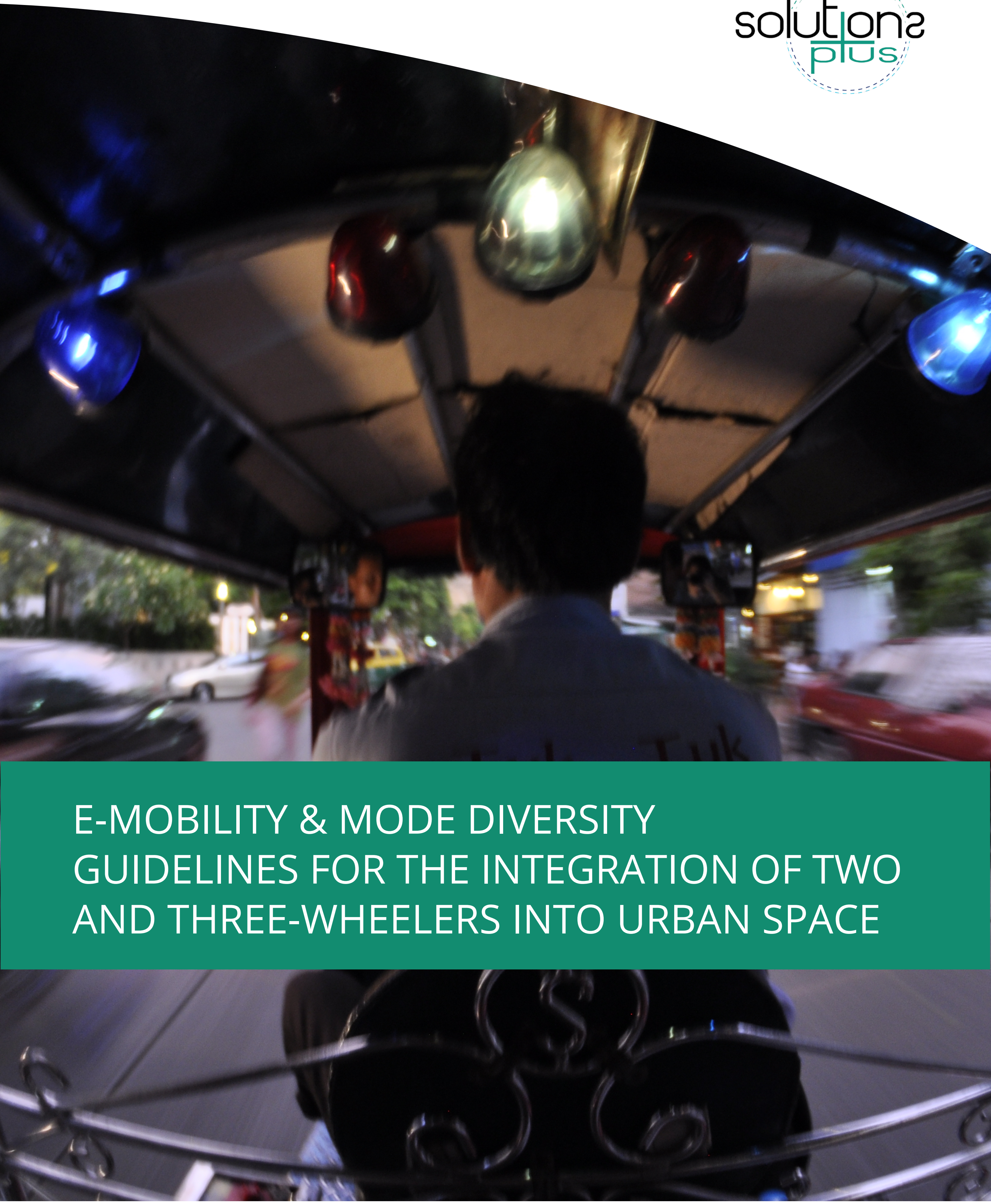

E-MOBILITY & MODE DIVERSITY GUIDELINES FOR THE INTEGRATION OF TWO AND THREE-WHEELERS INTO URBAN SPACE

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PROJECT PARTNERS

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EXECUTIVE SUMMARY

Figure 1. Two- and three-wheelers integration and parking are important (Dar es Salaam, Tanzania).

Two- and three-wheelers are not the solution to achieve an improved urban transport system but are part of the solution and must be adequately integrated into urban transport systems. They play an important role in complementing mass public transport systems, which are most efficient to transport high numbers of people through cities. Similarly, two and three-wheelers are also complementing non-motorized transport to increase speed to cover the last mile to the destination. A harmonized and integrated approach building on the particular strengths of all individual modes and effectively allocating the use of scarce urban space and public transport user's time resources will overall improve urban transport capacity, safety and convenience.

Two and three-wheeler are already being used massively in many places and a broader variety of vehicles with regards to speed, weight, size etc. will come alongside electrification of these vehicle modes. Decision makers must be aware of the various vehicle characteristics and manage challenges and benefits coming alongside their use.

Explicit decisions whether to incentivize / allow or disincentivise / ban certain vehicles from certain services, corridors, areas or even from being imported and / or locally assembled will need to be taken based on assessments of costs and benefits of each vehicle category and potential use case.

Better conditions for the strategic use of electric two and three- wheelers will enable better urban transport systems, enhance road safety and reduce energy use and emissions especially when these vehicles are speed-limited and light and or human power assisted. General recommendations to achieve that as presented in this paper include:

- Develop regulation with distinct requirements on insurance, licenses, data collection /reporting and surcharges or subsidies based on different vehicle characteristics.

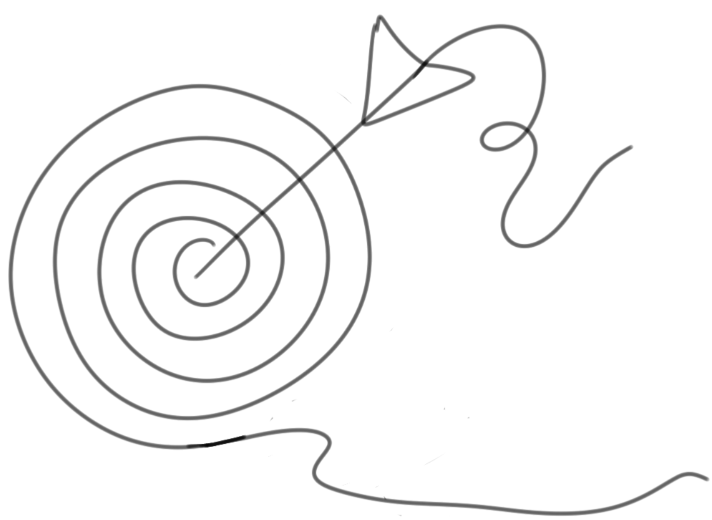
- Ensure road safety by means of infrastructure, vehicle and helmet standards enforcement, and training.

- Provide Infrastructure based on four types: integration with large motorized vehicles, segregation from others, integration with non motorized vehicles, or integration with pedestrians. This should be based on a clear vision of the role and priority of all modes, defining their rightful space on streets and roads. Regulations and the distribution of public funds should follow the defined priorities for all modes.

- Address parking needs explicitly for two- and three-wheelers for a more effective use of scarce space by providing clearer rules on pricing, facilities and communicate accordingly.

- Integrate two- and three-wheelers with public transport by designing multimodal transport hubs and strengthening the role of public transport.

Objectives of this policy paper



Objectives of this policy paper

Figure 2. Family using two-wheelers for their daily travel needs (San Andrés, Colombia).

In recent years, the emergence of relatively cheap, compact and powerful electric drivetrains drawing their power from batteries led to an increasing variety of light electric two and three-wheeled vehicles. At the same time, public transport services in many low and middle-income countries (LMICs) saw declining quality of service, increasing the demand for alternative ways of urban mobility. Many cities in the Global South will soon be facing the challenge of hosting a large variety of electrically propelled or assisted two and three-wheeled vehicles of different speeds, weights and footprints, which will compete for users on scarce urban infrastructure.

These new vehicle types have the potential to significantly increase mobility of citizens, and at the same time reduce energy use, greenhouse gas and air pollutant emissions and costs of urban transport. However, they need to be properly integrated in mobility systems based on parameters such as use case, vehicle size and speed to avoid increased competition with formal public transport systems, congestion and road safety issues, which in turn result in increased transport emissions and costs.

While much of the need for revised regulations and improved enforcement of existing regulations is not directly related to electric vehicles (EVs) only, the current shift to electric mobility in many cities in the Global South provides a great opportunity to leverage the fact that many of these light electric vehicles are part of digitally tracked mobility systems - which can be used to enforce and to improve future regulation of urban transport.

