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Research Article

From Global Models to Regional Solutions: Multimodal Transportation Strategies for Kachchh-Gujarat, India

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ABSTRACT

Amid rapid global shifts in transportation, regional areas like Kachchh, Gujarat face unique mobility challenges due to dispersed settlements and limited infrastructure. This study explores how global multimodal transportation strategies can be adapted to develop a sustainable, efficient, and context-sensitive framework for Kachchh. Using a comparative case study method, the research draws on successful models from Europe, Asia, Australia, America and Africa. The methodology integrates literature review, policy analysis, and synthesis of key performance indicators—ridership, emissions, and connectivity—alongside stakeholder consultations in Kachchh. Rather than employing a traditional control sample, the study benchmarks global best practices and emphasizes innovative approaches such as informal-formal transport integration and demand-responsive services tailored to rural-urban dynamics. Key findings reveal that integrated fare systems boost ridership by 12–18%, Mobility-as-a-Service (M-a-a-S) shifts 15–25% of trips from private vehicles, and Public-Private Partnerships (PPPs) accelerate infrastructure rollout by 30%. Additionally, hybrid transport models improve last-mile access by 20–35%, while Sustainable Urban Mobility Plans (SUMPs) reduce CO_2 emissions by 8–14%. The proposed framework combines state-led infrastructure development with user-centric service models, offering a scalable solution for underdeveloped regions. It aligns with global trends while providing novel insights into regional mobility planning, offering practical guidance for policymakers and transport planners aiming to enhance accessibility, sustainability, and efficiency in similar contexts.

Keywords: Demand-Responsive Services, Global Climate Targets, Multimodal Methods, Regional Mobility, Sustainable Transportation Systems.

1. Introduction

A noteworthy trend in many developed countries is the outward spread of settlements into rural and peri-urban areas surrounding major cities (1, 2). This spatial expansion of housing and commercial activities has led to a growing dependence on private vehicles for daily commuting. As a result, urban centers are increasingly burdened by traffic congestion, limited parking availability, environmental degradation, and mounting pressure on existing transportation infrastructure (3). These challenges underscore the urgent need for a regionally focused transportation strategy that enhances resource efficiency, aligns with diverse activity-based travel needs, and supports integrated infrastructure planning (4).
Transportation systems act as backbone of regional connectivity, enabling the movement of products and individuals across geographically dispersed regions. However, regional mobility encompasses more than just the movement of vehicles—it reflects the ability of individuals to travel seamlessly between scattered origins and destinations using a variety of transport modes (5). In this context, multimodal transportation emerges as a critical solution to address the complex mobility demands of regional populations. Unlike unimodal travel, which relies on a single mode of transport, multimodal systems integrate various options—such as buses, trains, cycling, walking, and private vehicles—into a cohesive network. This integration enables flexible, efficient, and user-friendly travel experiences (6).
At the regional level, multimodal planning emphasizes the coordination of land use and transportation systems to offer inclusive mobility solutions for diverse user groups. It prioritizes connectivity between urban cores and

rural peripheries, ensuring equitable access to essential services, employment opportunities, and recreational activities.
In regions characterized by greater distances and dispersed settlements, such as Kachchh in Gujarat, India, multimodal transportation is especially vital. A regional approach that fosters accessibility, reduces reliance on private vehicles, and promotes sustainable, interconnected networks can significantly enhance quality of life, support environmental goals, and drive economic development.

2. Multimodal Transportation Planning

In a regional setting, the idea of multimodal transportation planning places a strong emphasis on integrating land use and transportation systems to offer a range of mobility options that cater to different user groups' needs. According to [4], "integrated institutions, networks, stations, user information, and fare payment systems" are necessary for multimodal systems to operate effectively. This translates into coordinating transportation services, infrastructure, and policies in urban centres and their environs in regional planning.
Regional networks' transportation planning is a multifaceted process that includes assessing possible approaches, taking into account the opinions of various stakeholders, encouraging cooperation between agencies and organizations involved in transportation, and guaranteeing transparent, timely, and significant public involvement [7]. With dispersed populations and travel patterns that frequently call for a combination of modes like buses, trains, walking, and cycling, this strategy is essential for tackling the particular difficulties of regional mobility.
The seamless integration and use of various modes during the whole trip sequence is a crucial tactic in regional multimodal transportation systems. By lowering dependency on private automobiles, easing traffic, and minimizing environmental effects, this improves sustainability. Active forms of transportation like walking, bicycling, and public transportation are becoming more popular than passive car travel, according to recent transportation policies and trends [8]. This indicates a growing need for more accessible, effective, and ecologically friendly regional public transportation services.
A variety of demographic groups are being targeted by initiatives to encourage active travel, such as the general working population through workplace interventions [9], children and adolescents [10], and older adults [11]. These programs emphasize how crucial it is to incorporate active transportation options, like bicycling and walking, into regional transit systems. For example, using walking and cycling as first- and last-mile options can increase accessibility and promote active, healthy lifestyles for people of all ages.
Furthermore, new possibilities for optimizing regional multimodal systems are presented by developments in predictive modelling techniques. Planners can create systems that better serve the needs of a variety of populations by using high-accuracy predictions of the modes of transportation that people will choose [6]. The significance of regional public transportation systems that incorporate walking and cycling options is further highlighted by addressing sedentary lifestyles, which have an impact on individuals of all ages. These solutions have the potential to significantly influence the development of regional transportation networks that are inclusive, sustainable, and health-promoting.

