Formalizing Public Transit in Mid-Sized Developing Cities: A Review of Strategies for Sustainable and Resilient Mobility

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Abstract—**Mid-sized cities in developing cities face increasing demand to modernize their public transit (PT) systems to advance sustainability, equity, and resilience. Many of these cities remain dependent on informal transit modes such as minibuses, privately owned taxis, and shared vans which, despite their flexibility, often lead to operational inefficiencies, safety risks, and limited accessibility. This review examines strategies for transitioning to formal public bus transit (BT) systems through analysis of peer-reviewed literature. The analysis is organized around five core domains that directly reflect the structure of this study: assessment of the current state of PT systems, strategies for transitioning from informal to formal networks, selection of appropriate PT modes for mid-sized cities, planning processes for BT systems, and sustainable and resilient approaches for BT development. Based on these findings, this study proposes a structured decision-support framework in the form of a decision tree to guide context-sensitive formalization efforts. Future studies should prioritize long-term impact evaluation, inclusive transition mechanisms for informal operators, and the integration of smart and sustainable technologies.**

Index Terms—**Informal modes of transit, Public transit, Resilient bus transit, Sustainable bus transit, transit planning, Urban mobility.**

I. Introduction

In recent decades, rapid urbanization has been driven by economic growth and population increases worldwide. According to a report by the United Nations, by the year 2050, almost 68% of the global population will live in cities (Zhang, et al., 2024; Kuddus, Tynan and McBryde, 2020; Sun, et al., 2020). This results in more urbanized cities, particularly mid-sized ones, which are typically defined by populations between 50,000 and 500,000 and often characterized by rapid urbanization, limited institutional capacity, and a reliance on informal transit systems (Balk, et al., 2018). Cities in developing countries have grown at an extraordinary pace in terms of population growth, some even ahead of the growth in developed countries, taking decades to achieve (Henderson, 2002). For example, South Korea, which was classified as a developing country during that period, experienced rapid urbanization, transitioning from 40% urbanization in 1970 to 78% by 1990. In contrast, the United States, already an advanced economy, required approximately 90 years to achieve a similar level of urbanization (Henderson, 2002). Excessive concentration in megacities has been a consequence of this rapid urbanization, at the expense of mid-sized cities that have the insufficient infrastructure, weak institutions, and dependence on informal transit systems (Henderson, 2002). Mid-sized cities should adapt their infrastructure and services, especially public transit (PT), to handle this rapid growth.

In cities of developing countries, there is a serious need for a transition from an informal to a structured formal PT to improve sustainability and resilience. Urban transportation in these cities is often dominated by informal transit systems. These informal systems frequently result in inefficiencies, such as service unpredictability, traffic congestion from indiscriminate stopping, safety concerns from erratic driving, and environmental damage caused by using low-cost, poorly maintained private vehicles (PVs) (Cervero, 2000). To solve these inefficiencies, it is crucial to transform into sustainable and structured PT networks (Kumar, Zimmerman, and Arroyo-Arroyo, 2021; Cervero and Golub, 2007; Ahmed, 2003). For instance, in many cities in Sub-Saharan Africa, informal transit accounts for more than 70% of all motorized trips. However, the lack of route adherence, designated stations, and established schedules presents considerable obstacles to effectively manage informal PT systems (Kumar, Zimmerman, and Arroyo-Arroyo, 2021). Furthermore, when transforming to a formal PT mode, a more resilient system can be achieved by prioritizing accessibility, affordability, and other features of social equity (Santos, et al., 2020;

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Mehndiratta and Rodriguez, 2017), making cities robust and flexible, especially congested areas (Hensher, 2007; Schipper and Fulton, 2002). Addressing sustainability and resilience when transforming any informal mode of the transit system solves inefficiencies and makes the system more flexible, affordable, and accessible.

Buses represent a sustainable and resilient transportation mode, especially when formalized. There are multiple classifications of buses, in general, they are classified by operation and infrastructure features into conventional buses that operate in mixed traffic with basic infrastructure, bus transit systems (BTS) feature enhanced coordination with dedicated lanes, and bus rapid transit (BRT) which involves substantial infrastructure investment with separate lanes and high-speed reliability (Vuchic, 2007). In developing cities, buses serve as the foundation of PT and are an essential mode for low-income people to commute (Mehndiratta and Rodriguez, 2017). Informal modes, such as minibuses, microbuses, and shared vans, are flexible; cover wider areas; and can serve as a transitional means, but they cannot be used for regular services as they are not very sustainable and have lower service quality (Del Mistro and Behrens, 2015). Formalizing a conventional bus system is the most practical initial step due to its lower capital requirements and because it allows for the incorporation of existing informal operators into organized systems (Mehndiratta and Rodriguez, 2017). Cities experiencing growing demand may eventually require more advanced solutions. In such contexts, BRT systems provide substantial advantages, including decreased travel durations, reduced greenhouse gas (GHG) emissions, and improved dependability, providing them an appropriate long-term option for high-demand corridors (Mehndiratta and Rodriguez, 2017; Rodriguez, et al., 2017; Tun, et al., 2020). Unfortunately, institutional constraints, such as resistance from current operators, job losses, lack of financial support, and right-of-way concerns, hinder the starting of BRT in developing cities immediately (Del Mistro and Behrens, 2015; Vuchic, 2007). This leads to the most practical first step for these cities as a formal conventional bus system. The strategy is a more sustainable form of PT than informal minibuses and more economical to implement than a BRT network.

Although the need for structured transit is widely recognized, existing research continues to focus on large metropolitan areas, leaving mid-sized developing cities with their heavy reliance on informal systems understudied. Many studies emphasize high-capacity modes (BRT, metro, rail), overlooking bus transit (BT) as a cost-effective, scalable solution, particularly suited to mid-sized cities. These cities often face infrastructure constraints and limited institutional capacity that differ markedly from megacities. Moreover, an ongoing debate questions whether improving informal transit through regulation and modernization might suffice rather than fully converting to formal networks. Acknowledging these controversies grounds the discussion in real-world complexities, avoiding a one-size-fits-all approach. This narrative review addressed these gaps by providing a structured framework for transit formalization, evaluating BT as the appropriate mode, and integrating sustainability and resilience into the decision-making process. Therefore, the specific aims of the review were to:

- Analyze the global utilization of various PT modes and evaluate the performance of informal modes of transit used in mid-sized cities to identify critical inefficiencies.
- Determine why formal BT is the best choice for these kinds of cities, which are likely under urbanization and urban sprawl.
- Discuss the strategies that can be implemented in the transit planning process when developing a BT system in mid-sized cities to enhance resilience and sustainability.

II. Methodology

This study employed a structured narrative review approach to examine strategies and frameworks for formalizing PT systems in mid-sized cities, particularly in the context of sustainability and resilience. While narrative in structure, the review incorporated systematic search and screening techniques to improve methodological transparency and reduce bias.

A. Search Strategy

Literature was collected between December 2024 and March 2025 using four major academic databases: Scopus, Web of Science, ScienceDirect, and Google Scholar. To maximize coverage and conceptual depth, the search strategy used a mix of database subject headings and relevant keywords related to the core themes of the study. Boolean operators (AND, OR) were applied to construct composite search queries as shown in Fig. 1:

Filters were applied to limit results to peer-reviewed journal articles, conference proceedings, technical reports, and institutional publications dated from 2000 to 2024. Only English-language publications were included. In cases where keyword fields were not indexed (as in Google Scholar), simplified keyword combinations were used to screen the top 50 results sorted by relevance.

B. Screening and Deduplication

All retrieved citations were imported into EndNote 21 for reference management. Duplicate entries across databases were identified and removed using automatic and manual review. The remaining unique records were subjected to a two-stage screening process. The first stage was title and abstract screening where records were excluded if they were clearly outside the scope (e.g., focused solely on high-income countries, did not address urban transit, or discussed unrelated technological innovations). The second stage was a full-text review in which articles were retained only if they addressed at least one of the following core themes: PT definition and modes comparison, informal modes of PT, the transition from informal to formal transit systems, the relationship between urbanization, urban sprawl, and urban mobility with PT, PT mode selection for mid-sized cities, BT planning process, and integration of sustainability and/

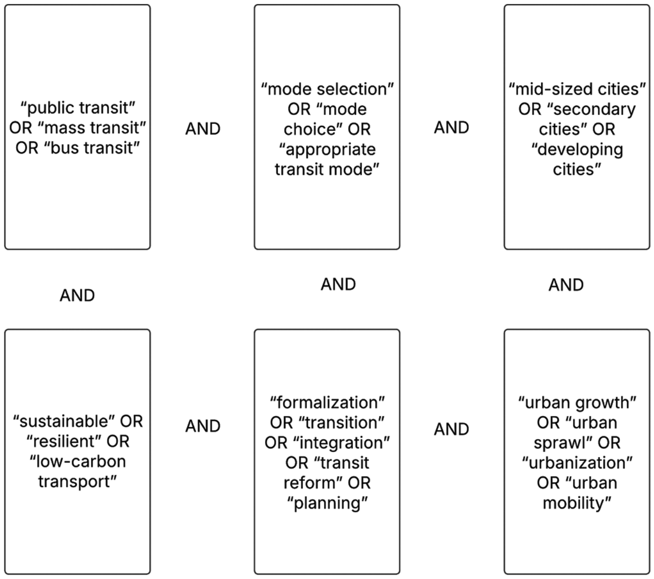

Fig. 1. Key terms and Boolean operators applied for the search strategy.

or resilience principles in public (bus) transit planning. Gray literature from multilateral organizations (e.g., World Bank, UN-Habitat, etc.) was also included when it met the same criteria, particularly for regions where academic literature was scarce. Cross-thematic synthesis enabled the identification of both convergent policy frameworks and regional gaps in evidence. Although this approach did not follow PRISMA or JBI scoping review protocols, it prioritized conceptual depth and interdisciplinary relevance, providing a broad yet critical understanding of emerging practices and strategies. The structured narrative format was selected deliberately to allow flexibility in capturing policy nuances, informal governance contexts, and multiscalar challenges that may not be consistently indexed in systematic reviews. This enhances the relevance of the findings to planners, researchers, and policy-makers operating in diverse urban contexts.

