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Integrating Bus Rapid Transit with Paratransit or Feeder Services: A Systematic Review of Approaches and Outcomes

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Abstract

Urban sprawl is a critical issue, especially given the rapid urbanization transforming megacities worldwide. As metropolitan areas expand and often overlook sustainable development, the growth of low-density, automobile-dependent communities exacerbates several urban challenges. Residents are usually distanced from urban centers and other essential locations, and their reliance on cars increases due to limited access to efficient public transportation. Improving the efficiency of mass public transit networks is vital, and integrated public transport serves as a foundational solution. This review aims to identify current models for integrating paratransit or feeder services with Bus Rapid Transit (BRT) by systematically synthesizing prior research. Three multidisciplinary databases were searched: ScienceDirect, Taylor and Francis, and Transportation Research International Documentation (TRID), focusing on articles published between 2000 and 2024. After eliminating duplicates and irrelevant articles, 68 articles were further screened to assess their alignment with the study objective; 17 met the qualitative review criteria. The key themes in public transportation service quality have shifted from efficiency to user satisfaction and perceptions. However, the literature on public transport integration in developing cities is limited. Therefore, studies should prioritize collecting comprehensive data on real-world travel experiences across multi-modal public transportation, with a focus on first- and last-mile access to transit stations. Aligning fare structures among BRT and other public transport modes will be crucial for evaluating the system's effectiveness. Such studies would yield valuable insights for policymakers and urban planners working to improve urban transport systems.

Subject Areas

Transportation Engineering

Keywords

Bus Rapid Transit, Paratransit, Integration, Efficiency, Multimodal

1. Introduction

Many cities in emerging nations are facing significant transportation challenges, particularly congestion, which leads to longer travel times, increased air pollution, and a higher incidence of accidents. The primary cause of the issue is the exponential expansion in automobile ownership [1]. The rapid growth in motorization increases demand for urban transportation services and infrastructure. Nevertheless, limited resources often prevent city authorities from meeting these needs, especially in megacities and large metropolitan areas [2]. Metropolitan regions are expanding outward, contributing to urban sprawl and longer trips. Frequently, traditional public transportation falls short of serving the entire community or meeting the travel needs of all groups. Furthermore, public transportation is poor and often congested [3]. Public transportation is seen as a viable way to reduce traffic congestion by reducing the number of kilometers vehicles travel. However, the inflexible routes, fixed schedules, limited network coverage, and long waiting times of public transport make it less appealing than cars [4]. The problem of limited coverage gives rise to the first-mile and last-mile (FMLM) issue, particularly in areas with low population density, where public transit is scarce or nonexistent due to economic constraints. Independent operators predominantly provide public transport services in many cities of the Global South. Local names for these services include jeepney (Philippines), trotro (Ghana), car rapides (Senegal), minibus-taxis (South Africa), and matatu (Kenya), highlighting the diverse contexts in which very similar services have evolved [5]-[9]. These services, often referred to as "informal transport" [10] [11], are sometimes mischaracterized as such because many operators hold licenses or are members of legally recognized agencies [9]. According to [12], paratransit is unplanned public transportation provided by small vehicles, such as micro- or minibuses, consistently operated by unregistered, cash-based firms.

Paratransit systems are considered more economical and efficient than other public transportation options in low-density suburban areas [13]. These systems meet the mobility needs of automobile-centric communities by enhancing existing transportation networks. However, an organized system is crucial for managing driver behavior, route allocation, and working conditions. In areas with high demand, they can contribute to traffic congestion and inefficient use of infrastructure. A thorough review of the entire transportation network is necessary to improve efficiency and implement paratransit systems where traditional mass transit is financially unfeasible or insufficient [14]. BRT serves as an economical transit solution that effectively alleviates congestion and addresses various other issues [15] [16]. Many cities in the global North and South have established BRT systems as a mode of public transportation, and others aim to implement similar systems to enhance public transport and address growing transportation challenges. Integrating different modes and feeder services can improve public transport convenience, but last-mile provision is often lacking in newly developed infrastructure that overlays existing informal settlements. In these cases, informal transport services supplement the public transit system by providing quick, cost-effective, on-demand service [16].