While literature exists with regards to the impact of micro-mobility including shared bike / e-bike and e-kick-scooter systems on urban mobility in the Global North and Asian context, little literature exists with regards to the growing variety of electric two and three-wheelers in the context of the Global South.

This document aims to fill that gap. Its objectives are to: 1.) Characterize and understand engine propelled two- and three- wheeled vehicles in urban mobility, given their increased presence, variety, and technological characteristics; and 2.) Provide recommendations to governments and other interested stakeholders on how to manage this large diversity of vehicles circulating on city streets and related infrastructure to improve liveability and sustainability.

The document differentiates between the following vehicle types: 1.) Small and light two and three-wheelers labelled micro-mobility, which do not have an internal combustion engine (ICE) but are either totally or partially electrically propelled (including pedal powered bicycles with electric-assist); and 2.) Traditional two- and three- wheelers, including motorcycles, two-stroke mopeds and scooters but also tricycles / tuktuks and their electric equivalents.

The document puts particular emphasis on the latter category of two and three-wheeled electric vehicles aiming at replacing traditional ICE two and three-wheelers used for passenger transport and goods delivery.

Two and three-wheelers in the urban context

Urban infrastructure and its natural scarcity

Figure 3. Urban space is limited and in great demand (Kampala, Uganda).

Cities have a finite space to provide for all their needs. Part of that finite urban space is allocated to infrastructure for movement of people and goods and parking of vehicles.

Modes in which people moved on urban roads have traditionally been:

- Walking – main mode in which cities' inhabitants have moved for centuries, with cities traditionally being planned around walkable distances;
- Different types of manual or animal driven pushcarts – for passenger and freight transport;
- Cycling – used in cities as a mode of transport since the end of the nineteenth century;
- Motorcycles – used generally for passenger, freight and delivery purposes;
- Three-wheelers – used with a predominantly utilitarian function for carrying goods and people;

- Four-wheel motorized vehicles – including a large category of cars, vans, lorries, minibuses and buses, taking up the majority of available urban mobility space;

- Rail based –mlargest vehicles with very high capacity for passenger or freight transport, in many cases with full right-of-way preference, and being either over- or underground.

Depending on characteristics such as speed, capacity (passenger-kilometers and ton- kilometers), weight and size of the vehicle, these modes have been allowed to use certain parts of the urban infrastructure. In many cases, the decisions to allocate space to certain vehicle types have been taken based on planning paradigms that favor motorized traffic and relegate all other modes (Ardila-Gomez & Ortegon-Sanchez, 2016; Goldman & Gorham, 2006; Norton, 2008).

Currently, over-ground transport infrastructure in cities comprises sidewalks, streets, parking spaces and roads mostly assigned for:

- Motorized – Mostly 4 wheeled private vehicles that travel along “mixed traffic” lanes;

- Non-motorized – People walking and cycling on roads and sidewalks

- In some cases, dedicated infrastructure has been assigned for:

- Public transport – In the form of exclusive bus lanes, tramways with varying levels of physical or signaled segregation;

- Bicycles – In the form of cycle-infrastructure of different typologies and levels of segregation;

- Motorcycles – Less common, in the form of motorbike lanes.

Recently, cities around the world have also introduced areas with restricted or no access for motorized vehicles, either because the area is designated as “car-free”, where no motorized vehicles are allowed, or because of emissions-based restrictions such as low emission zones. In the latter case, high-emitting vehicles are not allowed to travel or are only allowed to travel under certain conditions, such as paying a fee.

Two and three-wheeler mode development

Figure 4. Some new vehicle typologies have emerged, such as electric cargo bicycles (Bogotá, Colombia).

Traditionally, motorized two- and three- wheelers had an internal combustion engine though smaller, lighter, and not as powerful or expensive as automobiles. These vehicles often had a utilitarian function and emerged in large numbers in the interwar (Potter, 2007) and post-Second World War timeframe in the industrialized world (Alexander, 2009; Yamamura et al., 2005). With cars becoming affordable to large parts of the population in the Global North starting in the 1950s, the role of motorized two- and three- wheelers began to decline. However, these vehicles quickly spread over to the Global South, where their lower cost and utilitarian character has driven a surge in sales continuing up to today.

During most of the twentieth century, they were powered by two- and four-stroke internal combustion engines. More recently, liquefied petroleum gas (LPG) or compressed natural gas engines (CNG) have emerged in the two and three-wheeler segment, mostly because of availability of relatively cheaper LPG and CNG, and due to the retrofitting of gasoline engines. Traditionally, ICE engines for two and three-wheelers are in the range of 50-250cc, classes which emerged based on taxation of vehicles in European countries.

Over the past fifteen years, and mainly driven by the emergence of relatively cheap and small electric powertrains with battery energy storage, a large variety of new vehicles have emerged including:

1.) Small and light two and three-wheelers labelled micro-mobility, that do not have an internal combustion engine but are either totally or partially electrically propelled (therefore including pedal powered vehicles with electric-assist); and

2.) Electric equivalents to "traditional" two- and three- wheelers segments, including motorcycles, two-stroke mopeds and scooters but also tricycles, covering a power range of 500W-5kW (World Health Organization, 2017).

The new segment of micro-mobility (1) mainly refers to the rapid emergence of large bicycle and electric kick-scooter sharing systems. Starting in China, this new segment moved onto the United States (Shaheen et al., 2021) and later spreading to other parts of the world including European, Latin American and Southeast Asian capitals.

Figure 5. Scooters and shared bicycles (part of the "micromobility" definition) on a sidewalk (Mexico City, Mexico).

The diversification of the traditional two and three-wheeler types (2) happened mostly due to efficiency gains by means of electrification of the powertrain, an absence of restrictive regulation and registration of such vehicles, and the demand for new mobility services often triggered by declining public transport services in cities in the Global South.

This document will focus on the electric equivalents to "traditional" two- and three- wheelers segments, including motorcycles, two-stroke mopeds and scooters but also tricycles, covering a power range of 500W-5kW (World Health Organization, 2017).

Opportunities and challenges of engine propelled two and three-wheelers in cities in the Global South

Figure 6. Two- and three-wheelers are popular in many places in the world due to their usefulness (Kuala Lumpur, Malaysia).

The increase in two and three-wheeler types driven by the emergence of relatively cheap and powerful batteries is often amplified by unmet or partially-met needs for mobility in urban areas. The absence of sufficient, and high-quality, public transport infrastructure and rolling stock in combination with increased demand for mobility and higher disposable income in LMICs led to increased use of cars resulting in congested urban centers. Consequently, travel times in often uncomfortable buses and minibuses increase for the rest of the population. In response to this, users become more attracted to alternatives such as two- and three-wheeler taxis, which can have competitive costs per trip and which significantly reduce travel time and increase trip flexibility. This demand for new mobility services is also triggering people to acquire such vehicles as an asset for income generation, whether through owning and driving themselves or by investing in fleets of vehicles driven by hired drivers. In hindsight, the presence of affordable and fast two- and three-wheelers in large numbers increases congestion and puts even more pressure on formal public transport systems as the client base deteriorates. In addition, the relatively lower capacity of motorcycle taxis – most often only one passenger is carried – increases energy use and air pollution.

The following list provides an overview of the opportunities of engine propelled (or engine assisted) two- and three-wheelers (see also Bishop & Courtright, 2022):

- Practicality and versatility – Because of their size and weight, moving through crowded and narrow areas is comparatively easy and quick, following flexible routes and providing door-to-door service (Kumar et al., 2016);

- Possibility to carry passengers and goods - This applies to all but mostly to two- and three-wheelers with an engine (ICE or electric) including pedal assisted cargo bikes;

- Low capital and operating costs – Using these vehicles is often the cheapest option available to travel flexibly for relatively long distances in a relatively short amount of time (Cervero & Golub, 2007; Starkey et al., 2019; Tunje & Yogo, 2020);

- Greater access to jobs and direct job opportunities – Having the possibility to own and ride these vehicles makes it easier to arrive at destinations, and several job opportunities even require the ownership of a two-or three- wheeler (Hagen et al., 2016; Rodríguez et al., 2015);

- Efficiency advantage over the use of cars – When compared to automobiles, two- and three- wheelers occupy a smaller footprint and are more effective in moving people and goods (TUMI initiative, n.d.), also having a lower energy consumption (International Transport Forum, 2020)(International Transport Forum, 2020) in particular since very often only one passenger is transported using light duty vehicle taxis and car-based ride-hale systems (this is in particular since very often only one passenger is transported using light duty vehicle taxis and car-based ride-hale systems);

- Heavy congestion for other modes – While automobiles and public transport suffer from the effects of congestion, two- and three-wheelers generally circumvent traffic (Cervero & Golub, 2007);

- Complementarity to other transport – When properly integrated, two- and three-wheelers can become good ways to increase flexibility of public transport systems by continuing those trips commonly referred to as "last and first mile" connectivity (Moreno & Miralles-Guasch, 2017; United Nations, 2022). However, when improperly planned, these modes end up competing with mass transit transport systems to the detriment of quality of their service;

- Wellbeing – In the cases where users engage in some form of physical activity, e.g. using shared micromobility systems based on bicycles or engine assisted bicycles, using these vehicles helps to enhance physical and mental health (Abduljabbar et al., 2021).