III. Review Findings

In this section, the current state of PT in mid-sized cities relying on informal modes of transit was assessed. The aim was to determine whether transitioning from these informal systems to a structured formal PT network is necessary and feasible. Next, the selection of an appropriate PT mode for such mid-sized cities was examined, highlighting criteria such as cost, capacity, and compatibility with existing infrastructure. Finally, this review addressed sustainability and resilience in BT, outlining strategies to make bus-based systems more adaptable and environmentally responsible.

A. Assessment of the Current State of PT Systems

To understand how mid-sized cities can enhance their PT frameworks, it is necessary to evaluate the existing systems in general and those relying on informal modes. The transportation sector relies on PT, which provides various services and modes essential for urban mobility, often described as the "lifeblood of cities (Vuchic, 2017; Vuchic, 2002; Miller, et al., 2016; Gao and Liu, 2024)." PT which is a vital part of transportation "(also called public transportation, public transport, mass transit, and urban transit) includes (vanpools, buses, trains, ferries, and their variations) (Filho, 2021)." Globally, PT usage is distributed across various modes. Buses are a primary component due to their flexibility and cost-effectiveness, especially in urban and suburban areas (Vuchic, 2007). A study by UITP (2017) evaluated urban PT usage across 39 countries and found that buses dominate worldwide PT with 63% of travel, followed by heavy rail transit (HRT) and commuter rail transit (CRT) at 16% and tram/light rail transit (LRT) at 5%. However, these numbers change from country to country. For instance, in the United States, bus usage is approximately 50% of all PT modes due to its extensive route coverage and flexibility (APTA, 2023). HRT systems, including metros and subways, play a crucial role in high-capacity urban transit, accommodating significant daily ridership in densely populated cities. In major metropolitan areas, HRT contributes 36% of transit ridership, supporting high-capacity and high-frequency urban mobility (APTA, 2023). CRTs are high-capacity trains that connect suburban regions to metropolitan centers. They offer longer-distance services with fewer stops than urban transport alternatives. Globally, they account for a considerable part of passenger transport, constituting 3% of unlinked trips but 17% of passenger miles traveled, demonstrating their function in traversing greater distances effectively. LRT, such as trams, offers efficient and environmentally friendly options, with a global network length of more than 15,000 kilometers as of 2021, primarily concentrated in Europe (58%) and Eurasia (22%) (UITP, 2021b). Together, these transit modes collectively handle billions of passengers annually, underscoring their essential role in meeting the mobility needs of urban populations worldwide. The problem is that some cities, especially in developing countries, still do not rely on these formal modes; rather, they use informal modes of transit.

Informal modes are a vital means of transit in developing cities, particularly for low-income populations and urban areas that are not served by formal transit. Informal transport services, such as minibuses, taxis, vans, station wagons, motorcycles, and three-wheelers, play a complex role. These "small vehicle" modes offer crucial advantages, especially for low-income people, by providing on-demand access to essential services such as medical clinics and employment opportunities for low-skilled immigrants while also covering areas lacking formal transit options (Cervero and Golub, 2007). However, these modes are troublesome since drivers use a "fill-and-go" approach, which results in delays and dissatisfaction for users, they often depend on unregulated systems, which cause traffic congestion, air pollution, noise pollution, increased crashes, and road safety problems due to inadequate vehicle maintenance and a lack of proper traffic regulations (Cervero, 2000; Tun, et al., 2020). This often leads local authorities in low-income regions to abandon attempts at regulation, allowing these services to operate on the fringes of society (Cervero and Golub, 2007). Another downside of informal modes is that they share similar

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characteristics but typically consist of small, old, low-performance motor vehicles (Behrens, et al., 2021; Cervero, 2000). The vehicles in these modes are known by various names and capacities used in different countries (Fig. 2). As these cities continue to rely on informal transit modes, the need to transform such systems into a formal, structured, and efficient network becomes evident. The following sections examine strategies for making this transition.

B. Transitioning from Informal to Formal Transit Systems

Transitioning from informal to formal PT is significant in improving the efficiency, safety, and environmental sustainability of transportation services. For instance, formalizing the minibus taxi business in South Africa by vehicle registration, operator training, and compliance monitoring improved service quality and safer transportation conditions (Ahmed, 2004). However, that progress was supported by comparatively robust institutional frameworks and the Western Cape Provincial Department of Transport, which may not be replicable in regions with weaker governance or more limited financial resources. Similarly, integrating informal transportation into a structured system can minimize operational inefficiencies while increasing service reliability (Alcorn and Karner, 2020). In Lagos, Nigeria, efforts to include informal operators in a hybrid transport model helped minimize the "chaotic and inefficient" operations that characterize informal networks (Alcorn and Karner, 2020). Despite this success, scaling the model citywide reportedly involved significant coordination challenges and occasional pushback from informal operators reluctant to adopt new regulations or revenue-sharing structures. Case studies from Southeast Asia also support this analysis. In Phnom Penh, Cambodia, informal services such as Motodup and Remork continue to dominate, and the success of formal buses depends heavily on improvements in comfort, availability, and cost factors that directly affect usage frequency (Eung and Choocharukul, 2018). Furthermore, in Ethiopian cities, informal and intermediate transport modes remain vital for low-income mobility, but Tucho (2022) emphasized that achieving equity and sustainability requires integrating these systems into broader transport policies, institutional reforms, and infrastructure planning tailored to local socioeconomic conditions. Formalization was shown in these cases to be beneficial, but its effectiveness depends on government commitment, stakeholder buy-in, and the availability of funding. These cases, extending from Sub-Saharan Africa to Southeast Asia, highlight common problems as well as the variety of local constraints. Although regional contextual variation is still of significance, these examples also demonstrate the common issues, including safety, service coordination, and affordability, which favor the creation of flexible, as opposed to prescriptive approaches. Based on this, the proposed study will develop a flexible framework with transportable principles that can be adapted to mid-sized cities with similar institutional and governance limitations, such as in underrepresented areas such as the Middle East and smaller African urban centers.

The ease with which the informal operators are integrated into the formal PT systems usually depends on the transitional mechanisms that involve a trade-off between the efficiency objective and the protection of existing livelihoods. Examples are vehicle scrappage plans along with lease-to-own schemes, as with the South Africa taxi recapitalization plan, whereby minibus operators were given financial incentives to give up old vehicles and replace them with standardized and regulated vehicles (Ahmed, 2003). In Bogotá, Colombia, a gradual licensing of TransMilenio gave some informal operators the opportunity to join new BRT systems through consortium contracts, as long as they fulfilled training and fleet quality requirements (Rodriguez, et al., 2017). Another strategy observed in Cape Town and Accra involved forming cooperatives where informal drivers pooled resources to bid on formal routes, thus preserving employment while improving service coordination (Behrens, et al., 2021; Del Mistro and Behrens, 2015). These mechanisms illustrate that operator integration is most effective when accompanied by technical support, capacity-building, financial assistance, and institutional safeguards. However, there is a persistent tension between improving operational efficiency and safeguarding the income of informal workers. Overly rapid formalization without viable employment alternatives can

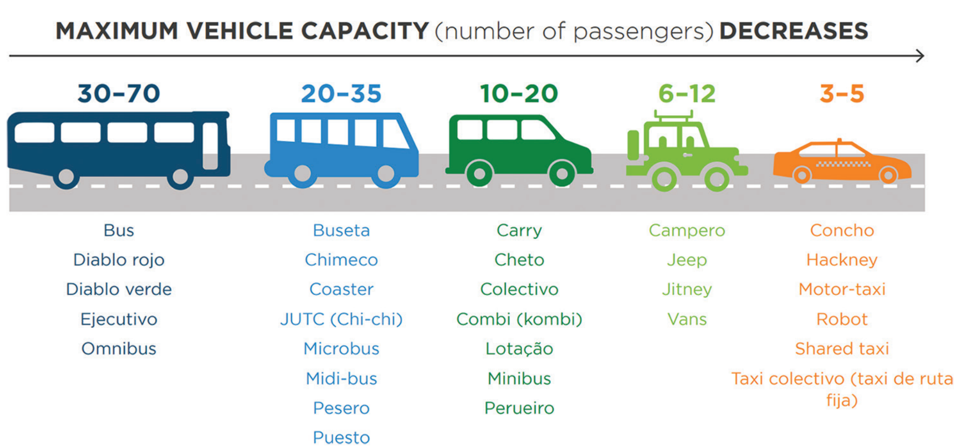

Fig. 2. Maximum vehicle capacity with different names of different modes (Tun et al., 2020).

lead to resistance or even sabotage. A balanced strategy must therefore emphasize inclusive transition plans, where existing operators are offered clear pathways into the new system, whether through retraining, cooperative membership, or service contracts. Without such inclusion, reforms risk undermining social equity and local political support. Beyond the operation of transit systems themselves, broader urbanization patterns and city form factor into the transit challenges of mid-sized cities.

Urbanization directly impacts the transportation sector of developed and developing countries. Globally, urbanization is considered one of the most transformative trends of the 21st century that redefines the face of both developed and developing countries (Živković, 2020). As urban populations grow, cities increasingly become hubs of economic development and cultural interchange (Almulhim, et al., 2022). However, fast urban growth creates a lot of problems, including environmental deterioration, housing shortages, and crowded transportation infrastructure (Sennett, et al., 2018). Such effects need to be reduced by developing a sustainable and resilient PT network that can reduce air pollution and socioeconomic inequities commonly associated with fast urbanization. For instance, in the case of Saudi Arabian cities, the level of urbanization increased the proportion of people relying on PVs because there were inadequate sustainable transport facilities in the region. This dependence has further worsened urban problems such as traffic congestion and air pollution. By promoting sustainable urban transportation for UN Sustainable Development Goal 11, cities can enhance the comfort, accessibility, and robustness of the built environment and promote a better urban environment (Almulhim and Cobbinah, 2023). Fig. 3 compares the percentage of urbanization in a range of Arab countries, such as Saudi Arabia, the United Arab Emirates, Qatar, Oman, Bahrain, Kuwait, Jordan, and Lebanon, demonstrating how these nations vary from about 30% to nearly 100% urban population, based on World Bank (2021) data.

