How to integrate paratransit data into GHG emissions calculations?

A methodological note based on the MobiliseYourCity's MRV framework and GHG Emissions Calculator

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Mobilise Your City

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Summary

1.Introduction

The term *Paratransit* was firstly coined in United States to describe all transport services that do not operate according to timetables or fixed routes (Baffi et al., 2023). Nevertheless, the concept has been expanded to include to those flexible, informal or semi-formal transport services that bridges the gap between private vehicles and formal public transport (Peters & Bhusal, 2020). *Paratransit* hence does not necessarily exist in opposition to mass transit but can be complementary. It encompasses a wide range of vehicles - minibuses, shared taxis, moto-taxis, tuk-tuks, jeepneys, *inter alia* - operating with flexible schedules, stops, and pricing (Cervero, 1997) with an economic rationale behind most of them: "that of an entrepreneur seeking short-term profitability and making all their own decisions."

In their contexts, some analysts suggest these informal services may move as many or even more passengers than all formal public transport modes combined (Lindsay, 2024). Exact figures are hard to pin down due to data gaps, but the scale is undoubtedly enormous. Formal public transport systems recorded on the order of hundreds of billions of passenger trips annually (e.g. 243 billion trips in 39 reporting countries in 2015)(UITP, 2017), and informal transport likely contributes a comparable magnitude.

Paratransit services can therefore be seen as important "gap filler" (Cervero & Golub, 2007) services to underserved as mobility-challenged populations when public transport is inaccessible, inconvenient, or unaffordable (Kustar et al., 2023). Informal transport services emerge to satisfy unmet transport needs of passengers who face transport disadvantages due to their geographical locations and/or social backgrounds. Beyond sheer ridership, these services provide essential employment for hundreds of thousands (if not millions) of drivers and operators worldwide (Lindsay, 2024). In addition, paratransit services contribution to greenhouse gas (GHG) emissions is significant, especially in cities striving to meet climate targets. Older, inefficient vehicles and fragmented service provision contribute significantly to urban emissions and air pollution. Yet the invisibility of paratransit in emissions inventories means its true contribution to urban GHG levels is often underestimated, or completely ignored. Recognising, measuring, and integrating this sector into national climate agendas is urgent (Almendros, n.d.).

Framed on this reality, this methodological note offers some guidance to facilitate that GHG emissions from paratransit are accurately estimated and managed in line with climate goals. This report consists of four sections:

- Section 1: *Why to promote GHG emission mitigation strategies in paratransit?* This section emphasises the reasons behind climate action in the paratransit sector. It highlights some typical mitigation measures and explains how to use the MobiliseYourCity GHG calculator to build climate scenarios.
- Section 2: *What data should be considered as input to MRV systems for the tracking of reduction targets in the paratransit sector?* Based on desk research, this section provides a Monitoring, Reporting and Verification (MRV) framework that may inform decision makers to set up protocols at local level to improve paratransit data gathering, processing and reporting for follow-up.
- Section 3: *How can the collection and processing of paratransit indicators be facilitated?* Describes six potential solutions for urban mobility MRV systems, focused on paratransit services.

- Section 4: *Monitoring, Reporting, and Verification (MRV) Framework for Paratransit GHG Emissions*. This section presents an overview of methodological and management options to facilitate the integration of paratransit information into GHG emission MRV systems

The objective of this report is to present the MobiliseYourCity secretariat team with different options to facilitate the use of the emissions calculator in planning contexts (i.e. SUMP and NUMP) where there is an intention to improve paratransit conditions and develop mitigation measures.

Key messages

- Decarbonising paratransit is not only a climate imperative, it is also an opportunity to enhance equity, improve air quality, and build more inclusive cities. However, **these benefits will remain out of reach if the sector continues to be overlooked in emissions accounting and reporting systems**.
- Investing in diagnostics and MRV systems must be a priority for cities, **transforming the current data vacuum into a strategic advantage**. The E-ASI[1] Framework offers a flexible roadmap, but it must be grounded in evidence. MobiliseYourCity's toolkits and GHG emissions calculator are good starting points, empowering cities to design policies that are not only ambitious but also achievable.
- Embedding the MRV tasks into **job descriptions of existing staff** (rather than relying on ad-hoc project teams) will help institutionalise it. If needed, external partners like development agencies (GIZ, World Bank, etc.) can provide an initial backbone, but with a transition plan to local ownership. For example, a city could start with a donor-funded pilot and within a few years, move it under the city budget as the value is demonstrated.
- Aligning the paratransit MRV with national MRV systems can reduce redundancy – data collected can feed into both city and national reports, and **technical methods can be standardised nationally to reduce transaction costs**.
- Translating vehicle activity, energy efficiency and emissions indicators into common metrics, as MobiliseYourCity's GHG calculator does, highlights the need for a ,comprehensive MRV framework for paratransit. This framework should include intensity metrics relevant to transport services, not just total tons CO_2, to make reported data actionable. Two valuable indicators are: **CO_2e per passenger-kilometre** and **CO_2e per vehicle-kilometre**. The former reflects service efficiency (emissions related to ridership) and enables comparison with other modes (e.g. BRT or private cars).
- Recognising that **"informal" does not mean "impossible"** when it comes to integrating multiple data sources in GHG inventories calculation and climate scenario projections. The verification in an informal transit context will likely adopt a **"trust but verify" principle**: trust operators enough to gather data from them, but verify via independent checks, triangulation with external records, and involvement of third parties. This layered verification approach ensures data reliability, which is especially important if the MRV results are tied to climate finance or formal policy targets.
- Underscoring the data gap many cities face, the lack of precise information reinforces the value of tools like the **MobiliseYourCity Emissions Calculator** and the **Paratransit Diagnosis Toolkit** for estimating baseline emissions and modelling decarbonisation impacts. These tools enable evidence-based planning and tracking progress, ensuring **alignment with climate goals even in the face of data gaps.**
- Improving MobiliseYourCity GHG calculator by providing a dictionary of paratransit vehicles linked to the Common Reporting Format used by IPCC, and avoid misclassification while users were defining "custom vehicle types". The orientation values offered by the calculator (Fuel Consumption and Occupancy/Loads) may be also updated with verified data from academic reports or revised government studies.

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[1] Enable – Avoid – Shift – Improve. Tangible actions and measures related to the EASI framework can be found in the MobiliseYourCity Paratransit Toolkit, specifically in Tool 3.

2. Why to promote GHG emission mitigation strategies in paratransit?

Although paratransit is essential to daily mobility many low- and middle-income cities, it continues to be a blind spot in climate planning. The MobiliseYourCity policy "Paratransit Decarbonisation" highlights that reliable and complete data on greenhouse gas (GHG) emissions from the paratransit sector is currently lacking. This data gap makes it difficult to accurately assess the environmental footprint of these services, from old minibuses to tuk-tuks,and to model the potential impact of decarbonisation measures.

The absence of robust data hampers the ability of cities to track progress, set realistic mitigation targets, or access climate finance. There is an urgency of conducting detailed diagnostics and establishing baselines, using tools like the MobiliseYourCity Emissions Calculator and Paratransit Diagnosis Toolkit. Without these, cities are left flying blind. In short: You cannot decarbonise what you cannot measure, and until cities gather and integrate data on informal transport, climate goals will remain incomplete.

Strategies to reduce emissions include improving service quality, integrating with public transport, promoting electric modes, and providing government support (Veng Kheang Phun & T. Yai, 2016). Battery-electric and fuel cell technologies show promise for lower emissions when powered by low-carbon sources (Anastasia Soukhov & M. Mohamed, 2022). "Demand response" transport services, which are comparable to paratransit, have been reported to consume approximately 14,660 British Thermal Units (BTUs) per passenger-mile. In contrast, standard transit buses consume about 4,578 BTUs per passenger-mile. This indicates that demand response services are significantly more energy-intensive per passenger-mile than regular bus services.

2.1. Potential measures for improving fuel efficiency and mitigating GHG emissions

Combining upgrading vehicles, optimising operations, educating drivers, adopting alternative fuels, and enacting enabling policies can substantially improve fuel efficiency in the paratransit sector. Real-world examples, from jeepney upgrades in the Philippines, to digital route maps in Bolivia, to electric rickshaw initiatives in India, demonstrate that these strategies cut fuel consumption and emissions and often improve service quality and drivers' livelihoods. Embracing these best practices can help paratransit systems become cleaner and more sustainable while continuing to provide vital mobility in cities worldwide.

The publication "Policy brief Paratransit Decarbonisation: Why It Matters and How to achieve It" (MobiliseYourCity, 2025) discusses the importance of decarbonising paratransit systems in urban areas, especially in the Global South, and provides a framework for achieving this goal. Paratransit systems, which include minibuses, tuk-tuks and shared cabs, are essential for connecting people to jobs, education and services, but also contribute significantly to greenhouse gas emissions and air pollution.

