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Optimization of Airline Support Facility Space at Non-Major Airports of India Using Goal Programming

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ABSTRACT

A forecast by the India Brand Equation suggests that the Maintenance, Repair, and Overhaul (MRO) industry will burgeon to US$ 2.4 billion by 2028. This anticipated expansion necessitates the strategic allocation of airport land for essential airline support facilities, which is pivotal in augmenting non-aeronautical revenue. In this study, land allotment practices at twenty-three Indian airports were evaluated against proposed optimization strategies for fuel stations, ground servicing equipment (GSE), hangars, and porta-cabins. Goal Programming was employed to minimize discrepancies in achieving land use and revenue benchmarks. The optimization, considering various constraints, revealed a potential 77% enhancement in area utilization and a 95% increase in revenue. Additionally, a model was formulated to determine the optimal allocation for commercial outlets, utilizing hypothetical data. The findings advocate for land resource optimization at non-major airports, where traditional traffic-based revenue is limited. This paper presents a roadmap for airport operators and policymakers, ensuring efficient resource management amid the aviation sector's growth.

1. INTRODUCTION

According to the Committee of Estimates of the Civil Aviation Ministry in India, as revealed in the Lok Sabha, it was noted that in the fiscal year 2021-2022, only 10 out of the 109 operational airports, which are part of the 136 owned and managed by the Airports Authority of India (AAI), generated revenue [1]. The predominant revenue source for airports internationally, including those in India, is attributed to the air traffic managed, encompassing both aircraft movements and passenger flows. Other sources, such as the allocation of land, space, and additional services, account for a smaller revenue fraction. Within the AAI, it has been reported that aeronautical revenue, including Airport Services and Aeronautical Navigation Services, constitutes 84%, while non-aeronautical streams contribute 16% to the aggregate revenue. This distribution is elaborated in Section 4.3 of the present study. Given the limited air traffic at non-major airports, the urgency to identify and exploit alternative revenue streams is underscored. The optimization of land and space utilization emerges as a strategic approach to bolster the financial profiles of these airports.

1.1 Prior studies and literature

Economic vulnerabilities in regional and small airports are primarily attributed to constrained traffic volumes and limited catchment areas, leading to diminished cash flow dynamics. In contrast to their larger counterparts, which benefit substantially from non-aeronautical services such as car parking fees, smaller facilities face challenges in diversifying income sources [2-6]. The economic impact of these airports on regional development is considerably less pronounced than that of metropolitan or major airports. Empirical data, particularly detailed origin and destination information (OD), are essential for elucidating the nexus between air traffic and economic progression [7].

A Data Envelopment Analysis (DEA) applied to assess the efficiency and economic sustainability of thirty-four Italian airports from 2006 to 2016 revealed insights regarding technical and scale efficiencies [2]. Doctoral research topics, collated from fifty US universities over a decade (2008-2017), indicate growing academic interest in public sector aviation [8]. The significance of physical and social infrastructure in the economic development of airport metropolis regions has been explored, emphasizing the importance of optimizing non-aviation potential for performance evaluation [9, 10].

Forecasts by aviation industry leaders indicated a consistent annual growth in revenue passenger kilometers (RPKs), with Airbus projecting a 4.5% increase and Boeing a 4.8% increase from 2016 to 2035. In 2014, an 8.2% growth in airport revenues was registered, with non-aeronautical sources contributing 46% to the total [11]. Land use compatibility programs developed in collaboration with local communities are instrumental in promoting communal growth and sustainability through aviation [12]. The strategic location of non-aeronautical facilities yields commercial advantages and facilitates effective public transportation service patterns [13].

The success of commercial developments in increasing non-aeronautical revenue has been exemplified by the aero-city project in Indonesia [14]. However, European regional airports confront hurdles in augmenting non-aviation revenue due to the prevalence of low-fare trends and the intensifying competition among airlines and airports [15]. In Spain, the financial difficulties of small airports have been linked to strict aeronautical revenue regulations and lackluster retail promotion [5]. The Airports Authority of India's tariff calculations for airport services at non-major airports were delineated in a consultation paper for the inaugural five-year control period beginning in 2019 [16].

Operations Research techniques have been employed across various facets of aviation, from schedule planning to revenue management and infrastructure optimization [17]. Methodological formulations for economic impact assessments have aided airport operators in decision-making [18]. The evolution and applications of Goal Programming have been extensively documented in scholarly literature [19].

1.2 Research gap

A comprehensive review of the existing literature has revealed a notable absence of studies focusing on the application of Goal or Multi-Objective Programming in the context of land and space allocation for airports. Investigations conducted by international scholars have largely been centered on assessing non-aviation revenue streams of small airports, with particular attention given to infrastructure and revenue quantification methods tailored to local operating conditions. Yet, these studies have not been fully applicable to the distinctive scenario presented by non-major and regional airports within India's extensive geographical terrain. Furthermore, there is a scarcity of research examining the optimal combination of airline support facilities and the use of land for maximizing lease revenue in these airports. This study endeavors to fill this gap by offering new insights pertinent to these underexplored areas.

1.3 Objectives of the study in the context of selected non-major airports in India

The objectives of this study within the framework of selected non-major airports in India are three-fold:

i) To catalogue potential non-aeronautical revenue sources as a component of the total airport revenue stream.

ii) To construct a rudimentary model for determining an optimal allocation of key airline support facilities—namely fuel stations, ground service equipment, hangars/flying schools, and port cabins—within a given area to realize the target lease revenue.

iii) To evaluate the prospective utilization of land leased against the current allocations and ad hoc revenue generation, with the aim of ascertaining whether there has been an enhancement.

