BACKGROUND PAPER

# The Contours of a Net Zero Emission Transport Sector in Asia

Sudhir Gota and Cornie Huizenga

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# THE CONTOURS OF A NET ZERO EMISSION TRANSPORT SECTOR IN ASIA

**Background Paper**

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Abstract

In Asia, many countries are committing to net zero emission targets. However, the decarbonization of the transport sector in Asia needs to take place in a growing transport sector with more transport infrastructure and passenger and freight activity. However, there is still a lack of a common understanding of the implications of the net zero transition in the transport sector in Asia. This paper identifies the broad contours, key insights, and characteristics of the zero-emissions transport sector and the consequences for transport policy, planning, and investments. We conclude that the transport sector decarbonization in Asia will require a systemic transformation. The route to net-zero emissions in Asia involves reducing transport demand, ensuring a shift toward the most efficient travel modes, and simultaneously decarbonising vehicles and fuels. The review identifies several headwinds and tailwinds in this transition.

**Keywords**

Net-zero emissions, transport, avoid, shift, improve, electric vehicles, fuel economy, public transport, fuel subsidy, decarbonization

**CONTENTS**

# ABBREVIATIONS

| | | |
|---|---|---|
| ADB | – | Asian Development Bank |
| ATO | – | Asian Transport Outlook |
| BRT | – | bus rapid transit |
| $CO_2$ | – | carbon dioxide |
| Gt | – | gigaton |
| IPCC | – | Intergovernmental Panel on Climate Change |
| ITF | – | International Transport Forum |
| km | – | kilometer |
| LDV | – | light duty vehicle |
| LTS | – | long-term emissions reduction strategy |
| MDB | – | multilateral development bank |
| NDC | – | Nationally Determined Contributions |
| OECD | – | Organisation for Economic Co-operation and Development |
| PRC | – | People's Republic of China |
| SAF | – | sustainable aviation fuel |
| SDG | – | Sustainable Development Goals |
| UNEP | – | United Nations Environment Programme |
| UNFCCC | – | United Nations Framework Convention on Climate Change |

# I. INTRODUCTION

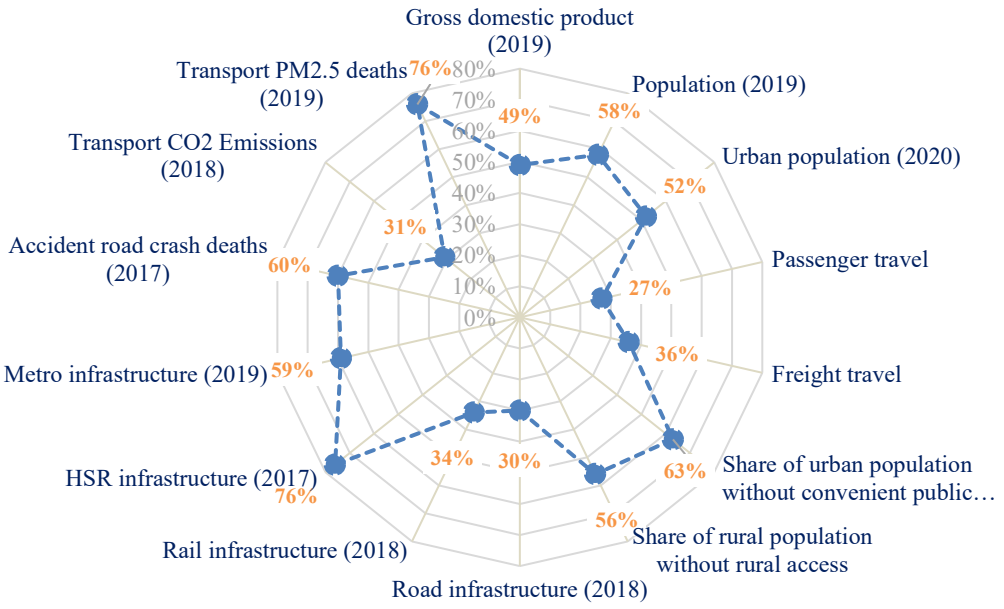
Following the adoption of the Paris Agreement in 2015, we are now seeing that a growing number of countries are committing to net zero emission targets. In Asia, about half of the countries have now announced a commitment to net zero emissions (ADB 2022). While these net zero emission targets vary in terms of time frame, 2050 is a common year for many of the net zero targets released till now. The net zero emission targets are formulated on an economy-wide basis; for them to become reality, such targets need to be implemented on a sectoral basis. Out of the about half countries in Asia that have set a net zero emission target, the number that have set some form of quantified transport-related carbon dioxide ($CO_2$) emissions reduction target or pathway is much smaller (Australia, Bhutan, Cambodia, the People's Republic of China (PRC), Fiji, Japan, the Lao People's Democratic Republic, the Marshall Islands, Thailand, and Viet Nam).

In 2018, the transport sector was responsible for 13% of total direct $CO_2$ emissions from fuel combustion in the Asian economies. Overall, $CO_2$ emissions from transport in Asia increased 3.9% annually, double the rate of the global transport emissions increase (1.9%). Transport sector emissions in Asia have grown faster in the last decade than in any other sector globally. Moreover, within the transport sector, transport $CO_2$ emissions have been growing more quickly in Asia than anywhere else in the world. Historically, the global narrative on transport sector decarbonization has two ostensibly contradictory messages. First, the transport sector is difficult to decarbonize because of rapid mobility growth (UNEP(b) 2014) (ITF(b) 2017) (IPCC 2007) (IPCC(b) 2014) (Gota n.d.). The other perspective is that rapid decarbonization is inevitable, and the transport sector has ample potential to decarbonize with existing and emerging technologies (IEA 2019).

As countries adopt more ambitious economy -ide emission targets, including net zero emission targets, there is increasingly less opportunity for picking winners among sectors as

all sectors would need to participate to realize such targets. This means that realizing a net zero economy-wide target will not be possible without the almost complete decarbonization of the transport sector. However, currently, there is still a lack of a common understanding of the policies and strategies that could lead to net zero in the transport sector in Asia.

**Figure 1: Transport Sector in Asia and the Pacific in Relative Share of Global Transport Sector**




$CO_2$ = carbon dioxide, HSR = high-speed rail, $PM_{2.5}$ = fine particulate matter.
Source: Asian Development Bank. 2022. *Asian Transport Outlook 2022*. Manila.

The decarbonization of the transport sector in Asia will be taking place in quite a different context than in the global north. Asia in 2019 had about half of the global population and it contributed also about half of the global domestic product, but it only had about one third of the global road supply and heavy rail infrastructure and about one third of transport demand in passenger and freight activity. Because of this, Asia still falls short of two key access related targets set out in the Sustainable Development Goals (SDGs). About 560 million rural residents, about 25% of Asia's rural population, still do not have all-season access to road

networks (SDG 9.1). 1.37 billion urban residents, 75%, in Asia lack efficient access to urban public transit (SDG 11.2). Further growth of the transport sector (in terms of infrastructure and transport activity) to enable economic development and poverty alleviation is a priority for all Asian governments.

This means that the decarbonization of the transport sector in Asia needs to take place in a growing transport sector with more transport infrastructure and passenger and freight activity. This is an additional challenge but also creates opportunities. Much of the needed transport infrastructure does not yet exist, and a large part of the vehicle fleet has not been manufactured and sold yet. This offers opportunities for policy makers in Asia and the Pacific to avoid some of the mistakes made by policy makers in the global north in the development of their transport sector which resulted in many cases in a car-dependent transport system with a large carbon footprint. Instead, policymakers in Asia can opt for policies that stimulate the construction of low-carbon transport infrastructure and vehicles.

The current scientific literature suggests that the abatement costs, technology maturity, political preferences, institutional, infrastructure and market conditions for subsectors, modes, and regions will influence decarbonization pathways. The transition toward net zero emissions is expected to create winners and losers among modes, energy systems, and stakeholders. A one-size-fits-all net zero pathway does not exist for the transport sector, and a significant degree of variance will occur in Paris Agreement-compliant transport decarbonization pathways.

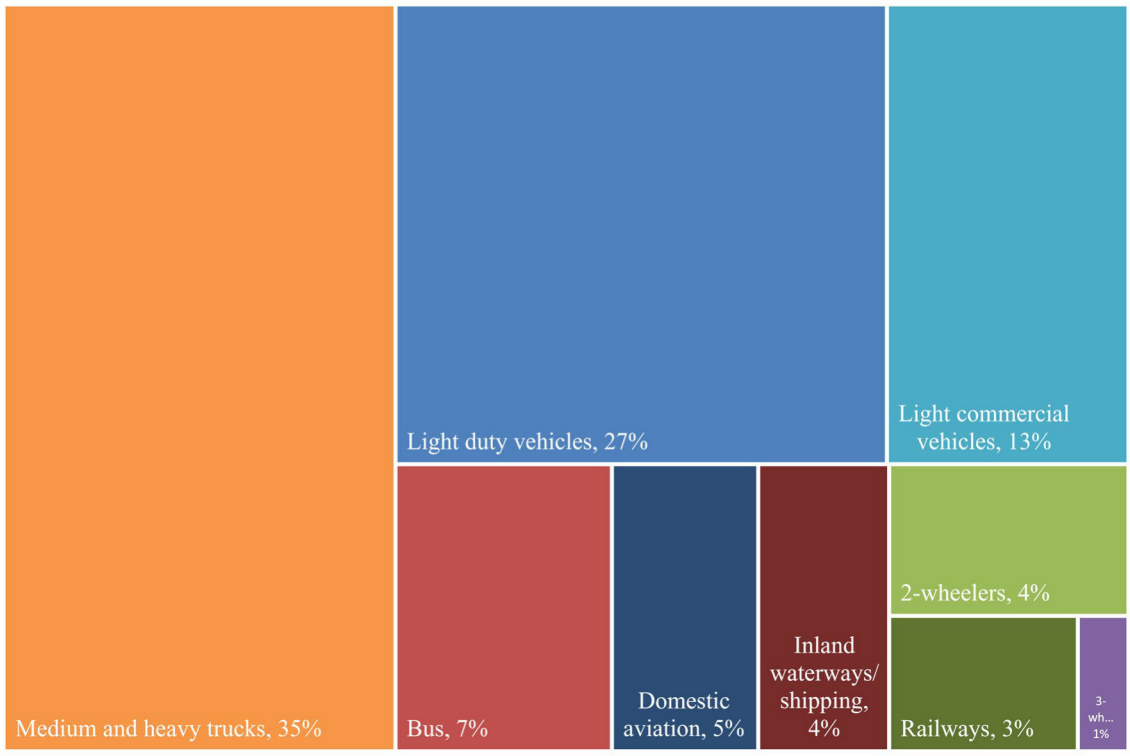
This paper does not aim to provide an exhaustive overview and analysis of decarbonization options and also does not provide a comprehensive pathway to reaching net zero emissions in the transport sector. Instead, we summarize the broad contours, key insights, and characteristics of the zero-emissions transport sector and the consequences and implications for transport policy, planning, and investments.

## II. TRANSPORT CARBON DIOXIDE EMISSIONS IN ASIA

### A. Historic Pattern

In 2018, the Asian transport sector accounted for nearly 8% of global energy sector $CO_2$ emissions or 2.6 gigatons (Gt) (IEA(b) 2020). Measured on a more comprehensive well-to-wheel basis, transport in Asia emitted about 2.9 Gt $CO_2$. Most transport carbon emissions in Asia are from the road sector, constituting about 89% of transport carbon emissions. Among subsectors, the freight transport share in total domestic transport sector $CO_2$ emissions was 56%, while the passenger segment share was close to 44% (Figure 2). Among regions, East Asia contributed about half of the transport $CO_2$ emissions in Asia. The second biggest contributor is Southeast Asia, with about 22% of emissions.

