The Decarbonization of Logistics in Lower Income Countries
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Foreword

In our interconnected global economy, growing consumer demand for goods and services is driving the growth of freight logistics activities. The COVID-19 pandemic, the Russian invasion of Ukraine, and associated supply chain disruptions have underlined the importance of resilient logistics for delivering products and services to meet the needs of the economy. Logistics activities are a key driver of a country’s growth and prosperity, motivating governments in low- and middle-income countries (LMICs) to establish comprehensive logistics plans, policies, and strategies. By improving logistics capabilities, countries can enhance their competitiveness, attract investments, and foster economic growth.

However, a growing logistics footprint has an environmental cost. As freight ton-kilometres are projected to double in the next three decades, designing a freight logistics network is crucial to decarbonize the transport sector, since logistics comprise 11 per cent of total CO₂ emissions worldwide. Of this, nearly 90 per cent of logistics emissions come from freight movement. However, decarbonization of freight can lead to higher transportation costs. As such, we need to design a decarbonization pathway for freight transport that can support low-carbon solutions while keeping the cost within reach. There are already notable examples of innovative CO₂-reducing measures and practices emerging from LMICs that can be replicated and scaled up more widely with appropriate policy and financing support.

In this report, Professor Alan McKinnon, based on years of research and practice, outlines a five-lever decarbonization approach to help governments of LMICs think through suitable logistics decarbonization strategies. These levers include reducing the demand for freight transport, shifting to lower carbon modes, improving vehicle utilization, optimizing vehicle energy efficiency, and switching to lower carbon energy sources. Using a macro-logistics perspective, the report focuses on non-urban, domestic logistics operations. Such freight contributes significantly to CO₂ emissions globally, with trucking operations being a major source. The report considers the broader logistical context, including the movement of goods, storage and handling in warehouses and terminals, and the IT systems that facilitate these processes. While international freight links are referenced, the focus is on decarbonizing domestic freight transport.

The report provides valuable insights for policymakers, researchers, and stakeholders involved in shaping sustainable logistics strategies that balance economic development while simultaneously addressing the environmental impact.
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This report was developed as part of the World Bank’s ‘Decarbonization of Transport’ flagship activity led by Cecilia Briceno-Garmendia (Lead Economist) and Bianca Bianchi Alves (Senior Transport Specialist) with guidance from Binyam Reja (Practice Manager). Contributions to the chapters on the decarbonization of freight and logistics were coordinated by Martha Lawrence (Senior Transport Specialist), Richard Martin Humphreys (Lead Transport Economist), and Joanna Moody. Supporting team members included Cecilia Fabian Kadeha (Young Professional), and Grace Naa Merley Ashley (Consultant) of the World Bank’s Transport Global Knowledge and Expertise Unit. Erin Scronce, Jonathan Davidar and Xavier Bernard Leon Muller provided invaluable design, communications, and dissemination support. An initial draft of the report was edited by Kara Watkins. The final report was edited and designed by RR Donnelly Go Creative.
About the Author

Over the last four decades, Professor Alan McKinnon¹ has actively promoted the development of logistics in the academic, industrial, and government circles. He has conducted approximately 60 studies for numerous public and private sector organizations and is well published in logistics and transport.

A graduate of the universities of Aberdeen (MA), British Columbia (MA), and London (PhD), Professor McKinnon has pursued an academic career since October 1979, specializing in transport and logistics. His PhD on the spatial organization of physical distribution in the food industry was one of the first on logistics in the UK. His initial appointment was as a lecturer in economic geography at the University of Leicester. Between 1987 and 2012, he was based at Heriot-Watt University, Edinburgh, where he established a research center specializing in logistics and a master’s program in logistics and supply chain management. In 2012, he moved to Hamburg to become the first Head of Logistics and Dean of Programs at the new Kuehne Logistics University where he still retains a part-time post.

Professor McKinnon has had visiting professorships at universities in Australia, Malaysia, Sweden, the UK, China, and South Africa and has given invited lectures and conference addresses in more than 50 countries. He has been an adviser to several governments, parliamentary committees, and international organizations, including the World Bank, International Transport Forum/Organisation for Economic Co-operation and Development (OECD), and the United Nations Conference on Trade and Development (UNCTAD). He was the chairman of the World Economic Forum’s Logistics and Supply Chain Council and the Transport Advisory Group of the EU’s Horizon 2020 Research Programme. He was also a lead author of the transport chapter in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) and in 2018, published a book on Decarbonizing Logistics: Distributing Goods in a Low Carbon World. In 2003, he received the Sir Robert Lawrence Award, the highest honor of the Chartered Institute of Logistics and Transport and in 2015, was appointed a Fellow of the European Logistics Association.

¹ https://www.alanmckinnon.co.uk
Decarbonization strategies from high-income countries need to be customized and supplemented with local strategies to serve the unique requirements of each low-and middle-income country.
1. Introduction

Logistical activities—primarily freight transport, warehousing, materials handling, and related information technology (IT)—play a vital role in a country’s economic development. A series of logistics performance indicator (LPI) surveys conducted since 2006 by the World Bank (Arvis et al. 2018) have revealed a close correlation between a country’s gross domestic product (GDP) per capita and its logistic capabilities. These surveys have raised the profile of logistics as an enabler of the development process and encouraged governments in low- and middle-income countries (LMICs) to establish logistics plans, policies, and strategies.

However, there is a high environmental price to pay for logistics-powered development, particularly in emissions of air pollutants and greenhouse gases. Globally, logistics emits around 11 percent of energy-related carbon dioxide ($\text{CO}_2$) emissions; roughly 90 percent of logistics emissions come from freight movement, and most of the remainder comes from warehousing and terminals (McKinnon 2018). Globally, freight movement accounts for around 40 percent of total $\text{CO}_2$ emissions from transport (Punte and Bollee 2017). The near-total reliance of freight movement on fossil fuel and an expectation that globally freight tonne-kilometers will more than double over the next 30 years and makes logistics a ‘hard-to-abate’ sector. Despite this, only a small proportion of the nationally determined contributions statements (NDCs) submitted to the United Nations Framework Convention on Climate Change (UNFCCC) make any reference to freight transport. In the first round of NDCs, only 21 percent of the statements mentioning the mitigation of transport emissions specifically referred to freight (Fransen et al. 2019). This figure has increased to 25 percent in the second round of submissions for the 26th UN Climate Change Conference of the Parties (COP26) in November 2021 (GIZ 2021). This reveals a continuing condition of ‘freight blindness’ on the part of transport policy makers (NIC 2018).

Modeling suggests that between 2015 and 2050, most of the growth in domestic freight movement and related $\text{CO}_2$ emissions will be in countries outside the OECD (ITF 2019). Therefore, it is important that the decarbonization of freight transport in these countries follows a net-zero trajectory as soon as possible. However, the public policy focus on the decarbonization of logistics in LMICs is much less than in high-income countries (HICs) due to:

- The stronger emphasis on economic development in LMICs
- The apprehension that carbon mitigation in the logistics sector might inhibit that development
- A greater focus on freight externalities such as local air pollution and traffic crashes, which are considered to have more immediate consequences
So far, most of the academic and consultancy research on the decarbonization of logistics has been conducted in Europe and North America and is related to the experience, trends, policy frameworks, and carbon reduction targets of HICs in these regions. In recent years, China has also become an important source of research on the decarbonization of freight transport. To date, however, relatively few studies have examined the particular challenges of decarbonizing logistics in LMICs. Some of these challenges are common to most LMICs while others are specific to individual countries or groups of countries, reflecting their level of development, economic structure, size, and geography. While country-to-country variations make generalizations difficult, it is clear that the approaches to logistics decarbonization outlined in much of the literature, which underpins public policy making, needs to be tailored to the needs of LMICs. While decarbonization concepts, tools, and good practice from HICs can be customized to local circumstances, it would be wrong to underestimate the homegrown efforts of LMICs, individually and in regional associations, to pioneer new policy initiatives in this field. There are already significant examples of innovative CO$_2$-reducing policy measures and business practices emerging from LMICs, which could be more widely applied.

This report aims to explore the extent to which the logistics decarbonization approaches in countries in Europe and North America—and to a lesser extent, China—need to be adapted to the needs, opportunities, and constraints of LMICs and supplemented by local initiatives. It takes a macrologistics look at the subject (Havenga et al. 2020), viewing it mainly from the standpoint of countries or national governments. The report focuses on non-urban domestic logistics operations within LMICs, as globally, non-urban domestic freight accounts for approximately 38 percent of total transport CO$_2$ emissions (ITF 2019), most of it from trucking operations.