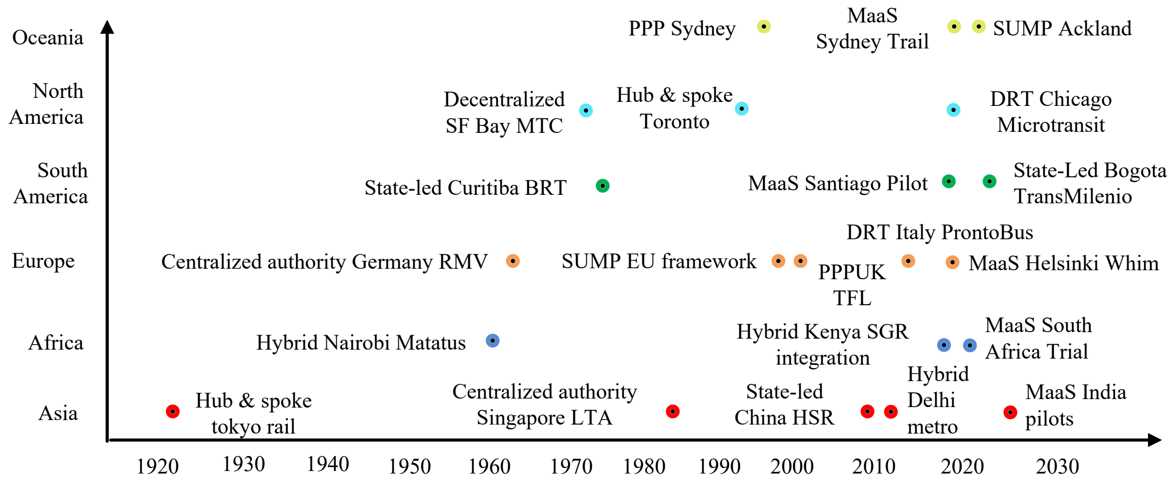

Figure 1. Timeline for the development of regional multimodal public transportation models used continent wise.

In conclusion, through the smooth integration of multiple modes of transportation, regional multimodal transportation planning places a high priority on sustainability, accessibility, and inclusivity. Regions can create creative solutions that address changing mobility needs and encourage healthier and more sustainable travel habits by emphasizing active transportation and utilizing cutting-edge planning techniques. **Figure 1**. Shows timeline for the development of regional multimodal public transportation models used continent wise.

3. Literature review

3.1. Africa

Seven studies in the literature on multimodal transportation in Africa emphasize the critical role that informal-formal hybrid systems play in meeting regional mobility needs, especially in urban areas like Nairobi, Lagos, and Lome. [12] And [13] highlight the integration of minibuses (like matatus) with formal rail and bus rapid transit (BRT) systems in Kenya, citing their affordability and wide coverage as advantages. But safety issues and regulatory gaps still exist, so policy changes are needed to close the gap between the formal and informal sectors [14]. Examines motorcycle taxis as a last-mile option in Cameroon, emphasizing their versatility while drawing attention to data and safety issues. Likewise, [15] in Togo find robust unofficial networks that combine buses and motorcycles, but cooperation with formal systems remains weak. **Table 1** shows Multimodal transportation model used for African Region.

In order to improve regional connectivity, broader African studies, such as those that concentrate on inclusive development and rail renaissance, integrate road and rail modes. Funding and cross-border coordination challenges confront these initiatives [16]. Nigeria's contributions, such as those in Lagos and Osun State, demonstrate a variety of modes (rail, buses, and ferries) and sustainable land-use planning; however, scalability is constrained by infrastructure deficiencies [17]. Although technology adoption is still a barrier, [18] introduce Mobility-as-a-Service (MaaS) in South Africa, integrating buses, ride-hailing, and rail to improve accessibility. All things considered, research from Africa shows a reliance on hybrid models, which have advantages in flexibility but disadvantages in infrastructure investment and regulation.

Table 1. Multimodal transportation model used for African Region

Country	Region	Modes Integrated	Model Used	References
Kenya	Captown	Minibuses, BRT, Rail	Informal-Formal Hybrid	Plano and Behrens (2022)
Kenya	Nairobi	Minibuses, BRT, Rail	Informal-Formal Hybrid	Behrens et al. (2017)
Cameroon	Nationwide	Motorcycle Taxis, Buses	Informal-Formal Hybrid	Kemajou et al. (2019)
Togo	Lomé	Motorcycles, Buses	Informal-Formal Hybrid	Olvera et al. (2015)
S. Africa	Nationwide	Buses, Ride-Hailing, Rail	MaaS	Bouraima et al. (2023)
Nigeria	Lagos	Buses, Ferries, Rail	Decentralized Municipal	Alcorn and Karner (2021)
Kenya	Nairobi	Minibuses, Rail	Informal-Formal Hybrid	Alcorn and Karner (2021)
S. Africa	Limpopo	Motorcycle Taxis Minibuses	MaaS	Enoch and Potter (2023)

3.2. Asia

With case studies from China, Japan, India, and Singapore, the six papers that make up Asia's multimodal transportation literature show a combination of technological innovation and state-led scalability. China's high-speed rail integration with buses is examined [19], they point out that rapid scalability is a strength, despite the persistence of coverage gaps in rural areas. In their analysis of Tokyo's hub-and-spoke rail-bus system in Japan [20] researchers have pointed out that it was effective at connecting hubs, high maintenance costs are a drawback. The investigation of the informal-formal hybrids mode in India that mixes buses, metro and auto rickshaws showed the importance of adapting to road conditions and rules in towns [21]. **Table 2** shows Multimodal transportation model used for Asian Region.