First-mile solutions often assume that individuals rely on private vehicles for this part of their journey or for the entire trip due to limited public transport options or a lack of incentives to use existing transit [17] [18]. Research on urban planning and transportation sustainability, improving access to transit networks or shared mobility, can reduce the use of private cars. The proposed solutions include automated micro-mobility systems with lightweight, quick vehicles such as e-scooters, monowheels, bicycles, or skateboards, alongside shared Autonomous Vehicles (AVs) to replace private cars on suburban trips [19]. The demand for effective, seamless public transportation networks has accelerated the implementation of laws that promote public transport integration in cities worldwide. The successful implementation of an integrated public transportation strategy requires the collaboration of numerous entities [20]. Collaboration between paratransit operators and official public transport providers is often necessary to deploy integrated public transport in the Global South [21].

Transport integration refers to using convenient inter-modal facilities to improve connectivity between different forms of public transportation for riders. This approach aims to simplify travel, reduce costs, and minimize potential hassles. An extensive information system enables quick identification and comparison of commuter routes. An organized combination of transportation modes reduces traffic congestion, increases commuter convenience, and enhances efficiency and cost-effectiveness. [22] asserts that integration entails the rapid, beneficial, and cost-effective assembly of services to create comprehensive journeys for commuters from their origins to their destinations. Integrating Non-motorized Transport (NMT) poses greater challenges than motorized transport due to distinct planning and design requirements [23]. This review aims to identify existing methods for integrating Bus Rapid Transit with paratransit or feeder services. To our knowledge, this review is the first to investigate the literature on integrating bus rapid transit (BRT) with paratransit or feeder services. Based on published articles over the years, no single study has developed a model for integrating bus rapid transit with paratransit. The limited number of studies in this area necessitates researchers to investigate how users' experiences in multi-modal networks can be improved by integrating BRT and paratransit systems. The review highlights a significant gap in assessing the impact of such integration, particularly in emerging urban areas. This review is crucial for guiding future research and policy development related to urban transport reform. It underscores the urgent need for more studies on the role of paratransit in multi-modal networks, where its integration with BRT systems could enhance urban mobility and accessibility.

2. Related Works

Historically, developing cities have struggled with a lack of formal transit services. Consequently, paratransit has emerged as the dominant form of mobility in African cities, Latin America, and developing regions of Asia [24]. Cities such as Bogota, Quito, Santiago, Lagos, and Johannesburg have implemented BRT-driven improvements to enhance their existing services [25]. Within a metropolitan area, formal and informal services often fail to coordinate, due to inadequate spatial alignment of routes and transfer opportunities, inconsistent hours of operation, and fragmented fare systems [26] [27]. Accessibility is a scientific principle in transportation planning that strongly influences policy-making decisions [28]. It represents the accessibility of activities from a specific location via a designated transportation system [29]. The benefits of a transit system are evident in its accessibility [30], enabling individuals to engage in various activities that generate socioeconomic value, depending on the level of accessibility provided. The duration of feeder transit passengers remaining in the vehicle is significantly correlated with the length of the shuttle's operating cycle [31]-[33].

[34] proposed a system for assessing transport investments in Latin American cities. The methodology employs the traditional Hansen equation to evaluate accessibility levels in urban environments. The study suggests that accessibility is a crucial criterion for assessing transportation strategies, encompassing urban structure, transportation quality, individual attributes, and economic capacity. [35] examined the effectiveness of feeder-trunk versus direct line configurations in urban public transport systems. The research utilizes analytical modeling to develop transportation networks and conduct policy evaluations. The study highlights the significance of transfer penalties and user wait times in determining the optimal transit framework. The feeder-trunk system is more effective in metropolitan regions due to the economies of density along trunk lines. Similarly, [36] study on the Ant Colony Optimization (ACO) methodology for designing multi-modal feeder networks highlighted the effectiveness of multi-modal networks in reducing costs, enhancing user experience, and lowering total system expenses compared to uni-modal networks. [37] formulated a multi-modal route selection and allocation model for public transportation systems, incorporating performance metrics such as modal use, service efficiency, and fleet deployment. The study reveals that flexible public transport is primarily used for less than 30% of journey distance, serving as a means of access to fixed public transport. The findings indicate that integrating fixed and flexible transportation reduces average waiting times compared to the exclusive use of either mode. A comprehensive multi-modal route selection approach minimizes travel impediments by combin-

ing fixed and flexible public transportation systems. The model is integrated into an agent-based simulation framework for the Amsterdam network. [38] established a flexible transportation service that diversified public transportation routes for consumers with limited mobility, allowing them to reach their starting and ending destinations. The authors defined the demand-responsive bus routing problem (DRBRP) and created a branch-and-price strategy. [39] developed a network flow model that integrates Mobility on Demand (MoD) with transit to enhance social welfare, introducing a tolling mechanism that reduces journey time, costs, and emissions. However, fixed routes, network coverage, and waiting times may lessen the appeal of public transit compared to personal vehicles, despite its sustainability and efficiency.