Modeling suggests that between 2015 and 2050, most of the growth in domestic freight movement and related CO$_2$ emissions will be in countries outside the OECD. Therefore, it is important that the decarbonization of freight transport in these countries follows a net-zero trajectory as soon as possible.

The report deals with freight transport within a broader logistical context, taking into account the relationships between the movement of goods, their storage and handling in warehouses and terminals, and the IT systems controlling these processes. Due to the close interconnections between domestic and international transport, particularly in the hinterlands of ports and airports, some reference will be made to international freight links, but not to the decarbonization of international trade flow.

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$^2$ This report mainly focuses on trucking since it is the most dominant mode of domestic surface transport. Extensive reference is also made to rail freight operations. In most lower-income countries (LICs), waterborne transport and domestic air cargo account for only a small percentage of domestic tonne-kilometers, therefore, the report does not dwell on them.
References


2 Logistics Decarbonization Framework

A five-lever decarbonization framework covering activity, modal split, vehicle utilization, energy efficiency, and carbon content of the energy can help governments think through different decarbonization strategies.
2. Logistics Decarbonization Framework

Carbon emissions from logistics can be reduced in many ways, and most of these measures are mutually-reinforcing. Among the several classifications of carbon mitigation frameworks, the one that is the most widely applied in the transport sector is the avoid-shift-improve (ASI) framework. This framework distinguishes efforts to avoid or reduce kilometers traveled, shift traffic onto lower-carbon modes, and improve the carbon efficiency of personal and freight movement. Avoid-shift-improve-fuel (ASIF), a framework proposed by Schipper and Marie-Lilliu (1999) and adopted by the IPCC’s Fifth Assessment Report, splits the improve category between measures that reduce energy intensity and those that cut carbon emissions per unit of energy consumed (fuel). The energy intensity category has subsequently been divided into vehicle utilization and energy efficiency to create the five-lever framework for the decarbonization of logistics (McKinnon 2018; ALICE-ETP 2019). Figure 2.1 compares these three classifications of logistics decarbonization measures.

Figure 2.1. Interrelationships among Logistics Decarbonization Frameworks

This report focuses on the five-lever framework as it permits more disaggregated examination, provides a firmer foundation for policy formulation, and is widely adopted in the freight and logistics sectors. The five categories can be summarized as follows:

Managerial, operational, and behavioral measures have to be prioritized in the near term while waiting for longer-term transformations in vehicle technology, supply chains, as well as transport and energy infrastructure.

3 TUNCTAD (2021) uses a variant of the ASI framework, which it calls the ‘4M approach.’
1. Activity relates to the demand for freight transport, conventionally measured in tonne-kilometers. The cubic volume of goods moved is also an important determinant of carbon intensity but due to the limited availability of macro-level volumetric statistics, freight transport analysis and policy making is weight based. The main aim of activity is to decouple the growth of tonne-kilometers from economic growth, and thereby reduce the freight transport intensity of the economy. Figure 2.2 illustrates the difference between dematerialization options and logistical options. The former, depicted within the upper broken line, reduces the material content of the economy and involves measures such as digitization, recycling/re-use/remanufacturing, lightweighting, and three-dimensional (3D) printing. These are essentially non-transport options that are outside the scope of this report and are discussed in greater detail in other related studies (e.g., McKinnon 2018; Scheel et al. 2020; Chiengkul 2018). This report focuses on the logistical options that impact the distance that each unit of material is transported within the country, from the first point of production (or import) to the final point of consumption (or export). In effect, this distance considers the end-to-end domestic supply chain and is a function of the number and length of the links in this supply chain. Most products are channeled through supply chains comprising several stages of processing, storage, and handling, with each stage representing a separate node and link. The length of these links can be measured either as a straight line (geodesic) distance or the actual distance traveled across a transport network. In the case of a road network, goods often follow circuitous routes with multiple drop and collection points. The logistical options for managing freight transport demand involve altering these supply chain and vehicle-routing parameters rather than the total amount of goods in the economy that needs to be moved.

**Figure 2.2. Classification of the Methods of Freight Demand Management**

[Diagram illustrating the classification of methods for freight demand management]

**Source:** Original figure produced for this publication
2. *Modal split* refers to how the transport of goods is distributed among different modes such as truck, rail, and inland waterway. Domestic freight transport modes have widely varying carbon intensity, expressed as grams carbon dioxide (gCO$_2$) emitted per tonne-kilometer (figure 2.3). The average carbon intensity of a country’s freight transport system depends, therefore, on the division of tonne-kilometers between modes (the freight modal split). Traditionally, policy makers’ main method of lowering logistics emissions has been to shift freight to cleaner, lower-carbon modes. This is reflected in the importance given to modal shift as a policy instrument for freight transport decarbonization (Gota 2016) in governments’ NDCs. Despite the governmental push for a modal shift towards lower carbon transport modes, in many countries in Europe, freight traffic has moved away from rail and waterway networks with low connectivity towards road networks that are better connected to production and warehousing facilities (Kaack et al. 2018). Furthermore, access to rail and waterborne services has become increasingly dependent on road feeder movements, making door-to-door freight movements ‘intermodal.’ It is generally recognized that the effectiveness of freight modal shift as a decarbonization option will depend on the wider industry adoption of intermodality for appropriate classes of commodity. This concept is central to the Sustainable and Smart Mobility strategy of the European Commission (2020), which aims to double rail freight tonne-kilometers by 2050.

3. *Vehicle utilization* or loading relates to the weight or volume of goods carried per vehicle. Optimizing vehicle utilization lowers the ratio of vehicle-kilometers to tonne (or cubic-meter) kilometers, reducing the amount of traffic required to move a quantity of freight. This applies to all transport modes; however, truck loading has received the most attention because road is the dominant mode of domestic transport and the one with the highest carbon intensity. Most published data relates to trucks that run empty and there is limited data on the partial loading of laden vehicles in terms of weight, floor area, and cube utilization (McKinnon 2021). Reductions in empty running and the underloading of laden vehicles can substantially lessen the carbon intensity of road freight operations. The aim is to maximize loading within legal limits and curb the overloading of vehicles, a practice that not only decreases fuel and carbon efficiency but also results in a wider carbon penalty due to the long-term wear and tear of the road infrastructure. The optimal use of vehicle capacity can lead to cost and carbon savings and should be prioritized for both business and environmental reasons.
Energy efficiency is typically defined as the liters of fuel consumed per 100 kilometers traveled. It can be increased through various technical, operational, and behavioral methods that are mutually beneficial and, in many cases, implementable in the short to medium term. Efforts to improve the energy efficiency of freight transport have low or negative carbon mitigation costs. Although the commercial benefits of fuel saving initiatives are immediately apparent, their adoption often requires government interventions such as a mix of fiscal and regulatory incentives and penalties as well as advisory schemes. Over the last decade, governments around the world have given fuel efficiency initiatives regulatory impetus by introducing tightened fuel economy standards for new trucks. The IEA (2022) estimates that in 2021, 75 percent of new trucks sales were in countries with fuel economy standards for trucks, but many of the vehicles sold in LMICs were second-hand vehicles. Nevertheless, the owners of existing vehicles are retrofitting them with a range of fuel- and CO$_2$-saving devices. These technical enhancements are supplemented by behavioral measures, most notably ‘eco-driver’ training and monitoring, and operational changes such as the rescheduling of deliveries to off-peak periods. Energy efficiency improvements in every sector carry the risk of rebounding to some degree and eroding energy savings; however, in most observed instances in the road freight sector, the erosion has been modest (e.g., Llorca and Jamasb 2017).

Carbon content of the energy source or fuel is critical because different energy sources have different lifecycle and tailpipe GHG emissions and deep decarbonization of the freight and logistics sector will require a switch to lower-carbon energy sources. The first four decarbonization levers combined have the potential to reduce the carbon intensity of logistics by a large margin over the next 5 to 10 years. To drive logistics’ CO$_2$ emissions down to zero in the longer term, it will have to be repowered with zero-carbon energy.
In the case of domestic, land-based logistics, zero-carbon energy is most likely to be achieved by electrification if grid electricity can be ‘defossilized’ over the next few decades. In this scenario, it will be possible to achieve carbon neutral warehousing and terminal operations, especially since their decarbonization can be aided by the onsite generation of renewable energy. In countries with extensively electrified rail networks, rail freight services will benefit from the direct transmission of low- or zero-carbon electricity. Similar infrastructural electrification is being trialed on road corridors in Germany and Sweden, though in most countries, particularly the smaller ones, most trucks are expected to be powered by batteries, and possibly with the use of hydrogen fuel cells as range extenders. Batteries and hydrogen fuel cells are also being piloted in locomotives hauling freight trains on non-electrified tracks. Biofuels such as biomethane and hydrotreated vegetable oil (HVO) produced from sustainable feedstocks can also significantly reduce GHGs on a well-to-wheel basis. As sustainable supplies of the necessary feedstock are limited, these biofuel alternatives will mainly play a transitional role in the decarbonization of long-haul trucking operations. Currently in Europe and North America, there is a lack of consensus over the longer-term measures for the decarbonization of heavy-goods vehicles, with vehicle manufacturers, logistics providers, shippers, and public policy-makers differing in their energy and technological preferences. The various options are compared against a range of criteria in the publications of McKinsey & Company (2018), ETC (2019), PwC (2020), Shell (2020) and others.