While many of these advantages are essentially the same regardless of the vehicle powertrain, some caveats apply to the use of electric two- and three-wheelers: electric vehicles have yet to convince the public at large. This is especially true for use cases that require long daily driving distances, where electric propulsion systems are still perceived to be less competitive in comparison to ICE vehicles due to restricted battery energy storage and the current inadequate provision of vehicle charging or battery swapping infrastructure.

Much of the scepticism towards electric two- and three-wheelers is due to the user's unfamiliarity with the new technology and the absence of large-scale operation of these specific type of vehicles in most countries. Where EVs are available in large numbers they become very popular. One example for this is China, where electric kick-scooters, scooters and mopeds for individual mobility with ranges below 50km per day and a maximum speed of 45km/h constitute more than 50% of all purely electric engine propelled vehicles (IEA, 2022). In general, current battery ranges are already enough to cover most pendular trips in all world regions. For example, a typical trip in a large city like Bogotá, Lagos or Bangkok is between 5 and 10 kilometres resulting in daily distances of pendular trips between 10 and 20 kilometres. Battery ranges for electric two- and three-wheelers are well above this and are sufficient to commute to- and from- work, and to perform even several trips in a chain for mobility of care purposes. Therefore, electric mopeds and e-scooters for individual motorized travel can be regarded a competitive product in such circumstances.

In the motorcycle taxi and delivery industry, the penetration of electric vehicles is still much lower. This has to do with long daily driving distances of up to 130 km and more, the need for relatively high speeds to comply with market demands of the service (e.g. 60 km/h and above) and the ability to transport heavy loads of around 150kg and more. Based on these specifications, a rated continuous engine power of at least 3,000 watts and more is required, necessitating battery capacity of 5 kWh and more, or the availability of a network of stations with standardized swappable battery packs, similar to those of petrol stations.

Figure 7. Current technologies have enabled services such as app-based public transport services (Dar es Salaam, Tanzania).

The following list of reports provide examples of some of the typical uses of two and three-wheeled vehicles:

- General utilitarian and transport related uses (ASEAN, 2020; Bishop & Courtright, 2022; Hook & Fabian, 2009);
- Safety guidance for powered two and three wheelers (World Health Organization, 2022);
- Personal use for daily travel (World Health Organization, 2017);
- Mobility of care (Alcaldía de Medellín et al., 2022; Blomstrom et al., 2018);
- Freight (logistics, delivery) (Schünemann et al., 2022) – the use of two and three-wheelers for delivery increased significantly with the rise of app-based delivery services. Also, e-cargo bicycles have recently begun to have a greater role in formal delivery services in several countries;

- Public transport (bike taxi, boda boda, tuktuk, rickshaws)(Bishop & Courtright, 2022; GIZ SUTP, 2019)- this use in particular has also been enhanced greatly by means of app-based services such as Gozem, Safemoto, Yegomoto, Safeboda, Uber, Bolt;

- Shared services (Fishman, 2016; ITDP, 2018; T4America, 2020) – mobile applications have also disrupted these services to what is now called "4th generation" and "dockless" mobility services of smaller vehicles, some of which are electrified;

- Leisure (Fyhri & Beate Sundfør, 2020; Mcqueen et al., 2020; Rose, 2012).

Figure 8. Motorcycles are associated with road safety risks (Bangkok).

However, increased use of engine propelled or engine assisted two- and three-wheelers also comes with significant challenges. Negative aspects associated with the use of these vehicles in cities include:

- Crashes, injuries and deaths – Motorcycles have become a disproportionately large contributor to injuries and deaths worldwide. As per the Global Road Safety Report of 2018, "In South-East Asia and the Western Pacific, the majority of deaths are among riders of motorized two-and three-wheelers who represent 43% and 36% of all deaths respectively" (World Health Organization, 2018). This is in part due high speeds, high physical exposure in case of accident, little to no infrastructure provisions for their safe circulation, and lack of personal protection (often no helmet wearing). Smaller and slower vehicles (e-scooters, for instance) and those which have factory-defined speed limiters, have much lower probability of injury (OECD / ITF, 2020a).

- Increased competition for scarce urban transport infrastructure, resources and passengers – The “war of the cent” (Moscoso et al., 2020) has been documented as a negative aspect of ill-regulated public transport, and is also applicable to two- and three-wheelers in that these also compete for passengers, and for space on the street.

- Detriment of public mass transport – As a consequence of increased competition, studies have found that motorcycle taxis are used mostly as a replacement to public mass transport (Irawan, Belgiawan, Joewono, et al., 2020; Irawan, Belgiawan, Tarigan, et al., 2020; Jou & Chen, 2014; Márquez et al., 2018; Rodríguez et al., 2015). Therefore, proper planning and integration of modes is of utmost importance to make them complementary rather than competitive.

- Impact on climate and air quality – Compared to mass transit vehicles such as minibuses and buses, conventional two and three-wheelers have relatively low efficiencies. A study published in 2022 found that fuel economy of ICE motorcycles in Indonesia, Vietnam and India are about 1.94, 1.76 and 1.74 l/100km, respectively. In the African context, fuel efficiency of motorcycle taxis is around 3 l/100km. Compared to 12m city buses with space for 50 (seated) passengers and more and consuming around 45l/100km, or typical midi buses with on average 35 seats and consuming around 30l/100km motorcycle taxis with capacity for one passenger are therefore much less fuel efficient per capita. In addition, in absence of emission regulations for two and three-wheelers in many low-and-middle-income countries, outdated engine technology based on the use of carburettors instead of electronic injection, or the permission of two stroke engines lead to a high contribution to air pollution.

- Association with criminal behaviours – In many cities in the Global South motorcycles are used as getaway vehicles for robbery and other crimes causing a bad reputation (Pardo, 2022).

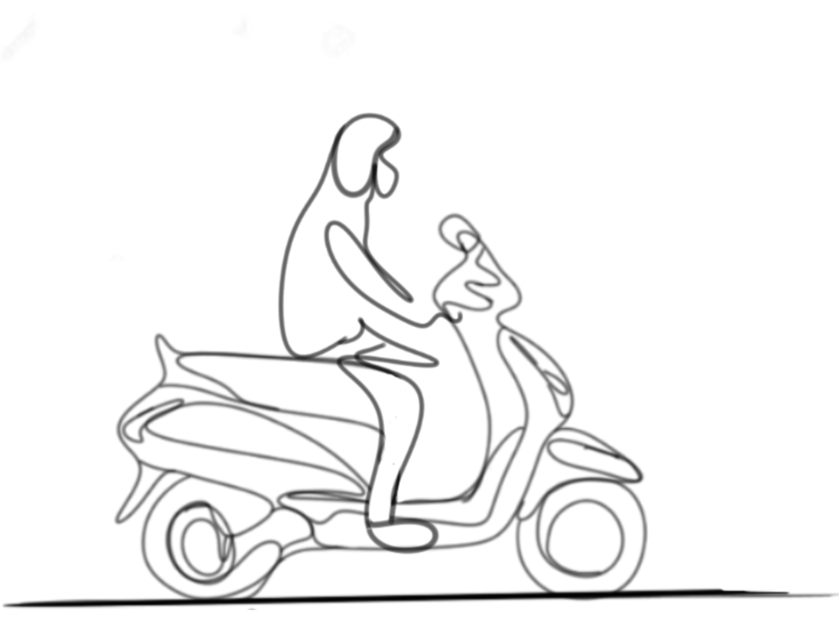
- Bad driver behaviour (Haworth, 2012) and lack of compliance with traffic laws – Ease of purchase as often no license is required, lax enforcement of rules, early age of use (sometimes as early as 13 years old (Khan et al., 2022)), and lack of driver experience all result in lack of compliance with traffic rules, unsafe riding and therefore high occurrence of crashes leading to injuries and deaths;

- Equity – Some social groups might be excluded from using two and three-wheelers including e-scooters and bike share systems. This is because they require a certain level of physical ability, experience & technical adeptness, a driving license and in the case of app-based platforms a credit card associated to higher purchasing power (Milakis et al., 2020).