3. Research Methodology

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines were established, which ensure a thorough, comprehensive, transparent, and reproducible report. [40] presented the PRISMA statement. There are two methods of using PRISMA: meta-analysis and systematic review. The PRISMA statement's primary purpose is to help scholars and practitioners produce clear and complete literature review reports [41]. The PRISMA approach has three primary stages: scanning the literature, evaluating article eligibility, extracting information from selected articles, and preparing an article summary [42].

3.1. Database Selection and Time Frame

To ensure a thorough and comprehensive review of the existing literature, three multidisciplinary databases were searched for relevant scholarly articles: ScienceDirect, Taylor and Francis, and Transportation Research International Documentation (TRID). These databases were selected because they encompass academic articles on transportation and urban studies. The review covered articles published over the past two decades, specifically from 2000 to 2024, to identify the most recent development approaches in earlier studies. This allowed us to consolidate our findings and draw conclusions. In addition, the search was limited to the last 20 years to capture the latest advancements and discussions on integrating Bus Rapid Transit with paratransit. As the world changes, the Bus Rapid Transit (BRT) system has evolved into a modern solution to address traffic congestion, driven by population growth and increasing automobile use. The current changes have created transportation problems in developing cities, suggesting that previous findings may not apply to the current review. This time frame was chosen to ensure the review highlights modern methods and innovations, while recognizing that earlier articles may be less relevant due to changes in the urban mobility system.

3.2. Search Strategy and Methodology

The search strategy was developed using the PICO framework. Population (P) is

Bus Rapid Transit; Intervention (I) is Integration; Comparison (C) is Paratransit or Feeder; and Outcome (O) is to identify existing models for integrating bus rapid transit with paratransit. To find related articles, a single search strategy was used: "Bus Rapid Transit" OR "Fixed Route Capacity Bus" AND "Integration" AND "Paratransit" OR "Feeder Services." These keywords were used to gather articles that address the research question and establish a systematic, reproducible literature selection strategy. The three multidisciplinary databases were searched in November 2024. Only peer-reviewed journal articles were included to capture the methods and results from prior studies on integrating BRT with paratransit services (See Figures 1-3).

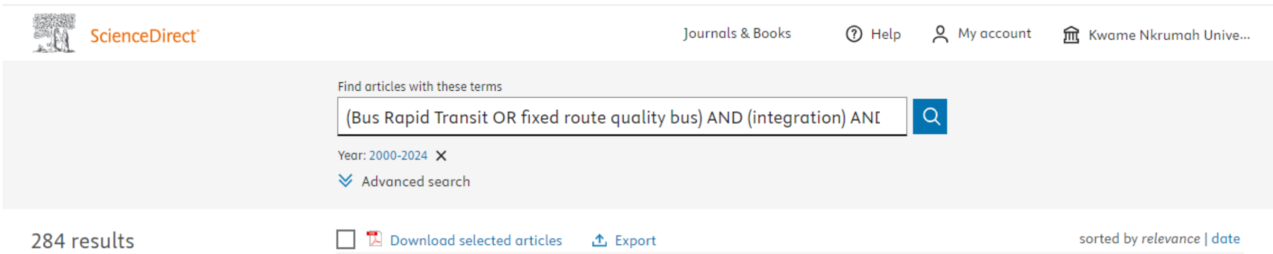

Figure 1. The number of documents accessed on the ScienceDirect database using the search string.

Figure 2. The number of documents accessed on the Taylor and Francis database using the search string.