The document presents the E-ASI (Enable, Avoid, Shift, Improve) framework as a systematic approach to identifying and prioritising interventions to decarbonise paratransit. The framework addresses both environmental and operational inefficiencies. The article outlines several measures for each pillar of the EASI Framework, such as formalising operations, optimising routes, integrating paratransit with public transport, and improving vehicle technologies. It also emphasises the importance of data collection and progress monitoring to ensure the effectiveness of decarbonisation efforts.

Moreover, Tool IV of the MobiliseYourCity´s Paratransit Toolkit presents 11 case studies of cities that have already reformed or are reforming their transport provision on a small scale. These cases highlight potential problems and best practices for solving them.

Paratransit decarbonisation offers environmental benefits, promotes social equity by improving mobility for vulnerable populations, and provides economic benefits by reducing fuel costs and congestion. Improving fuel efficiency in the paratransit sector requires a mix of technological upgrades, better management, and supportive policies. Key strategies include:

2.1.1. Vehicle Upgrades and Maintenance

Replacing or retrofitting old vehicles can dramatically improve fuel economy especially as many paratransit fleets are aging. For example, Kenya's *matatus* average 17 years old, and their fuel efficiency is *2–3 times worse* than when new (Kustar et al., 2023). Even without full replacement, regular maintenance and tune-ups can preserve fuel economy, cleaning air filters, proper tire inflation, and fixing engine issues prevent the excessive fuel burn that poorly maintained vehicles suffer. In addition, Manuel et al. (2017) explain that a new 15-seat van consumes about 0.73 L/100 pkm versus 1.21 L/100 pkm for an old jeepney.

2.1.2. Route Optimisation and Efficient Operations

Operational improvements can reduce "wasted" kilometres and idling, boosting fuel efficiency. Many paratransit services have overlapping routes or spend time cruising empty to find passengers. Route optimisation involves better planning of routes, stops, and schedules so that vehicles travel fewer empty miles. For example, deploying higher-capacity vehicles on busy routes can carry the same number of passengers with fewer trips. Likewise, staggering departures or using dispatch systems can avoid convoys of half-empty vehicles competing on the same corridor. One best practice is "fill-and-go" dispatch at terminals: vehicles wait at hubs until reasonably full, then depart in a more coordinated way, reducing the number of half-full vehicles on the road. However, this must be managed to prevent excessive waiting and idling (Kustar et al., 2023).

Digital technology is increasingly used to streamline informal transport operations. Mobile apps and mapping platforms help match supply and demand. For instance, in La Paz, Bolivia, the Trufi app enables riders to find routes combining formal buses, microbuses, and informal shared taxis. Another strategy is using GPS-based fleet management or simple two-way radios to dispatch vehicles only when and where needed. In some cities, pilot projects have implemented centralised control for paratransit routes to ensure that when a minibus is full and dispatched, the next one waits its turn. This helps to reduce vehicle clustering and idle time.

2.1.3. Driver Training and Driving Behaviour

Different drivers' behaviours in vehicles operation have a significant impact on fuel consumption. Therefore, training paratransit drivers in eco-driving techniques can lead to substantial fuel savings. For instance, instructing drivers to avoid rapid acceleration and hard braking, to shift gears optimally, and to maintain moderate speeds improves mileage. Studies in the freight and bus sectors have shown 5–15% reductions in fuel use after implementing driver training and feedback programmes (Akena P'ojok, 2014). Even simple habits like turning off the engine during long waits or not revving the engine unnecessarily save fuel. In paratransit, where many drivers are self-employed and fuel is a major expense (often >50% of daily costs), there is a direct financial incentive to drive efficiently.

Experienced drivers can mentor others through peer education by organically sharing best practices, which helps improve efficiency. Ultimately, driver's behaviour can either enhance or undermine all other fuel-saving measures, a well-tuned vehicle on a good route will still waste fuel if driven aggressively. In this way, driver training and awareness are low-cost but effective tools in improving paratransit fuel efficiency. Installing simple fuel consumption displays or telematics can give drivers feedback in real time, reinforcing economical driving habits. Some shared taxi services have begun ranking drivers by fuel efficiency or giving awards for lowest fuel use per km.

2.1.4. Alternative Fuels and Vehicle Electrification

Shifting to alternative, cleaner fuels can improve fuel efficiency (in terms of fossil fuel use) and reduce emissions. Many cities have encouraged paratransit operators to adopt Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG), or other fuels in place of gasoline or diesel. These alternatives often burn cleaner and can be cheaper per km. In India, for example, major metros like Delhi required all auto-rickshaws and buses to convert to CNG in the 2000s, virtually eliminating petrol-powered three-wheelers. CNG and LPG vehicles typically get similar distance per unit of fuel energy as petrol ones. Pune surveys found autorickshaws achieved ~20–25 km per litter (or kg) whether running on CNG, LPG or petrol. This means drivers can switch fuels without losing range while cutting pollutants and sometimes fuel cost. Auto-rickshaws and small taxis in South Asia and Africa have widely adopted LPG/CNG where infrastructure exists, improving urban air quality and often enjoying lower fuel prices. Some governments assist by building refuelling stations or offering tax breaks on CNG/LPG fuel.

Electrification is an emerging game-changer for paratransit. Electric three-wheelers and motorcycles are being rolled out in several countries as a replacement for fuel-burning models. Electric vehicles (EVs) have no on-board fuel consumption, which can dramatically cut operating costs if electricity is cheaper than gasoline.

2.2. Climate mitigation scenarios with MobiliseYourCity

The MobiliseYourCity (MobiliseYourCity) GHG Emissions Calculator can be used to develop and evaluate mitigation scenarios for paratransit policies by estimating potential GHG reductions from interventions such as fleet modernisation, route optimisation, fuel switching, electrification, and demand management. Below is a step-by-step approach to using the tool for scenario analysis.

<u>Step 1:</u> Establish the Baseline Scenario (Business-as-Usual - BAU)

Before creating mitigation scenarios, a baseline inventory of paratransit emissions must be established. This represents emissions under current conditions without any new policies. Input Required in the MobiliseYourCity Calculator for the BAU Scenario:

- → Activity Data (A) - Vehicle Kilometres Travelled (VKT): Collect data on total distance travelled by paratransit vehicles (e.g., minibuses, shared taxis, motorcycle taxis) each year. Sources: GPS tracking, surveys, traffic counts, transport models.
- → Fleet Structure (S) - Vehicle Type and Number: Identify different vehicle categories (e.g., minibus, shared taxi, motorcycle taxi). Estimate number of vehicles in operation.
- → Fuel Efficiency (I) - Fuel Consumption per Km: Use local fuel economy data from surveys, studies, or manufacturer specifications.
- → Emission Factors (F) - GHG per Liter of Fuel: Use default emission factors in the MobiliseYourCity tool or input local emission factors.

Figure 1 in next page shows how the schematic formula for calculating GHG emissions should include several data sources to provide relevant inputs.

Step 2: Define Mitigation Scenarios

Now, create alternative policy scenarios by modifying inputs to reflect interventions such as fuel efficiency improvements, fleet electrification, and better route planning. Common Paratransit Mitigation Scenarios:

- → Fleet Modernisation
- → Electrification of Paratransit
- → Route Optimisation and Demand Management
- → Fuel Switching (CNG, LPG, or Biofuels)

Eco-Driving and Maintenance Programmes

Step 3: Input the Mitigation Scenario Data in the MobiliseYourCity Calculator

For each mitigation scenario the user needs to input these, and the tool will automatically calculate CO_2 emissions for each scenario.

- Modify fuel economy (I) – Input improved fuel consumption data.
- Adjust VKT (A) – Reduce kilometres travelled for route efficiency measures.
- Change fuel type (F) – Input CNG, LPG, or electric vehicle assumptions.
- Update fleet structure (S) – Enter the share of electric or modernised vehicles.