**Figure 2: Breakdown of Transport Carbon Dioxide Emissions in Asia, 2018**

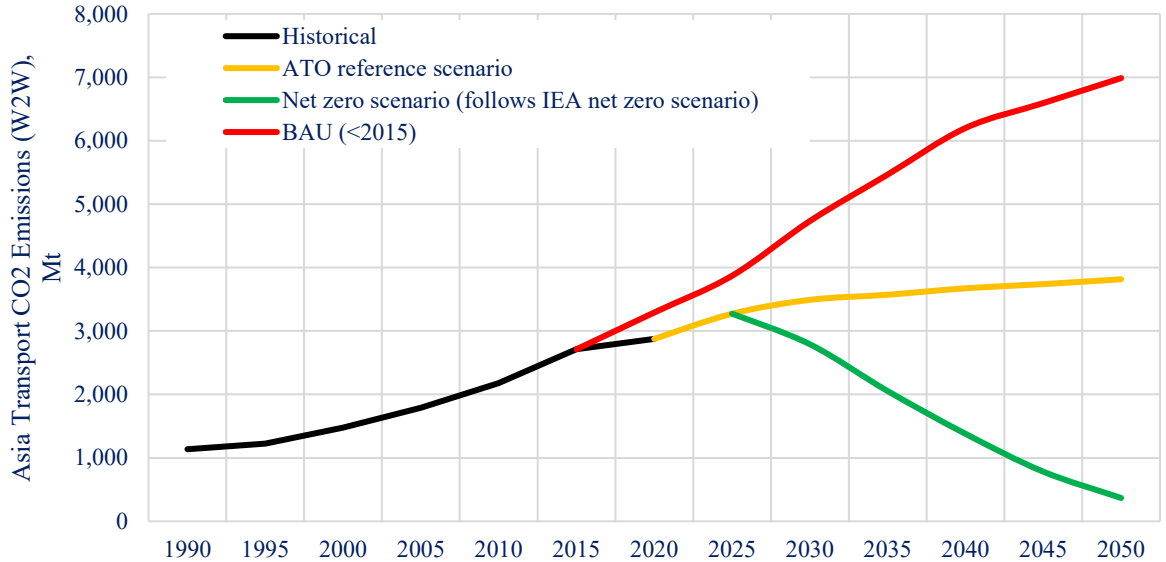



Source: Asian Development Bank., 2022. Asian Transport Outlook 2022. Manila

## B. Reference Scenario versus Net Zero

Until recently, it was believed that unrestrained growth in mobility could lead to transport $CO_2$ emissions in Asia increasing from about 2.9 Gt to about 7 Gt in 2050. This would make the transport sector in Asia a significant roadblock to the successful implementation of the Paris Agreement and the realization of economy wide net zero targets. Following the adoption of the Paris Agreement in 2015, we see a change in transport emission trendlines and a new scenario is emerging. Based on a combination of currently stated policy action and technological development, the Asian Transport Outlook (ATO) now considers a reference scenario of just below 4 Gt by 2050 for Asia. While this is an improvement over earlier scenarios, this still falls well short of what is considered necessary to be compliant with the objective of the Paris Agreement to keep temperature increases to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels. The current consensus is that, with such a target, transport $CO_2$ emission by 2050 would need to be somewhere between 0.3 Gt and 1.0 Gt (IEA 2019) (EU 2021).

**Figure 3: Transport Carbon Dioxide Historical Trends and Emission Scenarios Asia**



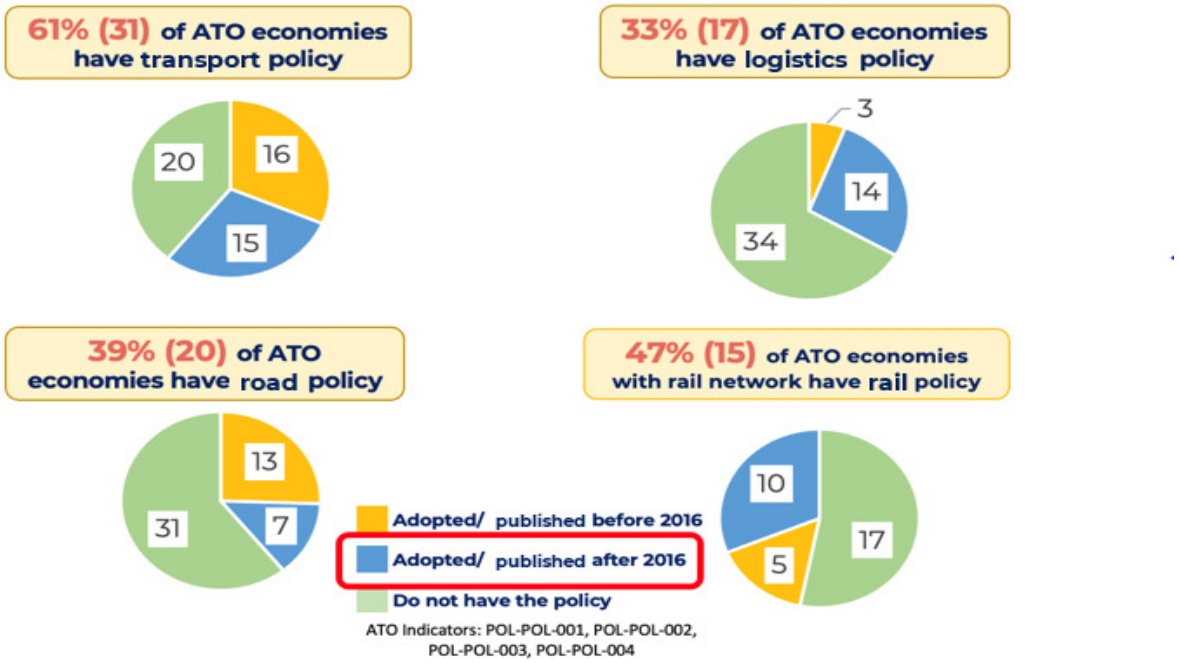

ATO = Asian Transport Outlook, BAU = business-as-usual, $CO_2$ = carbon dioxide, IEA = International Energy, Agency, Mt = megaton, W2W = well-to-wheel.
Source: Asian Development Bank. 2022. *Asian Transport Outlook 2022*. Manila.

## III. EXISTING POLICIES ON TRANSPORT AND CLIMATE CHANGE

### A. The Transport Policy Landscape in Asia is Underdeveloped

Overall, the transport policy landscape in Asia is not well developed (Figure 4). While 61% of the ATO economies have a national transport policy, the scores are much lower for logistics, road, or rail policies. Further, it is important to consider when the policies that are in place were developed. The Paris Agreement on Climate Change was adopted in 2015, as were the SDGs. It is not likely that different types of policies adopted before 2016 are aligned with the objectives of the Paris Agreement on Climate Change or the SDGs which were both agreed on in 2015.

**Figure 4: Transport Policy Landscape in Asia**



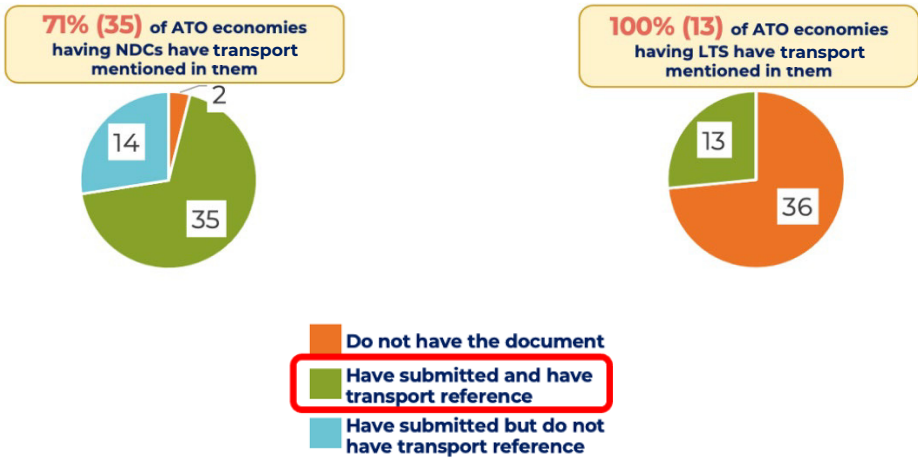

ATO = Asian Transport Outlook.
Source(s): Asian Development Bank., 2022. Asian Transport Outlook 2022. Manila

### B. Transport as Part of the Long-Term Emissions Reduction Strategies and Nationally Determined Contributions

A popular way to assess national climate ambitions and climate ambition in the transport sector is to assess the long-term emissions reduction strategies (LTS) and the Nationally Determined

Contributions (NDCs) submitted to the United Nations Framework Convention on Climate Change (UNFCCC). Not all countries have submitted an LTS to the UNFCCC but, out of the 13 countries that do have an LTS, all include measures on the transport sector. In the case of NDCs, we see that practically all countries in Asia and the Pacific have submitted a NDC and 71% have transport mentioned (Figure 5).

**Figure 5: Transport References in Long-Term Emissions Reduction Strategies and Nationally Determined Contributions**




ATO = Asian Transport Outlook, LTS = long-term emissions reduction strategy, NDC = Nationally Determined Contribution.
Source: Asian Development Bank., 2022. Asian Transport Outlook 2022. Manila

Further analysis of the NDCs indicates that only a very small number of LTS and NDC include quantified emissions reduction targets (10 %) (Bangladesh, Fiji, Georgia, Japan, and the Lao People's Democratic Republic) and, in most cases, references to transport do not consist of specific transport policy objectives, but instead are limited to mostly qualitative ambition statements on, e.g., the introduction of electric mobility, scaling up of public transport, or the use of low carbon fuels (ADB 2022) (GIZ n.d.). All in all, the majority of references to the transport sector are general in nature and certainly do not constitute a pathway to a net zero transport sector.

In recent years we are starting to see better linkages between the transport policy framework and the ambition on transport expressed in the LTS and the NDC. Examples of this are:

(i) Indonesia's biofuel targets are found across different policies.

(ii) Singapore's mode shift/access targets and internal combustion engine.

(iii) Phase out is also consistent across various types of policy documents.

(iv) Thailand's LTS reiterates the sectoral NDC action plans released a year earlier.

(v) Viet Nam released this year "Action Program for Transition to Transition to green energy and mitigation of carbon dioxide and methane emissions from transportation" that aligns with NDC and LTS.

(vi) Malaysia has adopted the "Low Carbon Mobility Blueprint 2021-2030".

(vii) In Nepal, climate ambition for the transport sector is included in 'National Sustainable Transport Strategy (NSTS) for Nepal (2015–2040) (2015)" and "The 'National Action Plan for Electric Mobility" gives an overview of all the policies in terms of electric vehicle.

(viii) The PRC's LTS calls for the development of a low-carbon transport system. Targets on new energy and clean energy-powered vehicles as well as transport energy consumption are in line with the 14th Five Year Transport Plan.

## IV. THE AVOID–SHIFT–IMPROVE APPROACH TO TRANSITION TOWARDS A NET ZERO TRANSPORT SECTOR IN ASIA AND THE PACIFIC

For the transport sector in Asia to contribute towards a net zero economy, it needs to develop a credible pathway that can guide all transport stakeholders in their efforts towards decarbonization of the transport sector. A helpful conceptual approach to structure the wide range of transport decarbonization policies and strategies is the Avoid–Shift–Improve approach. This combines three strategies: (i) rapid and significant reductions in demand (Avoid), (ii) the shift in travel from high carbon to low and zero carbon modes (Shift), and (iii) the wide-scale adoption of technologies to decarbonize fuel and vehicles (Improve). Usually, the specific Avoid–Shift–Improve measures are supported by a combination of crosscutting measures, which often include planning, institutional development and capacity-building measures. A wide range of Paris Agreement-compatible transport sector pathways (UN n.d.) (Gota, Huizenga, et al. 2018) refer to the Avoid–Shift–Improve approach.