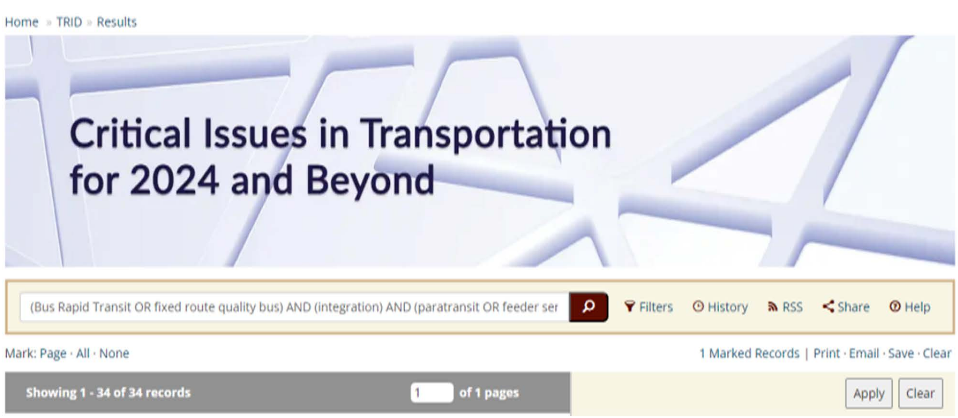

Figure 3. The number of documents accessed on the Transportation Research International Documentation database using the search string.

3.3. Title and Abstract Screening

Our thorough search approach yielded 1121 articles from the selected databases. In the initial investigation phase, duplicate entries were removed, which frequently occur when querying multiple databases. Mendeley was used to eliminate duplicate articles, a highly effective tool for identifying duplicates. A total of 23 duplicate articles were removed; therefore, 1098 articles remained for further screening. After removing the duplicates, the titles and abstracts were screened. At this stage, each reviewer thoroughly examined the abstract and title to exclude articles that did not focus on integrating BRT with paratransit or feeder services. Hence, 1030 articles were excluded at this stage.

3.4. Full-Text Screening and Independent Review

At this stage, the reviewers conducted a more comprehensive assessment of the articles by reading the full text, excluding those that did not align with integrating BRT with paratransit or feeder services. Sixty-eight (68) articles were screened to assess their alignment with the study objective and to select those relevant to the review aim. After a thorough evaluation, we deemed that 17 articles were suitable for the qualitative review. The screening process was carried out independently by two reviewers to ensure reliable and transparent selection. These reviewers worked independently to minimize bias and ensure the final selection process was suitable for studies combining BRT with paratransit or feeder services (See Figure 4).

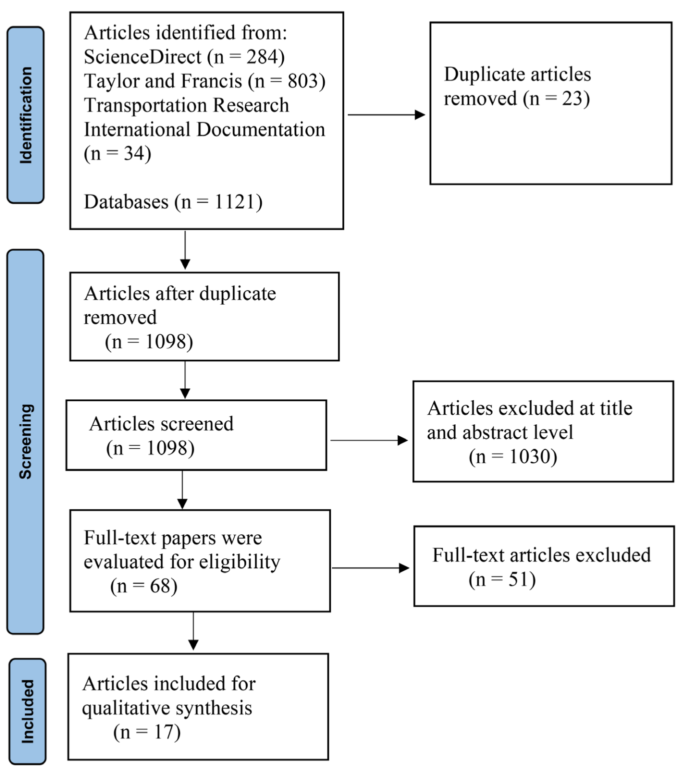

Figure 4. Flow diagram.

4. Classifying Papers Based on Application Domains

The categorization and merging of selected transportation articles is a complicated process. Nonetheless, for this classification and grouping, the experts' advice was relied upon. Consequently, based on the experts' ideas, the articles were categorized into five indicators: autonomous vehicles, ride-sourcing, paratransit, strategies, and structured surveys (See Table 1).