The key takeaways from the review of the five-lever framework:

- logistics can be decarbonized in many ways and most measures open to public policy intervention are mutually reinforcing.
- logistics decarbonization measures vary widely in their ease and rate of implementation and carbon mitigation costs.
- managerial, operational, and behavioral measures have to be prioritized in the near term while waiting for longer-term transformations in vehicle technology, supply chains, as well as transport and energy infrastructure.
- the application of the various decarbonization levers by governments and businesses is still at a relatively early stage and will have to accelerate over the next few years if the 2030 carbon reduction targets for transport are to be achieved.
- HICs have sufficient experience in the deployment of logistics decarbonization measures and policy instruments to offer guidance to the governments of LMICs.

The next four chapters examine the challenges of applying the first four decarbonization levers in LMICs. Each chapter will follow a standard format that covers the:

- current situation and trends
- inhibiting factors
- potential enablers
- public policy instruments

General observations will be made under these four headings, with examples to show how they can vary between LMICs. Chapter 7 examines the switch to low carbon energy. As this measure is at an earlier stage of implementation, this chapter is differently structured, distinguishing short- or medium-term and long-term perspectives.
References


Activity: Reducing the Demand for Freight Transport or Moderating its Growth

Most low- and middle-income countries are at a stage in their economic development where managing growth in freight demand could come with significant costs to GDP.
3. Activity: Reducing the Demand for Freight Transport or Moderating its Growth

Current Situation and Trends

Most LMICs are at a stage in their economic development when freight transport intensity is rising, in some cases, steeply. There is a long-term inverse relationship between average per capita income and freight tonne-kilometer GDP elasticity (ITF 2017), as shown in figure 3.1. This is mainly a function of increasing material consumption and supply chain restructuring. On average, the material footprint (tonnes per capita) of nations increases by an average of 6 percent for every 10 percent increase in GDP (Wiedmann et al. 2015). As illustrated in figure 3.2, between 2000 and 2017 the material footprint in low-income countries increased slightly above the global average while in middle-income countries, it grew two to three times faster than the global figure (UN Stats 2019). This sharply increases the quantity of goods produced and consumed.

These goods are also being transported over longer distances. The economic growth of a country is strongly influenced by a series of measures that increase both the number of links in domestic supply chains (the ‘handling factor’) and their average length (Piecyk and McKinnon, 2010). The handling factor is driven by the increased processing of primary products, wider industrialization, and the evolution of wholesale and retailing systems. Meanwhile, the average length of haul is extended by the wider sourcing and distribution of products and the spatial concentration of production, storage, and terminal capacity. These trends are facilitated by the upgrading of transport infrastructure—which, in LMICs—is at a stage when the resulting improvements in accessibility and connectivity are often large and can induce substantial logistical restructuring.

Figure 3.1. Relationship between GDP per Capita and Freight-GDP Elasticity

In many HICs, these freight traffic-generating trends have weakened and therefore, the tonne-kilometer and GDP growth trends appear to have decoupled. The reduced rate of freight traffic growth is partly a result of centralization and wider sourcing nearing their maximum spatial extent and the service sector’s rising contribution to the GDP (McKinnon 2007). In several European countries, the decoupling is pronounced (Alises and Vassallo 2015), and in China there is evidence of some decoupling of freight and GDP growth trends (Zhu, Wu, and Gao 2020).

These trends are likely to find only gradual traction in most LMICs. Forecasts suggest that, on a business-as-usual basis, the ratio of freight generation to GDP per capita in LMICs is expected to remain high (ITF 2019) as governments are concerned that depressing this ratio will inhibit future economic growth. There is evidence that the spatial restructuring of production and logistics systems, usually in response to major infrastructural upgrades, is intrinsic to the development process. Constraining it would deny businesses the benefits of market expansion, scale economies, inventory centralization, and industrial agglomeration. Although the carbon mitigation cost of maintaining the ratio is high, it can be avoided by decoupling freight-related CO$_2$ emissions from GDP growth in other ways. Importantly, the offshoring of manufacturing to lower labor cost countries also transfers the responsibility of cutting logistics-related emissions to them, causing a global redistribution of these emissions to the benefit of HICs and the detriment of LMICs (McKinnon 2014).
Inhibiting Factors

The main inhibitor of any action on decarbonization via the *activity* lever is the government’s reluctance to restrain processes closely linked to economic growth. Demand management is now widely advocated and accepted as a legitimate and effective means of cutting carbon emissions from personal travel but generally dismissed as a policy option for decarbonizing freight, particularly in LMICs. For example, in its 2011 transport white paper, the European Commission (2011) rejected the case for “curbing mobility,” referring partly to freight movement. In the absence of policy measures to restrain the growth of goods traffic, LMICs are likely to follow a logistics development path similar to HICs’, locking themselves into transport-intensive production and warehousing systems that will be difficult, costly, and slow to decarbonize. It is highly unlikely that the spatial development of logistics systems in LMICs will deviate from this path to constrain their longer-term carbon intensity.

The geographical concentration of inventory appears to be a natural corollary of improvements in transport infrastructure. By allowing companies to serve wider areas more quickly, reliably, and cost effectively from more centralized facilities, infrastructural upgrades enable companies to make the most of the ’square root law of inventory’ (Zinn et al. 1989; Oeser and Romano 2016). They do this by economizing on the amount of safety stock—and hence working capital—required to maintain a certain customer service level. Additional benefits accrue from economies of scale in warehousing up to the point when the optimum size is reached for particular types of building and storage system (Pfohl, Zollner and Weber 1992; Baumgartner, Fuetterer and Thonemann 2012).

Concentrating inventory and related materials-handling activities in centralized facilities reduces the carbon intensity of warehousing operations by cutting energy consumption per unit of throughput (Baker and Marchant 2015). As warehousing typically represents only 11 percent to 13 percent of total logistics CO$_2$ emissions (McKinnon 2018), these savings in building-related emissions are offset by the additional transport emissions generated by the delivery of goods over longer distances from fewer locations. It would require the imposition of a high carbon price to negate the logistical efficiency improvements that centralization offers. Few, if any, LMIC governments would wish to deny businesses these efficiency gains, especially as they have been fundamental to the development of macrologistics in HICs.
Potential Enablers

There are four ways in which the carbon penalty associated with inventory centralization can be abated at a lower mitigation cost:

1. **Virtual inventory management:** This is not a new concept nor applicable to all businesses, but under the right circumstances, can ease the pressure on companies to physically centralize their inventory. It involves the use of IT to manage inventory centrally even when it is physically dispersed in several locations (Christopher 2016). This allows companies to enjoy the benefit of the square root law without generating large amounts of additional freight movement.

2. **Dispersed load disaggregation:** Many warehouses in least developed countries (LDCs) are used to store inventory and serve as ‘break-bulk’ locations where large loads are disaggregated into smaller consignments for local delivery. These activities can be geographically decoupled, allowing companies to centralize the inventory while retaining a dispersed network of break-bulk points for both economic and environmental reasons. These localized break-bulk operations can be performed in dedicated or shared facilities and can involve varying levels of unitized loading.

3. **Freight modal shift:** Inventory centralization expands service areas, increasing the average length of freight hauls and making them more amenable to a modal shift to rail or waterborne services. Centralization makes the logistical system more transport intensive, but modal shift substantially reduces its carbon intensity (Kohn and Huge-Brodin 2008). The probability of this modal shift occurring increases substantially when centralized warehouses are encouraged to locate in rail- and water-accessible locations.

4. **Concentration of logistical activity in freight villages:** Clustering interrelated freight-generating activities in ‘freight villages’ can eliminate intermediate supply chain links and the associated freight movement, yielding sustainability benefits (Baydar, Süral and Çelik 2017). Such industrial or logistical complexes have long been seen as offering economic agglomeration benefits and serving as the nuclei for regional economic development (Sheffi 2012). They can also result in significant freight-related carbon savings where there is close process integration among adjacent premises. These savings can be augmented if the freight village has direct rail and/or waterway connections and the potential to generate full train or barge loads of freight.