2. SOURCES OF REVENUE FOR AIRPORT FROM LEASE

Per the commercial land policy and manuals of the Airports Authority of India [20], a portion of airport land and building space is allotted on lease to about nineteen and twenty-nine activities, respectively (see Table 1).

Out of the nineteen possible options for land and twenty nine for floor area, four essential airline supporting facilities and four passenger supporting facilities were considered respectively for the present study.

2.1 Land

The assessment of an airline's decision-making process regarding the continuation and initiation of new operations at an airport is contingent upon the evaluation of both traffic demand and the responsiveness of airport operators in terms of expanding or constructing new ground facilities. It is imperative to scrutinize the allocation of land for various purposes, with leasing options particularly beneficial for four key facilities: fuel stations, ground servicing equipment (GSE), flying schools or hangars catering to commercial general aviation aircraft/non-scheduled operators (NSOP)/MRO, and porta-cabins. The significance of these allocations is rooted in the following reasons.

2.1.1 Fuel stations

Airlines may opt to fuel their aircraft at specific airport locations based on factors such as convenience, logistics, and economics. Encouraging fuel companies to establish fuel stations at every operational airport becomes crucial to ensure a consistent and reliable fuel supply, especially considering uncertainties such as seasonal changes and emergencies. Additionally, the potential financial benefits for fuel companies can extend beyond aviation fuel by serving regular vehicles, given the strategic locations of airports with good highway access. This diversification can contribute to the financial health of fuel companies, ensuring timely rentals for airport operators. Operational airports universally feature at least one fuel station, with allotment areas across non-metro Indian airports ranging from approximately 400 sq. meters to 7400 sq. meters. Figure 1 below shows a typical fuel station photo.

Figure 1. Fuel station

2.1.2 Ground servicing equipment (GSE)

Various types of GSE, essential for loading and unloading passengers and cargo, towing, auxiliary mobile power, and servicing stationary aircraft, necessitate parking space at airports. While these GSEs are typically parked on the apron's edge, they occupy valuable paved apron space, potentially causing congestion and hindering free movement. Allocating a separate land area, distinct from the main apron, for GSE parking offers a more organized solution with quick access during ground operations. Each GSE unit may require a minimum land area patch of 30 sq. meters, and with the anticipated increase in the number of aircraft and operations, the demand for parking spaces for GSEs is expected to rise significantly. Figure 2 shows a typical ground servicing equipment (GSE) photo.

Figure 2. Ground service equipment (GSE)

2.1.3 Hangars / flying schools for scheduled airlines, non-scheduled operators (NSOP), and cargo

Scheduled airlines and non-scheduled operators (NSOP), including general aviation/charters, establish their bases at metro or major airports, where they station fleet aircraft for daily operations. These aircraft are often parked at remote bays exposed to the sky. Periodic checks, as per stipulated frequency and minor servicing, necessitate hangar sheds. Some State Government Aviation and private agencies run flying schools/academies from hangars at select airports. However, challenges such as high fees, limited student enrollment, restrictions on flying hours at congested airports, and delays in obtaining approvals have hindered these schools from adhering to their pre-decided training schedules. With Indian airline companies placing record orders for additional aircraft to meet forecasted aviation growth, the need for establishing flying training schools at more airports has become apparent. Reports suggest increased Revenue Market forecasts for Ground Handling Agencies (GHA) - INR 39 billion by 2017, General Aviation - INR 16 billion by 2017, and Maintenance, Repair, and Overhaul (MRO) - INR 70 billion by 2020. However, unforeseen reasons, financial constraints, and airline closures have impeded the realization of these projected potentials. Figure 3 below shows a typical aircraft hangar photo.

2.1.4 Porta-cabins

Scheduled and non-scheduled airlines, along with their supporting ground handling agencies, fuel stations, and other aviation-related entities, often require covered office space not available within airport buildings, airside, or cityside. Even if some space can be made available by the airport, it may not meet their specific location and urgency requirements due to higher rental rates. Factory-built or custom-made Porta-Cabins offer an attractive alternative due to their modular design, speed, and ease of placement or relocation as needed by the agencies or the airport.

It is noteworthy that Juhu Airport in Mumbai, handling about 100 small aircraft/NSOPs, including ONGC's offshore helicopter operations, features hangars and Porta-Cabins for approximately 22 NSOP/helicopter operators. Despite no regular operations of commercial airlines, Juhu Airport remains profitable, relying on lease and rentals from land, hangars, Porta-Cabins, and other sources. Therefore, it is recommended to publicize and allocate land for Porta-Cabins at every non-major airport. Figure 4 below shows a typical Porta-Cabin photo.

Figure 3. Aircraft hangers/flying schools

Figure 4. Porta-cabin

2.2 Sources of revenue from space rentals inside the terminal building

The comprehensive breakdown in the right column of Table 1, located under Paragraph 1 in the Introduction section, outlines twenty-nine potential categories of space or floor area allottees/concessionaires within the terminal buildings of Indian airports. Each commercial outlet or concessionaire within this space caters to the diverse needs of passengers during their time in the airport terminal, providing essential products and services. The total floor area of a terminal building is meticulously calculated based on international and domestic norms, prescribed service levels, and the volume of passengers during peak hours of aircraft operations.

Distinct differences emerge between airports handling international operations and those exclusively managing domestic flights, influencing the types, numbers, and locations of commercial outlets. Areas within an airport terminal generally encompass public concourses, departure check-in, secure holds, and arrival sections, tailored to accommodate the flow of departing, arriving, and transiting passengers between the city and air sides.