Table 1. Frequency of papers using various indicators.

Category based on indicators	Number of papers	Percentage (%)
Autonomous Vehicles	2	11.76%
Ride-sourcing	5	29.42%
Paratransit	4	23.53%
Strategies	4	23.53%
Structured survey	2	11.76%
Total	17	100%

4.1. Distribution of Paper-Based on Autonomous Vehicles

In recent years, researchers have investigated integrating autonomous vehicles with public transportation. [43] proposed a cohesive autonomous vehicle and public transport system to address Singapore's first-mile challenge during peak hours. They simulated fifty-two scenarios to evaluate the efficacy of the proposed AV-PT service. The study uses an agent-based supply-side simulation to assess the performance of the combined autonomous-vehicle and public-transportation system. The research compares simulated demand with actual usage using root-mean-square error (RMSE) to validate the result. The integrated AV-PT system was shown to improve service quality and optimize bus utilization. It uses fewer roadway resources and is economically viable. In addition, [44] focuses on optimizing a novel hybrid transit system. The research introduces an innovative hybrid public transportation system that utilizes modular autonomous vehicles (MAVs) along a designated base route. The study employed a mixed-integer nonlinear programming (MINLP) method, which was solved using the outer approximation technique. This technique involves relaxing certain conditions and applying a more substantial penalty. The research presents an innovative hybrid public transportation system utilizing modular autonomous vehicles (MAVs) to enhance efficiency. Compared to traditional fixed-route services, the hybrid service markedly decreases customer waiting and walking time expenses.

4.2. Distribution of Paper-Based on Ride-Sourcing

Previous studies have investigated the integration of ride-sourcing. [45] examined an integrated transit system in which ride-sourcing services enhance public transit to improve service quality and reduce costs. It simulates passengers' stochastic mode selection and drivers' zone selection, capturing their interactive decision-making processes. The research clarifies the operational framework of the integrated transportation system and suggests managerial techniques for ride-sourcing services. A 10% - 15% fare subsidy from transit agencies can enhance social welfare and boost transit revenue. With the integrated system, travelers can cut journey time by up to 57%.

The study looked into the integration of ride-sharing and public transportation, with a focus on demand modeling for multi-modal trips. To investigate multi-modal travel alternatives, the researchers used a mixed logit model with error components [46]. Young commuters in Beirut's proposed BRT system choose ride-sharing over regular feeder buses and jitneys. A 50% drop in ride-sourcing fares could increase BRT's market share from 33.53% to 36.89% of all motorized trips. Recent research by [47] developed an optimization model for a combined Mobility on Demand (MoD) and urban transit system to enhance multi-modal transportation efficiency. This model was used to determine transit routes, frequencies, and fleet sizes. The findings indicate that increasing the bus fleet size benefits passenger service levels more effectively than increasing the number of MoD vehicles. The integrated system reduces passenger vehicle wait times and manages demand more effectively than the baseline scenario optimized without it. Sensitivity analysis reveals that increasing the number of buses and vehicles enhances transit share, improves connectivity, and reduces wait times. [48] introduced a flexible transportation concept that combines fixed and demand-responsive transit. The results show that the approach effectively lowers user costs, shortens access times for essential services, and reduces overall expenses, including agency and user fees, even in the context of autonomous vehicles.

[49] study focuses on maximizing accessibility to central transit line stops through feeder services, specifically fixed-route transit (FRT) and demand-responsive transit (DRT) systems. The accessibility formula uses average travel time as the impedance, which is essential for assessing feeder service accessibility. The research finds that the potential accessibility to a central transit line depends on the number of fixed stops for FRT and the number of passengers served during a DRT cycle. The paper concludes that improving first and last-mile connectivity is crucial for increasing public transportation ridership, as many potential users are discouraged by limited access to transit stops.

4.3. Distribution of Paper-Based on Paratransit

[14] investigated the integration of paratransit and public bus systems in Izmir, Türkiye. The study provides a framework for assessing the costs and benefits of merging bus routes with paratransit services. It demonstrates that profit-loss analysis is crucial for assessing the feasibility of bus lines, their integration with paratransit, and the need to incorporate minibus jitneys into public buses to enhance the efficiency of mass transportation. Using minibus jitneys is expected to reduce losses from inefficient public bus routes. [23] investigated the use of rickshaws as

feeder services for Bus Rapid Transit (BRT) systems in Dhaka City to support sustainable transportation. The research employed an empirical approach, highlighting participatory methods and qualitative analysis to promote social sustainability in transportation. The study involved focus group discussions and interviews with key informants to gather insights on BRT station design. It demonstrates that well-designed BRT stations can enable safe transfers between rickshaws and BRT networks. Combining different transportation modes enhances overall efficiency, reduces congestion, and improves passenger convenience.