Table 2. Multimodal transportation model used for Asian Region

Country	Region	Modes Integrated	Model Used	References
China	Beijing-Shanghai	High-Speed Rail, Buses	State-Led	Chen and Haynes (2017)
Japan	Tokyo	Rail, Buses	Hub-and-Spoke	Huang et al. (2018)
India	Nationwide	Autorickshaws, Metro, Buses	Informal-Formal Hybrid	Badami and Haider. (2007)
Sinapore	Asia-Wide	Rail, Road, Buses	Demand-Responsive Transit	Iliopoulou and Kepaptsoglou (2019)
Multiple	Asia-Wide	Buses, Rail, Shared Mobility	Centralized Authority	Alumur, S et al. (2012)
Multiple	Asia-Wide	Rail, Road, Shared Mobility	State-Led	Yamamoto and Talvitie (2011)

Although it mainly relies on technological infrastructure, Singapore's technological advantage is demonstrated in this study, which examines dynamic rerouting across buses, rail, and road, demonstrating efficiency through real-time data [22]. In addition to focusing on connectivity and optimization, broader Asian studies on regional multimodal hubs, cargo-passenger network optimization, and infrastructure improvement (rail, road, and buses) also highlight equity and complexity issues [23]. Asia is included in a global review of digital twins for decarbonization [24], which suggests that implementation costs will limit the technological potential. The literature from Asia emphasizes state-led and hub-based models, which have advantages in terms of scale and innovation but disadvantages in terms of equity and access in rural areas.

3.3. Oceania

The six studies in Oceania, which are mostly from Australia and New Zealand, concentrate on demand-responsive transit (DRT) and multimodal integration using cutting-edge models like MaaS. **Table 3** shows Multimodal transportation model used for Oceanian Region. Although funding sustainability is a concern, Brisbane's BRT, bus, and rail systems were examined, with emphasis placed on urban-regional linkage and adaptability as strengths [25]. While cycling and walking were added in Adelaide [26], demonstrating the synergy of active transport, trams, buses, and rail were integrated in Melbourne [27], with emphasis placed on suburban connectivity; both face infrastructure and coordination challenges. Note the equity-promoting rail-bus integration in Perth, which is constrained by expansion expenses. Sydney was highlighted public-private partnerships (PPPs) for buses and metro were investigated with private innovation utilized [28] , and MaaS was tested with shared mobility and transit, providing flexibility but posing privacy concerns [29]. In Auckland, buses and ferries were integrated [30], with benefits gained from ticketing integration but scalability constraints encountered due to coastal geography. With rural reach gaps and urban connectivity strengths, innovation and integration are prioritized in Oceania's research

Table 3. Multimodal transportation model used for Oceanian Region.

Country	Region	Modes Integrated	Model Used	References
Australia	Brisbane	BRT, Buses, Rail	State-Led	Currie. (2006)
Australia	Adelaide	Buses, Cycling, Walking	State-Led	Pang et al. (2017)
Australia	Melbourne	Trams, Buses, Rail	Centralized Authority	Shiwakoti et al. (2019)
Australia	Sydney	Metro, Buses	PPP	Siemiatycki (2009)
Australia	Sydney	Metro, Buses, Shared Mobility	Public-Private Partnership (PPP)	Smith et al. (2023)
New Zealand	Auckland	Buses, Ferries	Centralized Authority	Chowdhury et al. (2018)

3.4. Europe

The ten papers from Europe show a developed research environment with a focus on technology-driven solutions, Sustainable Urban Mobility Plan (SUMP), and centralized authority. **Table 4** shows Multimodal transportation model used for European Region. In Germany, it was noticed that the Verkehrsverbund's integration of buses, trains, and trams, provided smooth travel but comes at a high operational cost [31]. Although public engagement and implementation vary, Sweden's SUMP focus was clear [32], integrating buses and rail for green adoption and quantifiable outcomes. While it was suggested to implement DRT micro transit in rural areas, improving connectivity with scalability challenges in Denmark [33] . In the United Kingdom, the PPP model for buses, rail, and the Tube was examined in order to achieve a balance between innovation and control [34].

Table 4. Multimodal transportation model used for European Region

Country	Region	Modes Integrated	Model Used	References
Germany	Rhein-Main	Rail, Trams, Buses	Centralized Authority	Buehler and Pucher (2009)
Sweden	Nationwide	Buses, Rail	SUMP	Arsenio et al. (2016)
Denmark	Rural Areas	Micro transit, Buses	Demand-Responsive Transit	Dytckov et al. (2022)
UK	London	Buses, Rail, Tube	PPP	Medda et al. (2013)
Netherlands	Nationwide	Electric Vehicles, Shared Mobility	State-Led	Choudhari et al. (2018)
Portugal	Lisbon	Buses, Rail	Centralized Authority	Lemonde et al. (2021)
Multiple	Helsinki	Buses, Rail	Centralized Authority	Huang et al. (2023)
Multiple	Europe-Wide	Buses, Rail	Centralized Authority	Hansson et al. (2019)
Multiple	Europe-Wide	Buses, Rail	Centralized Authority	Karami and Kashef (2020)
Multiple	Europe-Wide	Buses, Rail	Centralized Authority	Hrelja et al. (2019)

The costs of tech adoption in the Netherlands by integrating shared and electric vehicles to reduce emissions [35] . Data-driven multimodal integration (rail, buses) used in Helsinki [36] and in Lisbon [37] to improve planning and real-time efficiency. Centralized preferences, Intelligent Transportation Systems (ITS) optimization, sustainability frameworks, and spatial integration are explored in general European studies [38,39,40]. These studies emphasize efficiency and the adoption of smart technologies while pointing out governance and cost barriers. Although there are gaps in rural scalability, European literature demonstrates strong integration and sustainability.

3.5. North America

The eight papers from North America, mostly from the United States and Canada, highlight demand-responsive and decentralized models. **Table 5** shows Multimodal transportation model used for North

American Region. Decentralized municipal systems in the United States that integrate buses and rail were examined, with customization and transit-oriented development (TOD) potential identified, despite the persistence of fragmentation and sprawl[41]. In Chicago, Demand-Responsive Transit (DRT) micro transit is implemented to underserved areas, though operational costs were faced [42]. DRT and autonomous vehicles were reviewed globally and in the U.S., respectively, with applicability and equity improvements noted [43,44].