Table 1. Airport-sources of rental revenue from land lease and covered space (non-aeronautical revenue)

Revenue from Land Lease Outside the Airport Terminal	Revenue from Space Rentals Inside the Airport Terminal
1. Fuel Stations /Petrol Stations outside the operational area for general supply	1. Advertisement inside Terminal Bldg.
2. Non-scheduled operators (NSOP) house & maintaining their small aircraft and helicopters inside	2. Advertisement outside -Airside
3. Flying Training Institutes /Clubs/Schools /organizations -Central & State Govt aided /Edu. Societies/NCC-Private Commercial Organisations	3. Advertisement outside -City side
4. Parking of Ground Handling Vehicles/Ladders /Equipment of Scheduled Airlines	4. Car Parking
5. Maintenance, Repair and overhaul (MROs)	5. Restaurant
6. Cargo Establishments	6. F&B shops
7. Metro Railway	7. TR shops
8. Defence-IAF, Indian Navy, Army, BSF, ICG, NSG, CISF	8. Duty-Free Shop
9. CPWD, MET, Postal, DGCA, BCAS, Customs offices & Requesters	9. Money Exchange
10. Police Station & Electrical Substation	10. Car Rentals
11. Airport Health organization/State Health Dept	11. Radio Taxi
12. State Civil Aviation/Govt Establishment	12. Hotel Booking Counters
13. Porta Cabins for back office, storage of tools & equipment	13. Pharmacist shop
14. ONGC- for Helicopter operations on offshore oil rigs	14 Wellness Centre
15. Academic Schools	15. Baby /Mother Room
16. Hotels	16. Wellness Centre
17. Other commercial establishments	17. Pharmacist shop
18. Airport Construction sites	18. Medical Centre
19. Short & very short-term permission	19. Airline short-term offices
	20. Airline Counters
	21. Non-Scheduled Operators
	22. Helicopter Tourism
	23. CISF/Security office
	24. Immigration offices
	25. Customs offices
	26. Air Intelligence office
	27. Plant Quarantine and Health Office
	28. Railway Reservation office
	29. Tourist Information office

Expression of interest is invited from interested agencies, and open competitive bidding by the airport operator determines the allocation of floor areas to various commercial outlets. These areas are awarded either to the highest individual bidder or a Master Concessionaire. In instances where non-major airports experience minimal and fluctuating aircraft movements, clustering these airports can stimulate interest and responses from potential bidders.

Figure 5. Commercial outlet

The diverse commercial outlets serving passengers within the terminal building, with floor area rentals at notified rates, can be categorized into four main sub-heads: Retail, Food and Beverages (F&B), Offices, and Cab, Bank, and others. Additionally, advertisements predominantly on vertical surfaces inside and outside the terminal and city-side car parking serve as significant revenue-generating outlets. Contracts for these spaces may extend beyond a year, with monthly revenue comprising rent for floor area or a license fee or royalty—a percentage offered by the allottee to the airport operator based on sales.

To illustrate the allocation process and revenue generation from the earmarked floor area for commercial outlets, an Excel-based input utilizing the Goal Programming concept is presented in the subsequent paragraphs. Figure 5 shows a typical commercial outlet photo.

3. RATIONALE OF THE STUDY

As brought out above non-major airports have to explore more in utilising their land resource for enhancing its revenue. There are about nineteen possible sources of non-aeronautical or non-traffic based revenue coming from land rentals/lease at a typical Indian airport as compiled by the author and shown in Table 1. Depending on its location, extent of land that can be spared and the request from the users or airport dependent stakeholders, each airport may be able to offer its land on lease or rent. In this study first four common and essentially sought after facilities are only considered for optimizing with the help of Goal Programming.

4. METHODS

4.1 Use of goal programming for optimization

Caballero, R., Gómez, T., and Ruiz, F., in their paper titled "Goal programming: realistic targets for the near future," assert that Goal Programming (GP) is one of the most widely used multi-criteria decision-making techniques, specifically designed for real applications [19]. To underscore the advantages of Goal Programming over other optimization techniques, a paper titled "Comparison between goal programming and other linear programming methods" was consulted [21]. Unlike general optimization using linear programming, where the objective function can be fully maximized or minimized under certain constraints to achieve the desired outcome, Goal Programming deals with multi-objective optimization. It represents an extension of linear programming tailored to handle conflicting objectives. The optimization process involves minimizing positive and negative deviations from overall set targets when utilizing airport land and space resources under various constraints, including limited area, facilities with varying revenue returns, and a predefined revenue budget. The formulation of objective and constraint functions for Goal Programming was carried out, and the solution was obtained using the Simplex Program method with Excel Solver software. The selection of the number of non-major airports (sample), inputs, outputs, and a typical sample testing of data for one airport were based on the guidelines and challenges mentioned above. While the detailed test tables and outcomes for the other 22 airports are not included in the main manuscript to conserve space, they are available upon request from the author. The summary outcomes for all twenty-three airports are presented in table format in the subsequent paragraphs.

4.1.1 Model used for land lease mix

Knowing the average minimum areas required for each of the four types of facilities, i.e., fuel station, ground service equipment (GSE), hanger/flying school and port cabin, and the land area that can be spared, the airport operator may want to know the mix of numbers of land areas for allotting to the airline operators, fuel agencies or other related agencies.

a) The Assumed variables and equations for the weighted goal programming model are as under:

1. Fuel Station

$$X1 + d1^{-} - d1^{+} \quad (1)$$

2. Ground Servicing Equipment (GSE)

$$X2 + d2^{-} - d2^{+} \quad (2)$$

3. Hanger /Flying School

$$X3 + d3^{-} - d3^{+} \quad (3)$$

4. Porta Cabin

$$X4 + d4^{-} - d4^{+} \quad (4)$$

where, X1, X2, X3, and X4 represent the number of areas of land lease for fuel station, ground service equipment (GSE), hanger, and port cabin, respectively. d1, d2, d3, and d4 represent deviations in the above areas from the target value for the fuel Station, GSE, hanger, and port cabin, respectively. $d1^{-}$ and $d1^{+}$ represent negative and positive deviations from the target values of the number of fuel station areas. A similar interpretation holds good for the other three variables corresponding to the other three types of land lease areas.

b) Defining the goal constraints:

The total number of land lease areas for four types of facilities:

$$X1A1i + X2A2i + X3A3i + X4A4i + d5i^{-} - d5i^{+} = \text{Total Available Area at i airport} \quad (5)$$

A1i represents considered an average area for type 1 (for example, fuel station) facility at the airport i. A similar interpretation holds good for the other three variables corresponding to the three different types of land lease areas. $D5i^{-}$ and $d5i^{+}$ represent the negative and positive deviation from the assumed land area limit at the airport i.