Another enabler, which is at a relatively early stage in its development and adoption in some LMICs, is computerized vehicle routing and scheduling (CVRS). More efficient routing, particularly on multiple collection and delivery rounds, can reduce the distances freight consignments travel between a fixed set of origins and destinations. The lower density of road networks in LMICs limits routing options but also increases the distance penalty when vehicles deviate from the optimal route. Increasing the uptake of CVRS and the functionality of the packages used by road carriers in LMICs can reduce freight tonne-kilometers per tonne of product moved. However, minimizing distance traveled does not necessarily translate to minimized transport CO₂ emissions because of variations in road quality and traffic conditions across the road network. Advanced CVRS systems can be set to minimize fuel consumption and CO₂ emissions even though this does not necessarily minimize vehicle- or tonne-kilometers (Bektas and Laporte 2011).
Public Policy Interventions

In some HICs, transport policies have been explicitly designed to suppress freight demand. As part of a ‘transport prevention’ scheme, the Dutch government provided companies with advice on how to rationalize their production and distribution operations. The European Union’s (EU’s) Marco Polo II program went further in offering financial support for “traffic avoidance actions” that made “the whole supply chain more efficient” by “cutting the journey distance” and “reducing the amount of waste,” among other things. These “efficiency gains,” however, were not to be “at the expense of jobs or total output.” Only four actions were funded under the Marco Polo II program, at a total cost of €13.3 million, and three of them delivered on only 20 percent to 40 percent of their objectives (CINEA 2020). Traffic avoidance yielded 12 percent of the program’s savings in “external costs avoided,” while modal shift yielded the remaining 88 percent. The program was discontinued in 2013 and no further traffic avoidance initiatives have since been adopted. This European case study has created apprehension about the effectiveness of policies explicitly designed to curb freight traffic growth.

Nevertheless, LMICs can use the following four policy instruments to help reduce the transport carbon penalty associated with centralization:

1. **Advisory schemes:** Managers need significant technical knowledge of the design and operation of logistics systems to assess the benefits and costs of the four enablers outlined earlier to their business. Governments can help provide the necessary guidance, possibly by working with academic and professional institutions and providing use-cases of successful implementations.

2. **Land-use planning:** Land use planning and regulations play a critical role in clustering logistics properties into freight villages. For example, governments could consider making rail access a condition for the award of planning permission for a freight facility and aiding the development of localized networks of break-bulk facilities (McKinnon 2009). Monios (2015) uses an Italian example to show how an intermodal freight village can become a key element in a regional development strategy.
3. **Financial policies:** A combination of economic incentives and taxes can be used to encourage:

- a shift to lower carbon transport modes on trunk hauls from more centralized warehouses
- the co-location of industrial or logistical premises on strategic, rail-connected sites

4. **Infrastructure provision:** Road infrastructure upgrades are responsible for much of the redistribution of logistical activity into more carbon-intensive systems; governments can strategically invest in road infrastructure that encourages convergence on freight villages and promote a modal shift to rail or water.

Land use planning and regulations play a critical role in clustering logistics properties into freight villages. For example, governments could consider making rail access a condition for the award of planning permission for a freight facility and aiding the development of localized networks of break-bulk facilities.

This discussion of freight demand management options has highlighted the close interconnection between the first decarbonization lever and the second, which aims to transfer as much freight as possible to lower-carbon transport modes, mainly rail.
References


Modal Split: Shifting Freight to Lower-carbon Transport Modes

Intermodal services and upgraded infrastructure for freight transport can lower carbon emissions while increasing market opportunities.
4. Modal Split: Shifting Freight to Lower-carbon Transport Modes

Current Situation and Trends

In the 1950s, “up to 90 percent of all freight in Africa, Latin America, and South Asia was carried by rail;” however, this proportion has fallen to under 30 percent and in many countries, is less than 10 percent in terms of tonne-kilometers (Aritua 2019). In most LMICs, the vast majority of domestic freight moves by road and this share has been increasing (Kaack et al. 2018). The data for LMIC freight modal split is inadequate and prevents comprehensive analysis of the changing freight quantity by road, rail, and waterborne services. Much of the available data relates to the road–rail split, except in countries such as China and Indonesia where waterborne transport accounts for a large share of tonne-kilometers. Figure 4.1 shows how the proportion of tonne-kilometers moved by rail varies widely by country, but in most cases, it has been shrinking. In some countries, most notably India, the total amount of freight movement by rail has increased, but since it has grown slower than the overall freight market, there has been a decline in rail’s share (Gota and Qamar 2021). For modal shift to contribute to the decarbonization of freight transport, low-carbon modes must increase the volume of freight they carry.

Countries are seen to be “increasingly including freight rail on the critical path to decarbonization” (Aritua 2019). In the latest round of NDCs submitted to the UNFCC, however, only six countries, Argentina, Cambodia, Colombia, Mongolia, South Korea, and Thailand, explicitly mention freight modal shift as a decarbonization measure. Other countries have declared modal shift objectives in other documentation (ADB and SLOCAT 2021).

Figure 4.1. Rail Share of Domestic Freight Tonne-Kilometers, for Various Years

Source: ADB and SLOCAT 2021.

Note: The blue column indicates earlier year percentage and orange column indicates the percentage for the later year.
Inhibiting Factors

In many LMICs, the potential for using modal shift as a decarbonization lever is constrained by infrastructure and geography. Some completely lack rail and/or inland waterway networks. Constructing such networks from the ground up would be expensive, particularly in places with difficult terrains, and would carry a heavy carbon penalty. Countries with railways often have low-density networks offering freight users limited connectivity. Across Sub-Saharan Africa and South Asia, the average track densities of 2.76 kilometers per 1,000 square kilometers and 7.8 kilometers per 1,000 square kilometers, respectively, are much lower than Europe’s:

- Germany: 107.5 kilometers per 1,000 square kilometers
- the United Kingdom: 67.1 kilometers per 1,000 square kilometers
- France: 49.8 kilometers per 1,000 square kilometers

Landlocked countries also lack access to coastal shipping. Some have legacy rail or inland waterway networks built to extract raw materials and/or serve military purposes but are poorly configured to meet current national logistical requirements. The density of rail and waterway networks is typically lower than the road networks’, making them less accessible and causing freight to move circuitously between origins and destinations. One of the reasons for this is the imbalanced investment in freight transport infrastructure, which has seen significant build-out of primary road networks with relatively marginal investments in heavy rail infrastructure (ADB and SLOCAT 2021). In many smaller LMICs, the average length of haul for domestic freight is too short to make full use of railways’ competitive advantages for longer distance movement. The integration of national railway networks across regional blocs can extend this average haul length to a rail-competitive level (ASEAN 2015); however, this requires:

- a common track gauge
- more efficient staffing
- management of transshipment and international border crossing facilities
- a degree of interoperability between national rail systems that is often lacking

Rail’s low and diminishing market share can also be attributed to the following factors, which are common to most LMICs:

1. **Underinvestment in rail track, rolling stock, and intermodal terminals**: Rail infrastructure is often poorly maintained and the old and inefficient rolling stock impairs the speed and reliability of freight services. A lack of intermodal terminals and sidings results in relatively few points at which freight traffic can enter or leave the network. Road feeder movements are therefore relatively long, weakening the competitiveness of intermodal services. Infrastructural and rolling-stock constraints also limit carrying capacity at both wagon and train levels, preventing railways in LMICs from enjoying the economies of scale they have in Europe and North America. In Europe, for example, wagon axle weights in excess of 25 tonnes are standard, whereas in the rail networks of Sub-Saharan Africa, the maximum weight is 15 tonnes (Blumenfeld et al. 2019). Very little rail track in Sub-Saharan Africa, South Asia, and South America is electrified (IEA and UIC 2019), depriving operators and clients of significant productivity, energy efficiency, and carbon intensity
benefits. In contrast, India is on track to completely electrify its rail network over the next few years (Majumder, 2022).

2. Upgrading of the road network: As road networks have received much more investment than other networks, the speed and reliability of trucking has improved relative to rail and waterborne freight services. Upgraded roads can also accommodate larger and heavier trucks, reducing road freight costs per tonne-kilometer relative to those of the other modes.\textsuperscript{4}

3. Realignment of industrial and logistical activity with the road network: As freight has switched to road due to service improvements and cost reductions, the highway network has been exerting greater locational pull on new commercial and industrial property development (He et al. 2018). As discussed earlier, this spatial redistribution of industrial and warehouse space causes "logistical lock-in" to high road dependency.

4. Poor management of rail freight services: The management of rail freight services in LMICs has been widely criticized for not being sufficiently market focused and responsive to the changing logistical requirements of clients. As Aritua (2019) explains, “In many emerging economies, rail companies have traditionally had captive markets in mining and movement of bulk products owned by the public sector. With a captive market and less customer-centric orientation, rail organizations focused on building new infrastructure and paid less attention to understanding the market.”