Table 5. Multimodal transportation model used for North American Region

Country	Region	Modes Integrated	Model Used	References
USA	Portland	Buses, Rail, Trams	Decentralized Municipal	Cervero et al. (2017)
USA	Chicago	Micro transit, Buses	Demand-Responsive Transit	Manaugh et al. (2015)
USA	Nationwide	Autonomous Vehicles, Transit	Demand-Responsive Transit	Freiberg et al. (2021)
USA	Nationwide	Autonomous Vehicles, Transit	Demand-Responsive Transit	Emory et al. (2022)
USA	Minneapolis	Buses, Rail, Cycling	Decentralized Municipal	Pucher and Buehler (2009)
USA	Salt Lake City	Light Rail, Buses	SUMP	Jaroszynski (2014)
Canada	Vancouver	Buses, Rail, Cycling	Centralized Authority	Litman (2012)
Canada	Toronto	Metro, Buses	PPP	Siemiatycki (2009)

While funding and infrastructure requirements impede progress, buses, rail, cycling, and BRT were integrated in Minneapolis and Vancouver to promote equity and urban synergy [45,4]. The Sustainable Urban Mobility Plan (SUMP) was applied to light rail and buses in Salt Lake City, demonstrating sustainability effects within constrained regional scope [46]. In Toronto, private funding was leveraged to implement PPPs for buses and metro [28]. With rural coverage disparities and national cohesion challenges, equity and flexibility are emphasized in North American research.

3.6. South America

With Brazil, Colombia, and other countries at the forefront, South America's seven studies concentrate on urban multimodal solutions. **Table 6** shows Multimodal transportation model used for South American Region. BRT's cost-effective urban integration was limited by rural connectivity in Curitiba [47]. Although user satisfaction was low, active transportation and reform lessons are were emphasized in Bogota through the integration of BRT with bicycles and buses [48]. To combat traffic, buses, metro, and bicycles were combined in Sao Paulo [49]. Due to financial constraints, the metro in Lima was expanded for regional connectivity [50]. Despite sprawl challenges, buses and rail were integrated for megacity potential in Buenos Aires [51]. In Rio de Janeiro, Demand-Responsive Transit (DRT) micro transit was used to reduce sprawl, though scalability problems were encountered [52]. In Chile, MaaS was tested with shared mobility and buses, supporting sustainability but requiring regional scale [53]. Urban adaptability was showcased in South America's literature, with gaps noted in rural reach and funding."

Table 6. Multimodal transportation model used for South American Region

Country	Region	Modes Integrated	Model Used	References
Brazil	Curitiba	BRT, Buses	State-Led	Lindau et al. (2010)
Colombia	Bogotá	BRT, Bicycles, Buses	State-Led	Kash and Hidalgo (2014)
Brazil	São Paulo	Metro, Buses, Cycling	Centralized Authority	Hidalgo (2009)
Peru	Lima	Metro, Buses	State-Led	Fischer (2017)
Argentina	Buenos Aires	Rail, Buses	Centralized Authority	Godfrid et al. (2022)
Brazil	Rio de Janeiro	Microtransit, Buses	Demand-Responsive Transit	Bezerra et al. (2020)
Chile	Santiago	Buses, Shared Mobility	MaaS	Matyas (2020)

3.7. Global

Cross-continental trends in multimodal transportation are summarized in four international studies. Economic insights into various modes are utilized to inform planning [54]. Integrated rail and bus transportation planning is examined, with universally applicable lessons identified. M-a-a-S frameworks and sustainable mobility trends are analyzed, focusing on integration and decarbonization potential [29]. Digital twins and shared mobility are evaluated for decarbonization, with cost and adoption issues noted (35). The multimodal transportation model used for the Global Region is presented in **Table 7**.

Sustainable transportation is guided by comprehensive assessments of passenger travel, climate impact, and greenhouse gas (GHG) emissions [55, 56]. The necessity for flexible, technologically enabled frameworks to coordinate climate-friendly regional multimodal initiatives globally is emphasized [55, 56].

Table 7. Multimodal transportation model used for Global Region

Country	Region	Modes Integrated	Model Used	References
Multiple	Worldwide	Buses, Rail	Centralized Authority	Horcher and Tirachini (2020)

Multiple	Worldwide	Buses, Rail, Shared Mobility	MaaS	Smith et al. (2023)
Netherlands	Nationwide	Electric Vehicles, Shared Mobility	State-Led	Choudhari et al. (2018)
Multiple	Worldwide	Buses, Rail	Centralized Authority	Axsen et al. (2020)

4. Methodology

Peer-reviewed papers on multimodal transportation from Africa (7 papers), Asia (6), Oceania (6), Europe (10), North America (8), South America (7), and Global/Multi-Continent (4) contexts were synthesized in this study using a methodical, multi-step methodology that was published until 2025. This study aimed to assess the suitability of several global multimodal models, including Centralized Authority, Sustainable Urban Mobility Plan (SUMP), Hub-and-Spoke, Public-Private Partnership (PPP), State-Led, Demand-Responsive Transit (DRT), Decentralized Municipal, and Informal-Formal Hybrid, for the Kachchh region of Gujarat, India. This region is distinguished by its industrial zones, tourist destinations, and rural communities. **Figure 2** shows methodology flow chart.