[50] investigated public transportation integration in Tshwane, South Africa, and proposed a cooperative framework for the paratransit and formal transit sectors. The case study, which tested the framework on two formal public transportation systems, emphasizes the significance of recognizing and addressing the objectives and barriers at the Strategic, Tactical, and Operational (STO) levels to achieve effective integration. It recommends that neglecting these factors can lead to failure. [51] investigated informal transportation services in developing countries, pinpointing last-mile solutions and e-bike taxis in Shenzhen. The study systematically analyzes the spatial distribution of e-bike taxi informal stands (EBT-ISs) around rapid transit stops and villages in the city (ViCs). Data collection involves direct observation and remote sensing imagery from Baidu Maps. The study reveals the spatial characteristics of EBT services and their persistence in Shenzhen, highlighting urban reform on the city's physical form. The findings indicate that EBT services decrease significantly beyond a 1 km distance from rapid transit stops.

4.4. Distribution of Paper-Based on Integration Strategies

Integrating public transport is a way to build sustainable cities worldwide. [52] examined how BRT restructuring affects access and affordability in Johannesburg's transport system. The study revealed that the BRT trunk on the current network improves accessibility by 4% - 5%, and integrated feeder services boost accessibility and net wages by 6%. Furthermore, fare integration is essential for maintaining low-cost access for low-income customers. [53] empirically examined the spatial distribution of transit benefits for public transportation systems using accessibility criteria. The research found that although accessibility benefits have significantly improved in many areas of Seoul due to transport system integration, these benefits are unevenly spread across different locations. The findings highlight the importance of more equitable public transit regulations to address these gaps. [54] studied Mini-Bus Taxi (MBT) feeder service options within South Africa's transportation network. The results show that alternative approaches to corporatizing paratransit services are more affordable and that interventions to improve MBT services require minimal financial support. Similarly, [55] analyze the "first and last mile" (FLM) as a challenge for automated mobility services. The research employs design ethnography to investigate the meanings and practices of local mobility in a Swedish suburb. The study examines the "first and last mile"

(FLM) notion, highlighting the importance of a detailed knowledge of everyday mobility patterns. It emphasizes that mobility extends beyond commuting to include care work and social integration. The study suggests rethinking the FLM challenge through the everyday socialities and competencies of local mobility.

4.5. Distribution of Paper-Based Structured Survey

[56] employed an online survey to investigate movement patterns in New Cairo. The survey was analyzed quantitatively with pivot tables and a multinomial logit model. The study reveals that socioeconomic factors significantly influence the selection of first- and last-mile transportation options. The lack of efficient solutions for these segments harms public transportation ridership. A significant percentage of residents (66%) support improving infrastructure for pedestrians and bicycles. Additionally, [57] explored a similar survey targeting the general population, especially public transport users in Lahore. Structured interviews were conducted with the Punjab Metrobus Authority (PMA) and the Lahore Transport Company (LTC) to gather official data on routes and ridership. The findings reveal a substantial relationship between the number of modes used and the overall fare, underscoring the importance of allowing multi-modal trips. The study emphasized the need for a unified public transport system in Lahore to enhance convenience and efficiency (See **Table 2** and **Table 3**).

Table 2. The articles extracted from the literature.

Criteria	Inclusion	Exclusion
Article type	Journal articles	Conference proceedings, Thesis, Book series
Language	English	Non-English
Timeline	2000-2024	
Subject area	Transportation Engineering	

Table 3. Summary of articles reviewed.