Total land lease revenue for four types of facilities:

$$X1L1i + X2L2i + X3L3i + X4L4i + d6i^{-} - d6i^{+} = \text{Total Lease Revenue at i airport} \quad (6)$$

L1i represents lease revenue for type 1 (Fuel Station) facility at the airport i. A similar interpretation holds good for the other three variables corresponding to the other.

Three types of land lease areas. $D6i^{-}$ and $d6i^{+}$ represent the negative and positive deviation from the assumed land area limit at the airport i.

$$\text{X1 to X4, A1 to A4, L1 to L4, i and d1 to d6} \geq 0 \quad (7)$$

c) The objective function for this weighted goal programming model:

$$\text{Minimize sum of \% deviations or } \text{Min}\sum 1/t\ g[(di^{-} + di^{+}] \quad (8)$$

where, t g is the target value of goal g.

4.1.2 Model used for commercial outlet numbers mix

Knowing the average areas required for each of the four types of commercial outlets, i.e., retail, food and beverages, offices and cab, etc., and the floor area earmarked. An airport operator may want to know the mix of numbers of outlets for allotting for setting up those four types of outlets by the interested agencies or concessionaires.

a) The assumed variables and equations for the weighted goal programming model are given below:

1. Retail

$$X1 + d1^{-} - d1^{+} \quad (9)$$

2. Food & Beverages(F&B)

$$X2 + d2^{-} - d2^{+} \quad (10)$$

3. Offices

$$X3 + d3^{-} - d3^{+} \quad (11)$$

4. Cab etc.

$$X4 + d4^{-} - d4^{+} \quad (12)$$

where, X1, X2, X3, and X4 represent the number of areas for retail, F&B, offices, cab, etc., respectively. d1, d2, d3, and d4 represent Deviations in the above areas from Target value retail, F&B, offices, cab, etc., respectively. $d1^-$ and $d1^+$ represent negative and positive deviations from the target values of the number of retail areas. A similar interpretation holds good for the other three variables corresponding to the three different types of floor area allotments.

b) Defining the goal constraints:

Total Number of Floor Areas for four types of outlets:

$$X1A1i + X2A2i + X3A3i + X4A4i + d5i^- - d5i^+ = \text{Total Earmarked Floor Area at i airport} \quad (13)$$

A1i represents considered an average area for type 1 (for example, Retail) outlet at the airport i. A similar interpretation holds good for the other three variables corresponding to the three different types of floor areas. $D5i^-$ and $d5i^+$ represent negative and positive deviations from the assumed and earmarked floor area limit for commercial outlets at the airport i.

Total Floor Rental Revenue for four types of outlets:

$$X1F1i + X2F2i + X3F3i + X4F4i + d6i^- - d6i^+ = \text{Total Rental Revenue at i airport} \quad (14)$$

F1i represents floor rental revenue for type 1 (for example, Retail) outlet at the airport i. A similar interpretation holds good for the other three variables corresponding to the other.

Three types of floor areas. $D6i^-$ and $d6i^+$ represent the negative and positive deviation from the assumed and earmarked floor area limit for commercial outlets at the airport i.

$$X1 \text{ to } X4,\ A1 \text{ to } A4,\ F1 \text{ to } F4,\ i \text{ and } d1 \text{ to } d6 \geq 0 \quad (15)$$

c) Objective function for this weighted goal programming model:

$$\text{Minimize sum of \% deviations or } \text{Min}\sum 1/t\ g\ [di^- + di^+] \quad (16)$$

where, t g is the target value of goal g.

4.2 Basis, source, and sample for determining the number of non-major airports for study and data collection

The Airports Economic Regulatory Authority (AERA), established in 2009 under the Ministry of Civil Aviation, governs tariffs, fees, and service quality in the aviation sector. Currently, AERA oversees twenty-three major airports, including joint ventures with annual passenger traffic exceeding 1.5 million. Non-major airports, excluding those under joint ventures and entirely operated by the Airports Authority of India (AAI), comprise eighty-three airports.

According to a consultation paper, non-major airports are categorized by passenger traffic as follows:

- Cluster 1 (C1): More than 1 million passengers per annum (MPPA) - 10 airports
- Cluster 2 (C2): Between 0.1 and 1 MPPA - 21 airports
- Cluster 3 (C3): Less than 0.1 MPPA - 52 airports

(Total: 10 + 21 + 52 = 83) - Category A

Deductions include:

- Civil enclaves or defense and joint civil operations - 20
- Airports with no traffic operations - 18
- Airports under the regional connectivity scheme - 20

(Total deductions: 20 + 18 + 20 = 58) - Category B

The remaining number of non-major airports after deductions (A - B = 83 - 58) is 25. Out of these, twenty-three airports were selected for the present study, as depicted in Figure 6 below.