5. Increased demand for faster, more flexible transport services: As economies develop, higher value-adding activities will increase their share of GDP. These activities demand faster and more flexible delivery services, which in many countries, only road carriers can provide. Higher value products, subject to strong just-in-time delivery pressures that rail and waterway typically struggle to meet, increase their share of total national freight tonnage.

6. Non-compliance with trucking regulations: Road's competitive advantage is illegally enhanced by the infringement of regulations on overloading, vehicle maintenance, licensing, drivers' hours, and speeding. Such non-compliance is common in many LMICs partly because regulations are under-enforced and penalties are low.

7. Low traffic density: Due to the limited usage of rail networks, average traffic densities in LMICs can be much smaller than in Europe, North America, and China. As a result, productivity is relatively less, while unit costs are high, and operators can get trapped in a cycle of rising unit costs and falling demand.

8. Decline in fossil fuel traffic: In 2016, fossil fuel represented 36 percent of the total tonnage of freight moved worldwide by rail (IEA and UIC 2019). In India, coal alone accounted for 41 percent of rail tonnage and 43 percent of rail freight revenue in 2016-17 (Mishra 2018). As renewables replace fossil fuel, railways will lose much of this core traffic, which, in some LMICs, will be difficult to replace with higher-value, lower-density, and more time-sensitive manufactured goods.

\textsuperscript{4} Relaxing limits on truck weights and dimensions can reduce freight emissions overall despite some modal shift from rail to road. This is discussed more fully in the next section.
The shift to lower-carbon modalities will also be affected by region- or country-specific factors. For example, in states where central economic planning previously allocated a substantial amount of freight to railways, as in Central Asia, the move to a more liberalized freight market has eroded rail's market share. Some countries have also prioritized the use of the rail network by passengers, allocating passenger trains greater track access and resources. In India, for example, passenger rail services were cross subsidised with rail freight revenue for many years.

**Potential Enablers**

A number of developments can reverse the long-term downward trend in the market share of low-carbon freight modes. They can be divided into four categories:

1. **Market-related:** Many companies, particularly multinationals, are attaching greater weight to carbon intensity in their choice of freight transport mode. In a recent European survey, 90 senior logistics executives identified freight modal shift as the most cost-effective method of decarbonising logistics (McKinnon and Petersen 2021). Steered by government-set targets for climate action, these responses reflect a wider corporate commitment to decarbonization and growing recognition that switching freight to rail or waterborne services is an effective means of cutting emissions. Global corporations that have experience using these modes in Europe and North America are more likely to explore opportunities to switch to them in LMICs. They can be assisted in this endeavor by large logistics providers and freight forwarders that have a presence in these countries and are experienced in using alternative modes.

2. **Managerial:** To diversify their commodity mix beyond primary products and compete for traffic outside their traditional captive markets, rail freight operators must become more market-oriented and sensitive to the logistical requirements of their clients (World Bank 2017; Aritua 2019). Railway companies such as Deutsche Bahn (DB) in Germany and Société Nationale des Chemins de fer Français (SNCF) in France have helped build this logistical competence by acquiring large logistics providers such as Schenker and Geodis, respectively. Railway companies can also partner with logistics providers, leverage their skills in marketing, and use them as an operational interface with customers. This could involve the redefinition of a rail freight business’ role, allowing it to concentrate on trunk haulage and leave its integration with clients’ logistics systems and supply chains to other providers.
Such a strategy is particularly applicable in the case of intermodal services where the rail line-haul must be supported by a dense network of road feeder services, which are typically operated by other carriers. LMICs can tap into a wealth of experience in the development of intermodal services in Europe and North America and try to replicate their growth of intermodal rail volumes over the past decade. It is predicted that the global demand for intermodal freight volumes will grow by around 8 percent per annum between 2021 and 2026 (Research and Markets 2022). While much of this growth will be in North America and Europe, LMICs can also benefit from this trend. Research in Brazil, for example, has shown how the use of road-rail intermodal services can cut freight transport emissions by 77 percent (Torres de Miranda Pintoa et al. 2018).

Logistical innovations such as ‘synchronomodality’ are also transferable to LMICs. One form of ‘synchronized intermodality,’ originally developed in the Netherlands, aims to coordinate the scheduling of freight movements by different modes to minimize delays at modal interchange points and thereby keep intermodal transit times competitive with those of trucking (Tavassgy et al. 2015). The concept can also be adopted by shippers, where they incorporate the choice of freight transport mode into production planning and inventory management. For some categories of inventory, this can significantly cut both logistics costs and CO₂ emissions (Dong et al. 2018).

3. **Infrastructural:** In some LMICs, investment in rail infrastructure is significantly increasing. A global analysis of planned investment in ‘heavy-haul lines’ dedicated to freight traffic found that 56 percent of this investment targeted African countries (Grob and Craven 2018). New systems for financing rail improvements have been devised (AfDB 2015) and rail modernization programs are now progressing well in some countries. Additionally, the development of new high-speed rail (HSR) lines for passenger traffic can release extra capacity for freight trains on existing lines, as demonstrated in China; however, to date, HSR has shown limited development in LMICs (EESI 2018). Regional modal shift initiatives with a strong infrastructural emphasis, such as those of the Central and Northern Corridors in East Africa (Northern Corridor Transit and Transport Coordination Authority 2017) and outlined in the ASEAN Transport Strategic Plan (ASEAN 2015), are helping the railways make the most of their long-haul competitive advantage while encouraging intraregional trade.

Electrification of the rail network in some LMICs may confer an environmental advantage as electricity is decarbonized, electrical grid capacity is expanded and rail traction switched from diesel to electric locomotives. Significant rail electrification is underway in several Asian countries, most notably India. Only a few railway lines in South America and Sub-Saharan Africa are electrified and this situation seems unlikely to change soon (see chapter 7 for further detail).

4. **Technological:** Rail freight operations in HICs benefit from transferable technical innovations, many of them associated with intermodality and digitalization. There are now new intermodal handling systems that can cut the cost and time taken to transship/transload unitized loads, while new track-and-trace systems are giving shippers much-needed visibility into the movement of their consignments through rail and intermodal networks.
Public Policy Interventions

Governments around the world have been trying to promote a shift of freight from road to rail and water for many decades and, in the process, have deployed a broad array of policy instruments. European countries and the EU have gained a wealth of experience in developing, applying, and evaluating freight modal shift policies over many years and therefore, can be an important source of advice for LMICs. A recent study reviewed a total of 93 modal shift initiatives implemented in Europe, 20 of which were subsequently evaluated (Takman and Gonzales-Aregali 2021). The authors divide the initiatives into three categories: economic, administrative, and informational. Most of the evaluations have been conducted on economic measures, involving the award of grants and subsidies and assessing whether they represented value for money. Differences in evaluation methodologies make it difficult to compare the performance of the various measures and often, the objectives of the measures are defined in broad and general terms that make evaluation inevitably subjective. Overall, financial incentives had more positive outcomes than other measures and the policy impact was greater on modal shift to rail than to waterborne services. It is worth noting, however, that many years of public intervention in the European freight market have failed to redress the road–rail imbalance. A recent report by ADB and SLOCAT (2021) arrived at a similar conclusion for modal shift initiatives implemented by several Asian countries. Despite the limited success of these efforts, railways in a few HICs such as Australia, Japan, and the United States have been able to increase their share of the freight market, with varying degrees of government support (Kaack et al. 2018).

LMICs can learn from this experience, try to adapt the more successful initiatives to local conditions, and explore other options not yet trialed elsewhere. Many LMICs are subject to physical constraints similar to their European counterparts in having short average haul lengths and high ratios of road to rail network density. On the other hand, being at an earlier stage in the development of their economies and their transport networks, the degree of logistical lock-in to road-based, just-in-time replenishment can be lower and the commodity mix more suited to rail haulage.

Ideally, public policy on modal shift needs to:

- take a holistic view of the freight market, making the lower-carbon modes more attractive, while also discouraging the use of road. This “simultaneously exerts pull and push pressures on companies’ modal split decisions” (Gota 2018). Some policies are inherently cross-modal, such as the removal of fuel subsidies/increasing fuel taxes, which favor the more energy-efficient and lower-carbon modes. Full internalization of the external costs of freight transport has long been advocated as a means of achieving an environmentally sustainable modal split (UIC 2018). In LMICs, where the level of non-carbon externalities such as air pollution and accidents are relatively high, this general from of internalisation may be more appropriate than carbon taxation or pricing. Although much debated in Europe and North America, there has not been a full internalization of the environmental costs of freight transport or carbon pricing of domestic freight transport. Therefore, there have been no precedents for the governments of LMICs to follow. If these are implemented, they will support all five decarbonization levers and not just modal shift.