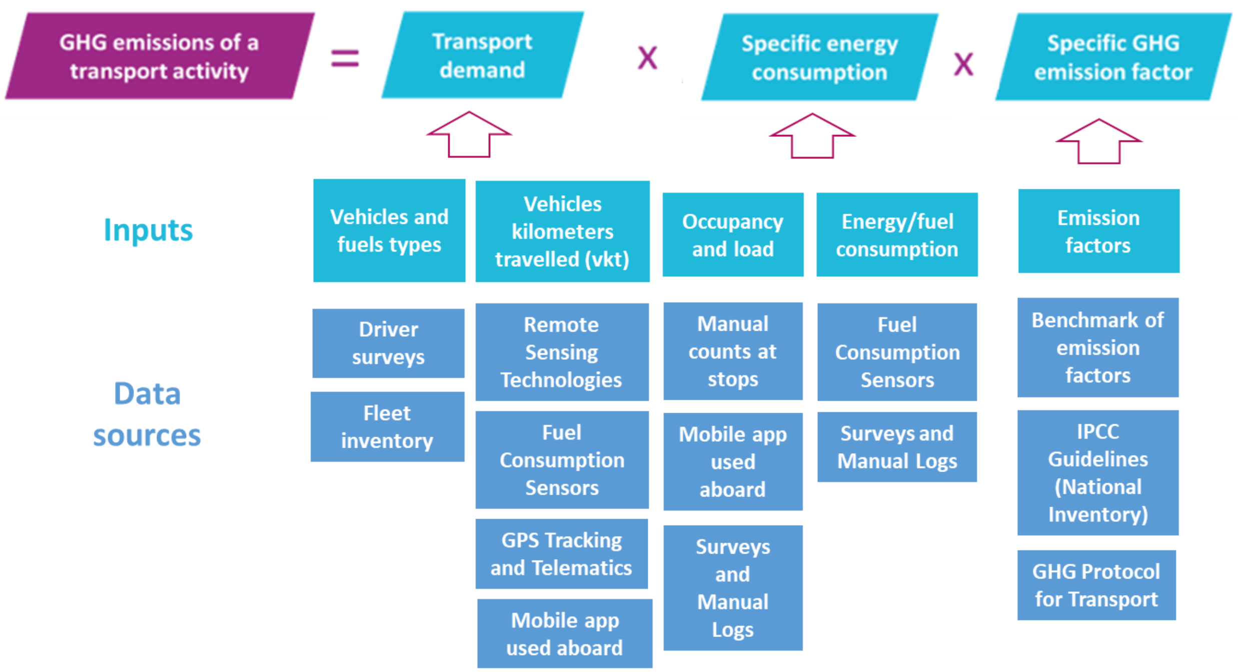

Figure 1. Data sources that may provide input data for MobiliseYourCity Calculator

Step 4: Compare Results and Assess Impact

Compare mitigation scenarios vs. the BAU scenario. Identify GHG reduction potential (%) from each intervention; and Evaluate cost-effectiveness of each policy. Next table shows an example of a Results Table to compare GHG impact results.

Scenario	Total Emissions ($MtCO_2$/year)	% Reduction vs. BAU	Notes
Baseline (BAU)	3.5 $MtCO_2$	0%	Current paratransit emissions
Fleet Modernisation	2.8 $MtCO_2$	-20%	New vehicles reduce fuel use
Electrification (50% EV adoption)	1.5 $MtCO_2$	-57%	Large emission savings
CNG Conversion	2.4 $MtCO_2$	-31%	CNG burns cleaner than diesel
Eco-driving & Maintenance	3.2 $MtCO_2$	-10%	Small but cost-effective
Route Optimisation (-20% VKT)	2.7 $MtCO_2$	-23%	Fewer wasted km improves efficiency

Prioritise high-impact scenarios: If electrification gives the highest reduction, focus investments on EV incentives; Develop an implementation strategy for prioritised measures (i.e. Phase-in fleet renewal, charging stations, CNG infrastructure, or training programs); and integrate results into urban transport plans: Align findings with Sustainable Urban Mobility Plans (SUMPs).

3. What data should be considered to feed MRV systems for following up mitigation goals in paratransit?

Paratransit, despite their ubiquity, lacks reliable and complete data on the greenhouse gas (GHG) emissions in most cities, severely limiting their ability to develop evidence-based climate strategies. Without accurate baselines, emissions modelling, or tracking systems, cities' decarbonisation efforts risk being misaligned, underfunded, or ineffective. Closing this data gap is not a secondary issue, it is a foundational requirement for coherent climate planning (Almendros, n.d.).

While specific emission factors for paratransit services can vary based on vehicle type, fuel efficiency, and operational practices, data from several reports and academic papers provide some insights. This section presents a panorama of scientific literature aiming to quantify emissions from paratransit, and a benchmark of emission and energy efficiency factors that could serve as a reference when calculating paratransit emissions in contexts with scarce data available.

3.1. Literature review

To identify a framework for quantifying emissions and setting up monitoring, reporting, and verification systems, we have conducted research by screening papers from scientific literature databases provided by Semantic Scholar. We screened papers that met these criteria:

- → Geographic Focus: Does the study focus on paratransit services in Global South countries?
- → GHG Methodology: Does the study present or analyse specific methodologies for calculating GHG emissions from transportation services?
- → Transport Service Type: Does the study include analysis of informal or semi-formal transportation services (rather than focusing exclusively on formal public transportation)?
- → Methodological Detail: Does the study provide sufficient methodological detail to allow replication or analysis of the GHG calculation approach?
- → Study Type: Is the study an empirical study, methodological paper, or systematic review that details calculation methods?
- → Methodology Assessment: Does the study include either uncertainty analysis or discussion of methodology limitations?
- → Calculation Detail: Does the study describe the calculation methodology rather than only reporting emission values?

We gathered about 150 papers informing us of the most common methodologies for calculating GHG emissions from Global South paratransit services. Using a language model provided by *Elicit*, we extracted the most relevant ones based on the criteria listed above. Table 1 shows the paper list, stressing location, vehicle types, and methodology they cover.

Studies from Nigeria, Indonesia, South Africa, Kenya, India, and a broader region in Sub-Saharan Africa employ several distinct methods for quantifying greenhouse gas (GHG) emissions from paratransit services. Two studies follow a bottom-up approach based on IPCC guidelines that derive emissions from driver-reported fuel consumption. Two other studies utilise second GPS tracking to capture detailed energy consumption patterns in minibus taxis. Two cases combine fuel consumption surveys with real-time GPS monitoring to generate conservative emission estimates, and one study relies on micro-traffic simulation, albeit with a tendency to overestimate energy use.

Table 1. List of most relevant papers identified within the desk research

Study	Location	Methodology Type	Vehicle Types	Data collection approach
Ahove et al., 2021	Lagos, Nigeria	Intergovernmental Panel on Climate Change (IPCC) Bottom-Up approach	Tricycles (Keke), Minibuses (Shuttle), Commercial buses (Danfo)	Driver surveys, fuel consumption data
Giliomee et al., 2023	Sub-Saharan Africa	Micro-traffic simulator	Minibus taxis	Global Positioning System (GPS) tracking, simulation
Hull et al., 2022	South Africa	GPS-based energy consumption	Minibus taxis	Per-second GPS tracking
Hull et al., 2023	Stellenbosch, South Africa	GPS-based energy consumption	Minibus taxis	Per-second GPS tracking
Mbandi et al., 2019	Nairobi, Kenya	Fuel economy estimation	Private cars, motorcycles, light and heavy trucks, minibuses (matatus), three-wheelers (tuk-tuks), goods vehicles (AskforTransport), two-wheelers (boda-bodas)	Vehicle characteristics and activity data
Nugroho and Zusman, 2015a	Bandung, Indonesia	Comparative Greenhouse Gas (GHG) emission baselines	Motorcycle taxis (ojeks)	Revealed preference surveys, GPS tracking
Nugroho and Zusman, 2015b	Bandung, Indonesia	Fuel consumption and efficiency approach	Motorcycle taxis (ojeks)	Revealed preference surveys, GPS tracking
Raparthi and Phuleria, 2022	Mumbai, India	Bottom-up methodology with Monte-Carlo Simulations	No mention found	Questionnaire surveys at fuel stations

Source: Own elaboration based on Elicit AI Language model

The collection of papers explores various aspects of paratransit and public transport systems, particularly in African and Latin American cities. Paratransit is recognised as a crucial component of urban mobility in many developing countries (J. & Clémence, 2019, Virginie et al., 2020). However, traditional transportation planning has often overlooked or undervalued these systems, focusing instead on large-scale infrastructure projects (Boutueil et al., 2020). The papers also discussed the importance of data analysis and technology integration in improving public transportation systems (Ramirez-Guerrero et al., 2022; Massobrio & Nesmachnow, 2020). The development of key performance indicators and sustainability evaluation methods for public transport are also explored (Morse et al., 2017; Velasco Arevalo & Gerike, 2023), emphasising the need for context-specific frameworks, particularly in Latin America.

Moreover, research on data collection for paratransit services in Latin America is limited, but some relevant studies exist. Mapping projects have emerged to document minibus systems in Latin American cities, improving visibility and informing planning conversations (Klopp & Cavoli, 2019). Studies have explored IT integration in Colombian urban transit systems (Ramirez-Guerrero et al., 2022) and sustainability evaluation methods for public transport in Latin American cities (Velasco Arevalo & Gerike, 2023). MobiliseYourCity has also some research included in its Paratransit Toolkit, which is the fourth paper of the toolkit presents 11 case studies of cities that are reforming their transport provision on a small scale, including Nairobi , Dakar, Shangai, Istambul, Manila, and México, inter alia. These cases highlight potential problems and best approaches for solving them.

Monitoring activity and GHG emissions from paratransit is feasible but challenging due to its informal nature, diverse vehicle fleets, and lack of structured data. Despite difficulties retrieving accurate data from actual paratransit operations, it is feasible to increase reliability when monitoring and reporting both activity and emission factors. Papers included in Table 1 indicate that uncertainty when calculating GHG emissions from the transport sector, and particularly paratransit, depends on three factors: (1) using high-resolution (per-second) GPS data sharpens estimates by capturing micro-mobility nuances; (2) triangulating survey data with GPS observations improves baseline reliability; and (3) correcting technical aspects in simulation software, such as addressing waypoint progression and integrating virtual traffic help align modelled outputs with measured data.