Figure 6. Twenty-three non-major airports of India selected for study (shown in Green)

4.3 Breakup of aeronautical & non-aeronautical revenue of airports authority of India (AAI)

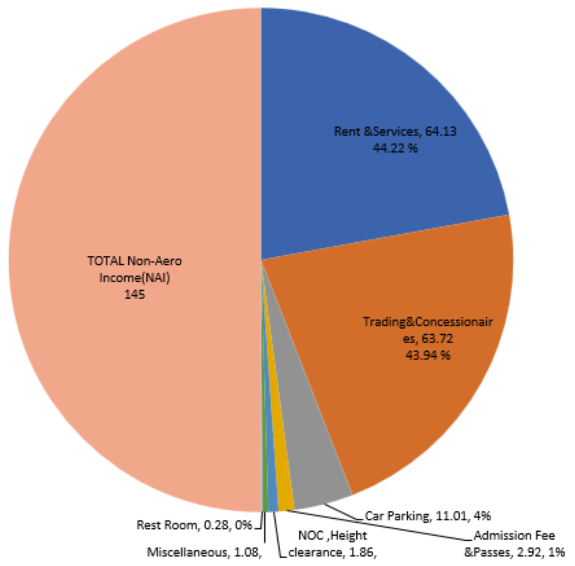

Figure 7. Break up of non-aero revenue of airports Authority of India during 2017-18
(1 US $=70 INR in 2018)

Typically, over 70% of the land at an airport, encompassing the runway, related pavements, and basic strip area, constitutes the operational area. Structures outside this operational area adhere to permissible height criteria outlined by the obstruction surfaces of ICAO and FAA Manuals. As per the

Airports Authority of India [22], excluding joint venture companies, the revenue breakdown (in million INR, with 1 US $ = 70 INR in 2018) is as follows:

- Airport Services: 425.77
- Aero-Navigational Services: 349.53
- Sub-total of Aeronautical Revenue (AR): 775.30
- Non-Aeronautical Revenue (NAI): 145.10
- Total Revenue (TI): 920.40

The contribution of aeronautical revenue (Airport Services + Aero-Navigational Services) and non-aeronautical revenue to AAI's total revenue was 84% and 16%, respectively. Further insight into AAI's non-aero revenue is illustrated in Figure 7. Rent and services, along with trading and concessionaires, collectively contribute 44% to the total non-aeronautical revenue (NAR) and 7% to the overall revenue. Refer to Figure 7 for a detailed breakdown of AAI's non-aero revenue components.

4.4 Model inputs

The analysis included compiling details of aircraft and passenger movements, area of land allotment along with its lease revenue and total revenue for twenty-three non-major airports during 2017-2018 and working out a desirable land lease allotment mix at all those airports for setting up the above four types of facilities by the airline & other supporting operators.

Assuming a hypothetical airport area features for working out a mix of four types of commercial outlet floor areas, i.e., retail, food and beverages, offices and cab, bank, and others, along with their rental revenue within the earmarked floor area of airport terminal building and the corresponding possible maximum rental revenue.

Inputting of above data in the form of an Excel spreadsheet using the Weighted Goal Programming Model and obtaining the optimal mix number of four facilities for each of those twenty-three airports. The increased revenue expected from the new land lease mix allotment model is compared with the existing allotted area to know the enhancement in total revenue.

5. DATA ANALYSIS

5.1 Land lease mix

The assumptions, variables, equations, constraints, and objective function described for the land allotment mix under Para 4.1.1 and building space allotment mix under Para 4.1.2 above are included in the Excel input and output table formats for using Solver analysis as brought out in the following paragraphs.

Weighted Goal Programming input table and Excel Solver have been used for each of the airports, and standard data input and output are described with the help of Table 2 and placed below:

Table 2. Sample excel input & output mix of land leases for applying weighted goal programming model (1 US $=70 INR in 2018)

Airport-Bhopal	**Fuel Station**	**GSE (Ground Servicing Equipment)**	**Hanger/ Flying School**	**Porta Cabin**	**Max Size**	**Max Lease**
Size in sq. Met (either existing or assumed)	*1712*	*30*	*2700*	*30*	*12518*	*32940770*
*Lease per unit (Target value * lease rate /sq. Met)*	*4562480*	*79950*	*7195500*	*10000*		
Lease per sq. (notified by authority)	*2665*	*2665*	*2665*	*333.33*		
	Fuel Station	GSE	Hanger/ Flying School	Porta Cabin	Total Size	Total Lease
Real Value (Calculated from the Model)	**3**	**3**	**2**	**6**	**10806**	**28378290**
Under	1	0	0	0	1194	3621710
Over	0	0	0	0	0	0
Actual Total (Target value + or - Real value	4	3	2	6	12000	32000000
Target Value	***4***	***3***	***2***	***6***	***12000***	***32000000***
Percentage (value under or over) /(target) *100	Fuel Station	GSE	Hanger/ Flying School	Porta Cabin	Total Size	Total Budget
Under	0.25 (B13)	0	0	0	0.0995	0.113178438
Over	0	0	0	0	0	0 (G14)
The weightage (1 for more priority and 0 for less priority)	Fuel Station	GSE	Hanger/ Flying School	Porta Cabin	Total Size	Total Budget
Under	0 (B16)	0	0	0	0	0
Over	1	1	1	1	1	1 (B17)
Objective =SUMPRODUCT (B13:G14, B16:G17)	0					

1. Input variables fed are shown in italic font.
2. The assumed target number of units for each proposed land lease for four facilities is shown in italic bold font.
3. The bold font is used for showing the Real Values after minimizing the deviations from the Target numbers & also satisfying the limits of earmarked area value and corresponding total Revenue.
4. For the assumed target values, weightage, and from the objective function, the actual or output values may be under or over the presumed target at varying magnitudes. However, when the objective function value shows zero, the proposed numbers of each land lease type are satisfied.
5. From the above Real Values, the Model calculates the total land lease area and the lease revenue for the airport.

