

Railway Service for Airport Connectivity: A Comparative Analysis

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Abstract—The efficiency of airport accessibility is crucial for both passengers and airport operators. This study explores the role of railway services in enhancing airport accessibility, comparing different rail-based systems and their implementation worldwide. Through a methodological approach combining literature review, data collection, and statistical analysis, we examine key factors influencing the choice of railway systems for airport connectivity. The findings indicate that railway connections significantly impact airport preference and competitiveness. Additionally, future trends suggest an increasing number of airport railway connections, emphasizing the importance of integrating sustainable and efficient transport solutions.

Keywords—railway service; airport; accessibility; metro

I. INTRODUCTION

Airport traffic consists of three main components, each with distinct characteristics that must be evaluated by researchers. The first category includes origin and destination passengers, who make a single access trip per flight. The second category comprises airport employees, who commute to and from the airport daily. The third component involves supply, distribution, and commercial activity vehicles, which transport goods and services to and from the airport.

Each of these categories represents at least 20% of the total movements to and from the airport, though this proportion varies depending on local conditions. The significance of passengers in airport access planning is not necessarily related to their numbers but rather to their unique characteristics. Unlike employees and commercial vehicles, who are dispersed across various airport locations, passengers are concentrated in the main terminal. Additionally, passengers are often anxious due to the urgency of catching their flights and, in many cases, their unfamiliarity with the airport layout. As a result, despite being only one part of the overall airport access issue, passenger movement tends to dominate transportation planning and infrastructure considerations.

The primary concern of air travelers is ensuring that they arrive at the airport on time. Reliability of travel time is a crucial factor, as missing a flight can result in serious consequences such as long delays, sometimes extending to the next day, additional costs for ticket replacement or upgrades, and disruptions to planned itineraries, including missed connections or canceled meetings.

In airport access planning, reliability is often more important than speed. To minimize the risk of missing a flight, passengers

tend to allocate extra travel time, effectively accepting a lower average speed in exchange for greater predictability. This trade-off underscores their preference for dependability over rapid transit.

Moreover, transport systems that provide access to only a limited number of locations and lack integration with a broader transit network fail to meet the needs of most airport users. While travel cost remains a relevant consideration in selecting an airport access mode, it is of secondary importance compared to reliability and accessibility.

Rail transport is a land-based mode of mass transportation that operates either electrically or mechanically using steel wheels on a dedicated corridor defined by two parallel tracks. It serves mobility needs across all distances and environments, including urban, suburban, peri-urban, regional, and intercity travel.

As a transportation system, rail is defined by three fundamental components: the railway infrastructure, rolling stock, and operations management. In recent years, there has been significant emphasis on integrating railway connections between airports and the urban centers they serve. In some cases, airports lack the capacity to expand road infrastructure, making railway connectivity the only viable solution. Thus, in many instances, airport railway connections are not merely an option but a necessity to ensure optimal airport utilization.

Railway connections offer several advantages over other modes of transportation. One of the key benefits is their high capacity, allowing for the efficient movement of large passenger volumes. Additionally, railway systems can achieve high speeds, enabling fast access to airports while bypassing road congestion. They also offer a high level of transport safety and operational reliability, with scheduling that remains largely unaffected by adverse weather conditions.

Environmental sustainability is another major advantage, as rail transport produces significantly lower emissions compared to road-based alternatives. Automation in railway operations further enhances efficiency and flexibility in movement. Moreover, train travel contributes to a more comfortable passenger experience, reducing travel stress and uncertainty. Rail services require relatively small land areas for infrastructure while providing high transport capacity and frequent service intervals.

Comparative analyses of door-to-door travel time and cost indicate that under favorable conditions, airport railway systems can be highly competitive with road-based transportation. Several factors influence this competitiveness.