In many cases, the circulation of commercial two- and three- wheelers is restricted or banned from city centres because of the negative effects associated to their use. An illustrative list of cities where this is the case include: Bujumbura, Dhaka, Guangzhou, Jakarta, Kampala, Kigali, New Delhi, as well as all cities in Ghana and Ethiopia (Hook & Fabian, 2009; Jitendra Shah & N.V. Iyer, 2002; Starkey et al., 2019). Such strict measures demonize these vehicles and their users, often without providing suitable alternatives.

A proactive solution to reduce negative effects and to enhance the benefits of two and three-wheeler use is to analyse the causes of these negative effects and to adopt more targeted measures to mitigate or eliminate them (Jitendra Shah & N.V. Iyer, 2002). Policy makers in national and city governments have many tools at hand to control and channel the use of micro-mobility and electric as well as ICE two and three-wheeler modes to maximize use of the currently available infrastructure and to reduce economic competition among various modes of public passenger and goods transport. However, this can only be achieved once vehicle types are properly categorised.

Categorization of engine propelled two and three-wheelers



Categorization of engine propelled two and three-wheelers

Many different micro-mobility and two and three-wheeler vehicle types exist around the world. Clear categorization of these vehicles is a prerequisite for any attempt to manage and channel them to beneficiary use cases. While globally there is a general understanding of overarching vehicle categories such as bicycles, motorcycles, cars, buses etc. there are differences in the way that countries and regions define sub-categories (e.g. a moped versus a motorcycle). Very often these sub-categories are named differently according to local use and features, resulting in different regulations and standards. For example, in the case of micro-mobility, there is a heated debate around the thresholds for power, speed, gross-weight etc. that define these vehicles and how they relate to other categorizations such as active mobility or non-motorized transport (Cook et al., 2022).

Table 1 presents a first attempt to define micro-mobility versus more traditional two- and three- wheelers using some of the standard definitions of ITDP (2021) and that SAE (2019). The main idea is to separate vehicles based on speed and vehicle footprint, assigning them to either circulate on 1.) Sidewalks and bicycle lanes; or 2.) Mixed travel lanes.

For example, the separation of vehicles permitted to drive on a bicycle lane also motivated the European Union to introduce a vehicle category called "light electric vehicles" (LEVs). LEVs are defined as "electric vehicles, with a number of wheels greater than or equal to one and less than or equal to four, designed for personal mobility, transport of passengers or goods in an urban setting, propelled by electric motor(s) in pedal assistance mode or in exclusive mode. Their maximum continuous power is 15 kilowatts (kW) and is reduced or interrupted when the vehicle reaches a maximum speed of 45 kilometers per hour (km/h) (maximum values)" .

Table 1. Comparison of characteristics between micromobility and two- and three-wheelers

Characteristic	Micro-mobility	Two- and three-wheelers
Power	Human- powered or partially or fully electric	Powered by an electric or internal combustion engine
Ownership	Often in shared fleets, self-driven by the mobility client (for passenger mobility) or by commercial drivers (often self-employed) for goods delivery	Individually owned for personal mobility or fleets by commercial drivers (often self-employed) or fleet aggregators for passenger transport and freight delivery
Weight limit	≤ 500 lb (227 kg)	None defined
Top speed	≤ 30 mph (48 km/h)	Defined in several thresholds (see e.g. Table 2)

Motorized vehicles are categorized to: 1.) Define specifications with regards to safety and environmental standards; 2.) Detail what rules apply to them when circulating on public roads; 3.) Apply tax schemes related to their purchase, registration, and use; and to 4.) Insure vehicle owners and users in case of accident.

Against this background Table 2 presents a more comprehensive approach to categorize engine propelled / assisted two- and three- wheeled vehicles. This table is however not intended to provide a complete taxonomy of vehicle types, nor does it aim for being comprehensive with regards to all potential use cases covering all world regions. Rather, it presents illustrative examples that will be useful when developing or adjusting national and city policies.

Other documents and standards have been published aiming to develop taxonomies and catalogues, for example:

- Efficient Urban Light Vehicles Report by European Commission 2020 https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5a6d2f420&appId=PPGMS

- European Commission's Regulation 2002/24/EC https://eur-lex.europa.eu/legal-content/ES/TXT/PDF/?uri=CELEX:32002L0024

- Institute for Transportation and Development Policy. (2021). Defining Micromobility. https://www.itdp.org/multimedia/defining-micromobility/
- OECD / ITF. (2020). Safe Micromobility. https://www.itf-oecd.org/sites/default/files/docs/safe-micromobility_1.pdf

- REGULATION (EU) No 168/2013 https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:060:0052:0128:en:PDF

- SAE. (2019, November 20). J3194: Taxonomy and Classification of Powered Micromobility Vehicles - SAE International. https://www.sae.org/standards/content/j3194_201911/

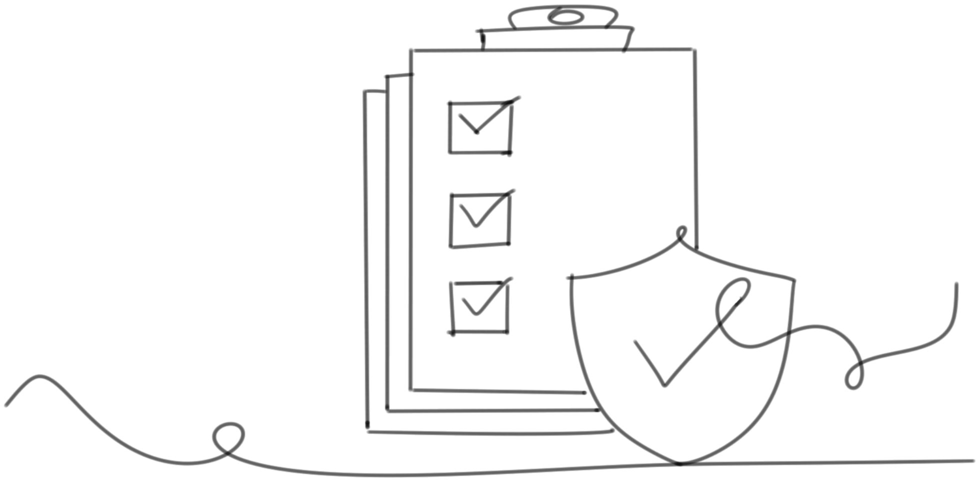
- United Nations Economic Commission for Europe (UNECE), "Classification and Definition of Vehicles," TRANS/WP.29/1045 – Special resolution no.1 concerning the common definitions of vehicle categories, masses and dimensions (S.R.1)

http://www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29classification.html

Table 2. Examples of vehicles and their characteristics (indicative values)

Vehicle name (where applicable, EU terminology)	Definition (and other names)	Typical purpose	Weight (range)	Capacity including driver	Speed (range or maximum)	Footprint (square meters)
ICE Motorcycle (L3e-A2/A3) 	Two-wheel ICE motorcycle without step-through frame (motorbike)	Personal /passenger and freight transport	100-250kg[7]	2	Between 45km/and 130km/h[8]	2
ICE Moped (L1e-B)	ICE motorcycle with a small engine (~50 cc)	Mainly personal, some passenger transport	Maximum weight of 65kg[9]	2	≤45km/h[10]	2
Vehicle name (where applicable, EU terminology)	**Definition (and other names)**	**Typical purpose**	**Weight (range)**	**Capacity including driver**	**Speed (range or maximum)**	**Footprint (square meters)**
E-tricycle (L5e-A) 	Electric three-wheeler for passenger transport (e-tuktuk, e-rickshaw)	Passenger transport	350- 700 kg[23]	2-7	20 to 45km/h[24]	6
Power e-bike / Speed-EPAC (L1e-B) 	Electric two-wheeled bicycle (with throttle) for personal use	Personal and transport	≤35 kg	1	≤45 km/h[25]	2
E-cargo bike	Electric (two- or three- wheeler bicycle for freight	Freight transport	30-50 kg	100 kilograms	45km/h[26]	6
Vehicle name (where applicable, EU terminology)	**Definition (and other names)**	**Typical purpose**	**Weight (range)**	**Capacity including driver**	**Speed (range or maximum)**	**Footprint (square meters)**
	transport (with or without throttle).					
E-bicycle (L1e-A) 	Electric-assist (ie. no throttle) two-wheeled bicycle (e-bike, pedelec)	Personal transport, delivery	≤35 kg[27]	1	≤25km/h[28]	2
E-kickscooter 	Electric, small, two-wheeled kick scooter.	Personal transport	10-20 kg	1	Up to 29 km/h[29]	1

Policy recommendations for better integration of motorized two and three-wheelers



Policy recommendations for better integration of motorized two and three-wheelers

Figure 9. Two Wheeler riders (Taipei, Taiwan).