Title	Author(s)/Year	Country	Method
A survey of driver attitudes to evaluate the impact of evening paratransit services on scheduled public transport in Cape Town.	Plano *et al.* (2020)	South Africa	Quantitative methodology
Evaluating the possibilities of bus rapid transit-induced network reconfiguration to facilitate economical access to employment	Venter (2016)	South Africa	Quantitative methodology
Integrating paratransit with regular public transportation: Case studies from Tshwane, South Africa	Mokoma and Venter (2023)	South Africa	Qualitative methodology
Assessing the appropriateness of the integrated public transport system: Lahore case study	Aziz *et al.* (2018)	Pakistan	Quantitative methodology
Modeling demand for ride-sharing as a supplementary service for high-capacity mass transit systems, concentrating on the planned Beirut BRT	Zgheib *et al.* (2020b)	Lebanon	Quantitative methodology

Continued

Integrating transit systems with ride-sourcing services: A study on the stochastic equilibrium problem system users face	Zhang and Khani (2021)	USA	Simulation
Adaptive transit design: Improving fixed and demand-responsive multi-modal transportation with continuous approximation	Calabro *et al.* (2023)	Italy	Simulation
Integrating Bus Rapid Transit Systems with Rickshaws in Developing Urban Areas to Foster Energy-Efficient Transportation	Rahman *et al.* (2012)	Bangladesh	Qualitative approach
Informal transportation is a supplementary mode for the rapid transit system geospatial examination of the e-bike taxi service in Shenzhen, China	Talamini and Ferreira (2019)	China	Field observations and interviews
Towards an integrated transportation system: Initial and terminal mile solutions in underdeveloped countries; a case study of New Cairo	Hussin *et al.* (2021)	Egypt	Quantitative methodology
Automating the initial and final segments of transportation? Reconceptualizing the "challenges" of quotidian mobilities	Brodersen *et al.* (2024)	Sweden	Ethnographic approach and interviews
Incorporating Shared Autonomous Vehicles into the Public Transportation System: A Supply-Side Simulation of Singapore's First Mile Services	Shen *et al.* (2018)	Singapore	Simulation
Assessments of the accessibility of feeder transport services	Chandra *et al.* (2013)	United State	Simulation
The Case of Izmir: Integrating Paratransit Systems with Urban Bus Transportation	Kalpakci and Karatas Unverdi (2016)	Türkiye	Smart card data
Assessing the transit advantages of accessibility through the integration of transit systems	Kim *et al.* (2024)	South Korea	Smart card data
Enhancement of an innovative hybrid transportation system with modular autonomous vehicles	Tang *et al.* (2024)	China	Field data
Designing integrated mobility-on-demand and urban transportation systems	Kumar and Khani (2022)	United State	Bender's decomposition approach

5. Discussion and Conclusions

This systematic review examined studies on integrating Bus Rapid Transit with paratransit or feeder services available in the ScienceDirect, Taylor & Francis, and Transportation Research International Documentation (TRID) databases. The comprehensive review revealed that no existing studies have developed a model for integrating Bus Rapid Transit (BRT) and informal public transport systems (IPT). The focus of public transportation service quality has shifted from efficiency to user satisfaction and perceptions. However, research on integrating BRT with paratransit in underdeveloped areas, particularly in Africa, is limited. The review revealed that four articles address the integration of Bus Rapid Transit in Africa. In many low- and middle-income nations, informal public transportation is the major mode of motorized urban transportation, meeting the mobility needs of city populations. Cities around the globe confront challenges that require immediate and comprehensive improvements to urban transportation. Rapid urbanization, growing automobile ownership, and inadequate transportation planning have exacerbated the effects of climate change and jeopardized public safety, resulting in more traffic-related injuries and fatalities. The absence of inclusive transportation infrastructure can lead to the social and economic marginalization of vulnerable communities, thereby perpetuating inequality.

Bus rapid transit systems have become a cost-effective approach to enhancing public transportation in response to these transportation externalities, particularly in densely populated urban areas. Bus Rapid Transit systems are being established in developed and developing countries to bolster urban transportation infrastructure. These systems provide high capacity, reliability, and efficiency through dedicated lanes and streamlined operations. However, the implementation of BRT has faced significant challenges in many African cities, largely due to well-established paratransit networks. Paratransit services are often seen as competitors to BRT, rather than being integrated into the formal transit framework. This disconnect may hinder the development of integrated, multi-modal transit networks. Therefore, optimizing transit systems in these contexts requires careful planning that involves all relevant stakeholders and incorporates strategies to integrate paratransit into broader urban transport systems. One viable strategy is to form partnerships with informal paratransit providers, as [58] emphasized the importance of collaboration models in enhancing last-mile connectivity and service coverage. Alternatively, introducing local feeder buses that complement BRT lanes could improve accessibility, reduce transfer times, and increase system efficiency.