When developing any mode of PT, it should be considered whether the city's urban form is under a sprawl or compact situation. Urban sprawl may take several forms. It may include low-density housing developments or so-called "edge cities" (clusters of people and economic activity on the metropolitan outskirts) that generate business activity such as office buildings, retail, and even manufacturing. It can also take the shape of planned towns with their own "downtown" or those located around a lake or park. Or, it can be individual dwellings that appear throughout rural regions. In any of these events, a popular technique to record the presence of urban sprawl across time is to look first at the growth of rural and urban population levels and then, within urban regions, at the growing interaction between suburbs and core cities (Nechyba and Walsh, 2004). Typically, the urban form has a favorable or adverse effect on citizens' quality of life (Kakara and Prasad, 2019). Nengroo, Bhat, and Kuchay (2017) stated that urbanization is not a major danger to the urban environment and urban development compared to urban sprawl, which affects the accessibility to facilities. Furthermore, Boontore (2014) identified urban sprawl as a major issue, citing factors such as poor vehicle capacity, increased pollution, and loss of land resources. Several indices were used to measure the amount of sprawl, including density, intensification, mixed-use, and road network (Kakara and Prasad, 2019). The compact city idea is one of the sustainable urban designs that may be embraced to minimize the function of the PVs and boost the role of PT and non-vehicle modes (Kakara and Prasad, 2019). More compact, dense urban developments can result in more active travel and higher PT ridership, whereas less long-distance travel can result in more people living in compact, mixed-use areas. (De Vos and Witlox, 2013). As a result, more compact urban areas lead to higher dependence

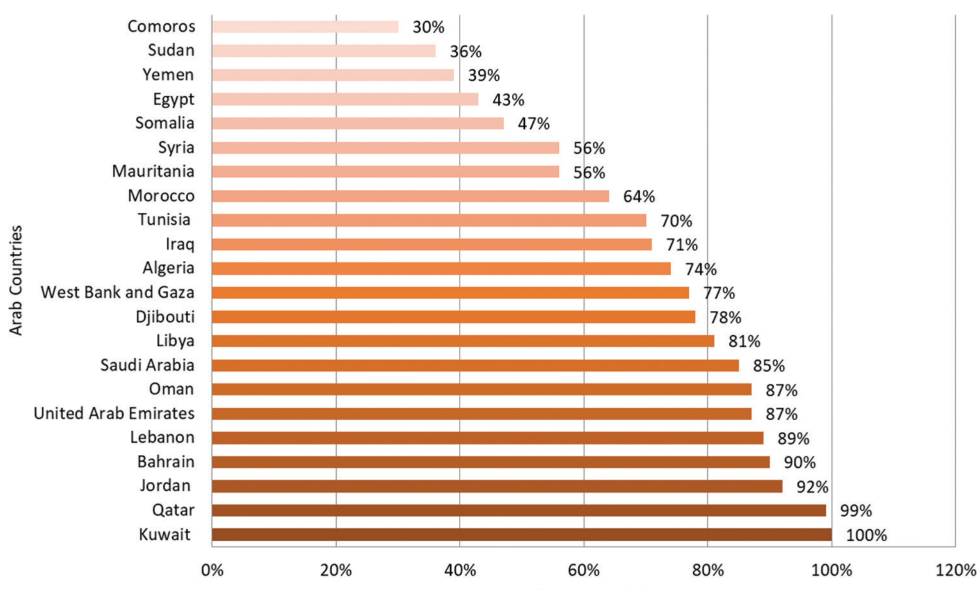

Fig. 3. Percentage of urbanization in Arab Countries using data extracted from the World Bank, 2021 (Almulhim and Cobbinah, 2023).

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on PT, but more sprawl makes cities depend more on PVs than PT.

Given that urban sprawl increases dependence on PVs, the future of urban transportation could prioritize PT to counter these inefficiencies and enhance urban mobility. According to Ceder (2020), more than half of the world's population lives in cities, and growth is predicted virtually solely in them. Although rapid urban expansion can promote healthier, more efficient, and more productive urban communities, the persistently high rate of PVs sitting parked (around 95%) highlights their inherent inefficiency. Given this inefficiency and applying it to autonomous and electric car development, PVs cannot compete with urban transportation systems' future potential of well-developed PT systems. Future solutions should be built on PT modes of transport. PT modes are generally regarded as a viable alternative for sustainable transportation in urban areas, as they provide benefits such as energy conservation, a reduction in traffic congestion and air pollution, and an improvement in mobility, all while maintaining social equity considerations (Kepaptsoglou and Karlaftis, 2009). However, in recent decades, the trend toward PVs and a reduction in the proportion of daily commuting by PT has been influenced by factors such as urban sprawl, the need for personalized mobility, the increase in PV ownership, and socioeconomic growth (Pucher, et al., 2007; Sinha, 2003; Kepaptsoglou and Karlaftis, 2009). To reduce the reliance on PVs, it is important to design an effective PT system to foster urban mobility and reduce environmental and social challenges. This clarification of how formal PT systems solve informal transit inefficiencies provides the basis for the next question: Which transit mode is most appropriate for mid-sized, rapidly urbanizing cities?

C. Selecting an Appropriate PT Mode for Mid-Sized Cities

Once the need for formalization is acknowledged, the pivotal question becomes: which PT mode is most effective for mid-sized cities? To choose an appropriate PT mode for a city, it is essential to assess some connected factors and highlight the specific conditions of the city. As shown in Table I, the key factors are urban density and land use, population size, land use planning, demand factors, economic factors, environmental impact, geographical and topographical factors, existing infrastructure, service integration and connectivity, and social and cultural factors. These factors demonstrate the challenges of designing functional and efficient PT to serve multiple needs across the urban domain sustainably and economically.

In evaluating transit mode options for mid-sized cities, financial feasibility remains one of the most decisive factors alongside technical, institutional, and operational considerations. Formalization strategies must account not only for service quality and capacity but also for the substantial variation in both capital and operating costs across transit modes. Informal modes such as minibuses and paratransit systems typically involve minimal upfront infrastructure investment but carry limitations in service coordination, safety, and environmental performance (World Bank, 2002a; Cervero, 2000; ITDP, 2017). High-capacity modes such as HRT and LRT require significantly higher capital expenditures, ranging from $20 million to over $300 million per kilometer, depending on system complexity and local construction factors (UITP, 2021a, World Bank, 2002b; Bruun, 2005). BRT offers an intermediate solution, combining dedicated lanes and improved operational efficiency at a fraction of rail costs, typically ranging from $2 to $15 million/km (Hidalgo and Gutiérrez, 2013; Nikitas and Karlsson, 2015). Table II synthesizes these comparative cost characteristics, providing policymakers with indicative financial ranges to support preliminary mode selection decisions. These estimates serve as important reference points in resource-constrained environments where fiscal capacity often defines the scope and pace of transit formalization.

TABLE I
Key Factors and Considerations that Influence the Selection of Appropriate PT Modes in Mid-sized Cities

ik9	Key considerations	Relevant references
Urban Density and Land Use	Dense areas support rail/BRT; low-density areas may use flexible, on-demand services.	Göransson and Andersson, 2023
Population Size	Small-medium sized cities: mainly conventional buses; Large cities: incorporate rail, BRT, and buses.	Tu, et al., 2014; Cervero and Robert, 2013
Land Use Planning/TOD[1]	TOD improves accessibility, boosts PT use, and reduces reliance on PVs.	Redman, et al., 2013; Göransson and Andersson, 2023
Demand	As demand increases, a shift to higher-capacity, lower-marginal cost options like rail transit may be warranted.	Sun, et al., 2017; Tirachini, Hensher and Jara-Díaz, 2010; Jara-Díaz, Gschwender and Ortega, 2012
Economy	Consideration of installation, operation, and maintenance costs against economic benefits,	Ben-Akiva and Morikawa, 2002; Göransson and Andersson, 2023
Environmental Impact	Choose modes that lower GHG emissions, like electric buses or LRT systems.	Göransson and Andersson, 2023; Boschmans, Mayeres and Zeebroeck, 2021
Topography	Steep terrains may suit cable cars; flat areas are ideal for buses or light rail.	Molander, et al., 2012; Göransson and Andersson, 2023
Existing Infrastructure	Utilizing pre-existing or abandoned transit corridors (e.g., old rail lines or bus routes) can reduce startup costs and implementation time.	Göransson and Andersson, 2023
Service Integration and Connectivity	Integrate networks for smooth transfers and enhanced efficiency.	Fatima, et al., 2020; Göransson and Andersson, 2023
Social and Cultural	Local perceptions and culture impact PT design and acceptance.	Hansson, et al., 2019; Göransson and Andersson, 2023

[1]Transit Oriented Development

TABLE II
Comparative Cost Characteristics of Major Public Transit Modes

Transit Mode	Capital Cost (USD/km)	Operating Cost (USD/km)	Typical Lifespan (years)	Key Characteristics	Relevant References
Informal Transit/Paratransit	<0.3M	0.5–1.5	5–8	Informal, low investment, highly flexible	World Bank, 2002a; Cervero, 2000; ITDP, 2017
Conventional Bus	0.3M–1M	1–2	10–12	Low cost, flexible, lower capacity	World Bank, 2002a; ITDP, 2017; Hidalgo and Gutiérrez, 2013
BRT	2M–15M	1.5–4	15–20	Dedicated lanes, medium capacity	Hidalgo and Gutiérrez, 2013; Hidalgo, Giesen and Muñoz, 2024; ITDP, 2017; Bruun, 2005
LRT (Tram)	20M–60M	4–8	30–40	Medium-high capacity, moderate cost	World Bank, 2002b; Bruun, 2005
CRT (Train)	20M–80M	5–12	30–50	Suburban/regional, longer distances, lower frequency	World Bank, 2002b; UITP, 2021a
HRT (Metro/Subway)	80M–300M	6–15	40–50	Very high capacity, fully grade-separated, expensive	World Bank, 2002b; UITP, 2021a; ITDP, 2021