Overall, there is considerable optimism concerning the mitigation potential of especially the Improve option to decarbonize the transport sector and significant pessimism regarding the potential impact of the Avoid and Shift options. For example, the IEA's 2015 Energy Technology Perspectives shows that policies on Avoid and Shift will only reduce global transport energy consumption and emissions by 15% or more by the middle of this century in a stringent mitigation case (IEA(c) 2015).

**Illustrative Overview of Avoid–Shift–Improve Related Interventions**

| Avoid | Shift | Improve | |
|---|---|---|---|
| Land use policy - mixed, compact | Bus rapid transit | Vehicle fuel efficiency standards | Electric vehicle purchase incentives |
| Cycling measures | Metro | Feebate | Electrification fleet/railways |
| Walking measures | Light rail transit | Efficiency labels | Internal combustion engine (gasoline and diesel) bans |
| Low-emission zones | Heavy railways | Aerodynamic technology | Smart charging policies |

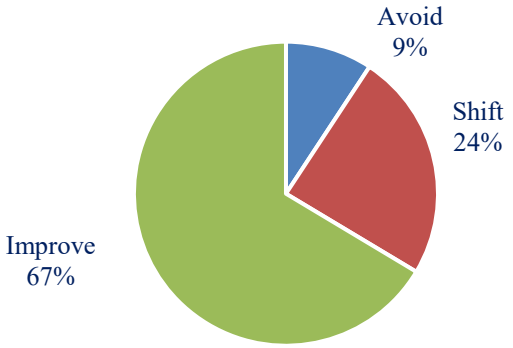
| Avoid | Shift | Improve | |
|---|---|---|---|
| Car/truck access restriction zones | High-speed railways | Tires Packages | Biofuels/ethanol |
| Congestion charging | Inland waterways | Telematics | Hydrogen |
| Fossil fuel subsidy elimination | Port infrastructure improvements | Lower-weight vehicles | Liquefied petroleum gas/compressed natural gas/liquefied natural gas |
| Carbon tax | Bus improvement | Route planning/optimization | Intelligent transport systems |
| Fuel tax | Express lanes/public transport priority | Ship efficiency improvements | Autonomous vehicles |
| Parking pricing | Intermodality measures | Green public procurement | Fuel quality improvements |
| Road charging and tolls | Shared mobility | Low-emission vehicle purchase incentives | Vehicle air pollution emission standards |
| Vehicle taxes | Mobility as a service | Eco-driving | Inspection and maintenance |
| Teleworking | Rural mobility as a service | Airport carbon dioxide certification | Vehicle restrictions (import, age, access, sale, taxation) |
| Alternative work schedules | Micro mobility | Port carbon dioxide certification | Vehicle/vessel scrappage scheme |
| Urban consolidation centers | Public transport information | Support on-shore power and electric-charging facilities in ports | Speed restrictions |
| Freight: asset sharing and digital platform | Public transport subsidies | Electric vehicle-charging infrastructure | Green infrastructure |
| Digitalization | Park and ride facilities | Electric vehicle readiness requirements for buildings | Traffic management |
| High-capacity vehicles | Environmental capacity constraints on airports | | Asset management |
| Improving load factors | | | |
| Packaging solutions | | | |
| Dematerialization | | | |
| **Crosscutting** | | | |
| Sustainable transport capacity building | | | |
| Data and modelling improvements | | | |
| General education and campaigns | | | |
| National mobility plans | | | |
| Sustainable urban mobility plans | | | |

| Avoid | Shift | Improve |
|---|---|---|
| Sustainable finance regulations | | |

Source: Authors

The dominance of Improve options also shows clearly in the LTSs and especially the NDCs submitted by the countries that are parties to the UNFCCC (Figure 6). Apart from a dominance of Improve-related mitigation measures, there is also far more coverage of passenger transport-related measures than freight transport-related measures in these documents.

**Figure 6: Typology of Climate Change Mitigation Measures in the Transport Sector in Latest Long-Term Emissions Reduction Strategies and Nationally Determines Contributions Submitted by Asian Parties to the United Nations Framework Convention on Climate Change.**




Source: Asian Development Bank. 2022. Asian Transport Outlook 2022. Manila.

## A. "Avoid" Strategies in Net Zero Pathways

Avoiding future $CO_2$ emissions in the transport sector is clearly a preferable option. To makes this happen it important to influence the future demand for passenger and freight transport. The International Transport Forum (ITF) in 2021 developed its most ambitious policy scenario until now. The ensuing Reshape+ scenario would enable the world to reach climate change mitigation goals faster and with more certainty, while supporting simultaneously the implementation of the SDGs. However, this most ambitious policy scenario would only result

in 2050 reductions of 13% and 19% in passenger and freight activity in the Asia and Pacific region compared to the recover scenario (reference scenario) (Figure 7).

**Figure 7: Potential Reductions in Passenger and Freight Demand in the Asia and Pacific Region under the International Transport Forum Recover and Reshape+ Scenario**


Source: International Transport Forum 2021. ITF Transport Outlook 2021. Paris

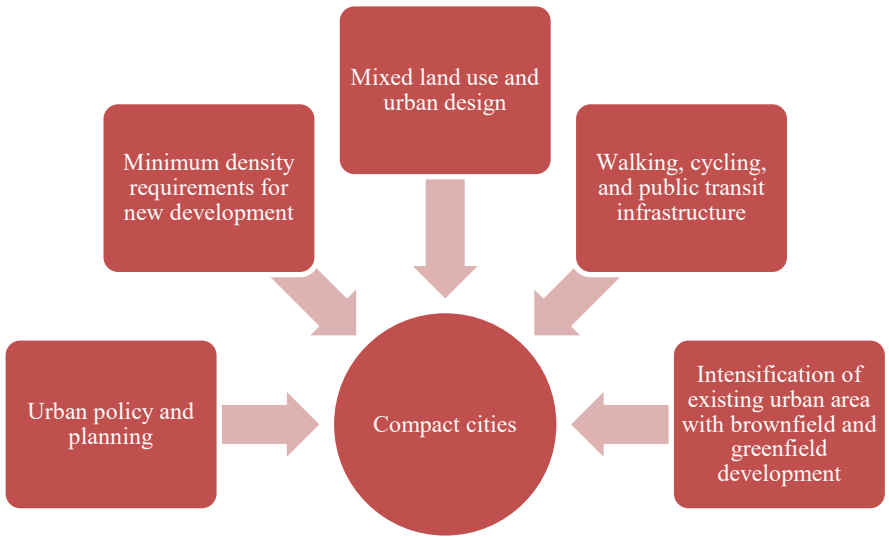
Avoid-oriented mitigation measures have, in common, required considerable political will as they directly aim to influence and reduce the amount of both passenger and freight activity but especially passenger transport. Many of the examples of Avoid-oriented mitigation measures mentioned in the table on page 8 depend on enabling policies and regulations. If such

policies and regulations are indeed politically feasible, they can be implemented relatively quickly. An added advantage is that Avoid-oriented measures generally do not require significant investments and, in some cases, like a carbon tax or other user charges actually generate income that can be used to fund other decarbonization measures in the transport sector. Also, if the Avoid-related measures are implemented at scale, the need for road transport infrastructure will be substantially lower, which will result in considerable savings. Avoid-related mitigation measures have a moderate relevance for the transport-related SDG targets, apart from climate change mitigation. Generally, they do not contribute in any form to improving rural access, but have some relevance for improving urban access. They contribute to minimizing road fatalities and transport-related air pollution through a reduction in the amount of travel.

### 1. Compact Cities

Typically, Asian cities have been dense. However, as Asian cities become more affluent, the urban land area can expand faster than the population residing in cities. Such urban sprawl results in declining urban population densities over time. As densities diminish, the per-capita road infrastructure requirement increases, subsequently increasing the transport emissions. A dense city is likely to provide better access to transit when compared to a sprawling city with the same population and transit length. As part of a net zero transition, Asian cities will have to use multiple strategies to develop more compact cities which are active mobility and transit-oriented (Figure 8). The transition from car-dependent lifestyles to more active mobility-oriented will enhance health, reduce air pollution and traffic crash fatalities, and enhance liveability. Globally, literature suggests a reduction of about 52% in person-kilometres travelled by car and motorcycle relative to a low-density sprawl-oriented scenario (ITDP 2021). In the net zero world, the "15-minute city" concept may become popular based on residents' ability to meet most of their daily needs within a 15-minute (walk/cycle/public transport) trip from home. A compact city, with mixed land use and urban design also allows for the implementation of freight and logistics concepts that reduce urban freight-related kilometers.

**Figure 8: Multiple Strategies in Support of Compact Cities**




Source: Authors

### 2. Economic Instruments

Transport demand tends to increase when costs decrease and vice versa (ADB-GIZ 2015). A net zero transition in the transport sector will require countries and cities to implement measures, such as road pricing, congestion charges, tolls, and parking fees to reduce transport demand.

Congestion charging is currently applied globally in only 11 major cities (with a majority of these outside Asia), but has proven to reduce traffic volumes by up to 27% (IEA 2019). Experience from Singapore suggests that, for congestion charging to be successful, cities need to carry out significant reforms and expansion in vehicle and fuel taxation policies, parking charges, and substantial augmentations to public transit services (FHWA 2021). Without these complementary strategies, cities in Asia will fail to implement successful congestion charging schemes.

In many Asian economies, transport fuel prices continue to be subsidized, which artificially increases travel activity. In 2019, Asian countries spent nearly $34 billion to support fossil fuels in the transport sector, accounting for about 44% of the global transport sector fossil

fuel subsidy (ADB(b) 2021). Therefore, as part of a net zero transition, countries would need to carry out fossil fuel subsidy reform (IISD 2021) and enhance fossil fuel taxes to reduce transport demand and enhance revenues for the transport sector transition.

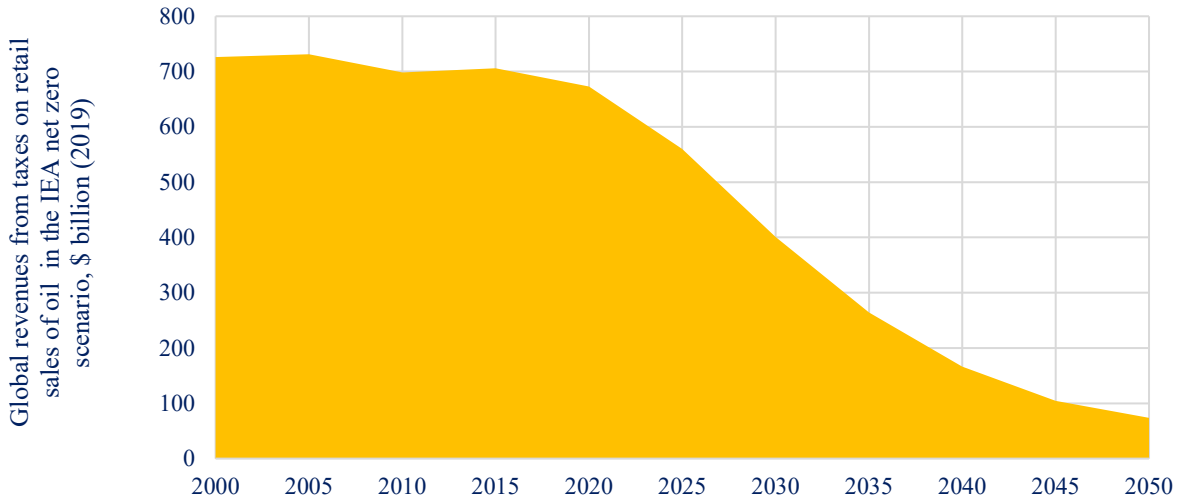
Experience from a wide range of countries has demonstrated the effectiveness of subsidies and financial incentives to speed up the transition to zero-emission vehicles.