This section aims at providing decision makers with ideas and measures to better understand and subsequently control the broad variety of two- and three-wheelers and make their use safer and more sustainable. It is mainly focusing on electric and engine propelled / assisted two and three-wheelers allowed to use mixed lane roads and not on micromobility. This very topic is thoroughly covered for example by other authors (see, for instance, EY, 2020; Institute for Transportation and Development Policy, 2021; Internationale Automobil-Ausstellung, 2019; NACTO, 2019; NUMO, 2019; OECD / ITF, 2020a; T4America, 2020).

The recommendations given in this chapter are structured as following:

1.) Policies and regulations developed at national level
i. Technical standards for local manufacturing, assembly and import of electric two and three-wheelers;
ii. Standards for registration and use of electric two and three-wheelers;

2.) Policies and regulations developed at city level:
i. Improved explicit regulations;
ii. Spatial regulations and access rights
iii. Infrastructure measures;
iv. Parking management;
v. Integration with existing public transport modes;

Policies and regulations at national level

Technical standards for local manufacturing, assembly, retrofit and import of electric two and three-wheelers

In many countries the shift to electric vehicles necessitates the review and adaptation of national regulations and technical standards for:

1.) Local production and assembly; 2.) Retrofit of ICE to electric two and three-wheelers; and 3.) Import of two and three-wheeled electric vehicles.

In this context, decisions need to be made with regards to the characteristics of vehicles such as size, weight, footprint, speed, gradeability and range of vehicles allowed to circulate on public roads, sidewalks and bicycle lanes.

Often, some of the decisions are not taken explicitly but rather implicitly, by allowing certain technologies and not anticipating their inherent consequences. For example, many countries which historically have seen a steady growth of gasoline or diesel engine propelled three-wheelers (often called tuktuks in Asia and Africa) for both passenger and goods transport also allow the import and use of electric engine propelled three-wheelers that use lead-acid batteries for power storage. While the latter are price competitive due to the use of the relatively cheaper batteries, they come with sub-standards characteristics with regards to speed, acceleration, gradeability and range. These slower electric three-wheelers propelled by lead-acid batteries have a similar footprint compared to their ICE counterparts, but the ICE versions are up to three times more powerful. Since three-wheelers in general have a footprint not much smaller than a small car, these slow vehicles can significantly slow down traffic flow, especially in hilly urban areas.

It is also important to define a set of characteristics clearly separating motorized and motor assisted vehicles from human propelled vehicles to regulate and / or prohibit their use on 1.) Mixed lane roads; 2.) Bicycle lanes; and 3.) Sidewalks and pedestrian areas in order to not affect traffic flow and safety on urban infrastructure.

Such characteristics aiming at providing for better mode integration shall include:

- Dimensions of the vehicle – for example regulating the maximum width of a two and three wheeled vehicle to be allowed on bicycle lanes

- Weight of the vehicle – for example regulating maximum weight of a two and three wheeled vehicle to be allowed on bicycle lanes

- Speed of the vehicle – for example regulating maximum speed of a two and three wheeled vehicle to be allowed on bicycle lanes and minimum speed of a two and three wheeled vehicle with load to be used on mixed road lanes

- Gradeability - Minimum speed of a two and three wheeled vehicle with load climbing a certain grade to be allowed on a mixed road lane

- Range – Minimum range per charge / battery swap for a two and three wheeled vehicle to be allowed on a mixed road lane

- Load – Minimum and maximum load of a two and three wheeled vehicle to be allowed on bicycle lanes and three wheeled vehicle to be used on a mixed road lane

Such regulations can be developed in addition to currently existing regulations which have been targeting motorized two and three-wheelers with ICE engines only and existing regulations should be adapted or revised accordingly.

In addition, clear regulations covering all new modes of micro-mobility and electric engine propelled two and three-wheelers needs to be developed and adopted at national level, including:

- Definition of vehicle safety standards: National government needs to ensure that appropriate safety regulations for all types of vehicles are in place, and explicitly covering new forms of micro-mobility and electric two and three-wheelers. These regulations need to cover safety of the vehicle and the driver, and need to be linked to any previously established technical standards to allow for local manufacturing, assembly, retrofit and import of these vehicles including maximum speed, dimensions etc. This should also include specifications with regards to lighting, presence of indicators and other vehicle characteristics. For example, China has regulations around product quality for e-bikes, and a transition scheme for the replacement of older, “non-standard” vehicles (Renewable Energy Laboratory et al., 2021).

- Definition of vehicle greenhouse gas and air pollution emission standards: Ideally, equivalent standards to EURO should also exist for these vehicles to regulate the energy efficiency of two and three wheelersas well as to ensure that carbon intensity of manufacturing is reduced over time.

• Definition of environmental standards with regards to end-of-life: Given their small size and lightness, many two- and three-wheelers have shorter lifetimes than larger vehicles. Specific timelines with regards to warranty etc. should be set and producers and importers should be part of Extended Producer Responsibility schemes to deal with battery-end-of-life issues including second life, and recycling and re-integration of precious materials into global battery value chains.

Regulation developed at national level and with regards to periodical inspection of vehicles both for private and commercial use pose a powerful mean to ensure roadworthiness and therefore increase safety of road traffic, including:

• Definition of control mechanisms for shared micro-mobility : it needs to be ensured that vehicles available for public use are in safe condition and parking of these vehicles does not hinder pedestrians and other city transport infrastructure
.
• Adaptation of periodical roadworthiness inspection to electric two and three-wheelers: specific procedures for these vehicles need to be developed, given their different size and overall configuration.

In addition, in many countries of the Global South basic regulation as to which vehicles fall under the category of micro-mobility with regards to safety, speeds, loads, dimensions and infrastructure use and parking such is still yet to be introduced. The literature provided in section can serve as a reference for the regulation of these modes.

Standards for registration and use of electric two and three-wheelers

Many decisions with regards to regulating the registration and use of engine propelled and assisted vehicles are taken at national level, directly impacting mobility in urban areas.

Much of the current regulation has been developed with regards to ICE propelled two and three-wheelers and was not designed covering a much larger variety of electric engine propelled or assisted derivates.

The uptake of e-mobility necessitates the revision of such regulation, also with an eye on traffic flow in densely populated urban areas, and anticipating existing and coming business models and use cases of informal passenger and goods transport.
As described in section 2.3, many of the issues arising from the use of engine propelled or assisted two and three-wheeled vehicles are related to misbehavior or misuse. Some of the flexibility, travel speed and hence travel time advantages stem from the fact that the vehicle drivers do not obey traffic rules: they do not use the designated transport infrastructure (using sidewalks), ignore traffic lights and travel counterflow in one-way roads.

National governments have numerous tools at hand to enforce existing regulation and traffic codes on micro-mobility and two and three-wheelers. Most often this has to do with identifying the vehicles and their drivers.

Therefore, the paper suggests the following:

• Revise regulation on licenses and license plates: A set of license plates should be required for engine propelled and assisted vehicles above for example a certain maximum speed and gross vehicle weight. The introduction of driving licenses for such vehicles could also be considered. Some countries such as China and Switzerland require license plates for electric bicycles (Renewable Energy Laboratory et al., 2021), and Germany for e—kick-scooters (FINBER, 2023).

• Obligation of insurance: an insurance policy should be required for the use of a vehicle when they pose significant risk to others because of their weight (and volume) or speed, or when the operation implies greater responsibility (e.g. in shared services). This means that vehicles with larger or more powerful engines or operating in a shared system would require insurance by law.

• Mandating helmet use complying with minimum safety standards: The use of helmets for both driver and passengers should be mandatory for all non-self driving, commercial purpose, engine propelled / assisted public transport vehicles. The helmets used should comply with minimum safety standards. The use of shared mobility e-motor assisted bicycles and e-kick-scooters can be considered without helmets.

• Enforcement of vehicle safety standards and compliance with traffic rules: National government needs to ensure that appropriate safety regulations and traffic rules are appropriately enforced by traffic police. Similarly, regulation for periodic inspections of vehicles can be used for enforcing safety standards. This will require respective budget allocations.