Given the key factors outlined in Table I and based on comparative cost considerations of major PT modes mentioned in Table II, buses are generally an appropriate fit for mid-sized cities with their ability to react to the varying demand for the system, low installation and operational costs, and easy integration in currently existing road networks, thus leading to sustainable and accessible development of transit. Some studies focus on higher capacity modes like rail or BRT because these modes have the potential to carry large ridership and limit the use of PVs (Mehndiratta and Rodriguez, 2017; Rodriguez, et al., 2017). These options usually call for large sums of money and solid political backing (Hensher, 2007). Such projects are financially constrained and impractical in many mid-sized cities (Del Mistro and Behrens, 2015) and financially unsustainable and cumbersome in smaller markets where high-capacity systems are in use (Vuchic, 2007). However, conventional BT systems can be rolled out incrementally, leveraging existing roads and bringing informal operators into a less capital-intensive framework. Well-planned, well-structured bus services with suitable vehicle standards and route planning are shown to improve both service reliability and emission reductions in both Latin America and Africa (Cervero and Golub, 2007; Alcorn and Karner, 2020). Although rail and BRT can be appropriate for certain high-demand corridors, the cost-effectiveness and scalability of conventional BT generally align more closely with mid-sized cities' governance and budget realities (Vuchic, 2007). Formalizing conventional BT is a more practical starting point, particularly for cities transitioning from informal networks to formal ones.

Buses are rubber-tired, steerable vehicles with a wide range of technical and operational features. Most buses feature a single body, two axles, and six rubber-tired wheels. Models can be articulated with three axles and up to ten wheels or double articulated with four axles and up to fourteen wheels. Bus capacity, normally about 70, can range from 15 (minibus) to 140 (double-articulated bus) as shown in Table III. There are different classifications of buses globally. They can be classified by function: they serve as city or transit buses for urban transport, suburban buses for connecting urban and suburban areas, intercity or tour buses for long-distance travel, school buses for student transport, shuttle buses for short, repetitive routes, and specialty buses for unique purposes like medical transport or sightseeing (Cromer, et al., 2024; Vuchic, 2007). Or classified by operational and infrastructure-based as conventional buses that operate in mixed traffic with basic infrastructure like curbside stops and limited speed, BTS features enhanced coordination with dedicated lanes, low-floor buses, and self-service fare collection, and BRT involves substantial infrastructure investment with separate lanes, advanced stations, and high-speed reliability (Vuchic, 2007). Also classified by propulsion are diesel, trolley, dual-mode, and hybrid (Vuchic, 2007). Diesel motors are by far the most popular mode of propulsion. Electric propulsion through overhead lines (trolleybus) is less prevalent but extremely efficient under specific situations such as hilly terrain and environmental sensitivity (Vuchic, 2007). Finally, they are classified by body type and capacity, as shown in Table III. Buses are the most widely used mode of transit today, with different classifications and characteristics. When compared to other modes of transit, buses are cheaper and more flexible, especially compared to rail-based and BRT transit systems, which require much larger investments (Button, Vega, and Nijkamp, 2010). Thus, they serve as the main transit mode in numerous cities worldwide, including major metropolitan areas (Mahmoudi, Saidi and Wirasinghe, 2024) providing essential transportation and forming the backbone of mobility for millions globally (Loh, 2014).

Choosing a suitable bus vehicle type for a city is influenced by several critical factors to ensure effective PT. According to Kosanoglu and Bal (2019), the primary criteria in this decision-making process include economic, environmental, technical, and social factors. Economic factors are crucial, focusing on the purchase cost of buses, fuel economy, and necessary infrastructure preparations; higher initial costs for electric buses can deter municipalities despite potential long-term savings on operational costs (Kosanoglu and Bal, 2019). Environmental considerations emphasize emissions and noise pollution, with electric buses typically producing fewer harmful emissions and less noise compared to diesel options (Wang and González, 2013). On the technical side,

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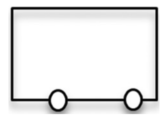
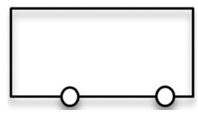
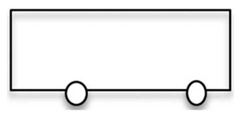
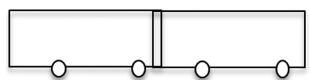
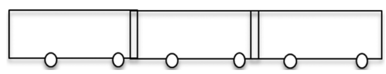
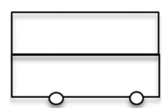
TABLE III
DIFFERENT BUS VEHICLE TYPES (VUCHIC, 2007)

Type	Sketch	Length (m)	Min/Max seats	Total capacity
Minibus		6–7	12/20	30
Midibus		8–10	16/30	50
Standard bus		10–12	35/55	85
Articulated bus		16–18	40/75	130
Double articulated bus		22–24	40/80	140
Double-decker bus		10–12	60/95	125

aspects such as maintenance ease and operational range are important, as buses that require less maintenance and can travel further without frequent refueling or recharging in the case of battery electric buses (Zhou, et al., 2016). The social aspect is lastly described as user comfort and accessibility for all community members, especially as cities attempt to enhance the public's satisfaction with transportation services (Shiau, 2013). Overall, a comprehensive evaluation of these factors is essential for municipalities to select the most suitable bus type that aligns with their sustainability goals and community needs (Kosanoglu and Bal, 2019). By the factors mentioned above, an appropriate bus type can be selected to suit cities' economic, environmental, technical, and social conditions. Having established that BT often stands out as the most adaptable and cost-effective solution. In the next section, we will explore how to plan and design an efficient bus-based system will be shown.

D. BT Planning Process

Designing a robust BT system requires a structured planning process from route design to scheduling those accounts for passenger needs and operational constraints. The BT planning process is extensive and can be divided into five stages: "Network design, frequency setting, timetabling, vehicle (bus) scheduling, and crew (operator) scheduling" (Ceder and Wilson, 1986; Guihaire and Hao, 2008). Because of this extensiveness, authors often name it as a problem. Farahani, et al. (2013) looked at the problem from another view and named it "Urban Transportation Network Design Problem" and divided it into three stages: strategic, tactical, and operational. Strategic decisions are long-term decisions connected to the infrastructures of transportation networks, including both transit and road networks, while tactical decisions are focused on the appropriate usage of infrastructures and resources of existing urban transportation networks. Operational choices are short-term decisions usually connected to traffic flow control, demand management, or scheduling challenges. On the other hand, Ibarra-Rojas, et al. (2015) divided the problem into six steps that were "(Transit Network Design, Frequency Setting, Transit Network Timetabling, Vehicle Scheduling, Driver Scheduling, and Driver Rostering)" and four strategies "(strategic, tactical, operational, and real-time control strategy)." Solving each of these steps simultaneously appears to be intractable due to the overall complexity, which has led most solutions throughout the years to be sequential, i.e., solving each step individually (Guihaire and Hao, 2008; Ferreira, 2020). For each of these levels, the researchers identify the inputs and outputs that they require, noting that the result of each step is a necessary input for the next step, but it is also retroactively relevant, i.e., the results of further steps can influence previous ones. This amounts to an almost iterative process (Ibarra-Rojas, et al., 2015), where to obtain near-optimal results, these steps should be repeated, including the previous results. The researchers also argue that this is a cumbersome process to perform manually, especially the last two steps, which show the advantages of automated computer applications to aid the planning process (Ferreira, 2020). These stages collectively aim to optimize PT systems while considering multiple objectives, including minimizing travel time, reducing operational costs, and ensuring service reliability (Guihaire and Hao, 2008). Fig. 4 presents information about the transit planning process and inputs and outputs from each stage based on knowledge gathered from different articles. With increasing environmental considerations globally, cities could

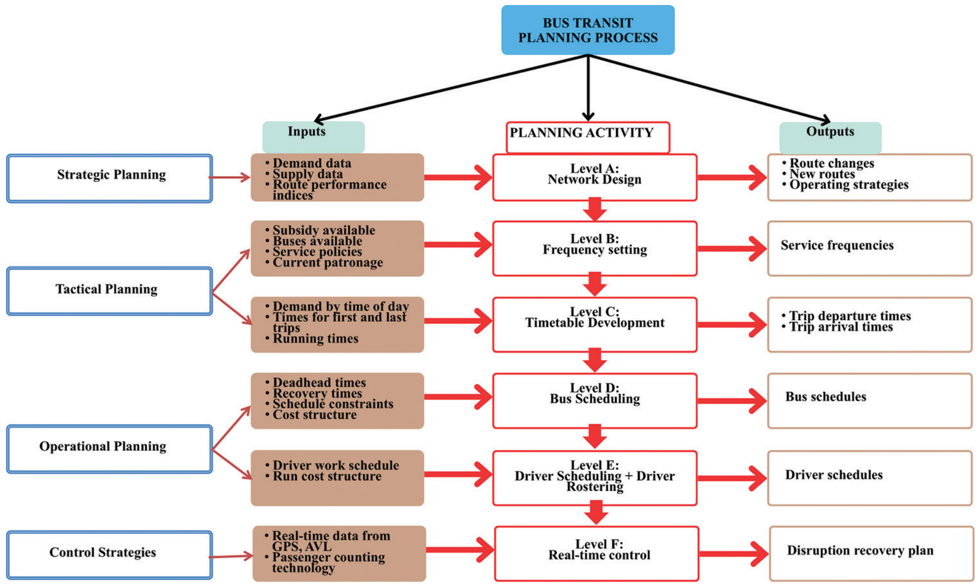


Fig. 4. Interaction between the five stages of the bus network planning process and real-time control strategies adopted from (Ferreira, 2020; Ceder and Wilson, 1986; Ibarra-Rojas, et al., 2015; Guihaire and Hao, 2008; Farahani, et al., 2013).

consider sustainable approaches and resilient strategies while developing a BT system by implementing these stages. The following section examines how integrating environmental, economic, and social considerations can shape a more sustainable BT system.