Prior studies have examined various indicators related to the integration of public transportation networks. These indicators include the use of self-driving cars with ride-sharing services as additional options, the role of paratransit systems, and information gathered through organized interviews with key stakeholders such as transportation operators, policymakers, and commuters. Taken together, these factors provide a comprehensive understanding of the transportation options that can promote mobility in urban contexts. However, there is an urgent need to investigate the relationship between transfer fees, also known as transfer penalties, and the travel behavior of passengers using feeder routes connected to Bus Rapid Transit (BRT) corridors. The alignment of fare structures among BRT and other public transport modes will be essential in evaluating the system's effectiveness. Implementing pricing strategies, such as unified ticketing and complimentary or reduced transfers, can provide significant benefits, especially for low-income commuters who are adversely affected by transportation fares. Transport planners and regulators must consider the influence of fare policy on accessibility and inclusivity. According to [59], fare limits are more than just administrative tools; they are critical to transportation equity. The lack of a cohesive public transportation system has significantly hindered many cities in developing countries from achieving efficient and effective public transportation. In these areas, travelers often need multiple modes of public transport for a single trip. Still, the lack of coordination among these modes frequently results in a fragmented, disjointed experience, making it difficult to transition smoothly from one mode to another. The disconnection between formal and informal public transportation networks in many cities creates inefficiencies in the overall transportation system. In many urban areas of developing countries, formal systems such as BRT operate independently of informal services such as minibuses, taxis, or tricycles. This discontinuity prevents the public transport system from functioning as a cohesive, user-centered network. Integrated public transit fosters a unified travel experience for commuters. This established integration provides travelers with improved simplicity, convenience, comfort, and safety when transitioning between informal and formal transportation modes.

Moreover, inadequate connectivity reduces accessibility. Systems marked by excessive walking distances to transfer points and unexpected waiting times hinder access, particularly in low- and middle-income countries. This lessens the appeal of public transportation, especially in middle-income nations. Coordinating various transportation modes within a multi-modal system offers several advantages, including reduced traffic congestion, greater convenience for commuters, enhanced efficiency, and cost-effectiveness [60] [61]. In addition, there is a lack of longitudinal studies to establish the efficiency and effectiveness of multi-modal transportation systems in developing cities. Therefore, future research involving longitudinal surveys is essential to create an optimization model for a combined BRT and IPT system, thereby enhancing multi-modal transportation efficiency. These studies should prioritize gathering comprehensive data on real-world travel experiences in multi-modal public transport, including access to transit stations, such as walking time, out-of-vehicle waiting time, in-vehicle waiting time, in-vehicle travel time, and associated travel expenses, especially for the mild trip. The studies should focus on capturing users' experience within a multi-modal network and developing models that explore BRT paratransit integration to achieve various mass transit headways, thereby reducing walking and waiting times at stations. Such research would provide valuable insights into how integrated systems could influence overall efficiency, accessibility, and user satisfaction in multi-modal public transportation. It is essential to develop a "multi-modal feeder network" that maximizes the use of each transportation mode.

6. The Future Research and Limitations

New technologies have enabled innovative data collection, providing fresh insights into real-time travel patterns. Studies are necessary to investigate commuters' mobility patterns in a network that lacks integration between BRT and IPT, as well as to assess the potential impact of first and last-mile solutions within a multi-modal mobility system. The goal is to develop frameworks for managing travel demand in a multi-modal context by examining the potential impact of integrating BRT feeder paratransit systems in developing cities. There is a lack of quantitative studies, particularly in developing countries where BRT coexists with paratransit systems. These studies can use travel time surveys in a multi-modal network with first- and last-mile connectivity to transit stations, along with machine learning techniques to explore how integrating BRT paratransit could enhance user convenience, reduce commuting time, and minimize delays that affect system efficiency. These studies can yield a comprehensive understanding of travel behaviour and patterns, which are vital for developing effective and efficient public transit services. Longitudinal studies, which observe trends over extended periods, would improve the robustness and reliability of future research results.

A couple of limitations of this review are worth noting. First, the search was limited to three databases, which might not cover all relevant literature and could have missed studies listed elsewhere or in grey literature. Second, only studies published in English were included, which may introduce language bias and exclude relevant evidence published in other languages.

Conflicts of Interest

The authors declare no conflicts of interest.

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