- Apply surcharges and subsidies at national level: Surcharges can be applied to dirty or dangerous vehicles to cover their externalities, and to subsidize purchase of clean and low-risk vehicles e.g. electric assist bicycles, which can perform many of the delivery jobs currently done by over-powered motorcycles. For example, subsidy schemes aimed at increasing the affordability of electric bicycles in the United States and in other places of the world which in some cases include scrapping old three-wheelers to receive an incentive such as India (Renewable Energy Laboratory et al., 2021). An example from light-duty vehicles is France's bonus-malus system, where a fund is replenished with a fee for the registration of polluting vehicles and is used to subsidize the purchase of cleaner vehicles (Yannick Monschauer & Sonja Kotin-Förster, 2018). Surcharges can also be "earmarked" for specific purposes, such as road safety.

Policies and regulations at city level

Explicit regulation

Figure 10. Some two- and three-wheelers are makeshift models where it is unclear what regulation applies or not (Lucknow, India).

City governments have numerous tools at hand to enforce existing regulation and traffic codes on micro-mobility and two and three-wheelers. While some regulations needs to be implemented at national level, execution often lies with cities.
Hence, local governments should:

- Improve data collection: Data collected by app-based mobility providers on speed, distance traveled and trip routes, can be used to develop and enforce traffic rules. Data exchange with authorities must, however, follow data privacy rules.

- Improve general enforcement measures: these include, for instance, strengthening penalties for drunk driving or exceeding speed limits, mandatory registration of vehicles; and licensing of powered two and three-wheeler operators as well as compulsory skill tests as a requirement to receive a driving permit.

- Impose access limitations: access to provide mobility services in urban areas can be granted only to registered vehicles with certain technical specifications (such as maximum speed, drivetrain) and, for example, operation with an app-based mobility provider only.

- Enforcement of vehicle safety standards: a permit to use a vehicle for public transport services can be linked to safety and emission standards of the vehicle, including maximum speed, drivetrain etc. While most should be covered at national level, cities can impose additional standards etc. when providing public service licenses or for circulation in certain areas (Low emission zones).

It is important that improved regulations for two- and three- wheelers goes hand in hand with sufficient institutional capacity to enforce the changes, follow up on their implementation and monitor their effects.

Table 3. General guidance for regulation of 2-3 wheelers with vehicle examples.

Vehicle / use case example	Insurance	License to drive	Data collection / reporting and standards	Surcharges, subsidies	Vehicle	Helmet	Enforcement
ICE Motorcycle	Mandatory	Mandatory	Mandatory	Surcharge (e.g. earmarked for road safety)	ABS brakes, factory speed limits, lights	Mandatory	All enforcement mechanism, special emphasis on registration for taxi – like use
ICE scooter							
ICE Moped			Recommended				
ICE Tricycle							
ICE Cargo tricycle			Mandatory				
E-motorcycle							
E-moped							
E-scooter			Recommended			Recommended	Encourage registration, skills courses
E- Tricycle			Mandatory		Lights / reflectors	Recommended but not mandatory	Encourage registration, skills courses
Power E-bike	Recommended	Not mandatory	Recommended	none		Mandatory	All enforcement mechanisms
E-cargo bike							
E-bicycle	Not mandatory for privately owned, mandatory for shared			Subsidy recommended			Encourage registration (not mandatory), skills courses
e- kick scooter				none		Recom-mended but not mandatory	Encourage registration (not mandatory)

Infrastructure

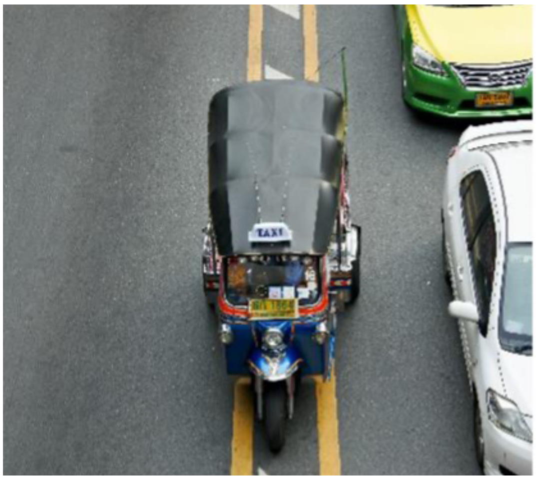


Figure 11. Every vehicle and mode must have clarity as to where they can travel and when they cannot (Bangkok, Thailand).

Cities have finite amounts of financial and spatial resources so they must be carefully allocated. Policies must guide budget allocation and spatial distribution for different modes of transport, including two- and three-wheelers, in line with equity and environmental objectives.

Cities need to be supplied with goods and provide their inhabitants with effective means to go to work, allow for childcare, to supply themselves with the needed commodities and go for leisure activities. How to enable appropriate passenger and freight transport capacities (in passenger-kilometers and ton-kilometers) will need to be matched with the geography of the city, the already existing built stock and its functions, the availability of budgets to significantly improve the urban infrastructure, the growth and age distribution of the population as well as current and future economic context including its structure (industrial, service oriented).

However, it is safe to say that efficient urban transport systems are a combination of high-occupancy vehicle serviced public transport corridors, and a dense network of feeder-lines often served by smaller public transport vehicles. Walking and cycling, as well as the use of other means of micro-mobility have the role as "first and last-mile connectivity". A good understanding of the urban transport system, its main corridors, feeder-lines and last-mile perimeters is a prerequisite to the allocation of certain vehicle types and modes to certain use cases, corridors and perimeters.

Urban planning instruments

It is essential to establish short, medium and long-term planning instruments and to explicitly consider engine propelled or engine assisted two and three-wheelers in:

- National Urban Mobility Policies that establish guiding principles and overarching projects that determine the role of each transport mode to achieve urban mobility purposes catering for existing and future trips including these all vehicle types;

- City planning tools such as sustainable urban development plans, istrict development, transport corridor development, transit-oriented development and general land use- transportation policies that can make travel more efficient in cities planned for mixed land use and compactness where smaller vehicles can be used effectively;
- Strategies of metropolitan transport agencies that will explicitly acknowledge the use of engine propelled or engine assisted two and three-wheelers in a metropolitan region and describe what role these agencies will have in improving conditions for these vehicles as part of an integrated transport system;

- Economic development / industry plans that provide clear incentives for engine propelled or engine assisted two and three-wheeler market deployment in consistence with city goals;

- Budget plans that make explicit allocations of funds for engine propelled or engine assisted two and three-wheelers to enable the development of infrastructure for their circulation and overall integration in mobility systems.

At the metropolitan or city district level the regulation of two- and three-wheelers cannot be done in isolation but must be in a context of other modes (buses, bicycles, people walking, cars, etc). The “inverted pyramid” approach (see Figure 12) provides a useful framework with regards to allocation of space and safety considerations: pedestrians are given the greatest importance and protection, followed by non-motorized vehicles (wheelchairs, bicycles, pushcarts, etc), followed by low-powered, low-speed, small electric vehicles and thereafter public transport and freight. Those with least priority include fossil fuel powered motorbikes and, lastly, cars.

Spatial planning for two- and three- wheelers should therefore always consider the priority of pedestrians, cyclists, and public transport / freight. For instance, neighborhoods should always have infrastructure and crossings that provide the greatest space and benefit to those modes, while public transport systems should be given priority in high-demand corridors (NACTO, 2016).

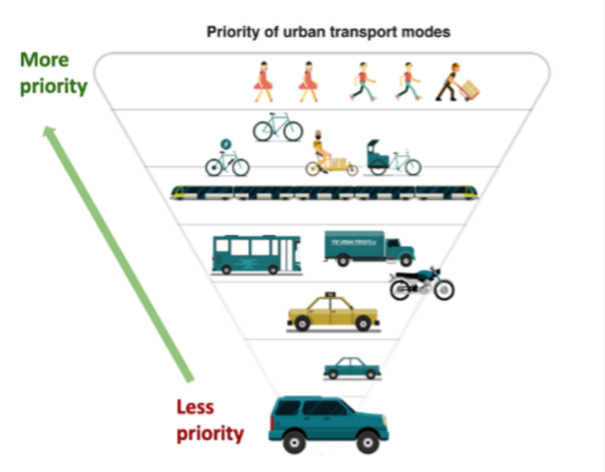


Figure 12. The pyramid of transportation visualizing the prioritization of modes. Adapted from: NUMO.

Concrete infrastructure measures

Figure 13. A wider array of vehicle types requires a better understanding of infrastructure allocation and categorization (Budapest, Hungary).

Road infrastructure in cities all over the world has traditionally been designed primarily for large, motorized vehicles and for purposes of high-speed travel, and a shift in this paradigm is a pre-requisite for safe use of two- and three- wheelers. Better road and street designs should respond to a differentiated definition of two- and three- wheelers and actively include these vehicle types (OECD / ITF, 2020b).