E. Sustainable Approaches and Resilient Strategies

Sustainability in PT is a crucial factor in modernizing BT systems in mid-sized cities. It emphasizes reducing emissions, optimizing routes, and ensuring equitable access to lower environmental footprints, enhancing economic efficiency, and promoting social equity. As Turner (2019) emphasized that effective mobility is essential for building sustainable communities and plays a key role in supporting vibrant urban centers through PT. The sustainability approach in PT addresses the negative environmental impacts of urban mobility through strategies such as lowering emissions, improving energy efficiency, and advocating for eco-friendly technologies such as battery electric buses and non-motorized vehicles (Etingoff, 2015). BT system, which is a mode of PT, similarly aims to combat environmental degradation, enhance economic productivity, and guarantee fair transit opportunities for all citizens (Shokoohyar, et al., 2022; Basheer, Boelens and Bijl, 2020) by deploying energy-efficient vehicles and optimizing routes to alleviate congestion and greenhouse gas emissions (Basheer, Boelens and Bijl, 2020). International organizations, such as the United Nations and the World Bank, actively support and fund such sustainable PT initiatives globally. In conclusion, integrating environmental, economic, and social sustainability is essential when developing any PT system, particularly BT, to tackle the complex challenges of urban mobility.

To make the public and BT systems in cities sustainable, a multi-component approach based on technology efficiency, policy changes, and urban planning is needed. A BRT case is implementable anywhere in the world because of its cost efficiency compared to rail systems, the flexibility of the network, and the dependence on high service frequency. The lesson from the experiences of Curitiba and Bogotá is that a well-planned and integrated BRT with dedicated lanes and feeder networks can enhance the PT system and at the same time, lower the use of PVs, thus reducing traffic congestion as well as emission problems which are associated with them (Schipper and Fulton, 2002; Hensher, 2007). In the case of conventional buses, electrifying bus fleets and embracing cleaner fuels like “Compressed Natural Gas” can be crucial in reducing transit-related emissions, as proven by measures under programs such as “Zero Emission Urban Bus System” and “European Bus System of the Future” (Fernandez-Sanchez and Fernandez-Heredia, 2018). Furthermore, the improvement of service quality through safety, comfort, reliability, and accessibility with improvements in technology as the provision of real-time passenger information and automated fare collection enhances the level of user satisfaction and increases ridership (Fernandez-Sanchez and Fernandez-Heredia, 2018; Sogbe, Susilawati, and Pin, 2024). Moreover, aligning PT improvements with broader urban policies, including congestion charging and land-use planning, is essential to ensure sustainable mobility for the future (Schipper and Fulton, 2002; Hensher, 2007). By implementing BRT, electrifying bus fleets, using cleaner fuels, improving service quality, and broadening urban policies, including congestion charging and land-use planning, cities can be more sustainable.

Building on sustainability, resilience focuses on a transit system’s capacity to recover quickly and maintain service despite challenges such as extreme weather events such as flood and wind, infrastructure failures, or unforeseen urban growth pressures. Resilience in public and BT networks has evolved as a critical concept, encompassing the ability of systems to resist, absorb, recover, and adapt to disruptions while maintaining functionality. Murray-Tuite (2006) developed the first resilience definition for transportation networks, suggested resilience measurements, and found ten resilience dimensions which can be named ROADSHIELD (Redundancy, Organization, Adaptability, Diversity, Strong, Harmony (Collaboration), Ingenuity (Efficiency), Elasticity (Quick recovery), Locomotion (Mobility), and Durability (Safety)). However, these aspects are complicated and interactive, making resilience measurement problematic. After studying transportation network resiliency in their "R4 framework", Ilbeigi (2019) proposed four resilience attributes: "redundancy, robustness, resourcefulness, and rapidity." Redundancy indicates the availability of alternate resources, whereas robustness assesses catastrophe resistance. Resourcefulness in transportation network systems refers to the ability to repair maintenance units after a disaster, while rapidity is the ability to fully employ these resources and quickly restore service levels (Zhou, Wang, and Yang, 2019). In PT, resilience is the ability of the system to resist, absorb, adapt to, and recover from shocks and still function. This requires technological, operational, and social enablers to manage the impacts of unpredictable events such as natural disasters, system failures, or extreme weather conditions. For example, a good PT system can increase service level by rerouting, the use of other modes, and providing guaranteed communication with the users (Mudigonda, Ozbay and Bartin, 2018; Vodopivec and Miller-Hooks, 2019; Zhou, Wang and Yang, 2019). As is the case with PT systems, a measure of BT resiliency is the ability of a system to perform and return to normalcy after being interrupted by unexpected occurrences. According to Huang, Huang and Wang (2023), it has four measures: resistance measures the ability to handle the first shocks, absorption measures the ability to handle the impact of disturbances, recovery measures the ability to bounce back to the pre-disturbance level), and adaptability measures the ability to learn and improve from disturbances. Resilience in public and BT is more than being able to survive shocks; it is also a capability to adapt and further improve performance in the face of unforeseen events, assuring service continuity and efficiency.

It is important to adopt a strategy that would enhance the resilience of BT systems through planning for contingencies, use of advanced technology, and engineering of transport infrastructure. Resilience frameworks should address the availability of operational capability during disruptions and quick restoration with demand redundancy and flexibility in transit networks (Huang, Huang and Wang, 2023; Azolin, et al., 2020). For instance, integrating alternative routes and active modes such as walking and cycling into the transportation system design can significantly mitigate the impact of system disruptions (Azolin, et al., 2020). Big data technology and intelligent transportation system (ITS) can provide real-time data for the dynamic management of routes and also allow for preventive strategies in disaster situations (Mudigonda, Ozbay and Bartin, 2018). Addressing transportation policies to make people more resilient in their communities may catalyze the integration of fares and subsidies for vulnerable people (Santos, et al., 2020). Resilience can be integrated into transport systems of urban hubs as this helps to minimize the effects of adverse environments and socioeconomic conditions toward sustainable and inclusive urban growth. Various studies performed to enhance the sustainability and resilience of public and BT systems are shown in Table IV.

Studies on sustainable and resilient public and BT systems (Table IV) highlighted various approaches cities worldwide use to address specific transit challenges such as route optimization, fare restructuring, and green technology adoption in different contexts. Geospatial city layouts – such as grid, random, or blob-type – were analyzed for their impacts on bus network efficiency and robustness, demonstrating significant improvements in route optimization and reliability (Pang, et al., 2015). Quality assessment aspects, including ticketing systems and seat comfort, were examined for their role in enhancing rider satisfaction in mid-sized urban contexts (Sinha, et al., 2017). MCA was applied to evaluate the sustainability of BT systems, considering social, economic, environmental, and institutional dimensions (Ribeiro, Fonseca and Santos, 2019). Incorporating citizen preferences into PT planning was found essential for enhancing sustainability and reducing resistance to change, particularly emphasizing tractability and clear timetabling (Moslem and Duleba, 2019). Fare restructuring and the implementation of dedicated BRT lanes were explored as effective strategies to boost ridership and substantially reduce emissions (Patel and Padhya, 2021). Sustainable bus technologies, including biodiesel, biomethane, and electricity, were identified as optimal solutions for improving environmental sustainability in bus fleets (Ammenberg and Dahlgren, 2021). Quantifying resilience factors, such as system robustness and recovery capacities, were highlighted as crucial for enhancing the adaptability of bus networks during emergencies (Huang, Huang and Wang, 2023). These studies underscore the need for holistic planning and tailored solutions to foster resilience and sustainability in public and BT across diverse urban environments.

Several key measures can be taken to develop a sustainable and resilient BT system in mid-sized cities that depend on informal modes of transportation. The first is to prioritize the transition from informal to formal transit systems, ensuring structured routes, schedules, and reliability of service (Cervero and Golub, 2007; Ahmed, 2003). Sustainable technologies, such as electric and hybrid buses, need to be introduced to reduce greenhouse gas emissions and enhance energy efficiency (Fernandez-Sanchez and Fernandez-Heredia, 2018; Schipper and Fulton, 2002). Infrastructure can be designed to withstand disruptions and incorporate redundancy through alternative routes and backup systems to improve resilience (Huang, Huang and Wang, 2023; Ji, et al., 2022; Azolin, et al., 2020). Dynamic route management and predictive maintenance can be made using data-driven technologies, including GPS tracking, smart ticketing, and real-time analytics (Wang, et al., 2022; Mudigonda, Ozbay and Bartin, 2018). In addition, accessibility, affordability, and social equity features for various demographic segments can be prioritized in community participation policies (Santos, et al., 2020; Mehndiratta and Rodriguez, 2017).