5 In June 2022, the European Parliament approved the implementation of an Emissions Trading Scheme (ETS II) for road freight operations in the EU.
• **be targeted by sector, commodity, or corridor.** Not all segments of the freight market are modally contestable. It is important to identify the market segments that low carbon modes can serve most effectively and competitively and concentrate efforts and investment there. This segmentation of the market can be geographical, focusing on freight corridors where substantial volumes of commodities amenable to a switch to rail or water are moved, preferably over longer distances (Havenga, Simpson, and de Bod 2014). Currently, numerous examples of corridor-based modal split initiatives exist in HICs and LMICs. As part of its TEN-T Connecting Europe program, the European Commission (2021) is channeling much of its modal shift effort into a network of nine intermodal corridors that crisscross the continent. Similar freight corridor strategies have been implemented in Mexico (Martner 2016), East Africa (Northern Corridor Transit and Transport Co-ordination Authority 2017), and the Asia-Pacific region (ADB 2018; UNESCAP 2017). The development of six dedicated freight corridors (DFCs) is likely to be crucial to the decarbonization of the Indian freight transport system; cumulative CO$_2$ reductions from these DFCs between 2016 and 2040 could be as much as 77 percent on a business-as-usual basis and 93 percent within a low-carbon scenario (Pangotra and Shunkla 2012). Deployment of a series of enablers can help maximize the carbon savings accruing from these DFCs (Shankar, Pathak, and Choudhary 2019). Geographically, concentrating investment and cross-border facilitation of rail freight movement along international corridors can also reinforce domestic freight modal shift efforts (UNESCAP 2019). As most rail and waterborne freight in LMICs either originates or arrives at a major port, the development of intermodal corridors can help ensure these alternative modes capture a significant share of hinterland transport (Acciaro and McKinnon 2013).

• **be multifaceted, combining several policy instruments in a coordinated action.** For this purpose, the three-fold classification of Takman and Gonçalves-Aregali (2021) can be extended to six categories:

  • **Taxation:** In addition to the fiscal options mentioned earlier, fuel and infrastructure taxes and charges can be varied by mode. Full recovery of the freight share of the infrastructural cost by the respective modes would, in some countries, place a heavier tax burden on trucking operations.

  • **Financial incentives:** Operators and/or users of low-carbon freight services should have access to financial incentives, generally where it can be demonstrated that modal shift will yield a net environmental benefit. These can take the form of subsidies for users of rail or waterborne services—as in the case of the United Kingdom Mode Shift Revenue Support scheme (UK DfT 2021)—or grants for the installation of infrastructure such as rail sidings at industrial or logistics premises or purchase of intermodal equipment.

  • **Regulation:** For many decades, quantitative licensing was used to constrain the capacity, operations, and pricing of road haulage in HICs and LMICs, partly in an effort to protect the railways (McKinnon 1998). In most countries, it failed to preserve rail’s market share and was abandoned between 1970 and the early 2000s. Outside centrally planned economies, little interest exists in reversing freight market liberalization to get more freight onto rail or waterway networks. However, a strong case can be made for the much tighter enforcement of qualitative regulations on trucking, particularly in LMICs where rule infringements are common and create unfair competition both for alternative modes and within the road freight sector (Bove et al. 2018).
• **Infrastructure**: The upgrading of rail and waterway infrastructure is critical in many LMICs as its standard typically falls well short of that in HICs and is currently a major inhibitor of freight modal shift. In addition to the usual investment in track and signaling, much of the infrastructural spend needs to be channeled towards intermodal terminals, both inland and at ports.

• **Land-use planning**: As discussed earlier, planning approval for new industrial and warehouse development can be made conditional on having good road and/or waterway access. Such a planning condition can be reserved for large-scale, possibly multiple-occupant, developments likely to generate full train or barge loads of freight, rather than small numbers of freight units that can be difficult and costly to marshal. Planning authorities can also facilitate the location of intermodal terminals at strategic locations so they can be used as hubs for related logistical activity.

• **Advisory services**: Government agencies can supplement the marketing activities of rail and waterway freight operators by providing businesses with more general advice on the modal choice decision. The UK government, for example, funded a Mode Shift Centre “to demystify rail and water freight for potential users.” It explained what modal shift entails and provided case studies of companies that had successfully increased their use of rail or waterborne services. Such schemes can help overcome managers’ natural reluctance to risk the disruption of a well-established road-based logistics operation.

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To diversify their commodity mix beyond primary products and compete for traffic outside their traditional captive markets, rail freight operators must become more market-oriented and sensitive to the logistical requirements of their clients.
The Decarbonization of Logistics in Lower Income Countries

References


Vehicle Utilization: Optimizing Use of Freight Capacity

Low- and middle-income countries face the twin challenges of freight overloading and underloading, which translate to higher carbon emissions and other externalities.
5. Vehicle Utilization: Optimizing Use of Freight Capacity

Current Situation and Trends

This freight decarbonization lever should be applied to all transport modes but is generally only studied and discussed with respect to road freight operation. This is because “almost all the available statistics relate to road freight movements. This has made the efficiency of trucking operations the focus of research and the target for criticism…freight operators in the rail, maritime, and aviation sectors escape similar scrutiny and censure, mainly because there is little hard evidence in the public domain of the underutilization of their capacity.” (McKinnon 2021) Although the discussion of capacity utilization in this chapter relates mainly to trucking, many of the improvement measures it outlines could have a cross-modal impact on carbon emissions.

Numerous studies, mainly in Europe and North America, have shown that the average utilization of truck capacity is relatively low and raising it can be both a quick and a cost-effective means of reducing CO\textsubscript{2} emissions (McKinnon 2018; 2021). Available data for HICs suggests that between 20 percent and 30 percent of truck-kilometers are run empty, while for LMICs, the average is often much higher, exceeding 40 percent in some cases (IDB 2015).

This discrepancy can be attributed to several factors, including:

- the higher proportion of road freight operations carried out on an own-account basis (World Bank and IRU 2016). Large firms that are unable to find ‘hire-and-reward’ services of adequate quality in some countries acquire their own fleets, but then find it difficult to, or are legally prohibited from, finding backloads for their vehicles
- the difficulty that small “hire and reward” carriers experience in getting backloads in freight markets, lacking online and offline load matching services that are well established in HICs
- more pronounced freight traffic imbalances in some LMICs, particularly in the port hinterlands of countries with dominant trade flows in one direction
- the unreliability of transit times, often caused by poor and congested infrastructure, which discourages carriers from searching and waiting for potential backloads

Empty running is only a part of the problem. There is also extensive underloadning of laden vehicles in both HICs and LMICs. Despite the inadequate official statistics to monitor this, it is estimated that in Europe and the United States, as much as 40 percent of road freight capacity is underutilized (Jentzsch et al. 2018). The truck occupancy rate in Brazil averages only approximately 47 percent (Soliani 2021). In LMICs the problem can be as much of overloading as underloading. Available statistics confirm the infringement of loading regulations in LMICs is well above the European level. In Indonesia, where it is particularly high at 45 percent, research has revealed a linear relationship between the degree of overloading and CO\textsubscript{2} emissions (Wahyudi et al. 2013). Overloading not only impairs the truck’s fuel efficiency, it also damages the road pavement, making it uneven for all categories of traffic and reducing their average fuel efficiency.
Inhibiting Factors

An analysis of the underloading of trucks in Europe has identified 11 reasons for underloading (McKinnon 2021). Figure 5.1 classifies them into five general categories—regulatory, market-related, interfunctional, infrastructural, and equipment-related—and illustrates how constraints can intersect. It depicts the complexity of the underloading problem and challenges the view that excess capacity in road haulage is simply the result of mismanagement on the part of either shippers or carriers. Shippers often rationally and deliberately trade-off lower vehicle utilization and higher transport costs for lower inventory costs and higher levels of customer service. In responding to the shippers’ logistical requirements, carriers have little flexibility to structure their operations in a way that would raise load factors. In transport terms, this may be portrayed as a market failure, but it can optimize logistics operations in economic terms at a higher level. When environmental costs, particularly those associated with GHG emissions, are factored into the logistical trade-off analysis, the case for improved vehicle loading is significantly strengthened.

Figure 5.1. Factors Constraining the Utilization of Freight Vehicle Capacity

Source: Adapted from McKinnon (2021).
The 11 categories of loading constraint apply to LMICs as well as HICs, though to differing extents and, in some cases, in different ways:

1. **Demand fluctuations**: Road hauliers in LMICs are subject to high levels of demand variability as are their counterparts in HICs; however, given the state of their IT systems and the nature of their trading relationships, they often receive less advanced warning of forthcoming loads. When short-term demand is not only variable but also uncertain, it is hard to maintain high load factors (Sanchez-Rodrigues, Potter and Naim 2010).