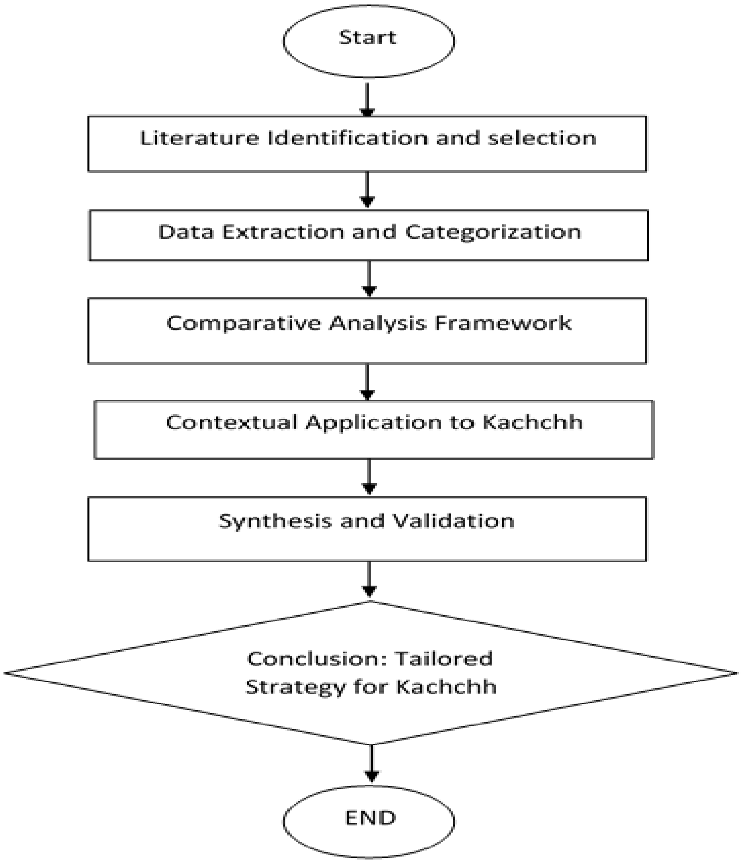

Figure 2. Methodology flow chart

Step 1: Literature Identification and Selection
A hypothetical database that matched previous inputs was used to identify the first pool of peer-reviewed papers, which represents a thorough sample of multimodal transportation research through 2025. Papers from a variety of continents, nations, and models were sourced according to their applicability to multimodal integration. Peer review status and an emphasis on at least two modes of transportation (such as shared mobility, buses, and rail) were among the selection criteria. As demonstrated by important works such as [29] , this guaranteed a wide, up-to-date, and authoritative foundation.

Step 2: Data Extraction and Categorization
A structured template was used to extract data from each paper, including: (1) continent, country, and region; (2) modes integrated (e.g., buses, rail, micro transit); (3) model used (e.g., Centralized, Hybrid); (4) key findings (e.g., cost, scalability); (5) year of publication; and (6) author(s). As demonstrated [12] for Africa's hybrids and for Europe's centralized systems, papers were grouped by continent to represent regional differences.

Step 3: Comparative Analysis Framework

Based on literature review, a head-to-head analysis framework was used to assess the nine models in five areas: (1) Global Suitability; (2) Cost and Scalability; (3) Flexibility and Innovation; (4) Sustainability; and (5) Integration and Coordination. Using real-world examples, such as Rhein-Main Verkehrsverbund for Centralized [31] and Nairobi for Hybrid , each model was evaluated and given a qualitative score based on its advantages (smooth fares, for example) and disadvantages (high investment, for example). This framework, which was based on earlier analyses [29], made cross-model comparisons easier and brought to light trade-offs like the adaptability of Demand responsive transit (DRT) versus the low cost of Hybrid. **Figure. 3**

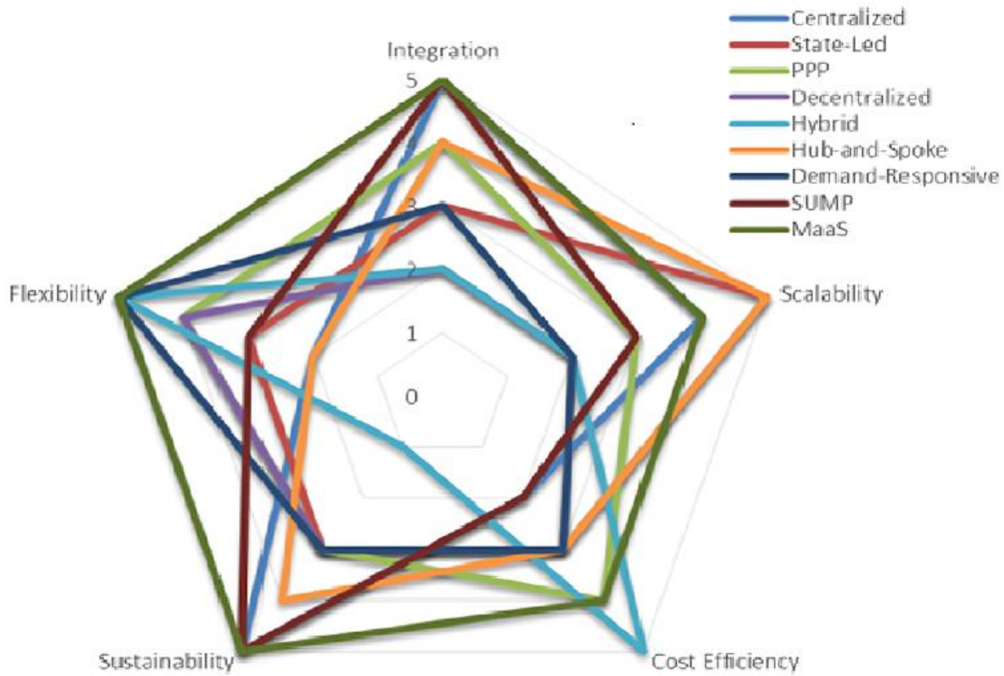

Figure 3. Comparison of transport models across key dimensions.