TABLE IV
Studies Considering Sustainability and Resilience While Developing and Optimizing Public (Bus) Transit Systems

Author	City	Research Question	Outcome/Impact
Pang, et al., 2015	Comparative: Manhattan, Sudan, Beijing, Greater Cairo	How do different geospatial city layouts (e.g., grid, random, single-blob, dual-blob) impact bus network efficiency and robustness?	• Efficiency improved by 20–50% in optimized routes compared to random • Dual-blob networks were found to be efficient but less robust to targeted failures
Sinha, et al., 2017	Patna, India	How can quality assessment improve public bus services and promote sustainable transportation in mid-sized cities like Patna, India, using the TOPSIS method?	• The ticketing system ranked highest (C[2]*=0.914). • Comfortable seats second (C*=0.553). • Bus information (C*=0.006) and frequency (C*=0.059) ranked lowest.
Ribeiro, Fonseca and Santos, 2019	Marco de Canaveses, Portugal	How can MCA[3] be used to evaluate the sustainability of urban bus systems across social, economic, environmental, and institutional dimensions?	• Sustainability index evaluated using 18 indicators. • CO[4] emissions: 18.33 units; • Particulate matter emissions: 2.20 units. • Bus frequency: 16.8 buses/day. • Spatial coverage: 0.76 km/km^2. • Transfer hubs: 33.33% meet standards.
Moslem and Duleba, 2019	Mersin, Turkey	How can citizen preferences be effectively incorporated into PT development decisions to enhance sustainability and reduce resistance to change?	• Tractability scored highest: 0.623. • Transport quality: 0.311; Service quality: 0.155. • Recommendations prioritize timetable perspicuity.
Susanto, et al., 2020	Malang, Indonesia	How can a resilient PT system be developed in Malang City to address urbanization challenges and limited resources?	• 114 road projects prepared to reduce congestion. • Public transport users report high costs and unreliable service. • 1.5 million people affected by poor transport, requiring urgent policy intervention.
Patel and Padhya, 2021	Bengaluru, India	How can fare restructuring and BRT lanes improve the efficiency and sustainability of Bengaluru's PT system?	• Fare restructuring of BMTC[5] bus service increased mode share by 2%. • Revenue rose by 15%. • BRT lanes boosted ridership by 4%, and revenue by 23%. • Emissions reduced: NOx (−12%), CO (−9%), CO2 (−6%).
Ammenberg and Dahlgren, 2021	Sweden	How can PT authorities evaluate the sustainability of various bus technologies to support green public procurement?	• Demonstrated increased use of renewable technologies in Swedish bus fleets, with over 60% of buses running on renewables by 2017. • Highlighted biodiesel, biomethane, and electricity as optimal choices for sustainable transit.
Li, Dong and Lu, 2021	China	How can hybrid heuristic algorithms improve the prediction of transportation-related carbon emissions and support low-carbon transportation policies?	• Carbon emissions increased 4x from 2000 to 2017. • Root mean square error for genetic algorithm optimized extreme learning machine: 35.36 megatons; • Maximum absolute percentage error: 0.6%. • Prediction error significantly lower than other models.
Huang, Huang and Wang, 2023	Beijing, Chin	How can resilience be quantified and modeled in urban bus networks to improve their response and recovery during emergencies?	• The resilience index improved with the CRITIC-entropy method. • Recovery time quantified with resilience factors. • Resilience model identified high-priority routes for intervention
Frieß and Pferschy, 2023	Graz, Austria	How can mixed-fleet zero-emission public bus systems be optimized to minimize life cycle costs while considering operational and infrastructural requirements?	• Reduced fleet costs by up to 12% using a mixed fleet. • Found that opportunity charging decreased life cycle costs by 10% compared to overnight charging. • Demonstrated scalability to networks with 4000+trips.
Al Suleiman, et al., 2023	Oviedo, Spain	How to Improve PT Usage in a Medium-Sized City: Key Factors for a Successful Bus System?	• Comfort and information are top satisfaction factors. • Average satisfaction: 3.99/5. • Identified factors (Comfort and Information, Service Performance, and Integration) influencing satisfaction.
Foda, et al., 2023	Oakville, Canada	How can a battery electric bus system, using GTFS[6] data, be optimized to enhance resilience against charging station disruptions while maintaining operational efficiency?	• Base model annual cost: $6,959,381.19. • Robust models increased cost by 3.26% (k[7]=1) and 8.12% (k=2). • Single failure reduced service by 34.03%; two failures by 58.18%. • Robust model-maintained service with cost-efficient adjustments.
Sriprateep, et al., 202	Mueang Ubon Ratchathani and Warinchamrab, Thailand	How can urban bus routes be optimized for resilience, sustainability, and safety while promoting tourism?	• 12.24–17.02% improvement in resilience • 5.71–12.12% improvement in sustainability • 9.52–17.39% reduction in total travel distance • Accessibility score of 2300 achieved

[2]C: TOPSIS Index Score (the higher, the better)
[3]MCA: Multi-Criteria Analysis
[4]CO: Carbon Monoxide
[5]BMTC: Bengaluru Metropolitan Transport Corporation
[6]GTFS: General Transit Feed Specifications
[7]K: conservative risk level in the two-stage robust optimization model

By aligning these methods with urban policies, particularly in land use planning and congestion control, mid-sized cities can develop a robust and flexible BT system that addresses current and future mobility needs (Hensher, 2007; Schipper and Fulton, 2002). Thus, mid-sized cities can develop a BT system to suit future challenges and current demand by implementing sustainable technologies, resilient infrastructure, data-driven methods, and policies in urban planning strategies.

IV. Discussion

Informal transit systems often provide unreliable service, create traffic congestion, and raise safety concerns and environmental issues; therefore, mid-sized cities need a transition to an appropriate formal PT mode. This transition should be based on key factors and considerations, including urban density, land-use patterns, population size, land-use planning, travel demand, economic conditions, environmental impact, geographical and topographical impact, existing infrastructure, service integration and connectivity, and sociocultural factors, to ensure the solution meets local needs (Table I) (Göransson and Andersson, 2023; Tu, et al., 2014; Redman, et al., 2013; Tirachini, Hensher and Jara-Díaz, 2010; Sun, et al., 2017; Ben-Akiva and Morikawa, 2002; Boschmans, Mayeres and Zeebroeck, 2021; Molander, et al., 2012; Fatima, et al., 2020; Hansson, et al., 2019). In practice, conventional buses often emerge as the most suitable formal mode due to their lower capital requirements, greater operational flexibility, cultural acceptance, and ability to adapt to existing road networks (Mehndiratta and Rodriguez, 2017; Rodriguez, et al., 2017). Even within bus-based systems, choosing the right bus type depends on a city's financial resources, technical capacity, environmental priorities, social factors, urban planning, and geometry of roads (Tables II and III) (Kosanoglu and Bal, 2019; Wang and González, 2013; Zhou, et al., 2016; Shiau, 2013; Khakimov and Tanaka, 2024). Opting for buses, instead of more costly alternatives like rail or BRT, enables mid-sized cities to gradually enhance transit service without the high costs and institutional demands associated with high-capacity systems (Hensher, 2007). This positions formal BT as a practical first step for cities currently depending on informal modes.

Besides, other factors can contribute to the goal of sustainable and resilient BT planning: sustainability and resilience considerations. From a sustainability perspective, the goals to achieve include environmental conservation, improvement of economic performance, and social justice in the provision of transit services (Basheer, Boelens and Bijl, 2020; Shokoohyar, et al., 2022). Achieving these outcomes requires specific actions like electrifying or hybridizing bus fleets, implementing real-time passenger information systems, and aligning transit improvements with wider urban policies (e.g., congestion pricing and land-use regulations) (Fernandez-Sanchez and Fernandez-Heredia, 2018; Schipper and Fulton, 2002). Additionally, exclusive bus lanes and intersection priority strategies have been proven effective in enhancing bus service speed, reliability, and overall PT efficiency and sustainability (Khakimov and Tanaka, 2024; Nitti, et al., 2020). These measures facilitate emission reduction, traffic congestion mitigation, and overall operational efficiency through the continued support of citywide sustainability initiatives by transit investments.

When it comes to resilience, it is important to note that a BT system's capacity to maintain its functionality and operate effectively even in disruption is significant. Resilience encompasses the network's capability to resist, absorb, recover from, and adjust to incidents like extreme weather, infrastructure failures, or sudden increases in ridership (Huang, Huang and Wang, 2023; Mudigonda, Ozbay and Bartin, 2018). In this study, it is proposed that more light is thrown on the fact that proactive planning and advanced technologies can greatly improve the level of security in transit systems. Key strategies involve designing redundant routes, implementing ITS for dynamic re-routing, and adopting inclusive policies that safeguard vulnerable populations during service interruptions. These actions allow a city to sustain transit operations when confronted with unexpected challenges, reinforcing the reliability of bus services under pressure (Mudigonda, Ozbay and Bartin, 2018; Huang, Huang and Wang, 2023; Azolin, et al., 2020; Santos, et al., 2020).

A. Proposed Decision Framework for Transit Formalization

Based on the study findings and the evidence in Tables I–IV, this study proposes a structured decision-support framework presented as a multi-stage decision tree. The process begins with Fig. 5, which evaluates the urban context, including population, density, land use, governance capacity, and the scale of informal operations. Fig. 6 examines the suitability of transit modes by considering financial resources, infrastructure readiness, and travel demand, followed by the BT planning of routes, schedules, and operations. In Fig. 7, sustainability measures are integrated, such as fleet electrification, cleaner fuels, and route optimization aligned with urban environmental goals. Fig. 8 addresses resilience by incorporating redundancy, dynamic management, and inclusive social policies, ultimately leading to implementation and adoption.