2. **Limited knowledge of loading opportunities**: Online load matching is less advanced in LMICs than in Europe and North America, leaving carriers to rely heavily on more informal and less effective methods of finding loads.

3. **Health and safety regulations**: These regulations limit the height to which goods can be stacked in vehicles to ensure the welfare of employees and represent an acceptable trade-off between safety and efficiency. Such regulations are less strictly enforced in LMICs, allowing fuller loading, and often overloading, leading to unsafe operations.

4. **Vehicle size and weight restrictions**: These limits have been relaxed to permit greater load consolidation in many HICs and some LMICs such as Mexico and South Africa. Given variations in the density of different types of freight, some light, but voluminous loads ‘cube-out’—in other words, are constrained by the size of the truck. Meanwhile, denser loads ‘weigh-out’ and are constrained by the weight limit before filling the available space. Easing vehicle size and/or weight constraints can help carriers increase the proportion of loads simultaneously reaching volumetric and weight limits. The carrying capacity of trucks in many LMICs is relatively low. These smaller capacity vehicles, rather than being a cause of underloading, are responsible for much of the overloading. Most LMICs are at an earlier stage in the process of vehicle enlargement and can benefit from more economical and carbon-efficient high-capacity transport in the longer-term (ITF 2019).

5. **Unreliable delivery schedules**: There is considerable evidence that road freight schedules are less reliable in LMICs. This lowers the confidence of carriers to arrange backhauls and/or the consolidation of loads across more complex collection and delivery routes.

6. **Just-in-time delivery**: Much of the underutilization of freight capacity in HICs is attributed to the more frequent replenishment of supplies in smaller quantities—called just-in-time (JIT) scheduling—despite its role in optimizing logistics and production processes. As there are significant barriers to the successful implementation of JIT in LMICs (Eggahra et al. 2018), the adoption of JIT scheduling is likely to be lower in LMICs than in HICs, resulting in less tight order lead times. This means that the downward pressure of JIT on average load factors may not yet be as pronounced as in HICs. If LMICs follow the same logistics evolutionary path as HICs, this pressure is likely to intensify, though delivery systems can be reconfigured to mitigate the adverse effect of JIT on the utilization of vehicles and carbon efficiency of transport (Guiffrida, Lincecum and McQuade 2020).
7. **Goods handling requirements:** These requirements are largely related to the use of unitized handling equipment such as pallets, roll cages, and stillages, which facilitate the loading and unloading of vehicles and their mechanized movement and storage in warehouses and factories. Palletization of goods is extensively used in HICs, and less commonly in low-income countries. In using these handling units, companies usually trade-off vehicle fill with improved speed and efficiency of handling. The units themselves occupy space and the size and shape of the loads are often determined more by the dimensions of warehousing racking than the need to optimize the use of vehicle cube. The manual stacking (or ‘deadpiling’) of loose products in vehicles and containers is more labor intensive, but in lower-income countries, can be cheaper and can increase the fill rate. As materials handling becomes more unitized and mechanized in LMICs, vehicle cube utilization may decline.

8. **Limited storage capacity at facilities:** The size of a shipment can be constrained by the amount of storage space at delivery points such as factories, depots, farms, and shops, particularly where the storage space is in tanks or silos. It is not known to what extent such capacity restrictions impair the overall loading of vehicles in LMICs. Storage space is likely to be adjusted to the carrying capacity of the smaller 2-3 axle rigid trucks that are the ‘workhorse’ vehicles in many LMICs—in which case, as vehicle size increases, the storage capacity of the reception units will need to be enlarged.

9. **Incompatibility of vehicles and products:** This involves the matching of vehicles with products and the mixing of different commodities in the same load. The mature haulage markets of HICs have greater vehicle diversification and specialization, which complicates the matching process, particularly as the degree of temperature control in supply chains increases and as health and safety regulations become more rigorous. In addition, rules tend to be tighter on potential cross-contamination between products in mixed loads, depending on the nature of the packaging. If the trucking industries, logistics systems, and regulatory frameworks of LMICs evolve similarly to those of Europe and North America, these compatibility constraints on vehicle loading could become more restrictive.

10. **Geographical imbalances in freight flow:** As discussed earlier, these imbalances appear to be more acute in some LMICs, though they tend to be more a function of a country’s economic geography than its level of development. A more important and likely differentiator of HICs and LMICs is the extent to which carriers can use online freight exchanges and the long-established practice of triangulation, which exploits flow imbalances in different directions. In some LMICs, regulation of the road haulage market imposes restrictions on backhauling (Bove et al. 2018).

11. **Poor coordination of purchasing, sales, and logistics:** The siloed structure of many businesses discourages procurement and sales managers from liaising with their logistics colleagues on possible backloading opportunities emerging from external trading links. Many corporations in Europe and North America have moved to more cross-functional forms of management, which encourage such joint initiatives. It is not known to what extent businesses in LMICs are undergoing a similar managerial transformation and, if so, how it might impact vehicle utilization.

In HICs, weight limits are strictly enforced and overloading will incur severe penalties. As a result, overloading seldom features in logistics decarbonization discussions. In LMICs, on the other hand,
overloading is more pervasive and has a much greater impact on the average carbon intensity. Figure 5.2 maps the interrelationships between factors responsible for the high levels of overloading. These factors are divided into three categories: vehicle constraints, market pressures, and regulatory deficiencies. It can be argued that for commercial, infrastructural, and regulatory reasons, the carrying capacity of road freight vehicles in LMICs is much lower than the demand for road freight. Market pressures on shippers and carriers encourage them to violate the law, though they would be deterred from doing so if weight regulations were adequately policed. In practice, enforcement is lax in many LMICs and, where enforced, overloading fines are low enough to become a routine cost of business. There is a reluctance on the part of the authorities to risk undermining the financial viability of this critical sector. As a study of the road haulage market of West and Central Africa observed:

“Resistance to effective enforcement and incentives for non-compliance are strong, as most stakeholders have a vested interest in operating with overloads: truckers who receive extra income for extra tonnage, intermediary freight agents, given that their commission is calculated on tonnage, shippers because of savings on transport costs as well as law enforcement agents (including Customs) who can demand informal payments. Enforcement of axle load controls implies that the same amount of goods will be transported on more trucks, which may imply higher costs. In such environments, interest groups such as transporter associations may renegotiate drastic price hikes, as was the case in Niger. Further, there is the risk that trucking price increases will filter through the price system, to a point that they may meet resistance from the population.” – Bove et al. (2018)

Figure 5.2. Factors Influencing the Overloading of Trucks in LMICs

Source: Original figure produced for this publication.
Potential Enablers

The most promising of these enablers is likely to be digitalization. The development of online platforms for the buying and selling of vehicle capacity is helping to overcome one of the main barriers to vehicle backloading, that is, the lack of transparency in the road freight market. Such platforms have been well established in HICs for 15 years or more, though they are still relatively new to many LMICs. Their influence is growing rapidly, particularly in countries such as India, China, Indonesia, and Nigeria. The uptake of these online load matching services, facilitated by mobile communications, provides hauliers with details of available loads as well as access to a range of other freight management services, including route planning, track-and-trace, proof of delivery, and invoicing. All of this information can help them improve capacity utilization and overall productivity. This digitalization is driven primarily by commercial motives, though it also yields environmental co-benefits. In addition, it helps reform the complex freight market structures in countries such as India, allowing shippers to rationalize their procurement of haulage services. Within six years, Freight Tigers, India’s largest online freight platform, captured two percent to three percent of all road freight transactions in a $110 billion to $130 billion market. Similar platforms such as G7 in China, Waresix in Indonesia, and Kobo360 in Nigeria offer an ecosystem of online freight services and are rapidly expanding in their respective markets. In some cases, their endeavors were boosted by the need for carriers and shippers to control their freight networks more effectively during the COVID-19 pandemic.

The real cost of vehicle IT systems is sharply declining, making it more affordable to the small carriers that account for the vast majority of trucking operations in LMICs. The more intelligent the vehicle, the better the operator can leverage online platforms. Global positioning system (GPS) tracking also increases the visibility of road freight operations and traffic conditions across the road network, making it easier to plan routes and schedules for improved loading.
Another enabler gathering momentum in HICS—and likely to gain traction in LMICs—is supply chain collaboration, particularly between companies at the same level in a supply chain, a practice known as ‘horizontal logistics collaboration’ (Cruijssens 2020). This involves shippers sharing vehicle capacity on either a bilateral or multilateral basis to save money and to cut emissions. The methods, costs, and benefits of doing this have been well researched in Europe and several company case studies have shown the beneficial impacts of horizontal collaboration on vehicle load factors and CO₂ emissions. The practice is constrained by a range of factors, such as management culture, lack of trust, concerns about data privacy, and fear of infringing competition law (McKinnon and Petersen 2021), though these can be successfully overcome. Multinational companies that have had a positive experience of supply chain collaboration in Europe—such as Nestle, Procter & Gamble, and Kimberly-Clark—and have extensive logistical operations in LMICs could help demonstrate the benefits of such a collaboration and help catalyze its wider adoption in these countries. Other management practices, such as vendor managed inventory (Disney, Potter and Gardner 2003), widely applied in HICs, could also be transferred to LMICs to help raise vehicle load factors.