The common thread in all sectoral net zero pathways, including the transport sector, is mandatory carbon pricing, especially in more challenging subsectors, such as aviation, shipping, and long-distance trucking. A high(er) carbon price will moderate transport demand, increase the shift to lower carbon modes, and raise the appeal of alternative low-carbon fuels. For example, a carbon tax on aviation may shift inter-city travel demand to high-speed rail, while a carbon tax on shipping may induce a reduction in supply chain lengths. However, carbon pricing may disproportionately affect low-income households and impact business competitiveness if not adequately designed and balanced (World Bank 2021). For example, increased carbon pricing on shipping may reduce maritime connectivity, trade flows, and income for small islands developing states and least-developed countries (LDCs) (UNCTAD 2021).

If economic instruments are part of a net zero pathway in the transport sector, such charges and taxes may result in imperfections in other transport policies. For example, a subsidized electric car with cheap electricity may have significant rebound effects in the form of higher vehicle activity, increasing other externalities such as road crashes or congestion. There are also potential fiscal implications, which can be considerable. For example, current excise duties on fossil fuels used in road transport in Asian countries, like in the rest of the world, represent a significant share of tax revenue. However, this revenue stream would erode because of the transition away from fossil fuels in case of a successful net zero scenario (Figure 9). In such a scenario, alternate new or enhanced revenue sources for the transport sector, such

as a road user charge or carbon tax at the national level complemented by congestion charging or parking fees at the urban level, may future-proof tax systems and provide revenue stability.

**Figure 9: Projected Global Revenues from Taxes on Retail Sales of Oil in the International Energy Agency Net Zero Emission**




IEA = International Energy Agency.
Source: International Energy Agency 2021, Net Zero by 2050, IEA, Paris

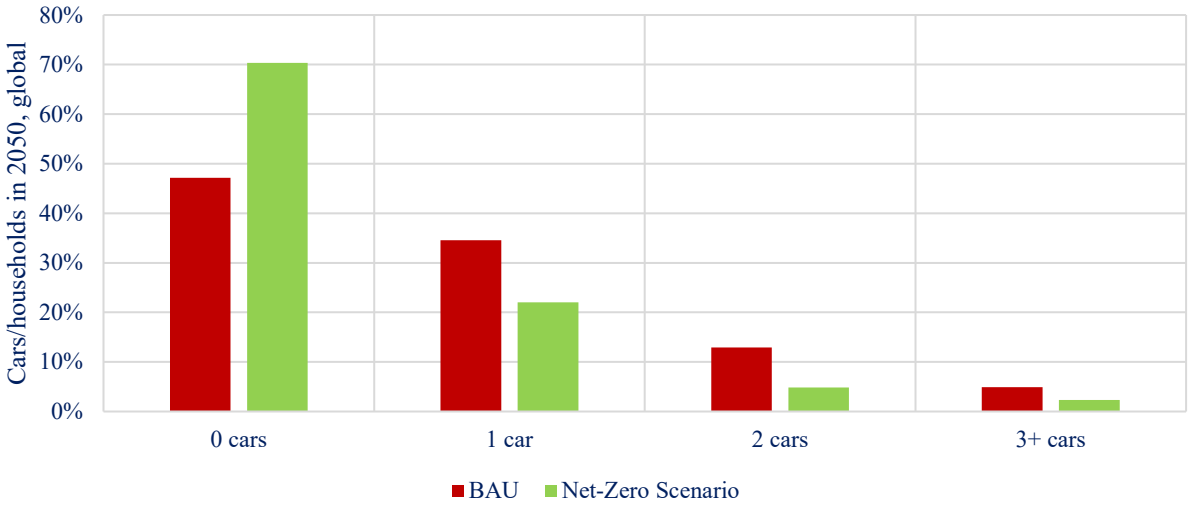
### 3. Reducing or Slowing Down Growth of Vehicle Ownership

Till now, not many countries in Asia have taken action to limit ownership of private car ownership. In the PRC, there are now 50 cities that, over the last decade, have put quotas in place for the registration of new private vehicles (Quan, Y., Xie, L 2022). In most of these cities, the registration of zero emission vehicles is made relatively easier. In most PRC cities, there has been already a ban on internal combustion powered motorcycles also. This has helped to make the PRC leading in the sales of electric 2-wheelers and 3-wheelers. Viet Nam is now replicating this strategy in some of its major cities. Singapore, which has had a quota for the registration of new private vehicles for several decades, has a zero-growth rate target for cars and motorcycles and a 0.25% annual growth rate for commercial vehicles until January 2025 (Ong 2021).

In 2000, Asia had 85 vehicles per thousand population. By 2020, Asia had 278 vehicles per thousand population. Every second vehicle in Asia is a 2-wheeler or 3-wheeler. Asia is

expected to continue to motorize, albeit at a slower pace. At the same time, it is important to note that motorization in the majority of Asian countries is not following the historical high motorization trends of the high-income economies (ADB(c) 2022). Considering the still relatively low automobile ownership rates in developing Asia and the political sensitivity of limiting vehicles ownership, it is not likely that the growth in private vehicle ownership will be actively pursued across Asian countries. Meanwhile the International Energy Agency (IEA), in its net zero scenario, does assume that, at a global level, including developing Asia, car ownership could be significantly lower compared to a business-as-usual case (Figure 10).

**Figure 10: Private Car Ownership in International Energy Agency Business-as-Usual and Net Zero Scenarios**




BAU = business-as-usual.
Source: International Energy Agency 2021. Net Zero by 2050. Paris

While especially developed countries in Europe and some states in the United States have announced, or are about to ban the sales of internal combustion powered light duty vehicles (LDVs) by 2030 or 2035, this is not yet the case in developing Asia. Until now, only Singapore has announced an intention to do so. The likelihood of regional scale zero vehicle regulations in Asia, resulting in banning the sales of internal combustion-powered LDVs are still very remote. It is noteworthy though that the IEA, in its most ambitious scenario, considers

that the gasoline and diesel car sales in major countries will be stopped in 2030 and globally in 2035 (IEA 2019).

In 2018, 56% of the world's travel and tourism was by travellers seeking leisure and recreation (ADB(d) 2022). Asia and the Pacific are now one of the fastest-growing markets for travel and tourism globally. However, in the net zero pathway, long-distance leisure and business travel, including in Asia, would need to reduce significantly, shift to regional or local travel and use zero carbon modes. While the IEA estimates suggest that, by 2050, aviation leisure and business travel should stay at 2019 levels in the net zero emission pathway (IEA 2019), other pathways indicate a possibility of a 34% reduction in flights from 2019 by 2050 (TGC n.d.).

### 4. The Impact of Digitalization

In Asia, as of 2020, 57% of the individuals use the internet compared to 3% in 2000. This digitalization trend is expected to continue as Asian countries will continue to rapidly increase the access to, and speed of, the internet. Innovations in mobility technologies, physical internet, and automation could lead to more connected, intelligent, low-carbon, reliable, and efficient transport systems. In some cases, it is expected also that the increased use of the internet will help reduce the number of physical trips because of, e.g., online meetings and administrative processes. However, this transformation requires considerable investments to develop and deploy new technologies and digital infrastructure at a rapid scale. For low- and lower middle-income countries, a slow pace of investment could initially widen the digital divide between developing and developed countries.

“Dematerialization" is a critical strategy in decarbonizing energy emissions and one which also has implications for the transport sector. Dematerialization involves the reduction of material consumption by product redesign, waste minimization, recycling, digitization, miniaturization, and material substitution (Alice 2019). Dematerialization interventions have

the potential to reduce freight demand by orders of magnitude, resulting in emissions reductions in the transport sector.

The Paris Agreement considers that emissions that cannot be eliminated must be balanced by removing an equivalent amount of $CO_2$ from the atmosphere (Rogelj, et al. 2021). This transition necessitates using negative emissions technologies and carbon capture and storage in the power and industry sectors. The shift towards such technologies will require optimum regional transport networks, especially shipping, railways, and pipelines that deliver captured $CO_2$ emissions from fuel combustion or industrial processes to storage locations or facilities that create valuable products and services. The associated increase in freight transport demand and the requirement for new infrastructure will create challenges for the transport sector's decarbonization.

## B. "Shift" Strategies in Net Zero Pathways

In net zero pathways, efficiencies of all transport modes are expected to improve over time and ultimately approach zero emissions. However, some modes fully decarbonize earlier than others. For example, most pathways consider 2-wheelers and 3-wheelers, railways, buses, and shared mobility trips to become net zero earlier and more completely than other carbon-intensive modes such as private cars. Trucks, planes and ships are expected to follow even later. Thus, changes in passenger and freight travel structure, i.e., modal shifting towards those modes that are now already lower in emissions and which are expected to fully decarbonize more quickly, play a critical role in achieving the net zero targets. For passenger transport, this would imply a shift from passenger cars and aviation to railways, buses, shared mobility, walking, and cycling trips. In freight transport, the change would be from trucks and planes to railways and shipping. Thus, to achieve net zero, future car and truck journeys must reduce and be replaced by trips on clean(er) modes.

Effective modal shift requires significant investments in existing public transit services and new transit lines to attract demand from cars, aviation, and trucks. However, this is only one part of the equation. To realize large-scale modal shifts, people need to be willing to change their behavior. A stronger political will is needed to accelerate modal changes. The performance and costs of low carbon modes needs to improve (Cuenot, Fulton and Staub 2012). To make a net zero pathway more feasible, high(er) carbon prices and eliminating fossil fuel subsidies are key preconditions combined with a large investment program in public transport.

The challenges of bringing about large-scale modal shifts are reflected in the ITF Reshape+ scenario, which considers only a modest modal shift up to 2050 for both passenger and freight transport in Asia and the Pacific region up to 2050 (Figure 11).

**Figure 11: Expected 2015 and 2050 Modal Shares Passenger and Freight Transport**


IPT = intermediate public transport, MFT = medium freight truck, HFT = heavy freight truck.
Source(s): International Transport Forum 2021. ITF Transport Outlook 2021. Paris

Shift-oriented mitigation measures in the transport sector in some cases require national level action, e.g., in the case of strengthening the role of railways but in many cases, on the other hand, shifting towards public transport or walking and cycling will require also local level action. This need for coordinated action by the national and local levels makes it potentially more challenging to achieve impact at scale when it comes to modal shifts.

The realization of almost all the Shift-focused mitigation measures have an at least medium-term (5–10 years) and, in several cases, even a longer-term time frame. An important exception to this being measures to enable a shift towards walking and cycling where substantive progress can be made in the short term, provided the political will is in place. This is helped by that shifting to walking and cycling also requires the lowest investments by far. All other Shift-related mitigation measures have, in common, that they require major investments, of which the lion share is usually carried by the public sector. This, combined with the often weak financial position of local governments in developing Asia, can act as an impediment to the development of these low- or zero-carbon modes of transport. Also, modes like metros, railways, bus rapid transit which are preferred from a climate perspective will require continued operational financial support, after construction, to break even.

As a major benefit, Shift-oriented mitigation measures have significantly contributed to a range of non-climate change transport-related SDG targets. They improve connectivity and access, and can help Asia to overcome the dual challenge of accommodating increasing transport demand levels, while fulfilling the need to zero emission levels. Asia is starving for more efficient transport connectivity and accessibility. The per-capita railways and public transit infrastructure is still significantly lower than in Organisation for Economic Co-operation and Development (OECD) countries. In addition to improving access and connectivity in almost all cases, this type of measures will also help to reduce road fatalities and serious injuries as well as help improve air quality.

### 1. Shift Towards Active Mobility

Walking and cycling are now already zero-emission modes of transport. Walking has been and remains the default mode of transport both in rural and urban areas for large groups in the population in developing Asia. Walking as well as cycling has, however, a visibility problem.