5.2 Commercial outlet mix

A hypothetical airport terminal has a total floor area of 20000 Excel and an earmarked floor area of 4000 sq. Met for commercial outlets was used. The analysis steps are the same as those from 1 to 4 above.

From the above Real Values, the Model calculates the total floor area and the rental revenue for the airport.

Table 3 shows for each of the twenty-three selected non-major airports, a comparative assessment of allotment of land area and lease revenue possible using the proposed model vs. the existing ad hoc practise of allotment just based on user s requirement. Further, the following observations on data are summarized.

Table 3. Airport-wise total income, passengers, aircraft movements, existing, proposed land lease areas & lease income (1 US $=70 INR in 2018)

Airport	Total Income in a million INR	Pax in million	Acfts in Nos	Old Land Allotment in sq. met	Lease Income at Existing Allotment Total in a million INR	Proposed Land Allotment in sq. met	Lease Income at Proposed Allotment Total in a million INR	Lease Rates /sqm per year in million INR
Shimla	2.8	0.009	526	915.00	0.320	2385.00	0.834	0.0035
Hubli	11.4	0.049	1086	673.00	0.468	4078.00	2.810	0.007
Bhavnagar	13	0.035	2066	2154.00	1.497	5333.00	3.706	0.007
Tuticorin	19.6	0.096	1404	50.00	0.018	3690.00	1.290	0.004
Mysore	20.1	0.02	473	3781.00	5.048	1830.00	2.380	0.013
Khajuraho	25.7	0.056	1015	1606.00	2.377	4948.00	7.250	0.015
Porbandar	33.1	0.042	1241	5019.00	8.733	6109.00	9.890	0.017
Rajahmundry	62.5	0.268	8570	530.00	0.186	11268.00	3.940	0.004
Gaya	103.9	0.186	2439	4258.00	5.344	13554.00	16.440	0.013
Dibrugarh	111.3	0.336	2706	8141.00	2.849	17166.00	6.000	0.004
Aurangabad	139.7	0.334	3758	3117.00	7.216	11992.00	27.280	0.023
Tirupati	151.2	0.584	7181	1248.00	0.867	6326.00	4.350	0.007
Vijayawada	192.9	0.746	11998	5848.00	4.064	13450.00	9.310	0.007
Imphal	215.9	0.987	6737	9435.00	3.302	19136.00	6.698	0.004
Surat	254.8	0.681	10762	12600.00	22.806	13890.00	25.141	0.018
Bhopal	258.3	0.722	7205	5860.00	15.617	10806.00	28.380	0.02665
Dehradun	263.4	1.124	12281	1544.00	0.795	7800.00	3.980	0.005
Vadodara	310.3	1	7338	2912.00	7.760	8764.00	22.930	0.027
Udaipur	401.8	1.147	9842	6448.00	5.255	11380.00	9.190	0.008
Madurai	419	1.442	13578	7312.00	19.340	10779.00	28.230	0.026
Raipur	514.6	1.628	12802	11634.00	10.122	16776.00	14.500	0.009
Indore	624.6	2.269	18692	6225.00	16.660	10932.00	28.990	0.027
Varanasi	889.6	2.087	15658	9052.00	10.138	3893.00	4.360	0.011
Total	**5039.5**			**110362.00**	**150.78**	**216285.00**	**267.88**	

The current (2022) air traffic and revenue figures handled by Indian airports are still behind those of 2018 due to falling traffic levels during COVID times.

1. Annual aircraft movements handled during 2017-18 ranged from 473 to 18692.
2. Passenger movements handled were ranging from 0.009 million to 2.26 million.
3. Reported total revenues ranged from 2.8 million Indian Rupees (INR) to 889.60 million INR.
4. Losses reported ranged from 38.9 million INR to 174.3 million INR.
5. Total land areas of those twenty-three airports ranged from 109 to 1218 acres.
6. Existing land allotment sizes ranged from 50 sq. Met (0.012 acres) to 12600 sq. met (3.11 acres).
7. Revenue from the existing allotment of the land lease ranged from 0.018 million INR to 22 million INR.

Typical sample inputs and results of the number of types of commercial outlets, area & revenue are shown in Table 4, placed below. The interpretation of the different font in this table remains consistent with that provided for Table 2 above.

Input and results of the suggested number of land lease mix for each of the four proposed facilities for each of the selected twenty-three non-major airports are summarized in Table 5 and placed below.

For each of the twenty-three selected airports, their respective ratios of land lease revenue to their total revenue as per the existing allotment and as per the proposed allotment model are furnished in Table 6 and placed below.

For each of the twenty-three airports, similar inputs and analysis as described were applied and twenty three output/result tables were obtained (Tables 7 to 29) but not included here to save space but the same can be sought for reference by contacting the first author whose email is psrksudh@gmail.com.

Table 4. Sample excel input & output mix of commercial outlets for applying weighted goal programming model (1 US $=70 INR in 2018)

Airport- Input	A Mix of Commercial outlet Nos Retail	F&B	Offices	Cab/ATM /Others		
Average Size in sq. Met of area	*Average floor area as taken from observations of six airports*				*Total Area*	*Total Income*
*Average. Income in INR(*0.1million)*	*INR (* area *Rent /sq./month*	*564250*	*457500*	*15250*	*3390*	*5169750*
Average Floor Area Rent - INR/sq. Met/month - 1525/-	Retail	F&B	Offices	Cab/ATM/ Others	Total Area	Total Income
Real Value	**Value from Model**	**3**	**3**	**3**	**3840**	**5856000**
Under	0	0	0	0	160	244000
Over	1	0	0	0	0	0
Real Total	Value from Model Under +Over	3	3	3	4000	6100000
Target Value	***Initially assumed Value***	***3***	***3***	***3***	***4000***	***6100000***
Percentage	Retail	F&B	Offices	Cab/ATM/ Others	Total Area	Total Income
Under %	Under/Target	0	0	0	0.04	0.04
Over %	Over/Target	0	0	0	0	0
Weightage	Retail	F&B	Offices	Cab/ATM/ Others	Total Area	Total Income
Under	1	0	0	0	0	0
Over	0	1	1	1	1	1
Objective Function	Minimize all % deviations using weights 0					