Moreover, surveys, driver interviews, and big data analytics can enhance accuracy by combining real-world fuel consumption with activity-based emissions modelling. While low-cost methods like smartphone-based tracking provide reasonable estimates, high-accuracy monitoring requires advanced technologies such as Portable Emissions Measurement Systems (PEMS) and AI-driven analysis. Successful implementation depends on collaboration between governments, tech providers, and researchers to integrate paratransit data into urban transport planning.

Table 2 includes seven common methodologies to estimate GHG emissions from the paratransit sector reported by the scientific literature gathered. It includes key limitations and implementation challenges. A deeper analysis of those challenges is included in section 3 of this document.

Table 2. Comparative Key Limitations on data gathering from academic papers research

Methodology Type	Key Limitations	Proposed Improvements	Implementation Challenges
IPCC Bottom-Up approach	Fluctuations in fuel prices, inaccuracies in fuel metering systems	Scale up the study, use bottom-up methods for more detailed estimates	Data accuracy due to price fluctuations and metering inaccuracies
Micro-traffic simulator	Overestimation of energy expenditure, inadequate modelling of paratransit	Address waypoint progression and reverse geocoding issues, incorporate virtual traffic	High costs and labour requirements for generating accurate 1 Hz mobility data
GPS-based energy consumption (Hull et al., 2023)	Limited to 62 trips in specific conditions	Use per-second GPS data for more accurate estimates	No mention found

Methodology Type	Key Limitations	Proposed Improvements	Implementation Challenges
Fuel economy estimation	Uncertainty in vehicular emission estimation due to lack of detailed data	No mention found	No mention found
Comparative GHG emission baselines	Irregular scheduling, erratic driving behaviour	Use driver survey data triangulated with GPS data for low-cost baselines	High transaction costs
Fuel consumption and efficiency approach (Equivalent to ASIF - Activity, Structure, Intensity, Fuel)	Irregular scheduling, routing, and driving patterns	Use driver survey data verified by GPS for constructing conservative baselines	Irregular scheduling, routing, and driving patterns
Bottom-up methodology with Monte-Carlo Simulations	Uncertainty in vehicular emission estimation	Use of Monte-Carlo Simulations to address uncertainties	No mention found

Source: Own elaboration based on Semantic Scholar and Elicit database

Considering difficulties in identifying local data to feed emissions models, next section presents a benchmark of GHG emission factors that could be used as reference when using calculation tools such as the MobiliseYourCity GHG Emissions Calculator[2]. These references can be used to estimate paratransit GHG emissions, but with some limitations. The tool follows the ASIF methodology (Activity, Structure, Intensity, Fuel) and allows users to input data for different modes of transport, including paratransit.

3.2. Benchmark of emission factors from different paratransit vehicle types

Table 3 summarises common CO_2 emission factors (per km per passenger) for key paratransit modes, based on studies in Latin America, Africa, and Asia. All values are tailpipe emissions of CO_2 (excluding upstream fuel lifecycle), and actual figures can vary according to the vehicle state, fuel type, and occupancy rates.

Studies and reports providing these estimates include: a World Bank transport report, academic analyses of developing-city transit, and local case studies (e.g. Egypt, South Africa) documenting vehicle fuel use and occupancy. All show a consistent pattern across Latin America, Africa, and

[2] The MobiliseYourCity Emissions Calculator is an open-source tool designed to assist cities and countries in estimating greenhouse gas (GHG) emissions from their transport sectors. Developed by the Institute for Energy and Environmental Research (IFEU) in collaboration with the German and French development agencies GIZ and AFD, this Excel-based tool allows users to: Inventory current emissions. Assess GHG emissions for a selected base year; Project Future Scenarios: Model Business-as-Usual (BAU) scenarios and alternative climate-friendly mobility strategies up to the year 2050 for both passenger and freight transport.

Asia regarding paratransit emissions per passenger. These empirical references underscore the potential climate benefit of consolidating trips into larger vehicles or improving vehicle technology in the paratransit sector.

Table 3. Typical CO2 emissions factors found in literature

Vehicle Type	Typical Emission Factor (Gr CO_{2eq}/pkm)
Minibuses (12–20 seat vehicles) In Latin America, many cities have informal collectives/microbuses with similar capacities and technologies, yielding comparable emission factor; In African cities (e.g. Nairobi matatus, Lagos danfos, South African minibus taxis), vehicles are often second-hand and older diesel models, falling in a similar efficiency range; In Asian cities, paratransit minibuses are also common (e.g. Jeepneys in the Philippines, Angkot in Indonesia)	Approximately 40–50 grams CO_2 per passenger-km for minibuses under typical operating conditions. Multiple sources report values in this range: • A World Bank analysis (with data from Mexico) notes that a small diesel bus ("minibus") emits ~43 g CO_2/passenger-km on average. This assumes ~15-seat capacity at ~50% occupancy (≈7–8 passengers) using an older Euro II diesel engine (Grutter et al., 2021) • Similarly, Wright & Fulton (2005) report ≈43 g CO_2/passenger-km for a 20-passenger minibus (diesel) in developing city conditions(Rouhani, 2013). This is notably higher per passenger than a standard 80-passenger city bus (~25 g CO_2/pkm) under comparable assumptions (Grutter et al., 2021) • An African fuel economy study for South African minibus taxis (typically 14-seater vans) estimated about 0.0433 kg CO_2/passenger-km (43.3 g/pkm), given ~13.8 L/100km fuel consumption and ~7 passengers on average. This aligns with the ~40–45 g/pkm range observed elsewhere.
Vans and Small Informal Buses (8–12 seat vehicles) "Vans" used in paratransit (e.g. Toyota HiAce or similar) often have 10–14 seats. When fully loaded, their per-passenger emissions can approach that of larger minibuses (~40–50 g/pkm). But the per-passenger figure rises under lighter loads or in heavy traffic (idling). In practice across Latin America and Africa, such vans operate near capacity at peak hours (keeping emissions per passenger relatively lower). Still, they may run below capacity at off-peak times.	50–80 g CO_2 per passenger-km, depending on occupancy. Vans overlap with minibuses in function, but if they carry fewer passengers their per-passenger emissions rise. For example: • The South African "minibus" example (43 g/pkm) assumed ~7 passengers. If the vehicle runs with only ~4 passengers, the rate would roughly double (~80+ g/pkm). • A study in Zagazig, Egypt recorded 0.3696 kg CO_2 per km for diesel microbuses (van-sized) vs 0.2408 kg/km for cars. Despite higher per-km emissions, the van carried more people (avg. 8 vs 2–3 in cars). This yields ~46 g/pkm for the van, versus ~96–127 g/pkm for private vehicles (El-Rahman Baz et al., 2023)
Shared Taxis (Sedan cars or similar carrying multiple passengers) Shared taxis in paratransit include anything from "taxi-brousse" services in Africa to app-based carpooling. Many are older gasoline cars. Latin America's colectivo taxis (e.g. in the	• ~80–130 g CO_2 per passenger-km in typical scenarios, highly sensitive to occupancy: • A standard taxi with 2 passengers emits roughly ~130 g CO_2/pkm. For instance, Wright & Fulton note a taxi (assumed 2 occupants) at 10.8 L/100km fuel use emits 130 g per passenger-km. This is only moderately better than a private car with single occupancy (~174 g/pkm)(Rouhani, 2013)

Vehicle Type	Typical Emission Factor (Gr CO_{2eq}/pkm)
Andes) and African shared cabs often cram 4–6 passengers in a car designed for 4, significantly reducing per-head emissions (albeit at comfort and safety expense).	• If that same vehicle is fully shared (4 passengers), emissions per passenger-km improve to roughly half the above (on the order of 50–70 g/pkm). For example, a mid-sized car at ~0.24 kg/km (240 g/km) carrying 4 people would be ~60 g/pkm. In West African cities where shared taxis often run full, per-passenger emissions can fall in this range.(El-Rahman Baz et al., 2023) • Real-world range: One city-level analysis assumed private cars and taxis emit 0.2408 kg CO_2/km per vehicle (≈240 g/km), carrying an average of 1.9–2.5 people. That gives ~125 g/pkm for private cars (nearly solo) and ~96 g/pkm for shared taxis (with ~2.5 ppl). With higher occupancies seen in some Asian paratransit taxis (e.g. Indian shared autos or Indonesian ride-shares), the factor per passenger can drop toward ~60–80 g/pkm (Rouhani, 2013)
Motorcycle Taxis (2-wheelers)	Despite high fuel efficiency, a single-rider motorcycle can emit around 50–60 g CO_2 per passenger-km. Wright & Fulton calculated ~53 g/pkm for a motorbike (at ~2.2 L/100km, one rider) already higher than a full minibus. In Asian cities where motorcycle taxis are common (e.g. ojeks in Indonesia or boda-bodas in East Africa), this indicates that shifting one rider from a motorbike to a fuller vehicle could reduce emissions.
Auto-Rickshaws (3-wheelers)	Small three-wheel taxis (common in South Asia, parts of Africa, etc.) have engines similar in size to motorcycles. If carrying 2–3 passengers, their emissions per passenger-km can be in the same ballpark or slightly better than a motorbike's. For instance, a conventional auto-rickshaw with a small petrol engine might emit ~40 g/km of CO_2 per vehicle. With ~2 passengers, that's ~20 g/pkm, and ~40 g/pkm if only one passenger. (Exact numbers vary by engine type – two-stroke engines can be quite polluting in other exhaust gases, though CO_2 output correlates with fuel burn.)