These modes are typically not reflected in transport statistics and the institutional responsibility for improving walkability and cyclability is both fragmented and not well assigned. As countries start motorizing and developing enabling road transport infrastructure, this is usually at the expense of pedestrians. The move towards more compact cities and the 15-minute city concept are expected to benefit the modal share for walking and cycling, provided that cities follow through with required investments in walking infrastructure (e.g., sidewalks, at grade crossings) and cycling infrastructure (dedicated cycling lanes).

Globally, there has been a renewed interest in cycling, which is influenced, in part, by the global coronavirus diseases (COVID-19) pandemic. This has resulted in a considerable number of pop-up bike lanes, some of which are now being converted in permanent bike lanes. To a limited extent, this is also happening in developing Asia. The position of cycling has benefitted also from the rollout of shared mobility in a range of Asian countries and cities.

### 2. Shift Towards Public Transport

Events like the COVID-19 pandemic have demonstrated how vulnerable public transport is to external influences. Apart from the temporary disruption of public transport and lower ridership, there is a danger that the risk of virus contagion in public and shared travel modes might result in a systemic change away from public transport trips to private transport.

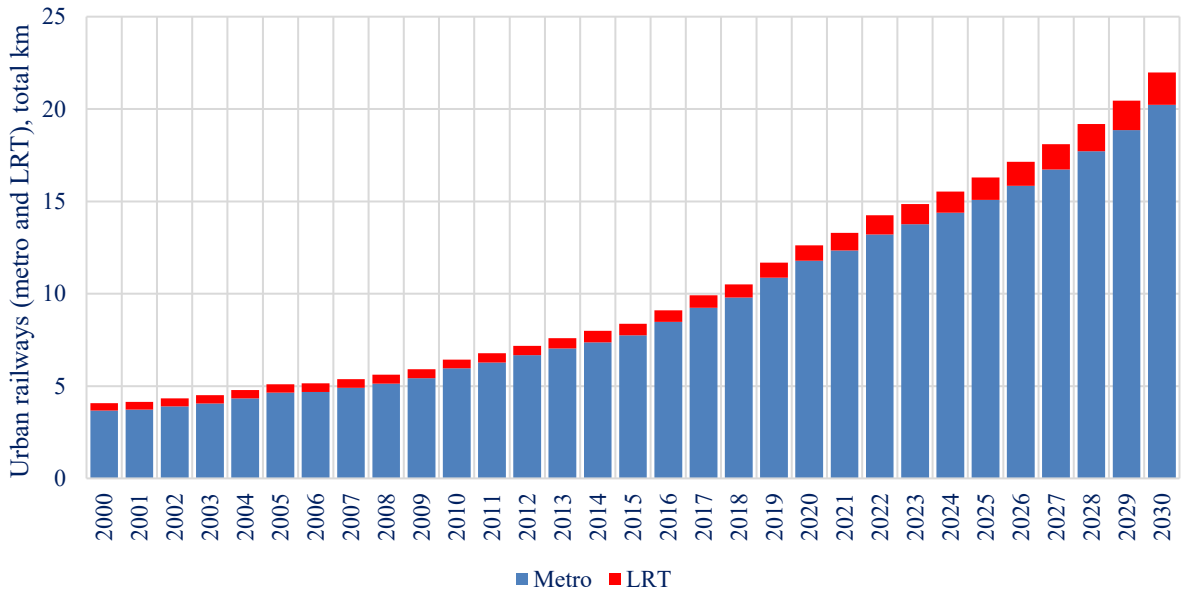
Public transport comes in many forms or shapes. A large part of current public transport in developing Asia consists of informal forms of transport. While efforts are underway to electrify some of these informal modes, it is doubtful whether this is a viable option that can be rolled out at scale. This means that countries and cities with a large share of informal public transport have a double challenge: to convince people to abandon individual modes of motorized transport in favor of public transport and to convert or integrate those forms of informal transport that cannot be electrified into modern zero-carbon transport systems.

Examples of the latter are the bus rapid transit (BRT) schemes in cities where the owners and operators of informal mini buses have been integrated in the new BRT schemes.

Much of the discussion on public transport focuses on rail-based urban transport or BRT systems. In a large part of the Asian cities, most of public transport, in addition to informal public transport, is provided by buses however. Unfortunately, the relative share of buses in total vehicle fleets is decreasing in almost all Asian economies as ownership rates of public transport vehicles have grown slower than private vehicle ownership. Currently, only 1% of total vehicles are used for public transit. In contrast, in 2000, it was about 2%. Active policy interventions are required to reverse this trend.

The construction of metro and light rail transport infrastructure in Asia has picked up over the last decade. Based on current planning and construction, it is expected that Asia could build about 158,000 kilometers (km) of metro and 13,000 km of light rail transit from 2020 to 2030 (Figure 12). This new construction over the next decade is the same as what Asia constructed over the last two decades and would not be sufficient to reduce the modal share of private cars substantially. A further concern is that close to 80% of new urban railways are projected to be constructed in the upper middle-income economies and a large part would be in the East Asia region. Taken together, this makes it clear that developing Asia as a region, currently, is not well positioned to accommodate a large shift from private cars to public transport.

**Figure 12: Historic and Projected Urban Rail Infrastructure Growth**




km = kilometer, LRT = light rail transit.
Source: Asian Development Bank. 2022. Asian Transport Outlook 2022. Manila.

### 3. Shift Towards Shared Mobility

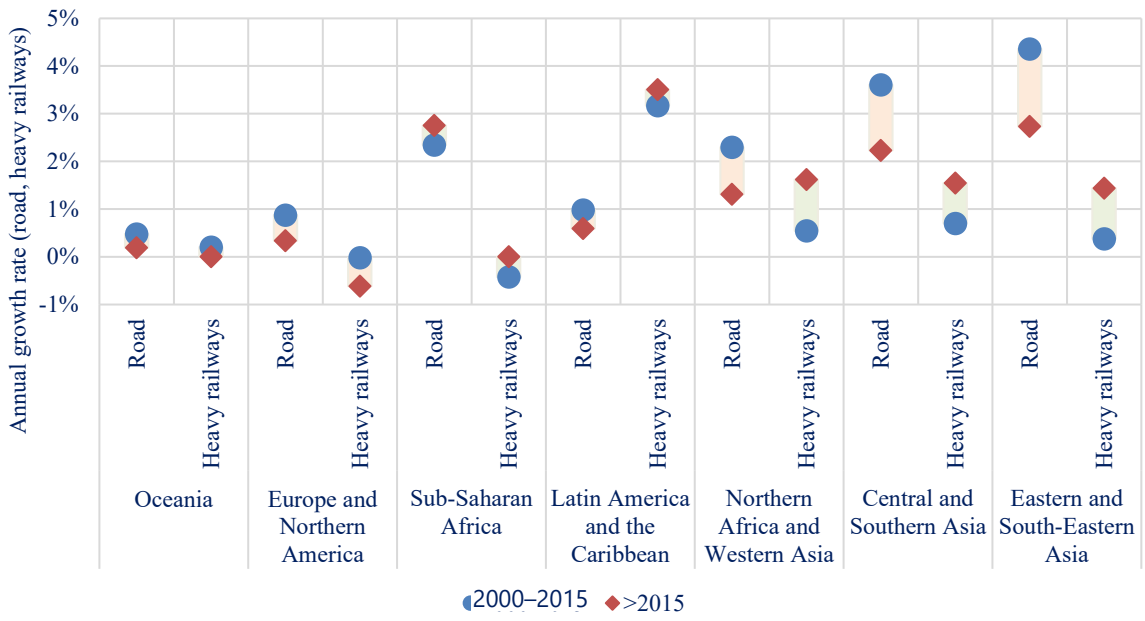
An often heard argument is that the future of passenger transport belongs to shared mobility. However, there is much uncertainty about the role of shared mobility in a net zero world. On the one hand, shared mobility trips could help reduce vehicle ownership and increase the use of public transit. On the other hand, it could attract predominantly public transit users, minimize transit ridership, and enhance urban sprawl. The main factors influencing the impact of shared mobility are how the regulations are framed, infrastructure is modified, what technology is used and subsequent behavioral changes. In cities with limited public transit, widespread use of electric shared mobility services could result in significant environmental benefits however.

### 4. Shift from Road to Rail

As part of a shift from individual to active or collective modes of transport, it is important to consider the possible shift from road to rail transport. This is especially relevant for freight

transport, which is projected to become the major source of $CO_2$ emissions in the transport sector if no corrective action is taken. Unfortunately, over the last years, an opposite trend can observed in Asia (Figure 13). Asia has constructed roads at a faster pace than heavy railways with the consequence that, in many countries, railways have lost modal share compared to roads, both in the case of freight and passenger transport. At present, only a few countries in Asia have targets on shifting modal share and, where these targets exist, they are modest in nature.

**Figure 13: Growth of Transport Infrastructure, Roads and Heavy Railway**




Note: The green bar shows the increase and the red bar shows the downward trend.
Source: *Asian Development Bank. 2022. Asian Transport Outlook 2022. Manila*

## 5. The Impact of Phasing Out Fossil Fuels on Freight Transport

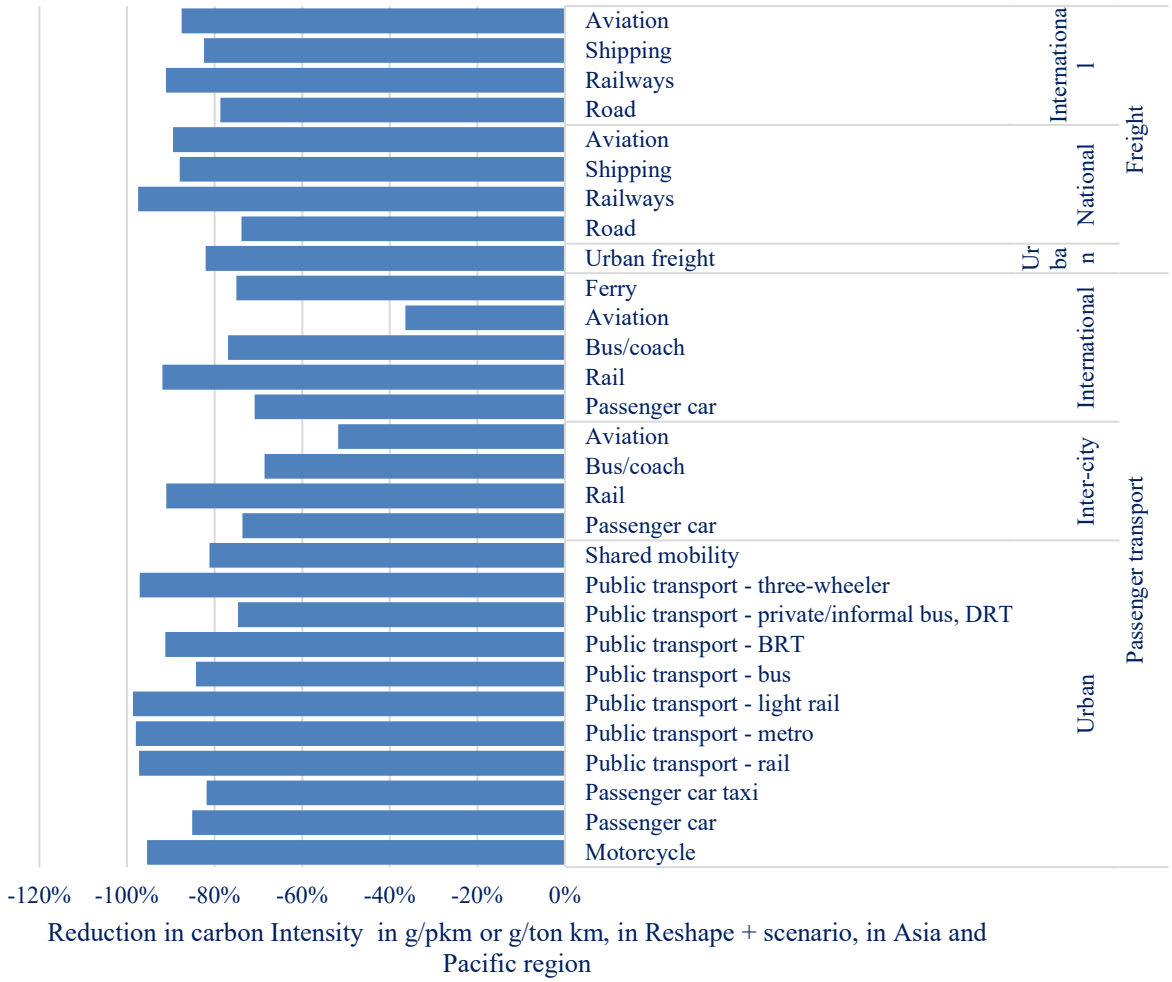
Globally, fossil fuels make up more than one third of global maritime trade (UNCTAD 2021). In addition, they are also transported using railways, pipelines, or trucks. In the case of a net zero transition, the transportation of fossil fuels will reduce and subsequently stop, decreasing the mode share of railways, pipelines, shipping, and trucks; thereby creating the risk of stranded assets for tankers and coal carriers. Reduced mode shares of greener modes will not only

increase the emission intensity of freight transport, but also create a fiscal challenge for rail and shipping operators (because of reduced profitability).