Table 5. Airport wise suggested allotment of land for four types of lease area and for enhancing income using weighted goal programming and excel solver (1 US $=70 INR in 2018)

S.No	Airport	Fuel Station Area in sq. Met	Ground Service Equipment (GSE) Area in sq. Met	Flying School /Hanger Area in sq. Met	Porta Cabins Area in sq. Met	Total Lease Area- sq. Met	Total Airport Land in acres	Total Lease Amount in a million INR	Land Lease Rates (2017-2018) /sq./year INR
1	Shimla	890	30	383	30	2385	109.44	0.834	350
	Units	2	4	1	3				
2	Khajuraho	929	110	2700	30	4948	590.13	7.25	1480
	Units	2	3	1	2				
3	Hubli	463	98	2700	30	4078	957	2.81	695
	Units	2	4	1	2				
4	Porbandar	1394	30	383	30	6109	278.3	9.89	1740
	Units	4	3	1	2				
5	Tuticorin	400	50	2700	30	3690	789.53	1.29	350
	Units	2	2	1	3				
6	Bhavnagar	1600	30	383	30	5333	294.7	3.706	695
	Units	3	3	1	2				
7	Gaya	1600	1058	2700	30	13554	904.46	16.44	1225
	Units	3	3	2	6				
8	Aurangabad	1558	30	2700	30	11992	557.55	27.28	2315
	Units	4	4	2	8				
9	Dibrugarh	4070	30	0	30	17166	403.98	6.0	350
	Units	4	3	2	2				
10	Imphal	4555	30	383	30	19136	1153.4	6.698	350
	Units	4	3	2	2				
11	Tirupati	745	126	2700	30	6326	1044.1	4.35	695
	Units	2	4	1	4				
12	Bhopal	1712	30	0	30	10806	1128.32	28.38	2665
	Units	3	3	2	6				
13	Vadodara	1456	30	2700	30	8764	630.6	22.93	2665
	Units	4	2	1	6				
14	Rajahmundry	1800	116	2700	30	11268	1218.88	3.94	350
	Units	3	3	2	4				
15	Udaipur	2054	348	970	30	11380	536.84	9.19	815
	Units	4	3	2	6				
16	Mysore	400	30	540	30	1830	500	2.38	1335
	Units	3	1	1	2				
17	Surat	400	30	6300	30	13890	784.05	25.141	1810

	Units	3	2	2	2				
18	Vijayawada	1063	1063	2700	30	13450	537.44	9.313	695
	Units	3	7	1	4				
19	Dehradun	700	30	2700	30	7800	326	3.98	515
	Units	3	4	2	6				
20	Raipur	3935	30	383	30	16776	937.71	14.50	870
	Units	4	3	2	6				
21	Madurai	2437	267	0	30	10779	502	28.23	2645
	Units	3	3	3	4				
22	Varanasi	1650	30	383	30	3893	774	4.360	1120
	Units	2	4	1	3				
23	Indore	1338	30	2700	30	10932	729.63	28.99	2665
	Units	4	4	2	2				

Table 6. Airport-wise total income ratio of land lease income to total income as per existing allotment and proposed allotment model (2017-2018, 1 US $=70 INR in 2018)

S.No	Airport	Total Income in a million INR	Land Lease Income as per Existing Allotment Total in a million INR	The Ratio of Land Lease Income to Total Income as per Existing Allotment (D/C)*100 %	Land Lease Income as per Proposed Allotment Model Total in a million INR	The Ratio of Land Lease Income to Total Income as Proposed Allotment Model (F/C) *100 %
1	Shimla	2.8	0.320	11.438	0.834	29.788
2	Hubli	11.4	0.468	4.103	2.810	24.649
3	Bhavnagar	13	1.497	11.516	3.706	28.511
4	Tuticorin	19.6	0.018	0.089	1.290	6.582
5	Mysore	20.1	5.048	25.113	2.380	11.841
6	Khujaraho	25.7	2.377	9.249	7.250	28.210
7	Porbandar	33.1	8.733	26.384	9.890	29.879
8	Rajamundry	62.5	0.186	0.297	3.940	6.304
9	Gaya	103.9	5.344	5.143	16.440	15.823
10	Dibrugarh	111.3	2.849	2.560	6.000	5.391
11	Aurangabad	139.7	7.216	5.165	27.280	19.528
12	Tirupati	151.2	0.867	0.574	4.350	2.877
13	Vijayawada	192.9	4.064	2.107	9.310	4.826
14	Imphal	215.9	3.302	1.530	6.698	3.102
15	Surat	254.8	22.806	8.951	25.141	9.867
16	Bhopal	258.3	15.617	6.046	28.380	10.987
17	Dehradun	263.4	0.795	0.302	3.980	1.511
18	Vadodara	310.3	7.760	2.501	22.930	7.390
19	Udaipur	401.8	5.255	1.308	9.190	2.287
20	Madurai	419	19.340	4.616	28.230	6.737
21	Raipur	514.6	10.122	1.967	14.500	2.818
22	Indore	624.6	16.660	2.667	28.990	4.641
23	Varanasi	889.6	10.138	1.140	4.360	0.490
	Total	5039.5	150.782		267.879	

6. RESULTS AND DISCUSSION

The consolidated findings from the analysis of land lease combinations for four types of facilities (fuel stations, ground service equipment - GSE, hangars, and porta-cabins) using the Goal Programming model [15, 20] and Excel Solver are presented in Tables 5 and 6 as discussed in the preceding section.