Additionally, energy efficiency measures for the main paratransit modes are presented below; actual measures may vary depending on vehicle condition, fuel type, and occupancy rates. (Hull et al., 2022; Mbandi et al., 2019)

Table 4. Typical energy efficiency found in literature

Vehicle Type	Energy Consumption Range
Minibuses (12–20 seat vehicles)	Approximately 33.1 ± 2.5 L/100 km, under Urban public transport operating conditions, sensitive to Vehicle type and occupancy rate.
Vans and Small Informal Buses (8–12 seat vehicles)	Approximately 0.43 MJ/passenger-km, under Urban public transport operating conditions, sensitive to Vehicle type and occupancy rate.
Shared Taxis (Sedan cars or similar carrying multiple passengers)	Approximately 1.39 MJ/passenger-km, under Urban paratransit operating conditions, sensitive to Occupancy rate maximisation

Vehicle Type	Energy Consumption Range
Motorcycle Taxis (2-wheelers)	Approximately 4.6 ± 0.4 L/100 km, under Urban paratransit operating conditions. Sensitive to Vehicle characteristics
Auto-Rickshaws (3-wheelers)	Approximately 33.1 ± 2.5 L/100 km, under Flat Caribbean region operating conditions, low speeds (<40 km/h). Sensitive to engine size, and curb weight

Figure 2. Typical CO2 emissions factors and energy efficiency

NOTE: Total annual emissions and energy efficiency deeply depend on occupancy rates of vehicles.

Source: Elicit research report with different sources – See Annex 1

4. How can the collection and processing of paratransit indicators be facilitated?

Though Measurement, Reporting, and Verification (MRV) systems within transport sector can be expensive and resource-intensive, **authorities can implement simple but accurate-enough methods for tracking activity and emissions** without the need for full-scale automation or costly tech stacks. Some examples are listed below:

- → **Use GPS or Mobile Tracking for Route and Distance Data with Basic Devices:** Even low-cost GPS devices or driver smartphones can capture essential trip data such as distance travelled, routes taken, and idle times. Free or affordable apps can support manual trip logging with GPS location capture.
- → **Apply Fuel-Based Emissions Estimation Using Simple Logs:** Drivers or dispatchers can log fuel usage per trip or day. When paired with known vehicle fuel efficiency and emission factors, this gives a reliable basis for estimating GHGs, especially for fleets without telematics.
- → **Standardise Minimal Data Collection with Forms or Apps:** Authorities can create standardised forms (paper or digital) that collect key variables, such as trip length, number of passengers, vehicle type, and fuel used. A simple protocol ensures consistency across operators.
- → **Prioritise High-Impact Metrics, Not Full Data Sets:** You do not need everything, just a few well-chosen variables (e.g., fuel consumption, kilometres travelled, number of trips) can enable useful emissions estimates and trend tracking.
- → **Train drivers and operators on** why **and** how **to report.** With basic training and clear templates, drivers and small operators can be engaged in the process. Emphasising that better data helps improve services and access funding creates buy-in.

In this way, it is feasible to deploy solutions tailored to each city and region to close the information gap in paratransit services. The following paragraphs describe six potential solutions to facilitate the capture and reporting of information required to monitor climate and transport goals.

4.1. Solution 1: Cost-effective and scalable methods

Collecting detailed emissions data can be expensive and resource intensive. Paratransit operators often have limited profit margins and may not be able to afford new technology, and city agencies may lack funding for large-scale monitoring programs. Thus, it is key to focus on **cost-effective and scalable methods**. This is true not only for the management of operational data, but also for making adequate diagnoses of the current state of paratransit services (as explained in MobiliseYourCity Paratransit Tool II); and for promoting reforms that improve both the quality of service, business models, and working conditions throughout the value chain (See Paratransit Tool III).

Instead of outfitting every vehicle with pricey sensors, an instrument is a small representative fleet to gather detailed data and extrapolate from there (a sampling approach). Subsidies or grants can be sought for pilot programs – international development organisations are increasingly interested in data for sustainable transport, and small grants could fund GPS devices or training. Where possible, piggyback on existing systems. For example, if a city is rolling out a cashless fare or GPS dispatch system for minibuses, integrate the MRV data collection into that system to share costs.

Engage tech startups or universities to develop low-cost sensors (e.g. Arduino-based fuel trackers) or to analyse existing data like mobile phone location data, which can be cheaper than manual surveys. In addition, it is important to consider leveraging **carbon finance.** If the MRV framework can demonstrate emissions reductions (say through a future fleet modernisation), the city could earn carbon credits or climate funds that help pay for the monitoring system. In terms of human resources, working with students, interns, or NGO volunteers for data collection can drive to reduce labour costs and build local capacity at the same time.

Emphasise **simplicity** in the framework. A simpler methodology that is 80% accurate but affordable and repeatable is better than a theoretically perfect system that is never implemented. This often means beginning with paper forms and spreadsheets in the beginning rather than expensive proprietary software, ensuring the framework aligns with cities' existing capacities and can be upgraded as resources become available. where they are in terms of capacity. Over time, as funding allows, it can be upgraded.

4.2. Solution 2: Data Collection opportunities in Informal Networks

Paratransit operations are decentralised and unregulated, so gathering data relies on voluntary cooperation not on standardised companies´ data management procedures nor legal obligations. There is often no mandate for informal operators to report anything, and many aspects (exact number of vehicles, routes, fuel usage) are fluid or undocumented.

Therefore, **stakeholder engagement and incentives** are key. Working with paratransit owner associations, unions, or cooperatives as partners in the MRV process. Early engagement should highlight the *benefits to operators* of tracking fuel and efficiency. For instance, demonstrating that fuel monitoring can help them identify maintenance issues or fuel theft, ultimately saving money. In some cases, local governments can offer small incentives for compliance: reduced permit fees, priority in route allocation, or even direct financial incentives (stipends, fuel vouchers) for those who consistently report data. Peer influence is also important: if the leaders or respected figures in the informal transport community champion the MRV effort, others will follow. This was evident in some pilot studies where securing the participation of driver cooperatives was challenging but crucial (Durant et al., 2023); approaches like community meetings, co-designing the reporting format with drivers, and ensuring the process isn't overly burdensome helped gain buy-in.

Regulatory levers should also be considered even in informal contexts. For instance, city authorities could tie certain privileges to reporting. For instance, only operators who participate in the MRV (or broader transit improvements) can get access to microloans for vehicle upgrades or are allowed in a planned BRT feeder system. This softly "formalises" a requirement to report. Another tactic is to integrate MRV into any *formalisation initiatives*. Many cities plan to formalise or improve informal transport by making emissions monitoring part of that package (with necessary support) can institutionalise data collection. Overall, building trust with the informal sector is critical as it assures that data will not be used to penalise them (e.g. no immediate new taxes or bans based on the numbers), but rather to identify funding and modernisation needs. As one WRI analysis noted, governments should **acknowledge and incorporate informal transport in policy**, rather than ignore or outlaw it (Kustar et al., 2022). Embracing this philosophy, the MRV effort should be framed as a step toward recognising the value of paratransit and securing support (financial, infrastructural) for it, which encourages operators to participate rather than feel threatened.

4.3. Solution 3: Ensuring accuracy and avoiding misreports

Data from informal sources may be error-prone or intentionally misreported. Without a strict regulatory environment, some drivers might under-report fuel use or overstate efficiency if they fear blame for high emissions. Also, manual data handling can introduce errors.

In this context, is key to implement **quality assurance measures** and foster a culture of accuracy. As discussed in the verification section, random audits or cross-checks (e.g. checking fuel receipts) will discourage falsification. Public recognition can also motivate honest reporting. For example, awarding an "Eco Driver" certificate or small reward to drivers whose data is consistently complete and within expected ranges. On the flip side, if blatant discrepancies are found, **handle them with education first (maybe the driver logged in the wrong units) before assuming malfeasance**. Using technology to minimise manual errors: digital forms with validation (no alphabetic characters where a number is expected, etc.) and automated calculations reduce arithmetic mistakes. Training sessions for those recording data can also improve accuracy like teaching them why, say, recording *all* fuel is important, not skipping the small top-ups, and how it ultimately benefits the analysis. Over time, as data streams stabilise, more sophisticated methods like **anomaly detection** using software can flag suspicious entries (e.g. a vehicle reporting the same mileage for two months, or an impossible fuel economy). These can be followed by the MRV team. By gradually improving data reliability, the MRV system builds credibility among external stakeholders, which is crucial for its sustainability.