### C. "Improve" Strategies in Net Zero Pathways

Improve-oriented climate mitigation strategies aim to improve the environmental footprint of motorized transport. This is to be achieved through a combination of zero or low-carbon engine technology and fuels used. This leads to many of the net zero emission scenario's projecting radical reductions in the carbon intensity of different transport modes. As such, the Improve-oriented climate change mitigation options typically score much higher than Avoid- and Shift-oriented mitigation options in net zero pathway studies. This is also the case in the ITForum Reshape+ scenario. By 2050, many transport modes could reach nearly zero emissions per passenger or freight activity (Figure 14).

**Figure 14: Projected 2050 Reduction in Carbon Intensity by Mode in International Energy Agency Reshape + mode**




DRT = demand-responsive transport, km = kilometer, pkm = passenger-kilometer.
Source(s): International Transport Forum 2020. Good to Go? Assessing the Environmental Performance of New Mobility. Paris

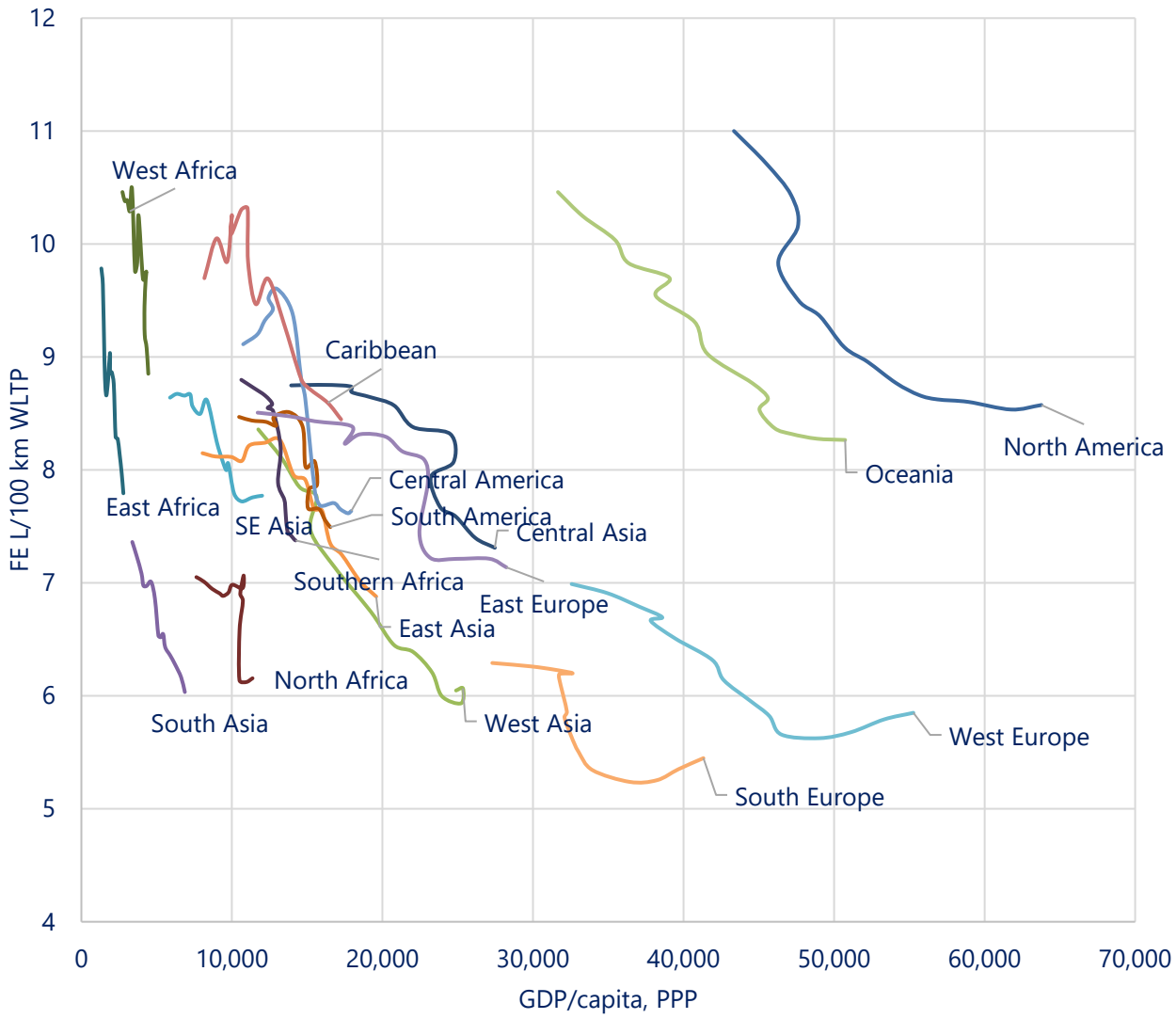
As in the case of Avoid and Shift approaches, Improve-oriented mitigation measures are well suited to be implemented at a national level, e.g., fuel economy standards. However, in a significant number of cases, they are implemented at an urban or pilot level as in the case of the introduction of different types of electric vehicles. The first impact of Improve measures can be felt relatively quickly. However, the full impact of Improve measures is only noticeable in the long term. In part, this is because technological innovations need to work their way through the vehicle fleets. In the case of developing Asia, this can take well over 10–15 years

because of the relatively long lifetime of vehicles. Unlike for Avoid and Shift measures, to a large extent, the costs of Improve measures are carried by the owners and users of the vehicles. However, there are substantial investments required to transform vehicle manufacturing, set up battery production, and develop charging infrastructures. To a large part, these are carried by the private sector. The public sector needs to set the policy frameworks to guide the transition, fund subsidies and incentives to accelerate the transition, and help develop the battery industry. Improve-oriented mitigation options make no contribution to the realization of access-related transport-related SDG targets, but can be an important contributor to reducing transport-related air pollution.

### 1. Fuel Efficiency Measures

Improved fuel efficiency has a crucial role to play in the net zero transition. Improving fuel efficiency of gasoline- and diesel-powered vehicles is a complementary policy to electrification, which is especially relevant as long as the majority of the vehicle fleet still consists of fossil-fuelled vehicles. In the case of developing Asia, it can be expected that, even in the most optimistic electrification scenarios in the next decades, the bulk of on the road vehicles will be gasoline- and diesel-powered vehicles. The United Nations Environment Programme (UNEP) has estimated that, until now, the average fuel economy of passenger cars ranged from 4.7 to 13 liters of gasoline-equivalent per 100 km (Figure15). This means almost a factor of three between the most-efficient and least-efficient markets (Gota and Fabian 2022). Personal cars in Asia are still relatively low in weight compared to other global regions, because they have a relatively good fuel economy. If Asia would follow the global trend towards heavier vehicles, this could affect the currently relative favorable fuel efficiency.

**Figure 15: Relationship Fuel Economy and Gross Domestic Product per Capita for Different Global Regions**




FE = fuel economy, GDP = gross domestic product, PPP = purchasing power parity, SE = Southeast, WLTP = Worldwide Harmonised Light Vehicles Test Procedure.
Source: Sudhir Gota 2022.Is the glass half empty or half full.Shifting to Efficient and Zero Emissions Vehicles in the Global South.Nairobi

Globally, there is an increasing consumer preference for more powerful and heavier cars with large engine displacements. The IEA has estimated that the share of sports utility vehicles in total passenger car sales globally increased from 22% in 2005 to 44% in 2019. Such sports utility vehicles typically, because of their weight, use more fuel per distance travelled.

In a net zero pathway, in the short to medium term, countries will need to increasingly use policies, incentives, standards, regulations, and taxes to reduce the engine displacement, kerb weight, and power of passenger cars and enable the shift to smaller electric cars. Such a net zero pathway with lighter, smaller, and fewer electric vehicles would contribute significantly to reducing air pollution and road crash fatalities and serious injuries.

## 2. Transitioning Towards Zero Emission Vehicles

Some leading vehicle markets and automotive companies have adopted zero-emission vehicle plans and road maps. Unlike in Europe and other developed vehicle markets, there is no clear road map in place in Asia for the phase out of internal combustion engines. Several countries have issued aspirational policy statements, but generally these are not yet converted in binding policy targets. Countries can adopt a two-pronged approach in moving forward on this topic. The first is to establish medium- to long-term commitments to zero-emission vehicles; the second is to adopt short-term actions to accelerate the penetration of zero-emission vehicles with behavior change. To ensure the effectiveness of these measures, countries should ideally eliminate or reduce fossil fuel subsidies and put in place effective electric vehicle subsidies. To trigger a change in consumer behaviors, countries can also differentiate between electric and non-electric vehicles in terms of access, parking rules, urban zoning restrictions, road charges, and feebates, in all cases favoring low-emission vehicles. Another trigger could be to impose stringent requirements for zero-emission vehicles in public procurement programs for buses and other government-owned fleets.

The lowest common denominator of all existing net zero pathways in the transport sector is a rapid shift to electric vehicles. In terms of the scale and speed of transformation, some consensus-based targets have emerged (Figure 16 shows the share of electric vehicles in total stock.) (GFEI 2021):

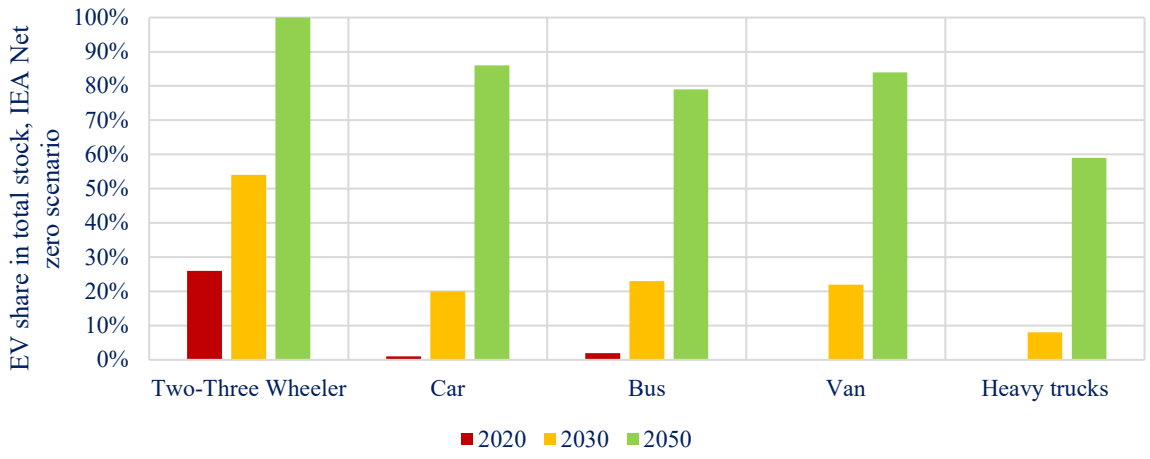
(i) 2-wheeler and 3-wheeler sales to become 100% electric by 2030–2035,

(ii) urban transit buses sales to become 100% electric by 2030–2035,

(iii) LDVs sales to become 100% electric by 2030–2040, and

(iv) truck sales to become 100% electric by 2038–2045.