1. For each of the twenty-three airports, the land allotment areas ranging from 1830 sq. meters (0.452 acres) to 19136 sq. meters (4.73 acres) would accommodate all four facilities (refer to Table 5) [12].

2. The lease revenue for each airport location, based on notified annual rates per sq. meter, varies from 0.83 million INR to 28.99 million INR (refer to Table 5, with an exchange rate of 1 US $ = 70 INR in 2018).

3. The expected total lease revenue for the land lease areas of all twenty-three airports sums up to 267.88 million INR, covering 216,285 sq. meters (53.45 acres) (refer to Table 5, with an exchange rate of 1 US $ = 70 INR in 2018).

4. The cumulative increase in total land area and revenue, considering the proposed land lease mix for the four facility types, is 95% for land area and 77% for land lease revenue, compared to the existing land allotment revenue at notified rates (refer to Table 6, with an exchange rate of 1 US $ = 70 INR in 2018) [10].

5. Comparing the ratios of land lease revenue to total revenue between the existing allotment and the proposed model, there is approximately a 95% increase in the latter (refer to Table 6, with an exchange rate of 1 US $ = 70 INR in 2018).

6. The analysis incorporates average values for area requirements and average floor rent per sq. meter per month from six airports. Assumptions include a 20% floor area limitation for commercial outlets and corresponding income, forming the basis for the weighted Goal Programming Model.

7. In Table 4 under Para 5, the Solver Model's output of "0" in the Objective Function Cell signifies the successful

minimization of deviations based on the selected weightage for each of the six deviations. The resulting total area is 3,840 sq. meters within the earmarked limit of 4,000 sq. meters, generating total rental revenue of 58.56 lakh Indian Rupees or 5.85 million. Further scenarios can be explored by modifying input target numbers and prioritizing types of allotments, even with minor deviations, without complete depreciation (refer to Table 4, with an exchange rate of 1 US $ = 70 INR in 2018).

8. By adopting the presented methodology and results, the optimal mix of land and space allotments for enhancing revenue from both airport land and space resources can be determined within the given limitations [2, 7, 10].

In a chapter titled "Statistical Methods as Optimization Problems," George Mason University's publication highlights various approaches to accommodate multiple objectives and constraints in optimization problems. The simplest method involves forming a weighted sum, where constraints are incorporated as a weighted component of the objective function, allowing control over the extent to which the constraints are met. In optimization, there often requires interaction between decision-makers and the optimization procedure.

While formulating an optimization problem, careful consideration is essential to ensure it accurately captures the objective of the real problem. The impact of assumptions about the real problem can be magnified in optimization, necessitating caution in both formulating and analyzing the underlying problem. Even when the problem is correctly formulated, difficulties may arise in applying the optimization problem in a statistical method. In contrast to regular regression models, which can be validated using statistical parameters/tests such as sample size, R square, p-values, and assessments of multicollinearity, the validation of multi-objective models like Goal Programming involves addressing practical resource allocation problems under constraints while minimizing deviations from the objective function. The author acknowledges the absence of direct references to specific statistical tests for validating Goal Programming models. Furthermore, emphasizing that interpreting and validating a model solely from a statistical viewpoint may not always be feasible or justified. The above process, including the basis for data (pertaining to twenty-three airports), assumptions, etc., was thoroughly explained in the preceding subsections covering Methods and Data Analysis. The outcomes and validation of the model, presented as an optimal mix of land allotments for each of the twenty-three airports, were summarized in Tables 3 and 6 and discussed above.

7. CONCLUSIONS

With the projected exponential growth in aviation, particularly due to the substantial increase in aircraft fleets and the urgent requirement for establishing flight training and airline supporting facilities, allocating spaces on spare land at every airport becomes imperative. While aviation services are typically demand-driven, operating primarily between major cities, busy airports often have limited space for essential facilities like aircraft servicing hangars, aviation-related training centers, offices, and fuel stations. Given the varying sizes of these facilities across different non-major airports in India, the Model incorporates target values for the potential number of land patches, limits on total lease area, and expected lease rates. Traditional Linear Programming, which aims to maximize a single goal within a single resource constraint, may not be suitable for airports facing limitations and uncertain air traffic conditions. Instead, adopting a flexible approach that minimizes negative and positive deviations from selected goals by adjusting inputs (such as the number of outlets and resulting area and income within the limited space) proves more beneficial for airport operators. This study demonstrates that utilizing the Goal Programming method and comparing land and revenue area allotments with existing practices could result in a 77% increase in area utilization and a 95% increase in revenue outcomes.

8. LIMITATIONS OF THIS STUDY AND SCOPE FOR FURTHER RESEARCH

This paper focuses on sorting, compiling, and modeling data from twenty-three non-major airports out of a total of eighty-three classified by the Ministry of Civil Aviation. Including the remaining airports would broaden the study's scope, allowing for a comprehensive assessment of potential revenue enhancement through land leasing and space renting. The model, utilizing the Weighted Goal Programming approach, calculates the number of units for leasing land to four types of facilities, encompassing both land and building space. For assessing additional revenue from spare land and building space, other frameworks or models, such as dynamic programming, non-linear frameworks, or simulations, could be explored. Future work may involve comparing the results with other multi-objective optimization methods, conducting sensitivity/risk analyses, and considering dynamic traffic and financial factors. Exploring alternate methods will contribute to a more comprehensive understanding of the potential revenue generation at non-major airport.

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