The size of the airport plays a critical role, as larger airports generate sufficient demand to cover operational costs and support frequent service, reducing passenger wait times. The presence of an extensive local rail network also facilitates lower connection costs for integrating the airport into the transport system. Furthermore, seamless connections to a metropolitan public transport network enhance accessibility. Finally, limited airport accessibility by private vehicles—such as in the case of island airports or airports located far from city centers—further increases the necessity and appeal of rail transport solutions.

This study investigates railway services as a means of airport connectivity. The main objectives of the current study are presented below:

- The primary objective is to assess and compare different railway systems that serve airports based on their characteristics.
- The study aims to determine the factors influencing the selection of railway transport as an airport access mode.

The methodology follows three key steps:

- A comprehensive literature review on airport accessibility and railway services.
- Collection and classification of data on existing and planned railway connections to airports using Microsoft Excel.
- Statistical analysis of these connections to identify trends and key influencing factors.

II. IMPORTANCE OF AIRPORT ACCESSIBILITY

The importance of airport accessibility cannot be overstated, as it plays a crucial role in enhancing the overall efficiency of air travel and the economic development of regions. Accessibility to airports significantly influences passenger choice, operational efficiency, and regional growth. The relationship between airport accessibility and passenger behavior is multifaceted and deeply intertwined with urban planning, economic policies, and social inclusivity.

One of the primary factors influencing airport accessibility is the availability and quality of ground transportation options. Liu emphasizes the need for comprehensive studies that link airport ground access with intercity transport connections, suggesting that the environmental and economic impacts of these access modes are critical for future urban planning initiatives [1]. This perspective is supported by Putro et al. [2], who assert that travelers often select airports based on proximity and low access costs, indicating that effective transportation links are essential for enhancing airport attractiveness. Furthermore, Zhu et al. [3] argue that the valuation of airport access time is vital for policymakers, as it directly affects travelers' decisions regarding airport choice and departure timing.

The physical environment of airports also plays a significant role in shaping passenger experiences and satisfaction. Moon et al. identify key elements such as layout accessibility, facility aesthetics, and cleanliness as significant determinants of traveler satisfaction, which in turn influences their overall

travel experience [4]. This is particularly relevant for individuals with disabilities, as Gotti et al. [5] highlight the necessity of inclusive design in airport facilities to ensure that all passengers can navigate the airport environment comfortably. The emphasis on accessibility for diverse user groups, including families with children on the autism spectrum, further underscores the need for airports to adopt inclusive practices that cater to various needs [6].

Moreover, the economic implications of airport accessibility extend beyond individual passenger experiences. Halpern and Bråthen discuss how airports can catalyze regional development by improving accessibility, which in turn fosters economic growth and social development in surrounding areas [7]. This is echoed by Ralphs et al. [8], who explore the impact of small airport accessibility on regional growth in the UK, suggesting that improved access can stimulate local economies and enhance connectivity. The interconnectedness of airport accessibility and regional development is further illustrated by Kisia, who emphasizes the importance of understanding travel patterns and access modes for effective airport planning [9]. In addition to economic considerations, the social dimensions of airport accessibility are crucial for fostering inclusivity and equity in air travel. The need for airports to adapt to the diverse needs of passengers is highlighted by Gotti et al., who argue that accessibility practices should be integral to airport planning and development [5]. This aligns with the findings of Chi, who demonstrates that transport accessibility, including airport access, significantly affects population dynamics across different urban contexts, thereby influencing local demographics and community development [10]. Furthermore, the integration of big data technologies in assessing airport accessibility, as discussed by Shen, provides a more nuanced understanding of how various factors contribute to the overall accessibility landscape [11]. By leveraging data analytics, airport authorities can better plan and implement strategies that enhance connectivity and improve passenger experiences. In conclusion, the importance of airport accessibility is multifaceted, encompassing economic, social, and environmental dimensions. Effective airport accessibility strategies are essential for enhancing passenger experiences, fostering regional development, and ensuring inclusivity for all travelers. As airports continue to evolve in response to changing travel patterns and societal needs, the integration of comprehensive accessibility measures will be critical for their long-term sustainability and success.

