher-fare passengers, but **may reduce total occupancy** if demand for lower classes is high.

T-23 Summary Table of Air India Using EMSRa

Weekdays

Class	Seats Available	Protected Seats	Available for Lower Class
Business	25	25	0
Premium Economy	25	24	1
Economy	175	173	2

Weekends

Class	Seats Available	Protected Seats	Available for Lower Class
Business	30	30	0
Premium Economy	30	29	1
Economy	180	176	4

Holidays

Class	Seats Available	Protected Seats	Available for Lower Class
Business	30	30	0
Premium Economy	30	29	1
Economy	170	162	8

Conclusion

The Expected Marginal Seat Revenue (EMSR) model is a cornerstone of revenue management in the airline industry. It enables airlines to strategically allocate seats across different fare classes, ensuring that higher-paying customers are prioritized while still catering to budget-conscious travelers. The findings demonstrate that EMSR effectively balances the trade-off between load factor (occupancy) and yield (revenue per seat), leading to optimized profitability. However, the analysis also reveals several challenges:

- **Demand Fluctuations:** Demand varies significantly between weekdays, weekends, and holidays, requiring airlines to adopt flexible strategies to manage capacity and pricing.
- **Overbooking Risks:** While overbooking maximizes revenue, it can lead to customer dissatisfaction if not managed carefully.
- **Price Sensitivity:** Travelers are highly price-sensitive, with Economy class being the most in-demand due to its affordability. This underscores the need for dynamic pricing strategies to attract customers across all fare classes.

Implement Dynamic Pricing Strategies:

Use real-time data to adjust fares based on demand fluctuations. For example, during peak periods like holidays, increase fares for Economy class to maximize revenue, while offering discounts for Premium Economy and Business class during off-peak periods to boost demand.

Improve Demand Forecasting:

Invest in advanced data analytics and machine learning tools to improve the accuracy of demand forecasting. This will enable better seat allocation decisions and reduce the risk of overbooking or under booking.

Adopt Flexible Capacity Management:

Adjust the number of seats allocated to each class based on real-time demand. For example, during holidays, allocate more seats to Economy class to meet high demand, while during weekdays, increase the number of Business class seats to cater to corporate travelers.

Enhance Customer Segmentation:

Use customer segmentation to better understand the preferences and behaviors of different traveler groups. For example, target corporate travelers with tailored offers for Business class, while offering budget-conscious travelers discounted Economy class fares.

Refine Overbooking Policies:

Review and refine overbooking policies to minimize the risk of customer dissatisfaction. Consider offering incentives, such as vouchers or upgrades, to passengers who are willing to be rebooked on later flights.

Refine Rebooking Policies

Revenue management has become an essential component of the aviation industry, particularly in highly competitive markets. ICT technologies have significantly enhanced the efficiency of revenue management systems by enabling real-time data analysis, automated pricing, and dynamic seat allocation.

The EMSR model remains one of the most effective tools for optimizing seat inventory and maximizing revenue. The case of Mumbai International Airport demonstrates that ICT-enabled revenue management systems can significantly improve operational efficiency and financial performance.

Future research should explore the integration of artificial intelligence and machine learning with EMSR models to further enhance revenue optimization strategies in the aviation industry.

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