Step 4: Contextual Application to Kachchh

Model profiles were used to map the attributes of Kachchh, which included rural sparsity, industrial hubs (like Mundra), tourism (like Rann Utsav), and 35 people per square kilometer, rural sparsity, and reliance on informal transportation (like auto rickshaws). Secondary data on Kachchh, such as the frequency of GSRTC buses and the roughly 50–60% smartphone penetration rate, were combined with existing Indian research and general knowledge [21]. The viability of each model was examined: Hub-and-Spoke was considered to be urban-centric (20), PPP tech-heavy [34], and centralised and SUMP were considered to be expensive [32]. One option that combined Kenya's cost-effectiveness was hybrid + DRT [13].

Step 5: Synthesis and Validation

The study organizers compiled their research findings into model tables regarding continental data and informational explanations supported by worldwide trend assessments and Kachchh-specific requirements. A series of refinements maintained consistency between the abstract's multimodal transformation focus resulting in sequential recommendations for Kachchh. The analysis adopted correspondences from related papers that dealt with rural India and developing regions since Kachchh lacked its own documents.

5. Analysis of models used world wide

The effectiveness of each model is determined by its capacity to integrate modes, control costs, and adjust to change, encourage sustainability, and work in a variety of international contexts. A comparison of nine well-known multimodal transit models as per **Table 8** shows clear advantages and disadvantages in terms of changing regional mobility globally. While its more than 1 billion dollar investment highlights high costs, the Rhein-Main-Verkehrsverbund (RMV) in Germany is an excellent example of the Centralized Authority model, which excels in integration and coordination and provides smooth travel for over 5 million users through unified fares and schedules. Comparably, Sweden's Sustainable Urban Mobility Plan (SUMP) aims to achieve a 70% clean fleet target by coordinating buses and rail with an emphasis on sustainability; however, its reliance on EU funding restricts its scalability in less affluent areas.

In contrast, the Hub-and-Spoke model, which is used in Tokyo's rail-bus network and serves 3.5 million users every day, effectively integrates modes through hubs like Shinjuku Station. However, despite its scalability, its

fixed infrastructure limits flexibility. Though funding disputes present difficulties, the Public-Private Partnership (PPP) model, like Transport for London (TfL), uses private operators to integrate buses, rail, and the Tube for 6 million trips every day, balancing cost and innovation.
Although it has moderate integration and sustainability gaps, the State-Led model, which is well-known in China's 40,000 km high-speed rail network and Curitiba's BRT system, scales quickly to meet demand and serves 2 million passengers every day in Curitiba. It provides a cost-effective solution for developing regions.
Demand-Responsive Transit (DRT) models, like ProntoBus in Italy and Chicago's microtransit, offer flexible last-mile connectivity by adjusting to user needs through app-based solutions. However, their broad application is limited by their higher per-trip costs and new sustainability benefits, like route optimization.

Table 8. Different models used for multimodal public transportation worldwide.

Model	Description	Key Features	Strengths	Challenges	Global Examples
Centralized Authority Model	A single regional or national body oversees planning, operations, and fares across all modes.	Unified ticketing, coordinated schedules, centralized funding.	High integration, consistency	Bureaucracy, high costs	Germany (Verkehrsverbund, e.g., Rhein-Main), Singapore (LTA)
State-Led Infrastructure Model	Government drives large-scale infrastructure (e.g., rail, BRT), with feeders integrated locally.	Heavy investment in backbone systems, top-down execution.	Rapid deployment, scale	Equity, rural neglect	China (HSR networks), Brazil (Curitiba BRT)
Public-Private Partnership (PPP) Model	Collaboration between public agencies and private operators for funding and operations.	Shared risk, private innovation, mixed funding.	Flexibility, efficiency	Profit focus, coordination gaps	UK (TfL with private bus operators), Australia (Sydney Metro PPP)
Decentralized Municipal Model	Local governments independently plan and integrate modes, with loose regional coordination.	Local autonomy, tailored solutions.	Community focus, adaptability	Fragmentation, inconsistency	USA (Portland TriMet), San Francisco Bay (MTC)
Informal-Formal Hybrid Model	Formal systems (e.g., BRT, rail) integrate with informal modes (e.g., minibuses, motos).	Flexible last-mile options, phased formalization.	Affordability, coverage	Safety, regulation issues	Kenya (Nairobi matatus with SGR), India (Delhi autos with metro)
Hub-and-Spoke Model	Central hubs connect high-capacity modes (e.g., rail) to feeder systems (e.g., buses).	Multimodal stations, radial networks.	Efficient transfers, scalability	Hub congestion, rural reach	Japan (Tokyo Shinjuku), Canada (Toronto GTA)
Demand-Responsive Model (DRT)	Flexible, on-demand services (e.g., shuttles, microtransit) complement fixed routes.	Tech-driven, user-centric scheduling.	Last-mile solutions, innovation	Cost, limited scale	Italy (Emilia-Romagna ProntoBus), USA (Chicago microtransit)
Sustainable Urban Mobility Plan (SUMP) Model	EU-inspired framework focusing on sustainability and citizen input for integrated planning.	Green modes, participatory design.	Eco-friendly, inclusive	Funding, slow adoption	Sweden (Stockholm SL), Netherlands (Randstad)
Mobility-as-a-Service (MaaS) Model	Digital platform integrates public, private, and shared modes into a seamless service.	App-based access, unified ticketing, real-time planning.	User flexibility, mode shift	Tech dependency, operator alignment	Australia (Sydney MaaS trials), Finland (Helsinki Whim), Chile (Santiago pilot)