B. Challenges and Limitations

However, existing research does not fully address the unique context of mid-sized cities. Much of the literature to date has focused on large metropolitan areas or isolated aspects of transit reform (e.g., specific technologies or policy initiatives), leaving a gap in holistic guidance for mid-sized cities. This study identified several persistent gaps in knowledge that need to be addressed. The first is a long-term impact gap: despite the promise of formal transit systems, the long-term outcomes of informal-to-formal transitions remain insufficiently documented. Most existing case studies, including those cited in this review, rely on short-term evaluations, with limited evidence spanning

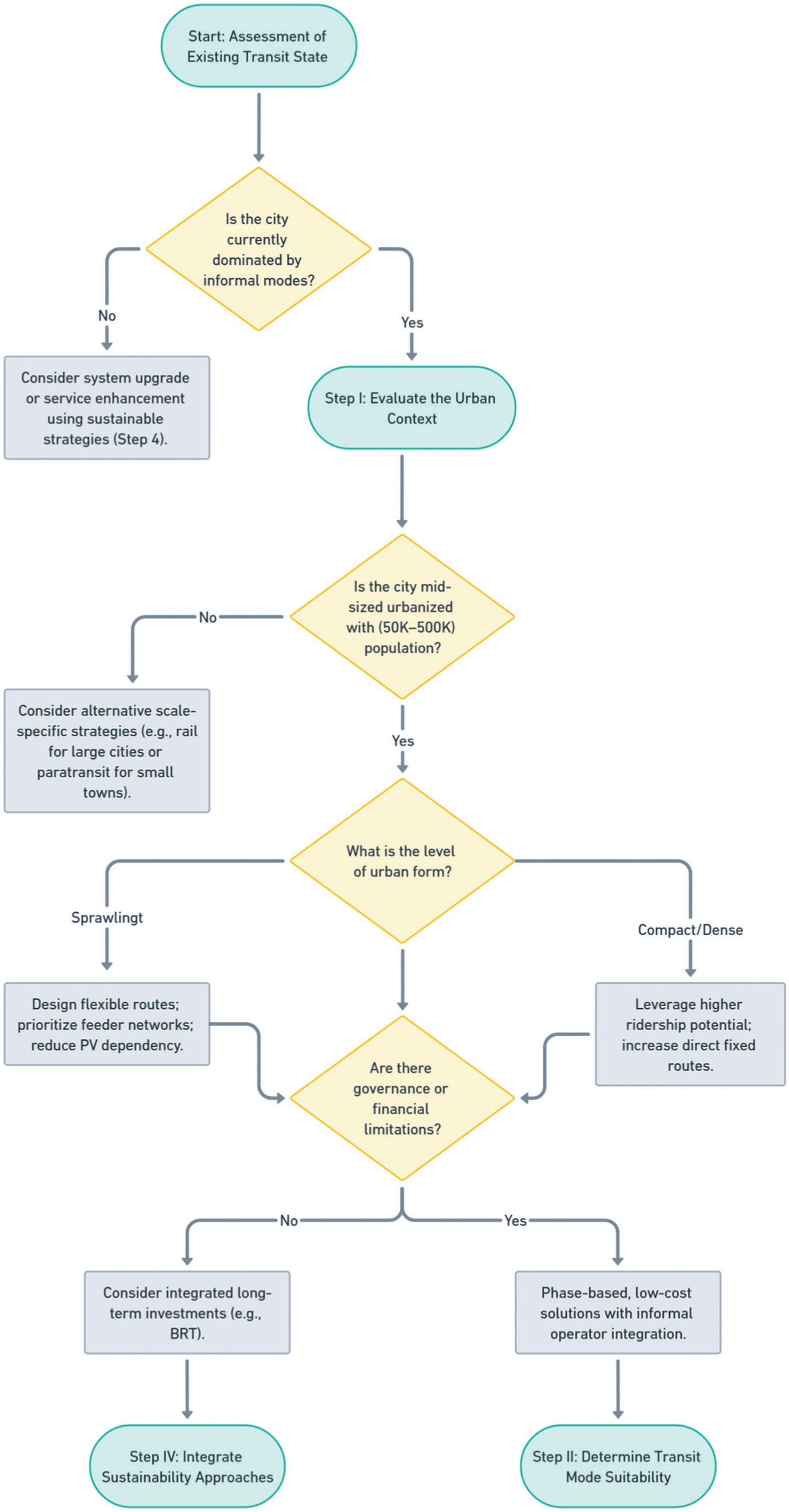


Fig. 5. Structured decision tree for transit formalization of mid-sized cities (Step 1).

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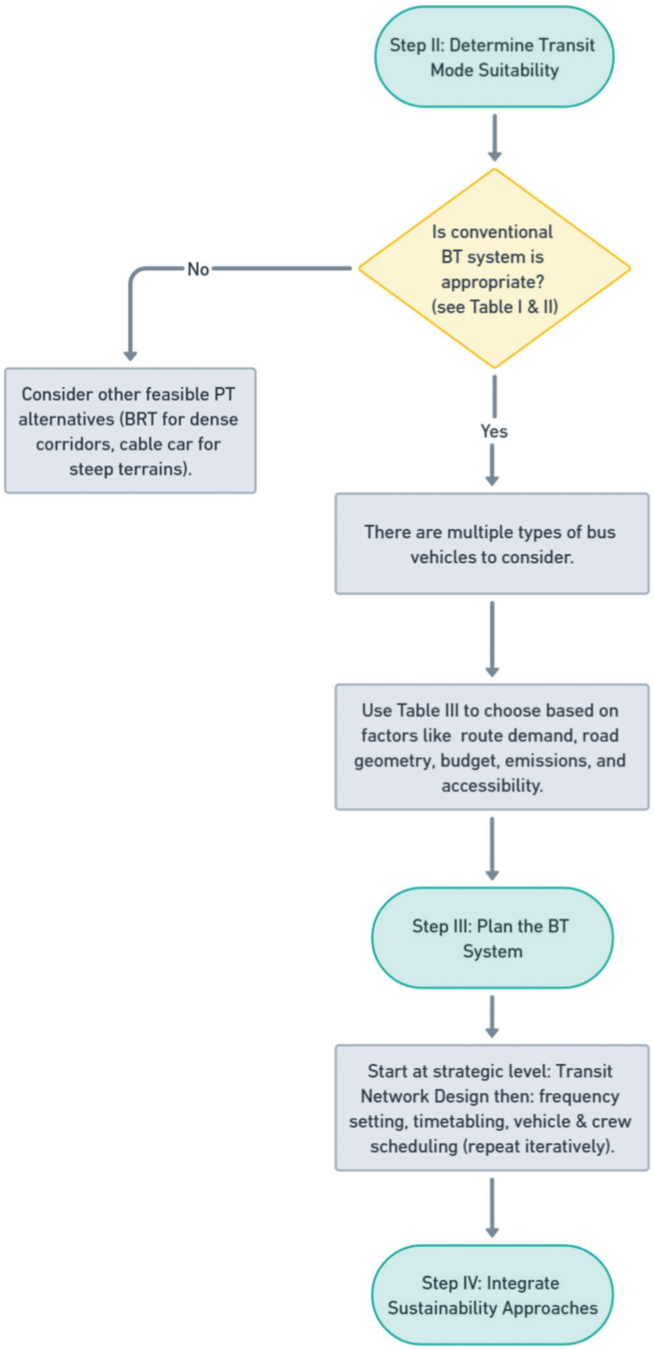

Fig. 6. Structured decision tree for transit formalization of mid-sized cities (Step II and Step III).

5–10-year post-formalization. This lack of longitudinal data constrains policymakers' ability to forecast sustainability, equity, or institutional outcomes with confidence. As a result, recommendations made in this framework must be seen as initial, adaptable guidance rather than prescriptive solutions. Pilot projects with embedded monitoring frameworks, stakeholder engagement processes, and outcome-tracking mechanisms could serve as intermediate solutions while longitudinal evidence is gradually built. In addition, fostering regional collaborations for data sharing can help bridge temporal gaps across cities at different stages of formalization. The second gap concerns geographic diversity. While this study has expanded regional representation, much of the existing literature remains concentrated in a few regions, particularly Sub-Saharan Africa and parts of Latin America; meanwhile, cities in the Middle East, Southeast Asia, and smaller African urban centers are still comparatively underexamined. Although this limited geographic distribution may affect generalizability, the framework presented here is intended for mid-sized cities that share similar institutional, financial, and transit characteristics with those commonly studied. At the same time, several core strategies, such as stakeholder coordination, informal operator integration, and phased implementation, are considered adaptable across diverse governance and cultural contexts. The third gap concerns the integration of informal operators. Although the literature on operator integration remains limited, emerging evidence suggests that transitional models such as cooperatives, retraining programs, and lease-to-own incentives can help mitigate livelihood risks while enhancing system efficiency. For example, these mechanisms have allowed informal drivers to transition into formal roles without immediate job loss, supporting both operational goals and social equity. Some studies, such as Alcorn and Karner (2020), have explored approaches to incorporate existing operators into formal networks, yet a systematic understanding of labor practices, regulatory adaptation, and long-term stakeholder engagement remains underdeveloped. Further research is needed to clarify how cities can design inclusive transitions that safeguard livelihoods while advancing formalization goals. Addressing these gaps would provide a stronger empirical foundation for planning and offer a broader perspective on the range of contexts in which formalization initiatives unfold.