The integration of alternative railway systems for airport service represents a critical advancement in enhancing passenger mobility and addressing the challenges of urban congestion. This synthesis will explore various models and frameworks that highlight the significance of air-rail intermodals, the operational challenges faced, and the potential benefits of such systems, drawing on a range of scholarly references. In conclusion, the development of alternative railway systems for airport service is a multifaceted endeavor that requires careful consideration of various operational, environmental,

and technological factors. The successful integration of air and rail transport can lead to significant benefits, including reduced congestion, enhanced economic competitiveness, and improved sustainability. However, addressing the operational challenges and ensuring that the needs of diverse passenger demographics are met will be crucial for the long-term success of these systems. As urban areas continue to grow and evolve, the role of integrated transport solutions will become increasingly important in shaping the future of mobility. Several railway systems cater to airport connectivity, each offering different advantages:

A. Metro

Metro systems operate predominantly underground, ensuring high frequencies and rapid transit. Key characteristics include:

- High passenger capacity.
- Frequent services (2-8 minutes intervals).
- Operational speeds of 30-40 km/h.
- Significant investment costs (~120-170 million EUR/km).

B. Tram

Trams provide an alternative urban transport solution, often integrated with road networks. Characteristics include:

- Lower costs (20-30 million EUR/km).
- Slower speeds (15-25 km/h).
- Suitability for short distances.

C. Suburban Rail

Suburban rail systems connect metropolitan centers with airport terminals, featuring:

- Travel distances of 10-150 km.
- Speeds of 45-50 km/h.
- Investment costs of 8-15 million EUR/km.

D. Monorail

Monorails are often used for short-distance travel within airport premises or between terminals. Their features include:

- Speeds of 25-35 km/h.
- Capacity of 2,000-8,000 passengers/hour.
- Investment costs of 40-60 million EUR/km.

E. High-Speed and Conventional Intercity Rail

High-speed and conventional intercity rail systems connect major cities and airport hubs, featuring:

- Speeds exceeding 200 km/h.
- Investment costs between 80-40 million EUR/km.
- Limited stops (spaced 80-200 km apart).

III. DATA COLLECTIONS AND ANALYSIS

As part of the study's development and for the purposes of analysis and drawing conclusions, a dedicated database was created regarding both existing and planned railway systems serving airports worldwide. The base year of the analysis is 2016 as was considered the date with the most recent data for most of the examined cases. To facilitate better classification and subsequent statistical processing of the data, Microsoft Excel was selected as the most suitable software.

A total of 2,198 data entries were recorded, with each railway system being assigned data according to the following structure:

TABLE I. DATA STRUCTURE FOR EACH AIRPORT RAILWAY SERVICE SYSTEM

Id	Refers to the assignment code.
Airport	The airport that is served by the railway system.
Continent	The continent to which the airport belongs.
Service Location	The primary location is served by the airport (Metropolitan Area Center).
Distance (km)	The distance of the airport from the service location.
Population	The population of the airport's service location.
Country	The country in which the airport is located.
Served Passengers	According to the most recent available data, the total number of passengers served by the airport is available (2016).
Railway Service	The railway system that serves the specific airport.
Railway System	The category of alternative railway systems to which the specific railway service belongs.

A total of 183 railway connections serving 166 airports were recorded across 44 countries and 136 cities. The combined number of passengers served by these airports amounts to 4,679,125,389. Additionally, it was observed that 30 airports are served by two different railway connections, while only one airport benefits from three distinct railway connections. The following figures contribute to the analysis and extraction of conclusions regarding the current state of railway services at airports.