More specifically, cities must determine how to allocate street space to certain vehicles, and whether they should be segregated or not. The lessons from cycle-inclusive planning are useful in helping determine this based on volume and speed of surrounding traffic and on the presence of large vehicles. Several design manuals provide details on the different typologies developed in the case of cycling-inclusive planning (Andersen et al., 2012; CROW, 2016; de Transporte de Colombia, 2016; for Transportation & Development Policy, 2011; NACTO, 2014, 2016, 2023).

Figure 14. An illustration of a mobility hub where several vehicles can be found and taken, stored or parked. Source: MovePGH.

When aiming for high transport capacity and safe mobility, the clustering of modes with similar speeds, sizes and safety features on dedicated spaces is desirable. One straightforward way to move forward is to assign one lane for two- and three- wheelers and to differentiate this lane from dedicated lanes for bicycles on major avenues, and to provide all secondary and minor streets with enough space for two- and three-wheelers to circulate at safe and homogenous speeds.

As the main backbone of sustainable transport systems, high-capacity public transport services should have priority in designated street space and designed to be accessed by two- and three- wheelers (e.g. via mobility hubs, see an illustrative image in Figure 14).

Context is very important in these decisions. A speed-controlled electric scooter riding along a segregated network of cycle lanes in the Netherlands finds itself in a very different context compared to a two-stroke motorcycle riding along a highway in Uganda. As such, the specific characteristics of a vehicle and those of the infrastructure it travels on must be well understood. This is not just because of the physical characteristics of the infrastructure or vehicle, but because of how these vehicles have been used and how that use is perceived by other road users in a specific geographic context . This has much to do with subjective perception of what is safe to do and what not, which again often is a learned condition mostly imposed by the context – for example the general condition of transport in a city. What would be considered safe in the Netherlands might therefore be very different from Uganda.

More specifically, vehicles that are slow, light and clean, i.e. micro-mobility should be allowed to circulate along infrastructure that has commonly been dedicated for cycling (ideally, wide cycle lanes that are segregated from larger and faster vehicles or lanes that are integrated into low speed neighbourhoods).

Conversely, vehicles that are fast, heavy and/or “dirty” should only be allowed on lanes for motorized mixed traffic. This is because the speed, weight and tailpipe emissions of vehicles must be consistent with the infrastructure in which they’re allowed to travel. While the connection between infrastructure and emissions may not be directly evident, polluting vehicles should not be allowed on infrastructure where people are exercising physical activity, for example riding a pedal-powered (or electric-assist) bicycle, as immediate air pollution can generate considerable harm in terms of respiratory diseases (Adamiec et al., 123 C.E.; Apparicio et al., 2021; Tainio et al., 2016).

While the decision to prohibit ICE propelled vehicles irrespective their speed and size from riding along sidewalks and bicycle lane is straight-forward, the inverse is not. Can moderately fast electric propelled or assisted vehicle travel safely in a high-speed highway? In some countries, e-kick scooters are allowed on cycle lanes; in others, e-kick scooters are allowed on all infrastructure and in a few countries, e-kick scooters are restricted to use the sidewalk. Decisions of that nature should be carefully weighed out, in terms of:

- Are these vehicles homologated and/or is their manufacture standardized by a professional body? If so, it will be easier to define where they are allowed (given that homologation gives greater clarity with regards to specific design and performance details);

• Can conditions be established for their safe riding on streets? Segregation between modes or traffic calming devices could help in reducing safety risks;

• What risk is imposed to other users of the same infrastructure? If riding a vehicle puts drivers, riders and other road users in considerable danger, they should not be allowed without safety and design precautions;

• What are the environmental externalities associated to the vehicle, including its manufacture, use and disposal? If there are considerable negative impacts, circulation should be restricted or allowed only in certain areas (e.g. major avenues and not in all neighbourhood streets) to encourage alternative modes of transport.

Several studies have analysed ways to allocate street space given the recent “micromobility explosion”(International Transport Forum, 2022). A simplified four-level categorization in which infrastructure can be allocated to two- and three- wheelers is provided by the following:

• Integration with large motorized vehicles: this is the general state of mixed road traffic, where two- and three- wheelers circulate along with cars, buses and trucks. This situation puts two- and three-wheelers in disadvantage because of size and level of protection, especially those with lower power as the difference in speed with other vehicles increases their risk exposure. This “integration” category is useful because it is simple and straightforward, but only safe for vehicles of similar speed and volume.

• Segregation from others (large motorized vehicles, cyclists, and pedestrians): this is a case seldom applied, where “motorbike lanes” are assigned along highways or corridors of high risk for these vehicles. There is significant debate as to the usefulness of this type of segregation, but research has shown that it can be increase safety in corridors where trips are long and vehicles don’t enter or exit the corridor too often (Ribeiro, 2023; World Health Organization, 2022).

• Integration with non motorized vehicles: this refers to allowing circulation of certain types of powered two- and three-wheelers on infrastructure that is designed specifically for non-motorized two- and three- wheelers. Design of this type of infrastructure and its conditions of design and use are well documented (CROW, 2016; for Transportation & Development Policy, 2011; NACTO, 2016), and low-powered, electric-assist, speed-controlled two- and three-wheelers can be integrated safely in these. This solution is very helpful for smaller vehicles that are also traveling at much lower speeds than motorized traffic, but there are some cases where segregation can become an obstacle when improperly implemented (e.g. in smaller streets where crossing and entering and leaving locations is frequent).

- Integration with pedestrians: It is not recommended to have large, heavy, polluting or fast vehicles in the same space as pedestrians. Only small, light, clean (electric) and slow (speed controlled) vehicles should be allowed to share spaces with pedestrians. In these case sidewalks should be widened and have signs warning about the presence of different users.

Table 4 presents guidance according to this categorization of space allocation.

<table>
<tr><th>Vehicle / use case example</th><th>Integration with large motorized vehicles</th><th>Segregation from others (e.g. motorcycle lane)</th><th>Integration with non motorized two- and three-wheeler</th><th>Integration with pedestrians</th></tr>
<tr><td>ICE Motorcycle</td><td rowspan="9">Allowed</td><td rowspan="10">Encouraged to use lanes with these characteristics when available</td><td rowspan="10">Not allowed</td><td rowspan="10">Not allowed</td></tr>
<tr><td>ICE scooter</td></tr>
<tr><td>ICE Moped</td></tr>
<tr><td>ICE Tricycle</td></tr>
<tr><td>ICE Cargo tricycle</td></tr>
<tr><td>E-motorcycle</td></tr>
<tr><td>E-moped</td></tr>
<tr><td>E-scooter</td></tr>
<tr><td>E- Tricycle</td></tr>
<tr><td>Power E-bike</td><td rowspan="2">Allowed, with significant risk</td></tr>
<tr><td>E-cargo bike</td><td rowspan="3">Allowed to use lanes with these characteristics</td><td rowspan="2">Allowed to use, with care for others</td><td rowspan="3">Allowed under special circumstances (short end-of-trip segments)</td></tr>
<tr><td>E-bicycle</td><td rowspan="2">Allowed, with significant risk; Encouraged to use other</td></tr>
<tr><td>e- kick scooter</td><td>Encouraged to use</td></tr>
</table>

Parking management

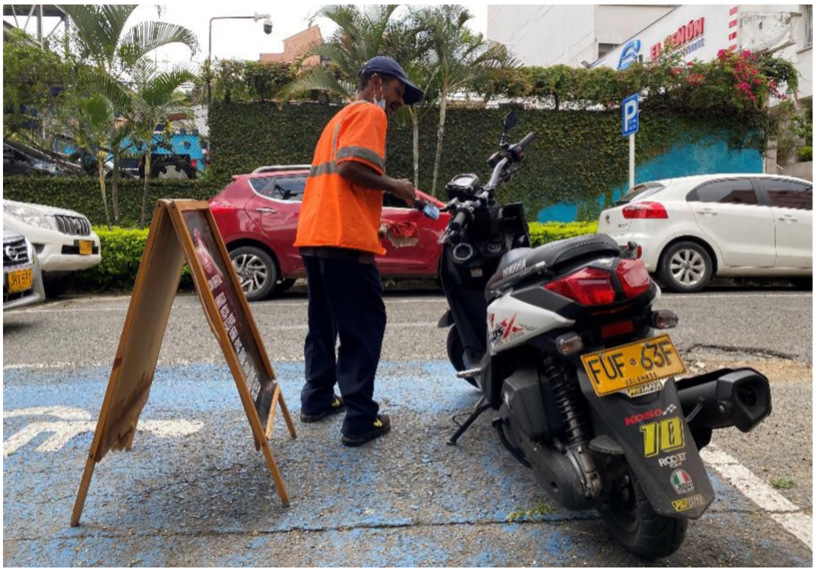


Figure 15. often parking practices do not make good use of existing parking spaces (Cali, Colombia).