In addition to research gaps, mid-sized cities face several practical challenges when implementing formal BT systems. These include funding constraints, as establishing or upgrading a bus system from acquiring vehicles to building dedicated lanes and stations requires substantial upfront investment and ongoing operating funds. These costs often exceed the limited budgets of mid-sized city governments, making financial sustainability a major hurdle for formal transit projects. Although financial considerations are widely recognized as a major barrier to transit formalization, few studies systematically compare the economic profiles of available transit modes. Table II provides a comparative summary of the capital and operating costs, lifespan, and defining characteristics of key PT modes, offering a practical reference for mid-sized cities facing funding and feasibility constraints. This benchmark table helps illustrate the wide cost differentials between modes from low-cost, flexible minibus systems to high-capacity but capital-intensive HRT. These indicative ranges of costs can serve as preliminary benchmarks for planners conducting feasibility assessments in data-scarce environments. Another major challenge is stakeholder resistance: entrenched informal transit providers may oppose formalization efforts that threaten their livelihoods or autonomy. Resistance from private minibus owners or

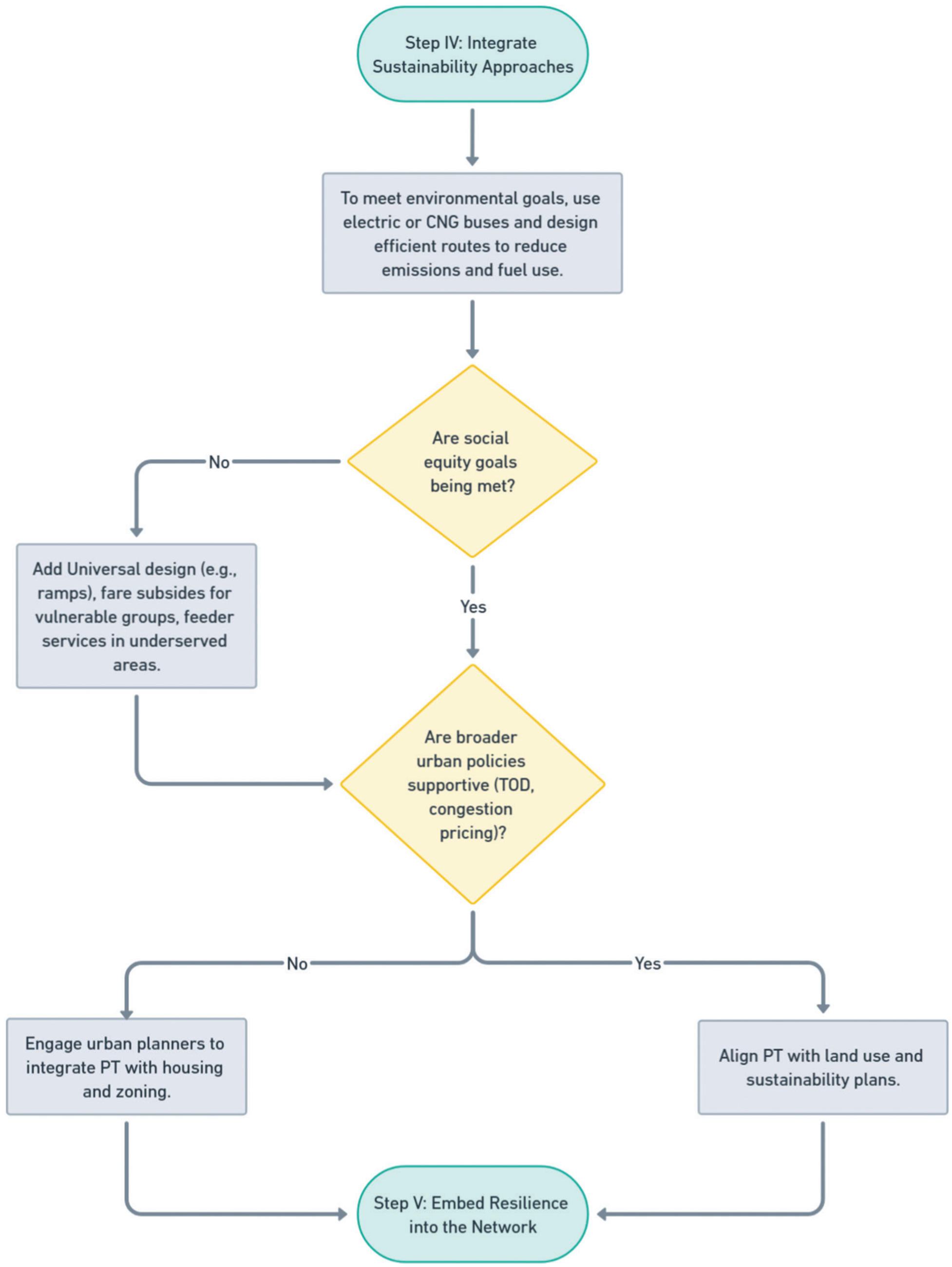

Fig. 7. Structured decision tree for transit formalization of mid-sized cities (Step IV).

informal transit unions can slow down or derail reforms, especially if alternatives for these stakeholders are not provided. Finally, many mid-sized cities face governance and capacity limitations. Implementing a formal transit system demands effective regulation and management, yet many mid-sized cities struggle with limited institutional capacity. Weak regulatory frameworks, fragmented municipal authorities, or inconsistent political support can impede the enforcement of routes, schedules, fare systems, and safety standards in a newly formalized network.

Such gaps show between the theoretical benefits and the real-world implementation of these issues. While the advantages of formal BT (better reliability, accessibility, and sustainability) are widely supported in the literature, cities face financial, social, and institutional barriers to realizing these benefits. Such strategies to bridge this divide will be deliberate: building local financial frameworks (dedicated transit funding or public-private partnerships), engaging and compensating informal operators as partners in the new system, and strengthening institutional oversight and planning capacity. Mid-sized cities can take proactive steps to fund, stakeholders, and governance first so that formal transit reforms can move from planning to action, where they can deliver on the promised sustainability and resilience outcomes.

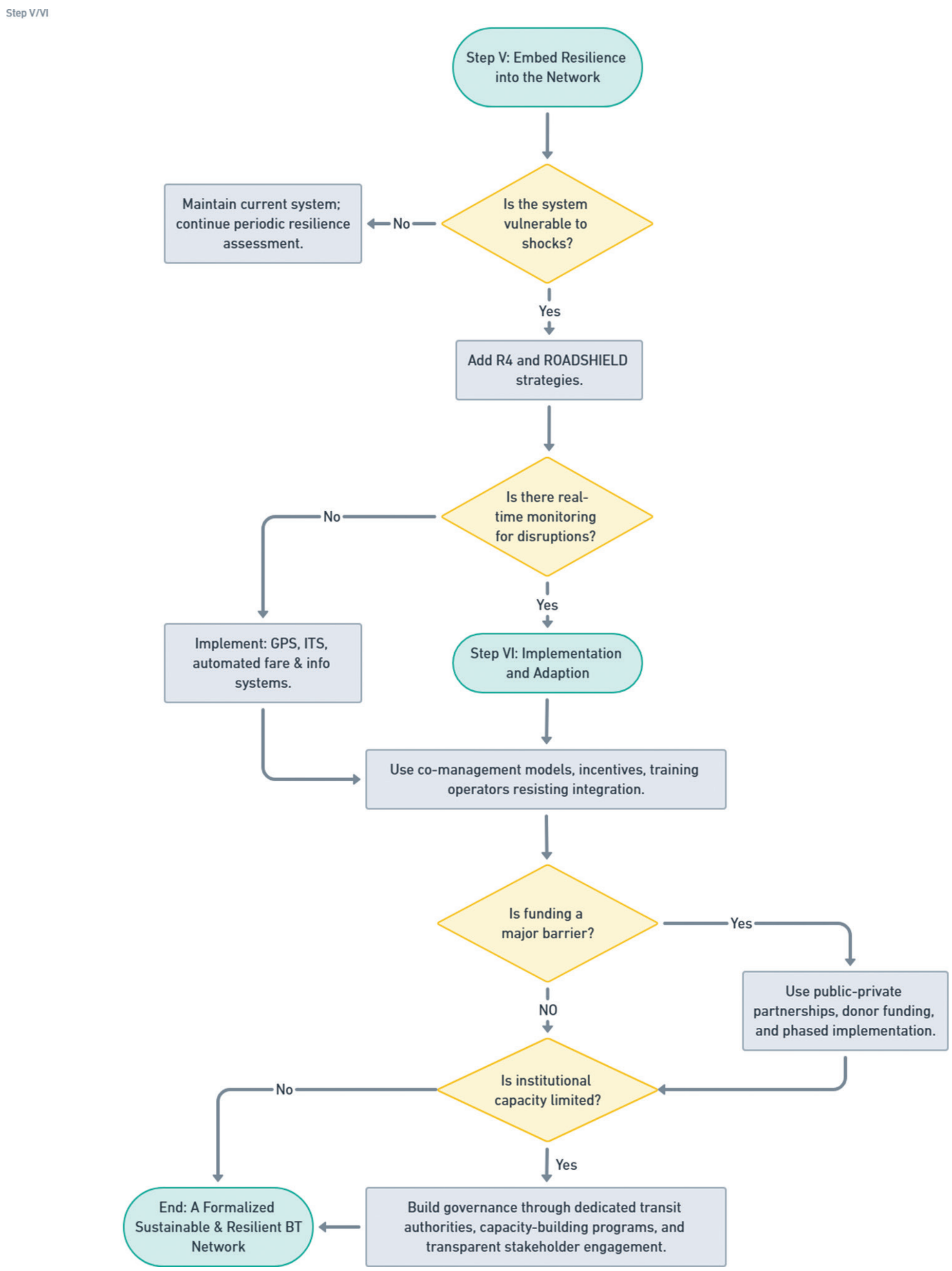

Fig. 8. Structured decision tree for transit formalization of mid-sized cities (Step V and Step VI).

V. Conclusion

This study underscores that formalizing BT systems in mid-sized developing cities offer a practical solution to long-standing inefficiencies in informal transit networks. The assessment of current PT systems shows that informal modes face irregular service, safety concerns, and limited coverage, especially for low-income people. Formal systems address these challenges through regulated operations, structured routes, and improved service quality. In evaluating transition pathways, the study highlights inclusive strategies such as cooperatives, retraining, and phased integration to ease resistance and build institutional capacity. In mode selection, conventional BT emerges as the most appropriate option due to its cost-effectiveness, flexibility, and compatibility with existing infrastructure. Implementation requires a structured planning process covering network design, frequency setting, scheduling, and crew management, optimizable through data-driven tools. To ensure viability, the study highlights sustainability and resilience through clean propulsion technologies, ITS, and resilience measures such as Roadshield and R4. A structured decision-support framework in the form of a decision tree is proposed to guide context-sensitive planning decisions. Its success depends on governance capacity, funding availability, and stakeholder coordination. A key limitation remains the lack of long-term assessments of formalization impacts on equity, land use, and system performance. Future studies could explore longitudinal outcomes, labor integration models, and the role of technologies such as electric buses and real-time analytics in strengthening system resilience. These efforts are critical to ensure formalization leads to improved transit and inclusive urban development.

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