**Figure 16: Electric Vehicle Share in Total Stock by Vehicle Category**




EV = electric vehicle, IEA = International Energy Agency.
Source: IEA International Energy Agency 2021. Net Zero by 2050. IEA, Paris

These are global targets and their application to developing Asia varies considerably. Not all countries will make the same progress in all vehicle types. Regionally and globally, the PRC is already leading in the rollout of electric vehicles. At the same time, most of the developing Asian countries are still at the very beginning of electrifying their vehicle fleets. It is to be expected that most of the Asian countries would adhere to the later target years. Two-wheelers and 3-wheelers are a key part of the transport fleet in a large number of Asian countries and may get priority in the decarbonization of transport in Asia.

To optimize the climate benefits of electrifying transport, electrification of transport will need to coincide with an increase in the share of renewables in the electricity grid. The IEA has estimated that the percentage of renewables in total electricity generation globally will increase from 29% in 2020 to more than 60% in 2030 and to nearly 90% in 2050 (IEA 2019).

The growth in electric vehicles has significant potential second-order implications. The growing battery demand will exert considerable pressure on the supply chain for materials like lithium, nickel, cobalt, graphite, and manganese. While countries with critical mineral resources can benefit financially, the production may not be carried out sustainably and responsibly, with demand outstripping supply for the foreseeable future. These potential adverse environmental and social impacts of irresponsible mining could derail the rollout of e-mobility. To address these issues, countries could insist on zero emissions supply chains for key minerals, which should encourage countries to provide critical resources to shift to climate-smart mining.

The increasing demand for electric vehicles will necessitate setting up massive rapid charging facilities. The net zero scenarios also consider a high magnitude of investments in digital grid technologies and intelligent charging facilities to transform electric vehicles' integration with grids. The basket of charging solutions being considered includes, in addition to the default of electric batteries as installed and used at the moment, the use of battery swapping, electrified road systems using conductive, or inductive power transfer to provide electricity to inter-city heavy-duty vehicles. Consumers will increasingly call for such a range of options, where they are likely to emphasize simplicity and autonomy for electric vehicles in the same manner as they do now for conventional vehicles (IEA(d) 2022).

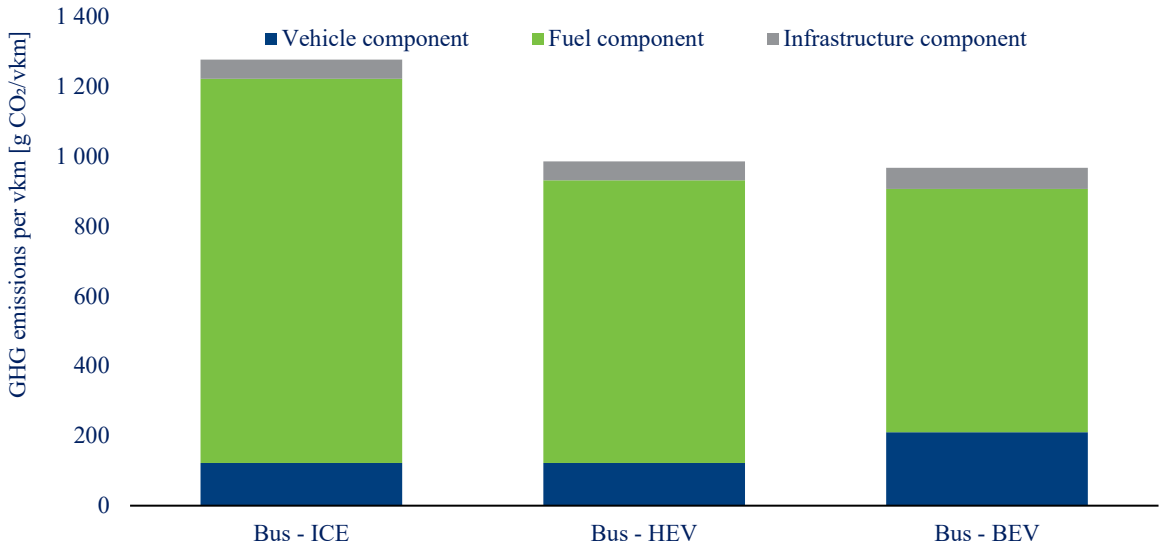
As traditional automotive manufacturers and suppliers will shift production from internal combustion engine components to electric vehicle components, this will disrupt the entire current automotive supply chain. It is believed that the manufacturing and maintenance of electric cars require less labor. The current estimates of employment lost in the traditional automotive segment and gained in the new electric vehicle segment, including battery manufacturing, are still highly uncertain however. Changes in the geo-political situation and high carbon prices in the maritime sector as well as supply chain resilience challenges could

result in countries prioritizing the indigenization of the supply chain to enable local manufacturers to build more cost-competitive products. This would have a positive impact on local employment. The new supply chains using new technologies will require a differently skilled workforce. With new employment and reskilling programs, the transport sector has a potential opportunity to raise the quality of employment in the automotive industry. If such substantial changes would indeed come to the automotive sector, this could also help to bridge the gender gap in this sector. Female participation in the transport industry is currently low, i.e., only about 11% (ADB(b) 2021).

The growth in electric vehicles also has potentially significant third-order implications. As both the global and north and south are both shifting to zero-emission vehicles, the used vehicle trade of internal combustion vehicles might shrink. For example, in 2015, 3.4 million used LDVs were exported globally. By 2019, this has increased to 4.8 million. Nearly 80% of used LDVs were imported from low- and middle-income countries (UNEP 2021). If the trade of used internal combustion vehicles is increasingly disrupted, this could lead to a lower vehicle economic life. This could result in an overall more efficient vehicle fleet, but also an increase in the share of vehicle manufacturing emissions in the total lifecycle emissions.

Transitioning to net zero vehicles will increasingly spotlight vehicle manufacturing and infrastructure construction emissions. The current assessment shows that, for diesel buses, the vehicle manufacturing and infrastructure construction emissions in the total lifecycle are estimated to be about 9% and 4%, respectively. In comparison, the manufacturing and infrastructure construction emissions in the battery-powered buses could be 50% higher because of the elimination of operating emissions (Figure17) (ITF 2020). To realize net zero emissions fully in the transport sector, the construction and manufacturing footprint needs to reduce to net zero in parallel.

**Figure 17: Carbon Dioxide Life Cycle Analysis Bus Manufacturing**




$CO_2$ = carbon dioxide, GHG = greenhouse gas, vkm = vehicle kilometer.
Source(s): *International Transport Forum 2020. Good to Go? Assessing the Environmental Performance of New Mobility. Paris*

### 3. Electrifying Railways

Railways are one of the most energy-efficient and least carbon-intensive ways to transport people and goods. Railways are also already the most electrified mode of the transport system. In Asia, 54% of the railway network is now electrified. All prominent railway corridors will have to become electric within the next decade as part of the net zero transition in the transport sector. In those corridors where electrification is not possible or limited, battery- and hydrogen-powered trains could be considered. This change to net zero in the rail sector requires immediate significant investments for retrofitting the infrastructure and purchasing electric or hydrogen locomotives for existing and new corridors. This change in technology is in addition to a substantial expansion of railway infrastructure as part of the Shift approach. Financing these simultaneous efforts of completing the electrification of railways and expanding rail infrastructure expansion could become a critical obstacle for railway ministries.

## 4. Decarbonizing Aviation

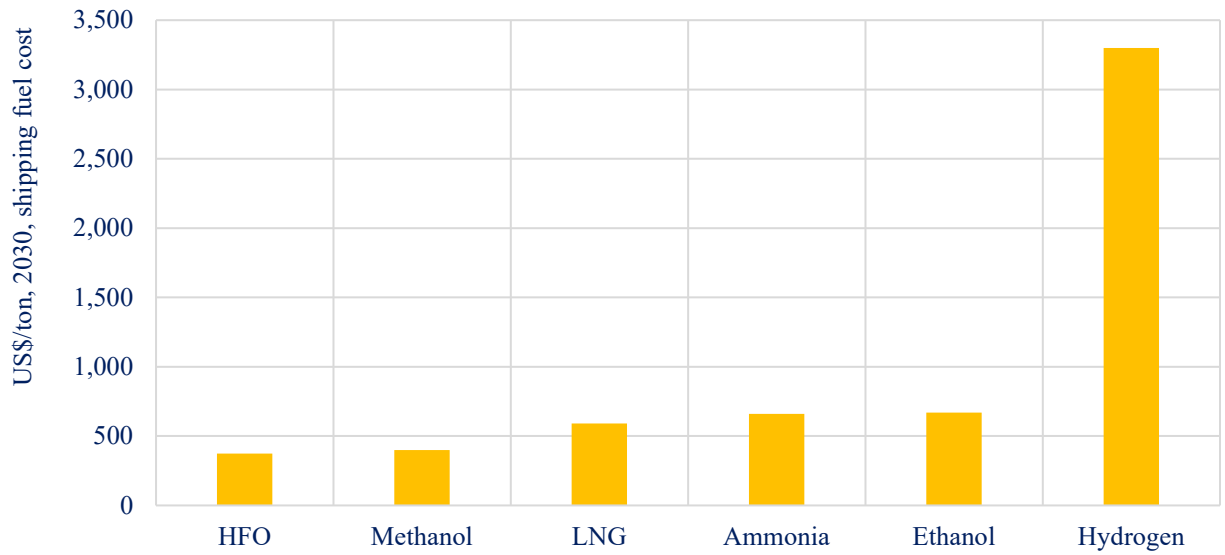
IEA has concluded that aviation is a complex sector to decarbonize and it remains a net emitter by 2050 in their net zero pathway (ICAO n.d.). The fundamental strategy in the aviation sector is the rapid adoption of sustainable aviation fuels (SAFs) and alternative fuel options such as electricity and hydrogen. Many pathways propose SAFs as the critical technology for decarbonization with a mitigation share of about 60%–65% (ICCT 2022) (IATA n.d.). However, SAFs are either made from biogenic feedstocks (waste cooking oil, agricultural residues, municipal waste) or through technologies such as power-to-liquid from recycled $CO_2$ and carbon-capture technologies. Neither option is able currently to produce SAFs on a large scale. Estimates indicate that, to reach the very modest 2030 targets set by the aviation sector, the production capacity of SAF needs to be increased by a factor of 5–6 compared to the currently existing or planned plants by 2030 (McKinsey & Company 2022). This would require intense coordination of efforts across governments, private airlines, airports, air navigation service providers, and manufacturers.

## 5. Decarbonizing Shipping

Realizing a net zero transition in shipping requires two technological breakthroughs. First, a shift from heavy fuel oil bunker fuels to a new generation of zero-emission bunker fuels. The second is that the ships entering fleets in the near term and existing ships in the fleet must be retrofitted to use zero-emission fuels. Since ships often last 2–3 decades, thousands of zero-emission ships would need already to be in the water by 2030. Possible zero-emission fuels being considered currently are green ammonia, closely followed by green hydrogen (World Bank(b) 2021). The challenge here is also the investments required for this transition. It has been estimated that about $2.4 trillion in funding would be needed for shipping to achieve net zero emissions by 2050 (BCG 2021). A special concern is the cost of green hydrogen (Figure

18). In a net zero pathway, shipping costs would spiral up with the costs of financing the green fuels and ships. This would be on top of a possible global carbon tax applied to the maritime sector. The resulting increases in shipping costs could adversely affect trade, resulting in the reorganization of supply chains.