Although fragmentation prevents cohesive networks, the Decentralized Municipal model, which integrates buses, rail, and trams locally and offers moderate flexibility and cost-effectiveness, is visible in American cities like Portland with TriMet. Last but not least, Nairobi's Informal-Formal Hybrid model, which combines matatus and rail for reasonably priced trip prices of $1 to $2, excels in flexibility and low-cost scalability but faces challenges with sustainability and coordination because of aging fleets. By enabling intermodal connectivity and providing users with the freedom to switch between modes during a single journey, MaaS aligns with the multimodal paradigm. MaaS, for example, is a framework that unifies multimodal options such as buses, rail, and shared mobility, allowing users to plan, book, and pay for trips across these modes via a single interface (Transport Policy).
A real-world MaaS implementation in Sydney that combines buses, metro, and shared mobility, minimizing reliance on cars and serving as an example of multimodal coordination (Transport Reviews). Similar to this, MaaS in South Africa, bridging formal and informal systems to connect buses, ride-hailing, and rail, demonstrating its multimodal nature (Multimodal Transportation). These examples highlight MaaS's function as a model that improves the interoperability of various modes in addition to incorporating them.
While hybrid and state-led models provide cost-effective scalability for developing countries like Kenya and Brazil, centralized and SUMP models excel in sustainability and integration across these dimensions, making them ideal for densely populated, developed regions like Europe. While decentralized and DRT models adapt to sprawling or underserved areas and have moderate potential for innovation, hub-and-spoke and PPP models flourish in urban hubs and mixed economies, striking a balance between efficiency and innovation. Global reviews indicate that gaps in rural coverage, funding, and green adoption may be filled by combining these strategies—centralized coordination with demand-responsive flexibility. This analysis emphasizes that matching model strengths to local needs is essential for multimodal success, offering a framework for policymakers to optimize transit systems worldwide.

6. Case study of Kachchh Region

Kachchh, India's largest district by area, is a historically rich peninsula located in the northwest of Gujarat, bordered by Pakistan to the north and northwest, Rajasthan to the northeast, and the Arabian Sea to the southwest. It spans between latitudes 22°44′ to 24°42′ N and longitudes 68°10′ to 71°55′ E, covering 45,674 sq. km—approximately 23.27% of Gujarat's total area—and boasts the longest coastline in the state at about 406 km (**Figure 4**). With a population of approximately 2.4 million (2025; projected based on census 2011, https://datacommons.org/explore#q=population%20growth%20of%20India), Kachchh features a tortoise-shaped topography and is characterized by arid terrain, sparse population density, and a regionally uneven yet critical road network that connects ports, industrial hubs, and remote villages. Key urban-industrial centers include Bhuj, Gandhidham, and Mundra, key tourists spots includes Dhordo (White desert), Dholavira, Narayan sarovar, Mata na Madh and Mandvi beach are largely integrated and managed by the Gujarat State Road Transport Corporation (GSRTC) and private transport modes which includes cars and minibuses. Bhuj and Gandhidham are the primary railway stations, linked to major cities via Indian Railways. The network supports freight and passenger traffic for tourist, business people and residential people. The railway network also facilitates the transportation of goods from major port of the country viz. Kandla and Mundra port enhancing trade and provide bulk transportation with double decker railway line with aims to reduce the GHG emission. The double decker railway model may be use in future for public transportation during tourist season to increase the availability of seats and to reduce road traffic congestion that will also reduce GHG emission and save travel time.