4.4. Solution 4: Clarify roles and integrate MRV into existing governance structures.

Ideally, the city or municipal authority should lead the paratransit MRV since they are closest to the operations. If a city has a transport department or a sustainable mobility unit (sometimes established under projects like Sustainable Urban Mobility Plans), that unit can host the MRV data and process. National governments can support by providing methodology guidelines and training (perhaps through environment ministries as part of climate action support). An MRV steering committee that includes key stakeholders – city officials, reps from transport associations, maybe a ministry observer and a civil society rep – can coordinate actions and solve problems.

The framework document should spell out who is responsible for data collection, who compiles and analyses it, and who reviews/approves the final emissions report. Embedding the MRV tasks into job descriptions of existing staff (rather than relying on ad-hoc project teams) will help institutionalise it. If needed, external partners like development agencies (GIZ, World Bank, etc.) can provide an initial backbone, but with a transition plan to local ownership. For example, a city could start with a donor-funded pilot and within a few years, move it under the city budget as the value is demonstrated. In this sense, it is very important that incentive schemes and legal and policy reforms are implemented (See Paratransit Toolkit III). This is to allow both the user and the service provider, as well as the state, to gain in quality, profitability, and reduction of risks and externalities.

Furthermore, aligning the paratransit MRV with national MRV systems can reduce redundancy – data collected can feed into both city and national reports, and technical methods can be standardised nationally to reduce transaction costs, as recommended for Pacific Alliance countries (Espinosa et al., 2021)

4.5. Solution 5: Leverage technology smartly, focusing on appropriate tech for the context

Do not assume the most high-tech solution is best. While AI and satellite-driven models are exciting but may not yet replace ground data for city-level decision-making. However, they can complement by filling data gaps. For instance, if a city cannot survey every route, an AI model using traffic data could estimate unmeasured routes' activity to supplement the MRV, as the Johns Hopkins APL project did for cities globally (Johns Hopkins APL, 2022). Likewise, satellite data on urban extent and nighttime lights can indicate where major trip generators are, helping allocate effort in data collection. AI-driven analytics can be applied to the data collected: machine learning could help predict fuel consumption patterns for the fleet and flag anomalies or estimate missing data. It can also assist in projecting future emissions under different scenarios – useful for planning mitigation measures.

On a more basic level, use widely available tech like smartphones for data capture and cloud databases for storage, which many local teams can handle with minimal IT infrastructure. There are open-source tools and templates (e.g. Excel-based calculators like *TEEMP* for transport, or the MobiliseYourCity emissions calculator) that can be adapted, avoiding the need to develop software from scratch (Alberto et al., 2013). If some vehicles start adopting telematics for other reasons (security, fleet management), integrate those feeds into the MRV. Also consider emerging low-cost IoT sensors – for example, a small group in Nairobi might pilot cheap OBD-II dongles on matatus to transmit data via the driver's phone. The framework should remain *technologically agnostic* to some degree – define what data is needed and how often, and allow cities to choose the tech (paper, app, sensor, satellite) that meets those needs within their means.

4.6. Solution 6: Demonstrate MRV's value and integrate with policy.

To sustain MRV, it must inform decisions and show benefits. This means periodically analysing the collected data and producing insights that matter like highlighting that paratransit emissions are, say, 20% of city transport emissions and growing, or that emissions per passenger-km have decreased after an intervention. Use the data to guide policy, like identifying routes with very old polluting vehicles for targeting an electric vehicle program. If city leaders see that MRV data supports grant applications (many climate funders ask for emissions baselines), they will be more committed to continuing it. Embedding MRV into policy frameworks (like city climate action plans, air quality management plans, or transport strategies) can make it a required activity rather than an academic exercise. For instance, a city could adopt a by-law that every year the transport department publishes a GHG emissions report covering all modes, including informal transport. Regional networks (e.g. C40 Cities, ICLEI) also encourage such reporting and can provide peer pressure and support.

Furthermore, keep the MRV framework **flexible and adaptive**. As formal public transport expands or as paratransit evolves (e.g., through fleet renewal or electrification), the MRV should adapt (such as updating emission factors when e-mobility is introduced or adding new metrics like electric vs. diesel VKT). Regular reviews of the framework with stakeholders will ensure it stays relevant. Sharing success stories such as how one city engaged informal drivers to cut emissions and got international recognition can also motivate others to keep the momentum.

In conclusion, while challenges to MRV in informal transit are significant, they can be mitigated by a combination of stakeholder engagement, smart use of technology, capacity building, and alignment with broader goals. The framework described is **actionable** in low-resource settings because it emphasises phased implementation: start with basic data collection and simple metrics, use available tools and people, and gradually build up accuracy and coverage. By accounting for economic constraints (through cost-sharing and incentives) and regulatory realities (working with the informal nature rather than against it), Latin American and African cities can establish a functional MRV system. This will not only quantify the GHG emissions of paratransit, making the "invisible" emissions visible, but also guide policies to improve these vital transport services in a climate-friendly way. With transparency and verification built in, the data can be trusted by local and international stakeholders alike, ultimately integrating the paratransit sector into the solution space for urban sustainability.

5. Monitoring, Reporting, and Verification (MRV) Framework for Paratransit GHG Emissions

Developing an actionable MRV framework for paratransit systems requires combining robust technical methods with pragmatic approaches that suit informal or semi-formal transit networks. Below, we outline methodologies for monitoring emissions, standardised reporting practices, verification processes for data credibility.

Moreover, to design and implement effective paratransit decarbonisation strategies, cities must first understand the baseline impact of the sector. This requires comprehensive diagnosis and quantification of GHG emissions. Then, after implementation, consistent data collection and reporting are essential. Progress should be monitored through indicators such as fleet renewal rates, emissions reduction, and modal integration. Mobility observatories can play a critical role in institutionalising monitoring practices and fostering transparency.

Considering these needs, we include below some recommendations to connect potential tools, techniques, and models with the MobiliseYourCity' MRV Frameworks, based on ASIF methodology.

5.1. Monitoring Methodologies

5.1.1. Direct Measurement Techniques:

Paratransit emissions can be monitored through on-vehicle sensors and tracking devices that capture real-world fuel use and activity:

- Fuel Consumption Sensors: Installing fuel-flow meters or *On-Board Diagnostics (OBD)* devices can directly measure fuel burned by minibuses, vans, or motorcycle taxis. In principle, knowing fuel consumed allows direct calculation of CO_2 emitted (since CO_2 from combustion is proportional to carbon in fuel). However, field trials in African cities found that retrofitting older informal vehicles with fuel probes can be technically problematic – sensors often malfunction or fail to communicate data, especially in aging fleets. For example, tracking minibuses in Freetown and Maputo had only one fuel probe function reliably; the rest had to be supplemented with manual fuel logs (Durant et al., 2023). Given these challenges, direct fuel measurement needs careful equipment selection and maintenance support.
- GPS Tracking and Telematics: Equipping vehicles with GPS trackers provides continuous data on distance travel, speeds, and idling times. When combined with engine data (via telematics units), one can estimate fuel consumption and emissions per trip. High-resolution GPS data from paratransit vehicles in South Africa, for instance, has been used to simulate energy use and plan electrification (NEYA et al., 2021). Even without direct fuel sensors, GPS-based distance tracking can feed into emission models if baseline fuel economy is known. The main hurdles are device costs, tampering, and ensuring vehicles stay within network coverage. Low-cost smartphone-based trackers are emerging as alternatives for owner-operators who cannot afford dedicated devices.
- Remote Sensing Technologies: In select cases, roadside remote emission sensing can be deployed to measure exhaust plumes of passing vehicles. Infrared/UV remote sensing units

can detect CO_2, CO, NOx, etc., allowing emissions sampling without vehicle installation (Bernard et al., 2019). Such systems have been used in pilot programs (e.g., in Kampala) to identify high-emitting vehicles and develop fleet emission factors. However, these are still relatively expensive and technically complex for widespread use in the Global South. Fully remote approaches using satellites and AI are being researched – for example, machine-learning models now estimate road traffic CO_2 by analysing satellite imagery of road networks and traffic patterns, combined with region-specific emission factors (Johns Hopkins APL, 2022). This offers promise for city-scale estimates where ground data is sparse, but it currently complements rather than replaces on-ground monitoring.