**Figure 18: 2030 Shipping Fuel Cost**




HFO = heavy fuel oil, LNG = liquefied natural gas.
Source: International Maritime Organization (2020).

# V. TRANSITIONING TOWARDS A NET ZERO PATHWAY FOR TRANSPORT IN ASIA

The starting points of Asia's subregions and countries on their path towards a net zero transport sector are very different because of their differing transport infrastructure access and mix, technological accessibility, emission intensities, and capacities to decarbonize. However, for the entire developing Asia region, it must be noted that, apart from growing carbon emissions, the transport sector also faces multiple challenges in the form of inadequate access and connectivity as well as road crash fatalities, air pollution, affordability. These developmental challenges also vary considerably between Asia's subregions, countries, and even within countries.

The possible components for accelerated action on mitigating climate change which, in this paper, are organized on the basis of the Avoid–Shift–Improve approach for the largest part are not new. For a number of years now, various international organizations, think tanks, and also a number of governments have already been arguing to organize the decarbonization of the transport sector along the Avoid–Shift–Improve approach. Therefore, it is important to give some further thought to how countries in developing Asia should go about taking the Avoid–Shift–Improve approach to scale and take the concerted and comprehensive action required to realize a net zero transport sector.

## A. Preparing for "2050" Decarbonization While Aiming to Peak Transport Emissions in Asia by 2030 or Shortly Thereafter

As mentioned, it is expected that, under a business-as-Usual scenario, transport emissions in Asia will continue to grow and that they will not peak before 2030. If an ambitious net zero pathway is adopted and implemented at scale, the peak in $CO_2$ emissions could come between 2030 and 2035 before they would go down and possibly reach net zero in the period 2050–

2070. This theoretical pathway is by no means a given. The experience of Europe, where action on transport and climate change is already better established than in Asia, the disappointing results in bringing down transport $CO_2$ emissions has shown how difficult it is to put the transport sector on a downward $CO_2$ emission trajectory.

The respective descriptions of measures under the Avoid–Shift–Improve approaches almost all pointed out that, to achieve impact at scale, there is a lead-time of at least 10 years and in several cases 15 years or even more. It is clear that Asia has started taking action on the decarbonization of the transport sector, but a review of LTSs, NDCs, and other transport policies in Asia makes it clear that climate ambition in the transport sector in many Asian countries is still mostly at the aspirational level. Asian countries would be well served if they use the 2020–2030 decade to agree on a comprehensive strategy that would guide their countries in the period 2030–2050 to a net zero status. Such a comprehensive transport decarbonization strategy can inform future updates of NDCs and be mainstreamed in transport and transport subsector policies. They can consider whether to replicate the approach that several European countries have taken in which there is a formal obligation to report on an annual basis on the alignment of transport emissions with a commonly agreed-upon climate change mitigation pathway. The requirement for such a reporting approach is usually spelled out in climate change legislation.

## B. Accelerated Technological and Policy Research

The viability of emissions reductions for many of the mitigation options discussed under the Avoid–Shift–Improve approaches has been well proven, but there remain gaps in terms of types of emissions that are not adequately covered by the catalogue of potential emission measures. Filling these gaps will be required if Asia, as well as other global regions, want to realize a net zero transport sector. A large part of the mitigation measures described in this paper are best

suited to reduce $CO_2$ emissions from the passenger transport subsector. Yet, current projections indicate that $CO_2$ emissions from freight transport could be larger than those of passenger transport in the foreseeable future because of the expected larger growth in freight transport activity. More research on the different technological and regulatory actions to reduce freight emissions will be needed.

A growing share of transport $CO_2$ emissions will come from shipping and aviation, especially if efforts to reduce land transport-based $CO_2$ emissions will be successful and if the growth of shipping and aviation continues as it did in the last decades. Shipping- and aviation-related mitigation measures are still in their infancy and much additional technological research will be needed before robust action can be taken to reduce $CO_2$ emissions from these two sectors.

The research needed to decarbonize freight, aviation, and shipping in Asia, in many cases, will be global research that is not carried out in Asia but elsewhere in the world. It will be important that specific requirements of Asia are fully reflected in such research and that Asian countries have full and open access to such research. However, a significant part of the research will be done in Asia as is demonstrated by the leading role that Asian countries have played in the development of high-speed rail, electric busses, trucks, cars, and 2-wheelers and 3-wheelers. In this case, it is important that research results and their resulting technological applications are available to the entire Asian region and that it is shared with other global regions.

For developing Asia to be able to take up available and new technologies at scale, it is important that the costs of these technologies are in line with the economic status of the countries where these technologies will be deployed. To make this happen, it will be important to look at the pricing of transport and its different modes. Relatively little is known about the effectiveness of carbon pricing in the transport sector or about effective policy levers to

optimize the Avoid and Shift components. More policy research and debate will be required on these topics.

## C. Need for Effective Monitoring

In planning and implementing a net zero transformation, countries and institutions will benefit from tools that will help to identify priority issues, formulate and efficiently implement policies, and allocate resources. However, the knowledge currently available in Asian countries on the transport sector and the impact of transport investments on $CO_2$ emissions is not only insufficient but also potentially misleading (ASEAN 2019). To strengthen the knowledge base on transport in the Asia and Pacific region, the Asian Development Bank (ADB) has initiated the Asian Transport Outlook (ATO). The ATO is developed to support the planning and delivery of ADB Transport Sector Assistance. The ATO also supports Asian governments in transport policy development and delivery. For an effective transition to net zero, ADB can work with other interested parties in developing the ATO as an effective instrument to track the implementation of SDGs, the Paris Agreement, and other relevant international agreements on sustainable development in the transport sector.

## D. Coordinated Policy Frameworks Guided by a Low Carbon Paradigm

A careful review of the Avoid–Shift–Improve-oriented mitigation measures described in this paper makes it clear that their successful implementation will require substantial policy and regulatory action at both national and, in several cases also, local levels. Such policy action will need to be taken by both the transport ministries and departments as well as a whole host of other ministries that also need to be involved. The exact mix of ministries and the involvement of local governments will depend on the detailed institutional structure in the different Asian countries.

Net zero transport can only be achieved if transport-related policy makers start to own and internalize the concept of zero carbon transport systems. At present, there is still a tendency in Asian countries that ministries of environment and/or climate change dominate the policy discussion on climate change, including sectoral action on climate change. Such ministries are rightfully taking the lead in setting economy-wide targets, including overall net zero targets. Following this, sectoral ministries should be however responsible for setting and achieving targets specific for their sector. In the case of the transport sector, the responsible ministry should actively coordinate and cooperate with other relevant ministries on this. Linked to the dominance of the coordinating environment and/or climate change ministries, there is still a tendency in the international community to look at LTSs and NDCs to determine the climate ambition levels of a country. Transport-related climate ambition is determined by the presence of transport-specific targets and/or references to specific mitigation measures in the LTSs and NDCs. However, this is not policy making for a net zero economy and certainly not policy making for a decarbonized transport sector. If Asian countries are serious about developing and implementing net zero transport pathways, they should all have, latest by 2030, approved zero carbon-focused transport policies in place.

However, there is a serious impediment for having such approved zero carbon-focused transport policies. At present, about two thirds of Asian countries either do not have an overarching transport policy, or it is a policy that was developed before 2015, when the Paris Agreement was adopted. However, it is encouraging that, as observed in this paper, some countries have developed specific low carbon transport strategies. Overall, however, in 2022, 8 years after 2015 and 8 years before 2030, a minority of countries have a transport policy that prioritizes low carbon development of the transport sector and none have a clear net zero carbon pathway.

The adoption of zero carbon-focused transport policies is an important first step, but by no means enough. An effective implementation of such policies will require a huge amount of institutional and capacity development in transport and related ministries. In a majority of cases, transport and infrastructure ministries are still biased towards road building and expertise in areas like railways, electric mobility, as well as walking and cycling is very limited. The successful implementation of Avoid–Shift–Improve-oriented mitigation measures also requires new partnerships. Transport policy makers will need to tap into the academic community to get assistance in the development and monitoring of zero carbon-focused transport policies, new partnerships, especially with the private sector, will be required in support of a massive rollout of electric vehicles. To achieve the required changes in behavior, it would be good to mobilize civil society and media.

## E. A Revised Funding and Financial Structure for the Transport Sector

Considering that low carbon-oriented transport policies in Asia are still very much the exception, it is entirely logical that current funding and finance mechanisms in the transport sector in Asia continues to be geared towards the development of road transport, the most carbon-intensive mode of transport, often through individual transport sector infrastructure projects. The adoption of policies that aim at the decarbonization of the transport sector will have clear implications for transport funding and finance. It is not implied that Asia should stop funding and building roads. The infrastructure gap is too large for that and urban and rural access still too poor. However, the change in policy focus will need to be accompanied by making more funding available for low carbon transport infrastructure, e.g., railways, walking and cycling infrastructure, as well as charging infrastructure for electric mobility. In addition, pricing of transport needs to be structured in a manner that it promotes shift towards and greater use of low-carbon modes of passenger and freight transport.

The e-mobility revolution needed to accomplish net zero in the transport sector will require financial incentives for the buyers of electric vehicles, support for the creation of a battery industry, as well as support for the commercial parties that take the initiative to set up large-scale charging infrastructure. Developing and implementing such financial support mechanisms have been key for the quick take off of electric mobility in Europe. Developing Asia will need to decide how they want to do this in their specific context.

Current methodologies for the economic and financial assessment of transport investments are largely driven by the current automotive-dominated transport model and is putting disproportionate emphasis on vehicle operating costs and time savings when assessing new transport projects. Many of the advantages of the Avoid–Shift–Improve-related mitigation measures, apart from lower $CO_2$ emissions, consist of improved road safety, lower air pollution, or improved access to economic and social opportunities.

## F. A New role for Development Corporation

Finally, any movement towards a net zero transport sector in Asia could benefit hugely from a reorientation of development cooperation in the transport sector. We have seen that transport-oriented civil society organizations have a played a large role in raising the profile of the transport sector in climate change and in elaborating and promoting the Avoid–Shift–Improve approach as a key concept for the transformation of the transport sector. It can be expected that they will continue to play an enabling role in raising awareness. However, it is the bilateral and multilateral development organizations that have the capacity to assist Asian countries in their efforts to transform their transport sector through technical and financial assistance.

Donor organizations have traditionally focused their assistance on the development of transport infrastructure, mostly roads, followed by railways and public transport systems. In many cases, this financial assistance has been accompanied by institutional development and

capacity-building assistance. Over the years, transport donors have increasingly aligned themselves with international development agenda's such as the SDGs, which resulted others in a Multilateral Development Bank (MDB) Working Group on Sustainable Transport. More recently MDBs announced at the 2021 United Nations Climate Change Conference (COP 26) in Glasgow that all assistance provided by MDBs in the future would be aligned with the objectives of the Paris Agreement. Currently, MDBs are elaborating sectoral guidelines which will spell out what Paris Agreement alignment means for the different sectors, including the transport sector.

This Paris Agreement alignment process can be an important impetus for scaling up action on the decarbonization of the transport sector. We observed that Asian countries need to quickly act on the development of net zero oriented transport policies. Development organizations can help with that. It is expected that development organizations will increasingly shift financial support to dedicated low carbon transport infrastructure. These investments in low carbon transport will gain in impact if they are accompanied by institutional development and capacity-building support.

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