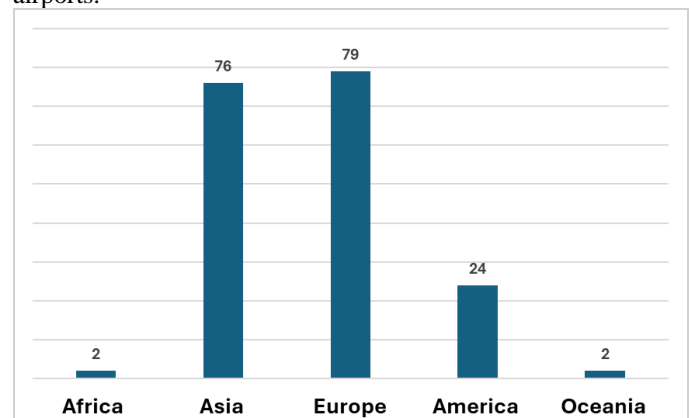


Fig. 1. Total number of airports with railway service by continent.

According to Fig.1, the bar charts illustrate the total number of airports with railway services across different continents. Europe (79) and Asia (76) have the highest number of airports served by rail, whereas America (24) lags significantly behind,

despite its large number of airports. Africa (2) and Oceania (2) have minimal railway connections to airports.

This distribution highlights the strong emphasis on railway integration in European and Asian airport infrastructure. The relatively low number in America suggests that other transportation modes, such as road-based services, dominate airport connectivity. This finding is somewhat unexpected given the high overall number of airports in America, indicating a potential gap in railway integration.

Fig.2 illustrates the distribution of alternative railway systems serving airports.

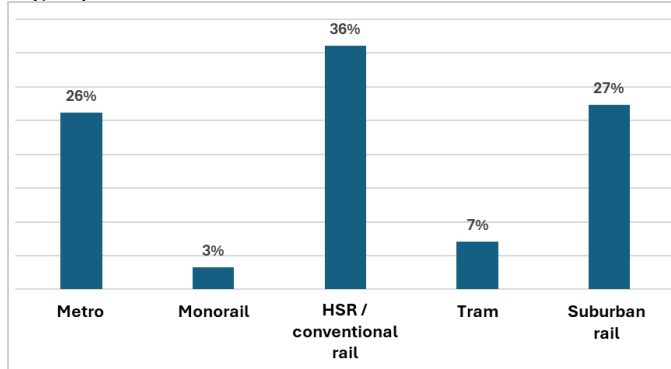


Fig. 2. The distribution of alternative railway systems serving airports.

High-speed and conventional intercity rail accounts for the largest share at 36%, followed by suburban rail at 27% and metro systems at 26%. Trams represent a smaller portion at 7%, while monorail systems account for only 3%.

This distribution highlights the dominance of high-speed and suburban rail services in airport connectivity, while monorails and trams play a minor role due to their lower capacity and operational scope.

Fig. 3 presents the distribution of served passengers (in millions) for airports with railway connections.

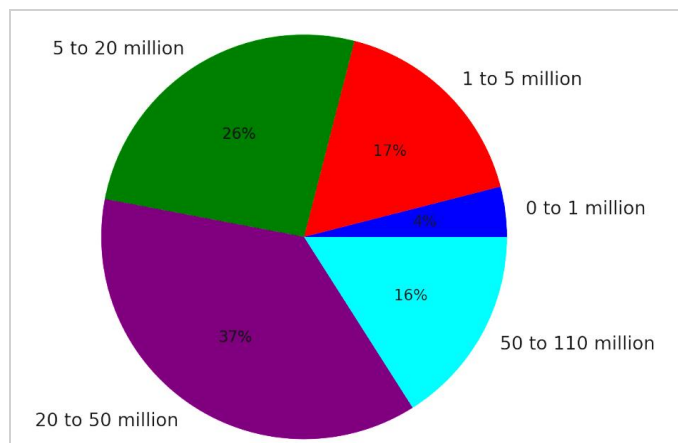


Fig. 3. Distribution of served passengers (in millions) for airports with railway connections.