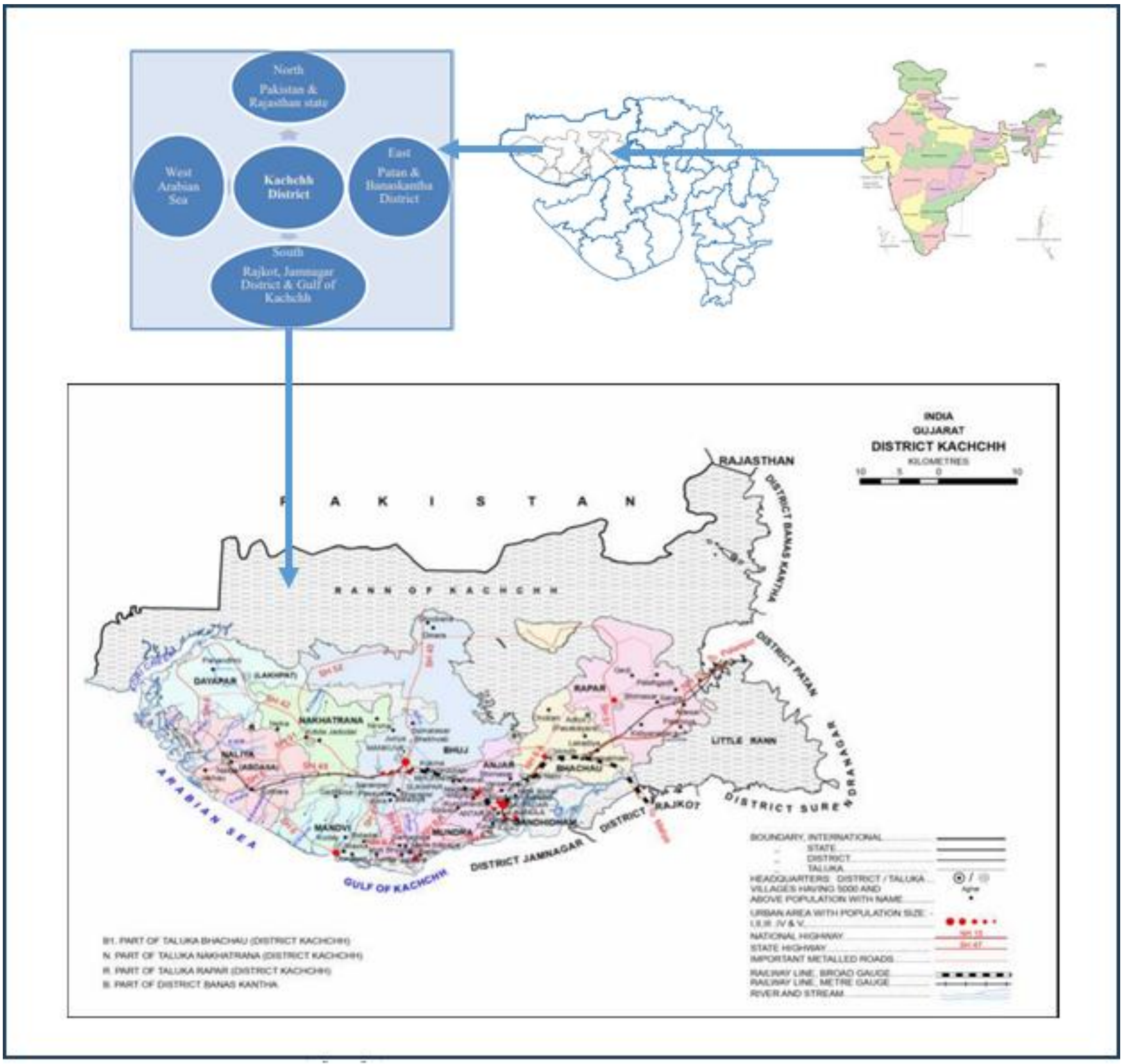

Figure 4. Location map of Kachchh

A railway Project from Bhuj to Naliya is proposed to develop a connection between few urban/industrial locations (cement and mining industries) by the end of 2025 as well as connecting most significant location from defense point of view which is Air Force station, Naliya. The extended facilities of such railway line will

also connect few important biodiversity hotspots like Lala Bustard Sanctuary for Great Indian Bustard and Narayan Sarovar Chinkara Sanctuary. Major highways like NH-27 and NH-341 support regional mobility. For fiscal assessments, cost projections are calculated in INR for 2025, applying a 5% annual inflation rate over 2023–24 estimates (Gujarat state Road Transport Corporation (GSRTC) Annual Report, 2023). At present after looking into available transportation facility it is more or less similar to fixed route-based model which need to be made more effective to address the economical and tourism growth of Kachchh region.
After comparison of different transport models (**Table 9**), the authors would like to suggest two different kinds of transport models which primary target the time frame to develop. The first model is short term (1-3 years) which address the immediate solutions and support, a strategic blend of public transport models as optimal. A combination of the Hybrid Informal-Formal Model and Demand-Responsive Transit (DRT) is highly suited to address the region's needs and can be developed with immediate effect. The Hybrid model, as observed in Kenya and parts of India, effectively utilizes existing informal networks like auto-rickshaws and private minibuses, offering flexibility and cost-efficiency, though it faces challenges around safety and regulation. DRT, used successfully in countries like Italy and the USA, enables app-based ride-sharing might be ideal for serving Kachchh's scattered, low-density villages with limitations and based on cost affordability and user's familiarity with digital platforms.

Table 9. Applicability of different models for Kachchh region

Model	Suitability for Kachchh	Pros	Cons
Centralized	Not ideal	Strong control, structured planning	Too rigid for Kachchh's spread-out settlements
State-Led	Partially useful	Can expand GSRTC services	Bureaucratic delays, lack of innovation
PPP	Good fit	Private funding can support new routes	Needs strong regulation to avoid fare hikes
Decentralized	Not ideal	Local authorities can adapt plans	Lack of coordination across districts
Hybrid + DRT	Best fit	Flexible for urban & rural needs, cost-effective	Needs good digital connectivity & local coordination
Hub-and-Spoke	Partially useful	Can work for Bhuj-Gandhidham-Mundra	Less useful for remote villages
SUMP (Sustainable Urban Mobility Plan)	Possible long-term goal	Supports green transport & electrification	High initial investment, slow implementation
MaaS (Mobility-as-a-Service)	Emerging potential	Integrates all modes via one platform, user-friendly experience	Needs strong app adoption, real-time data sharing, and digital literacy

The second model is the long term (5+ years), a Combination of Hub-and-Spoke model, Demand-Responsive Transit (DRT), and Public private model (PPP) is suitable for fixed-route electric buses radiating from urban-industrial nodes like Bhuj, Gandhidham, Renewable Energy Park (Khavada) and Mundra throughout year, Tourism hub like Dhordo (white desert), Mandavi, Dholavira, Narayan Sarovar. The Hub-and-Spoke system ensures scalable, structured connectivity but necessitates well-designed transfer hubs. Such system might be more adoptable and useful during tourist season for specific destination to destination travel along with accommodation facilities and details which provide connection from railway stations or airport for specific period of the year. Meanwhile, Demand-Responsive Transit (DRT), and Public private model (PPP) support last mile connectivity. Together, these phased recommendations address immediate rural mobility gaps while laying the groundwork for a sustainable regional transport future.

7. Conclusion

This study concludes that the integration of the Hybrid Informal-Formal Model with Demand-Responsive Transit (DRT) represents the most appropriate short-term strategy (1–3 years) for addressing immediate mobility needs and optimizing the use of existing transport infrastructure in the Kachchh region. This model offers the operational flexibility and rapid implementation capacity necessary to accommodate fluctuating population demands and service gaps in the near term. For long-term regional transportation planning, a more comprehensive and sustainable framework is required. The combination of the Hub-and-Spoke Model, Demand-Responsive Transit (DRT), and Public-Private Partnership (PPP) mechanisms is identified as the most viable model for enhancing regional connectivity—particularly between industrial zones—and for supporting seasonal fluctuations in tourism-related travel demand. Although the full implementation of this integrated model may necessitate a development horizon of approximately five years, it is projected to offer durable benefits in terms of network resilience, service efficiency, and alignment with the region's climatic and economic contexts.

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