5.1.2. Estimation Models (Fuel Economy & Distance)

When direct measurements are infeasible for an entire paratransit fleet, emission *estimation models* fill the gap. These models combine activity data (like vehicle-kilometres or passenger-kilometres travelled) with emission factors:

- Activity Data: Key parameters include the number of vehicles, average distance travelled per vehicle (daily or annually), and occupancy (to gauge passenger-km) (NEYA et al., 2021). In informal networks, these must often be obtained through surveys or samples, since odometer readings and official mileage records are rarely available (Durant et al., 2023). A simplified model used in West Africa, for example, relied on: (a) estimated fleet size by type, (b) average annual VKT per vehicle from driver surveys, (c) typical fuel economy for each vehicle type, and (d) standard emission factors per Liter of fuel. This approach can approximate total GHG emissions by summing up the fuel use of all vehicles
- Diversity of Vehicle Types: Paratransit fleets are heterogeneous – from 14-seater diesel minibuses and moto-taxis to tuk-tuks or minibuses – each with different fuel consumption and emission profiles. Models must segment the fleet into categories (diesel vans, gasoline motorcycles, etc.) and use appropriate fuel economies for each. Manufacturer specifications are often too optimistic for real-world informal operations. Field measurements in African cities found actual fuel consumption of minibuses 1.5–3 times higher than official figures due to overloading, old age, and congested stop-and-go driving (Durant et al., 2023). Thus, locally gathered data (even from small samples) is crucial to calibrate models to reflect conditions of *informal transport* (e.g. frequent stops, rough roads, vehicle age). Emission factors should account not only for CO_2 but also CH_4 and N_2O (which are minor for gasoline/diesel but relevant if CNG or biofuels are used).
- Trip Distance & Occupancy: For passenger-oriented metrics, estimating passenger-kilometres requires data on typical trip lengths and how many people vehicles carry. Surveys or pilot GPS logging can capture average trip length per route and average occupancy (which can vary by time of day). These feed into metrics like CO_2 per passenger-km. In practice, collecting reliable occupancy data in informal minibuses is challenging, but proxy methods (manual counts at stops, or using the knowledge of peak vs off-peak loads) can be applied. Even a conservative occupancy estimate helps avoid undercounting emissions per passenger.

5.1.3. Data Collection in Informal Networks

The most difficult part of the GHG MRV process is the data collection on operations and fleet performance that feed the models. Strategies to overcome the challenge of obtaining reliable data include:

- Surveys and Manual Logs: Engage drivers and operator unions in recording basic data. For example, daily fuel purchased, trips made, and odometer readings. In cases like Freetown and Accra, researchers had drivers log fuel bought (or reimburse receipts) and noted odometer values, since automated sensors failed. Though labour-intensive, these manual surveys yielded critical data, revealing, for example, that informal vans drove 150–250 km/day consuming 27–52 Liters of fuel per day on average (Durant et al., 2023). Training enumerators to ride along and record stops, loads, and fuel top-ups can improve data accuracy, albeit at higher cost.
- Fuel sales data: Obtaining accurate fuel consumption data for paratransit, crucial for quantifying its emissions, can be achieved through collaboration with fuel stations and the implementation of sales recording systems linked to specific vehicle types(Kaza, 2020). Using fuel sales data as an indirect and efficient methodology to overcome the challenges of information collection in the informal transport sector, demonstrating its potential to generate more robust and representative emission estimates.
- Mobile Phone Applications: Leverage the near ubiquity of mobile phones to simplify data capture. Recent projects in Ghana and Kenya have successfully used smartphone apps to map informal transit routes and performance. In Kumasi, for instance, a mobile app *TrandS* was used by student surveyors aboard minibuses to automatically log GPS tracks and stops, while inputting passenger counts at each stop (Ukam et al., 2023). These apps drastically cut data collection costs and improve coverage, as they can crowdsource data from multiple vehicles. The rise of low-cost, specialised paratransit data apps (for route mapping and travel time surveys) offers new opportunities for African and Latin American cities to gather operational data cheaply (Jia et al., 2022). For MRV, such apps could be adapted for drivers to periodically submit fuel purchase info or mileage, possibly incentivised by small payments or benefits (e.g. free airtime).
- Crowdsourced and Remote Data: In the absence of formal records, creative proxies can help. For example, cities can use periodic traffic counts or telecom data (to estimate travel demand on corridors) to infer paratransit activity levels. GPS traces from initiatives like Digital Matatus (Nairobi) or WhereIsMyTransport mapping can establish route distances and frequencies, which combined with vehicle counts per route give a rough activity measure.(Ribet, 2022)
- Drone or satellite imagery at terminals can even gauge vehicle throughput. While these indirect methods have uncertainties, they can flag major emission sources and trends until more direct data is obtained.

Note: A hybrid approach is often most effective when equipping a sample of vehicles with instruments while collecting self-reported or third-party data from others. The combination of digital tracking and supplementary manual data was shown to overcome many data gaps in the TRANSITIONS project case studies (Durant et al., 2023). Local universities and tech hubs can be valuable partners in designing appropriate data-collection gadgets or apps tailored to informal transit conditions.

5.2. Reporting Frameworks

Any reporting system should align with established GHG accounting standards to ensure credibility and comparability. For transport emissions, the two key references are the IPCC Guidelines for national inventories and the GHG Protocol (WRI/WBCSD) for organisational or project-level reporting. Both emphasise transparent calculation methods and consistent emission factors. On the other hand, GHG calculation tool such as MobiliseYourCity emissions calculator.

- → IPCC Guidelines (National Inventory): The IPCC 2006 guidelines for the transport sector encourage a tiered approach. Simpler (Tier 1) methods use aggregate fuel consumption by fuel type as the basis for CO_2 emissions (assuming full fuel combustion) (Wagner & Walsh, n.d.). More advanced (Tier 2/3) methods incorporate vehicle categories, technologies, and detailed activity data. For paratransit MRV, cities should document the methods used (e.g. "fuel-based estimate vs. distance-based model") and data sources, to allow verification and future refinement. Importantly, all fuel consumption or travel activity attributed to minibuses, shared taxis, moto-taxis, etc., should be included in the city's transport GHG inventory to avoid omission of this significant segment (MobiliseYour City, 2020). Even if informal transit is not officially reported in some national inventories, a city-level MRV should explicitly account for it as part of road transport.
- → GHG Protocol for Transport: At a project or fleet level (e.g. a paratransit cooperative or city program), the GHG Protocol provides calculation tools that mirror IPCC logic. It recommends reporting emissions in CO_2-equivalent, covering CO_2, CH_4, and N_2O from fuel combustion. Default emission factors (kg CO_2 per litter of diesel, etc.) are provided, but using local factors (e.g. if fuel quality differs or if vehicles have tampered emission controls) is encouraged for accuracy. Accounting should follow the *tank-to-wheel* emissions from vehicles; upstream emissions (fuel production) can be noted separately if needed. Cities in the Global South should also align reporting periods and scopes with their national reporting commitments (e.g. including paratransit emissions in tracking progress towards NDC targets for transport).
- → Methodology to Calculate and Monitor Transport Related GHG Emissions – ASIF framework: MobiliseYourCity approach to monitoring and reporting transport-related greenhouse gas (GHG) emissions advocates for tracking emissions at city and national levels through direct calculation rather than per individual mitigation measure. The process begins with establishing a current GHG emission inventory for the transport sector. This inventory is determined by transport demand (travel activity by mode), the specific energy consumption per mode for each activity, and the GHG conversion factor for each energy carrier used by each mode. MobiliseYourCity utilises a bottom-up approach based on the ASIF framework for this calculation. While ideally, city-specific data should be used for all parameters within a Sustainable Urban Mobility Plan (SUMP), data availability often limits this detailed localisation. However, the text notes that some parameters, like fuel carbon content, are less dependent on local contexts and can utilise national or IPCC default values. The chosen calculation method should also align with local data availability and resources, allowing for inventories based on either simpler aggregated data or more detailed advanced modelling. (MobiliseYourCity, 2020)
- → Common Metrics: The framework should include intensity metrics relevant to transport services, not just total tons CO_2, to make reported data actionable. Two valuable indicators are: CO_2e per passenger-kilometre and CO_2e per vehicle-kilometre. The former reflects service efficiency (emissions related to ridership) and enables comparison with other modes (e.g. BRT or private cars). For instance, climate bond standards set a threshold around 50 g CO_2 per passenger-km for low-emission transport projects (Strid et al., n.d.); Many paratransit systems today likely exceed this, but tracking this metric can inform improvement (through fleet upgrades or higher occupancy). *Fleet emissions intensity* can

be reported as ton CO_2 per vehicle per year, or grams CO_2 per km per vehicle, segmented by vehicle type. This helps identify which vehicle classes are the worst emitters. For example, an inventory might reveal old 14-seater minibuses emit X g/km while newer buses emit Y, making a case for fleet renewal. Additional metrics could include emissions per trip or per revenue hour, depending on data availability. The framework should standardise these calculations so that different cities or cooperatives can benchmark against each other.

5.2.1. Reporting Templates and Frequency

A standardised reporting template (paper or digital) should be provided to paratransit operators or city transport departments to log emissions data periodically. This template should include total fuel used (by type) in the period, total distance run, and ridership (if known), broken down by vehicle category.