Integrating engine propelled two and three- wheelers explicitly in parking policies is important. Historically, parking policies have been designed for use by four- wheeled motorized vehicles (Barter, 2011; Despacio & ITDP, 2013). In many cities around the world this leaves ambiguity resulting in often chaotic results when it comes to the parking of two and three-wheelers. A parking policy integrating two- and three- wheelers should :

- Indicate the proportion of space between parking for automobiles and two- or three- wheelers based on the modal share of those modes. For instance, a city where 10% of trips are made by cars and 5% by motorcycles (and urban mobility plans indicate that this modal share should be preserved), parking policies could require one parking space for motorcycles for every two spaces for cars;

- Provide specifications on the design of parking spaces for two- and three-wheelers. Typically, three motorcycles fit in the space of one car. For three wheelers, a detailed review of dimensions should be carried out to determine parking space allocation;

- Develop a pricing scheme for two- and three-wheeler parking. An initial indication of price would result from the space occupied by each vehicle, which follows the design parameters described above (for instance: if parking a car costs 3 USD per hour, parking one scooter would cost 1 USD per hour as it occupies one third of the space). In addition, the parking price could be adjusted based on policy priorities given to electric two- and three-wheelers. This would mean that higher prices should be charged for vehicles that are not desired on the road and lower prices for electric vehicles.

• Integrate parking in the design of holistic "mobility hub" solutions. Mobility hubs are areas where several transport services (and other key urban functions) are provided, incentivizing mode integration and efficient travel (Anderson et al., 2017; Assmann et al., 2020; Bell, 2019; DHL, 2017). Two- and three-wheelers should be integrated explicitly (see for instance Figure 14).

• Make use of charging infrastructure provision to guide parking of electric two and three-wheelers. Urban spaces reserved for the parking of two and three-wheelers should have a portion of parking lots reserved for charging these vehicles. This serves as an incentive to park and charge respective vehicles in designated areas.

• At stations, build secure parking locations where users can store their vehicle and helmet with adequate weather protection. If this service is provided for overnight storage, lockers are an option that reduces the probability of theft.

• Communicate with two- and three- wheeler drivers about the existence of these facilities and benefits of integration, focusing on the areas where integration will increase (geographic) catchment areas. This means, for instance, engaging two- and three- wheeler drivers at crossings in the vicinity of public transport stations to describe the options for integration and the benefits for them using these.

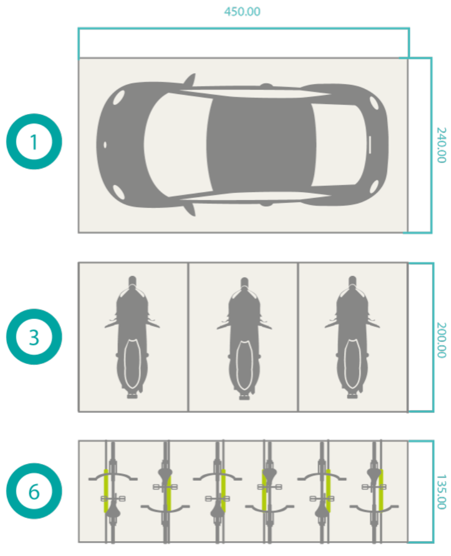


Figure 16. Example of space occupied by cars, motorcycles and (e) bicycles. Source: Despacio.org

Integration with public transport

Figure 17. e-kick scooters are integrated into mass transit (Bogotá, Colombia).

While integration with public transport has been addressed in detail in bicycle literature ((Association of Pedestrian and Bicycle Professionals, n.d.; Celis & Bolling-Ladegaard, 2008; Pardo et al., 2013; Pardo & Calderon, 2014; The American Public Transportation Association, 2018)), the topic needs to be expanded to include motorized two- and three-wheelers integration.

Public transportation and last mile connectivity should be integrated with the principal objective to widen public transport catchment areas to increase accessibility and dis-incentivize the use of individually owned mobility such as cars. For example, without integration catchment areas for public mass transport systems are as small as 300-500m, while proper integration through last mile connectivity by engine propelled two and three-wheelers can increase access to three kilometers or more (Moreno & Miralles-Guasch, 2017; Pardo et al., 2013; Pardo & Calderon, 2014; UTRECHT & co-operation office, 2004).

The role of motorized two and three-wheelers needs to be clearly defined in overall urban mobility plans. Areas and corridors of the city should be designated for certain modes, including two and three-wheelers. The following are specific recommendations:

- Identify suitable public transport stations for integration of designated waiting areas (also called "stages") for two and three-wheeler taxis and include charging infrastructure for EVs. Taxi drivers should be encouraged to wait for clients at designated and strategically developed places. The siting of such places would need to be determined with regards to other public transport modes, intermodality and last mile connectivity. For example, overcrowded stations will be relieved when a nearby station has integration and two and three wheelers take up some of its demand. In general, stations where people live ("origin stations") are more suitable given that these stations are farther from the city center than "destination stations" which are in denser areas and therefore have a shorter last mile trip.

- Integrate means of non-motorized transport within these stations. The areas where a public mass transport station effectively provides a service (called "Catchment areas") will be enlarged if multiple options of last-mile connectivity services are offered. Effectively increasing the coverage of the overall system can include integration with bike share systems, as well as parking facilities for individually used and owned bicycles.

- Define clear pricing policies for integration. While the benefits of mode integration can be significant, it is recommended to establish a fee for waiting / parking engine propelled or engine assisted two- and three- wheelers as it has a cost to society (Barter, 2011; Shoup, 1997). Alternatively, fare validation could be implemented at station entrances to avoid those who will not continue their journey on public transport leaving their individually owned two-wheelers at the station. The main purpose of integration is not to provide parking for anyone but to increase the viability of trip-chaining and making those trips more comfortable. EVs could be exempted from such a cost initially, to incentivize their uptake.

Figure 18. In some cases, motorcycle taxis are preferred over bus-based public transport (Bangkok, Thailand).

Conversely, protecting the role of public transport is also crucial to avoid cannibalization of these services in areas where public transport can be more effective and efficient. This is typically the case in dense urban cores and corridors that connect urban centers of high activity. Achieving this would require:

• Restricting the times and areas of circulation for motorized two- and three-wheelers used for public transport services – Commercially used two and three-wheelers chould be banned from certain areas and corridors where public transport provides a more efficient service overall and only allow them during times when and in places where public transport operation is low frequency or scarce coverage. This way utilization of more efficient mass transit modes is because economically viable.

• Increasing the efficiency of public transport by providing dedicated lanes, improved service frequency and overall quality of these services, as well described in other documents focused on that specific topic (Meakin, 2004);

• Data collection on the efficiency of public transport, how it can be improved, and what role two- and three-wheelers can play as a complementary mode. While public transport is a crucial transport mode in a city and the backbone of an urban transport system, monitoring its operation will ensure that it provides the adequate level of frequency and quality, which can avoid passengers leaving for other modes.

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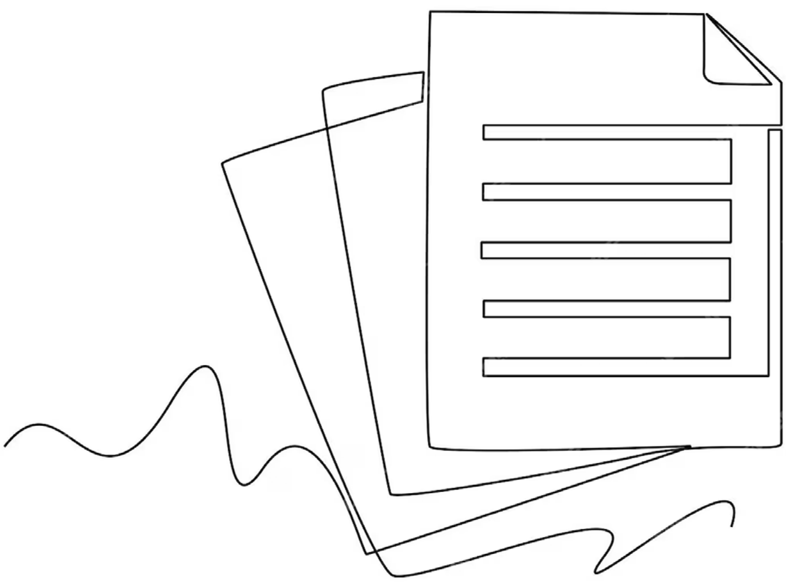

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