Most airports fall within the 20 to 50 million passenger range (37%), followed by those in the 5 to 20 million category (26%). Airports serving 50 to 110 million passengers make up

16%, while 1 to 5 million and 0 to 1 million account for 17% and 4%, respectively.

This distribution highlights that most railway-served airports handle a significant number of passengers, reinforcing the importance of railway connectivity in large and medium-sized airports.

Europe is the continent where airport railway services are distributed across a larger number of countries. Notably, a similar pattern is observed in America compared to Asia, despite Asia having significantly more airports with railway connectivity, as mentioned earlier.

Furthermore, a closer analysis reveals that four countries stand out with a particularly high number of railway connections to airports. These countries are China (26), Germany (16), the United Kingdom (15), and Japan (13), highlighting their strong commitment to integrating rail services into airport accessibility infrastructure.

The distribution of Fig. 4 highlights China's significant investment in airport railway integration, while Japan and South Korea also demonstrate strong commitments to rail-based airport access. Other countries have more limited railway connectivity, suggesting a potential area for future infrastructure development.

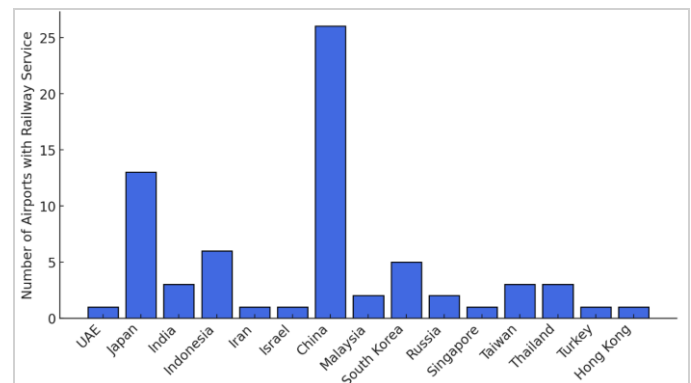


Fig. 4. Total railway service for airports in Asian countries.

According to Table 5, the railway systems serving airports are, on average, 21.75 kilometers away from the center of the metropolitan areas they serve. The shortest average distance is observed when the railway system is a metro, with an average distance of 16.02 kilometers, whereas the longest average distance occurs in the case of suburban rail systems, reaching 25.47 kilometers.

TABLE II. AVERAGE DISTANCE OF AIRPORTS FROM METROPOLITAN CENTERS BY RAILWAY SYSTEM

Railway System	Average Distance From Metropolitan Center (km)
Metro	16.02
Monorail	18.02
Suburban rail	25.47
Tram	16.73
High-speed / Conventional Intercity rail	24.40
Overall average for all railway systems	21.75

These distances indicate that the choice of railway system for airport passenger service is significantly influenced by the airport's distance from the metropolitan center it serves. The relatively high average distance of 21.75 kilometers underscores the necessity of railway connections, as these systems provide fast and efficient transportation, capable of moving many passengers quickly and reliably between the airport and the metropolitan center.

IV. KEY FINDINGS AND RECCOMENDATIONS

It is evident that the railway connection of airports is more of a necessity than a choice to ensure the maximum utilization of airports. The reduction of environmental burdens, improved service times, the ability to accommodate a large number of passengers, and the high reliability of trains within various transportation systems further strengthen this connection.

From the literature review, as well as the analysis and processing of the collected data, several reasonable conclusions have emerged. Airport railway services appear to be a significant factor in airport preference. Many airports are served by more than one railway connection, while railway service is more widespread in Europe and Asia. Additionally, trams and monorails serve airports to a limited extent. Finally, both the number of served airports and their distance from the metropolitan area center cater to be critical factors influencing the selection of railway connections.

According to the findings, a significant increase in airport railway connections is expected in the future. Therefore, it would be beneficial to examine the feasibility of expanding existing railway networks toward airports based on cost-benefit considerations.

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