- → Digital Reporting Tools: Where possible, digital platforms simplify data aggregation. A mobile-based reporting system can allow individual drivers or vehicle owners to submit monthly fuel and mileage data. For example, a simple SMS or WhatsApp bot could query drivers for odometer readings and fuel purchases at month-end, feeding into a central database. More sophisticated are smartphone apps that some cities are already using for dispatch or ticketing – these could be extended to gather environmental data such as Particulate Matter exposure if linked with low-cost sensors. *Open-source transit data platforms* (like those promoted by the open data community) can be modified for GHG tracking. Ultimately, a centralised database managed by the city or a partner organisation should compile all inputs, apply the agreed emission factors, and output the standardised metrics. The reporting frequency should balance effort and usefulness – quarterly or semi-annual reporting might suffice for informal operators, with annual aggregation to align with inventory years. MobiliseYourCity, for instance, suggests cities update their transport GHG inventory every 1–3 years, with key indicators in tonnes CO_2e (MobiliseYourCity, 2020).
- → Manual Logging Options: In many cases, digital systems will need to be supplemented with manual data collection (especially initially). The framework should not exclude low-tech approaches: printed logbooks issued to drivers to record daily fuel buys and trips, which are then collected by the city's transport office or an NGO partner. Reporting guidelines must account for low literacy levels too – using pictograms or simple formats if needed. Training workshops can teach drivers or union reps how to keep records that will feed into the GHG reports. Ultimately, even if only a representative sample of operators report regularly, it can be extrapolated to the whole system with reasonable confidence.

5.2.2. International Reporting Alignment

If the paratransit MRV is part of a larger climate action plan, its results should tie into international frameworks. For example, cities can report the paratransit emissions and reductions as part of their commitments to the *Global Covenant of Mayors* or submit them in National Communications to the UNFCCC via their national inventory process. Ensuring the methodology is compatible with IPCC Tier 2/Tier 3 methods (using local data but standard factors) will allow these numbers to be taken up in official reports. Additionally, aligning with methodologies like the CDM's AMS-III.T (a Clean Development Mechanism methodology for transport projects) or the GHG Project Protocol means any future climate finance (carbon credits or results-based financing) can trust the data. In summary, the reporting framework should produce transparent, scalable calculations of GHG emissions (total and per unit service) for the paratransit sector, consistent with global best practices, but in a format accessible to local stakeholders.

5.3. Verification Processes

Ensuring the reported emissions are credible is crucial, especially if they inform policy or finance. Verification in informal transit contexts must balance rigor with practicality:

5.3.1. Independent Verification & Auditing

Whenever possible, involve *independent parties* to verify emissions data and calculations:

- → Third-Party Audits: An unbiased third party (e.g. an accredited environmental auditor, engineering firm, or academic institution) should periodically audit data collection and calculation processes. In Latin America, one model is using nationally accredited bodies – for example, the Colombian Institute of Technical Standards (ICONTEC) has acted as a third-party verifier for transport emission reductions under programs like Medellín's cable car CDM project (Espinosa et al., 2021). Such entities can be contracted to verify paratransit emission reports against actual records. They would check a sample of vehicles, confirm fuel purchase receipts, inspect any sensor data, and ensure the estimations follow agreed protocols. Internationally, verifiers could be those accredited under ISO 14064 or carbon standards, but building local capacity is preferable for cost. Without formal auditors, forming a verification team from a local university's engineering department or an NGO could provide independent oversight.
- → First-Party vs. Third-Party: Recognise that some *first-party verification* (self-checks) will happen, especially if an organised cooperative or city agency manages the MRV. A city transport department can internally review and validate operator reports (for example, cross-check if a minibus claims unrealistically low fuel usage). However, relying solely on self-reported data carries risk of under-reporting or errors. Ideally, a combination is used: routine first-party checks and an annual third-party audit. In the Pacific Alliance countries, case studies have shown that while local authorities have technical capacity for verification, common standards are lacking. Therefore, establishing a clear verification protocol for paratransit GHG (who verifies what and how often) is essential to institutionalise the process.(Espinosa et al., 2021)

5.3.2. Standardised Validation Protocols

To streamline verification, the framework should include protocols for validating the data at multiple levels:

- → Cross-Verification with Fuel Sales: One powerful top-down check is comparing the aggregate fuel consumption reported by paratransit operators with government fuel sale records or tax data. Many countries track fuel imports or sales for taxation; while these are economy-wide, city or regional breakdowns (or even fuel station sales data in urban areas) can serve as a rough benchmark. For instance, if operators collectively report using X million Liters of diesel in a city, but the city's total diesel sales imply a much higher number for the transport sector, it indicates under-reporting. Governments could assist by providing data on fuel distribution (e.g. sales of subsidised fuel to public transport, if applicable). Even cross-checking trends (is fuel usage rising or falling in operator reports vs. official stats) can validate whether the MRV is capturing reality. In cases where paratransit fuel is informally sourced (black market fuel), this method is less reliable – but whenever official touchpoints exist (fuel purchase cards, depot refuelling records), they should be integrated into verification.

- Reconciliation with Operator Self-Reports: To ensure operators are honest and accurate in logging data, the protocol could use spot-checks. For example, select a random sample of vehicles each quarter and independently measure their fuel use (either via a fuel meter for a day or by accompanying the driver to observe operations). Compare this with what that driver reported. If discrepancies are large, adjustments or investigations follow. Over time, this builds confidence in the self-reported data and deters intentional misreporting. Association-level validation can also help: if paratransit routes are operated by associations or cooperatives, the leadership can compile fuel purchase totals from bulk receipts or supplier invoices. These aggregate figures can be matched against the sum of individual reports. Any standardised forms or mobile apps used should have built-in logic checks (e.g. flag if fuel economy implied by entries is outside plausible range).
- Data Quality Controls: The MRV framework should document procedures for handling missing data, errors, or outliers. For instance, if a certain percentage of operators fail to report in a period, define how their emissions are estimated (perhaps using averages from similar operators). If a fuel sensor yields anomalous readings, specify that it be discarded and replaced with modelled values. Keeping an audit trail of all raw data and calculation steps is vital for verification transparency. Using templates or software that automatically log changes can assist auditors in retracing the steps. In line with IPCC good practice, all emission factors and assumptions used should be documented in the report to enable replication of results(Wagner & Walsh, n.d.)

5.3.3. Building Local Verification Capacity

Strengthening local institutions to oversee and enforce the MRV is a long-term objective:

- Training and Guidelines: Provide training for local government staff (e.g. city environment officers, transport authority staff) on GHG accounting and verification techniques. They should become familiar with reading fuel logs, operating any measurement devices, and using the reporting software. Developing simple verification checklists or manuals will help institutionalise the process. For example, a checklist might guide an auditor through: "Step 1: Verify 10% of odometer readings on-site; Step 2: Check fuel receipts for at least 5 vehicles." Such guidelines ensure consistency even if personnel change.
- Leverage Existing Programs: Build on national MRV or climate reporting programmes that already exist. Some Latin American countries have voluntary GHG reporting programmes (like Chile's "Huella Chile" programme) that offer technical support and even recognition for entities measuring their carbon footprint. Notably, Huella Chile requires organisations to undergo third-party verification of their emissions reports and provides a registry for their data (Espinosa et al., 2021). Paratransit cooperatives or city transit departments could be enrolled in such programs, earning a certification or label for accurate GHG reporting – this external recognition can motivate compliance. In Africa, fewer such programs exist, but involving regional bodies (like environment ministries or climate change directorates) in designing the MRV can ensure it eventually feeds into national systems (e.g. linking with a National GHG Inventory System if one exists).
- Community and University Partnerships: Engage local universities or tech institutes in the verification process. Students in environmental science or engineering could perform parts

of the data gathering and validation as part of training, under supervision. Their involvement not only reduces costs but also builds local expertise. Likewise, driver associations can be made partners in verification. For instance, they can appoint trusted members as “data stewards” to coordinate data collection in their group and do an initial sanity check before submission. This peer verification can create accountability within the informal sector. As noted in a recent study, local stakeholders do have the capacity to implement verification when empowered. To illustrate, in Bogota’s TransMiCable system, the city’s own Mobility Secretariat successfully conducts first-party verifications for the cable car project (Espinosa et al., 2021). We can build on such models for paratransit by equipping local bodies with the right tools and authority.

- Audit and Feedback Loops: The verification process should be used not punitively, but as feedback to improve data and performance. After each verification cycle, a report should highlight issues (e.g. “fuel use on Route A seems under-reported by ~20%”) and recommend corrections. Sharing these findings with both the operators and policymakers closes the loop, as operators learn where reporting can improve, and authorities learn where emission hotspots or data gaps are. Over time, this iterative process will enhance the quality of the emissions inventory.

In summary, verification in an informal transit context will likely adopt a **“trust but verify”** principle: trust operators enough to gather data from them, but verify via independent checks, triangulation with external records, and involvement of third parties. This layered verification approach ensures data reliability, which is especially important if the MRV results are tied to climate finance or formal policy targets.

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