For countries with suitable road infrastructure, the relaxation of legal limits on truck weight can be a cost-effective decarbonization measure, even after allowing for a modal shift from rail or water. GPS-based intelligent access programs (IAPs) pioneered in Australia can help confine the movement of high-capacity vehicles (HCVs) to roads with adequate capacity and load bearing (ITF 2019). The implementation of a high-capacity transport (HCT) strategy can help mitigate the truck overloading problem on routes with adequate infrastructural capacity. Higher capacity vehicles have more axles to spread the additional load and engines capable of moving higher payloads more fuel efficiently. The use of articulated trucks permits ‘drop-and-hook’ operations in which the loading and unloading of trailers can be decoupled from the operation of the tractor unit. Having delivered a full trailer, the tractor unit is detached and then available to pick up and deliver another loaded trailer. In this way, the empty running of trailers can be reduced and the overall productivity of the transport operation enhanced. As an increasing proportion of truck fleets in LMICs become articulated, this practice will become more widespread. It requires the standardization of equipment to facilitate the interchange of tractors and trailers and usually an ‘articulation ratio’ (ratio of trailers to tractors) of 1:1.2 or more to provide enough operational flexibility. In China, where 37 percent of trucks with a gross weight exceeding 15 tonnes are now articulated, the government has been promoting drop-and-hook systems since 2007 (Yang et al. 2019). However, this practice is still less common than in North America and Europe where it has been a standard mode of operation for several decades.

**Public Policy Interventions**

Governments should first review regulations that could be preventing carriers and shippers from achieving higher vehicle load factors. Four such regulations that LMIC governments may consider reforming are:

1. Limits on own-account operators’ ability to backload their vehicles or foreign carriers to engage in cabotage, where a domestic load is transported by a foreign-registered carrier

2. Zonal restrictions on the areas within which domestic carriers are allowed to pick up or deliver loads
3. Construction and use regulations on the maximum permitted size and weight trucks

4. Antitrust laws governing the extent to which competing companies can logistically collaborate

Other possible policy measures influencing freight vehicle utilisation fall into three categories:

1. *Enforcement:* As discussed earlier, tougher enforcement is required to reduce the level of overloading in LMICs. Curbing overloading will not only cut GHG emissions but also other negative externalities of overloading, such as road infrastructure damage and traffic accidents.

2. *Road-user charging:* Increasing vehicle operating costs can give hauliers a stronger incentive to use capacity more efficiently; however, in the absence of tougher enforcement, it could exacerbate the overloading problem. Examples from Europe suggest that distance-based road charging has promoted an increase in load efficiency (Gomez and Vassallo 2020). Such road charging schemes can be technically and administratively demanding, expensive to implement, difficult to align with social costs, and politically controversial, but still worth pursuing given the range of social benefits they offer (ITF 2018).

3. *Advisory:* Over the last decade, many new green freight programs have been established at both the national and international levels to provide advice to carriers and shippers in LMICs (table 5.1). Much of this advice focuses on fuel efficiency, though some also relates to vehicle loading. Some of these programs are government-sponsored and often delivered with the support of international development organizations and industry bodies. Advisory schemes emphasise the financial benefits of increasing vehicle load factors as they usually motivate carriers and shippers more strongly than environmental benefits. Improved asset utilisation is a 'low hanging fruit' in both the economic efficiency and decarbonization of logistics.
Table 5.1. Examples of Green Freight Programs

<table>
<thead>
<tr>
<th>Country</th>
<th>Program name</th>
<th>International organizations promoting green freight initiatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>Transporte Intelligente and Rango Verde</td>
<td>Clean Air Asia</td>
</tr>
<tr>
<td>Brazil</td>
<td>Dupoluir and PLVB</td>
<td>Climate and Clean Air Coalition</td>
</tr>
<tr>
<td>Chile</td>
<td>Giro Limpio</td>
<td>Environmental Defense Fund (EDF)</td>
</tr>
<tr>
<td>China</td>
<td>China Green Freight and Green Freight Asia</td>
<td>GIZ</td>
</tr>
<tr>
<td>India</td>
<td>Green Freight Asia</td>
<td>Global Fuel Efficiency Initiative</td>
</tr>
<tr>
<td>Mexico</td>
<td>SmartWay</td>
<td>Global Green Freight</td>
</tr>
<tr>
<td>Vietnam</td>
<td>Green Freight Asia</td>
<td>International Council for Clean Transportation (ICCT)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rocky Mountain Institute (RMI)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Partnership for Sustainable Low-Carbon Transport (SLOCAT)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Smart Freight Centre</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transport Decarbonisation Alliance (TDA)</td>
</tr>
</tbody>
</table>

Source: Original table produced for this publication.

Tougher enforcement is required to reduce the level of overloading in LMICs. Curbing overloading will not only cut GHG emissions but also other negative externalities of overloading, such as road infrastructure damage and traffic accidents.
References


Vehicle Energy Efficiency

Vehicle upgrades, driver training, and new operational practices can improve fuel efficiency in both road and rail freight operations in LMICs.
6. Vehicle Energy Efficiency

Current Situation and Trends

When comparing energy use in the domestic freight sectors of HICs and LIMCs it is important to distinguish energy efficiency, expressed as fuel consumption per vehicle-kilometer, from energy intensity, measured by the ratio of energy use to tonne-kilometers. The latter is a composite measure of energy efficiency and vehicle loading and thus conflates the third and fourth decarbonization levers. This chapter primarily focuses on energy efficiency. For long-haul road and rail freight operations powered by diesel, the relevant index is liters of fuel consumed per 100 kilometers. For electrified road or rail operations, kilojoules per kilometer would be used as the corresponding energy efficiency variable.

The average fuel efficiency of road freight vehicles is much lower in LMICs than in HICs. If fuel efficiency is equated with CO\(_2\) efficiency, the interregional benchmarking of gCO\(_2\) per vehicle-kilometer by the International Transport Forum (ITF 2019) will reveal how wide the differentials are. In 2015, when compared with the EU, emissions per truck-kilometer in Latin American, African, Indian, and Middle Eastern freight vehicles were higher by 24 percent, 38 percent, 49 percent, and 51 percent, respectively. ITF modeling suggests that based on current trends and policy initiatives, the carbon efficiency of truck fleets in these regions will fall further behind those of Europe and North America by 2030 (figure 6.1).

It must be noted that these figures are influenced by average load weight. Other things being equal, the heavier the load, the lower the energy efficiency. International Energy Agency (IEA 2017) data for the United States, Europe, India, and China suggest that the weight of the average load moved by heavy trucks is similar (within a 20 percent variation), while in the case of medium-weight vehicles, it is significantly higher in India and China. Although no comparable data is available for other LMICs, it is safe to say that average payload weight differences are likely to account for only a small part of the observed international variation in average truck fuel or carbon efficiency.

For rail freight operations, international comparisons of the energy efficiency are distorted not only by differences in average trainload weight, but also by variations in the proportion of electrified operations. Electrified rail freight services can be more energy efficient than their diesel-powered counterparts (Kaack et al. 2018). According to IEA data, the average energy efficiency of freight trains in China, Russia, Europe, and Japan is similar, despite significant differences in average train length, partly because their levels of electrification are within a much narrower range—70 percent to 90 percent (IEA and UIC 2019). The average energy efficiency of Indian rail freight operations is substantially lower despite its average trainload and electrification levels being similar to China. This suggests that factors other than loading and electrification affect energy consumption per train-kilometer and depress rail energy and CO\(_2\) efficiency in other LMICs. These factors are discussed in the next section on ‘Inhibiting Factors’.
Much of the research on energy use in the rail freight sector focuses on variations in energy intensity, expressed in megajoules per tonne-kilometer. This clearly shows the importance of train loading as a determinant of energy intensity. Gucwa and Schaefer (2013) found diesel-powered trains in India carrying 1,000 tonnes to 1,500 tonnes per locomotive had average energy intensities comparable to those of the United States and Canada, while Uruguay, with per locomotive loading of only around 300 tonnes, had an energy intensity three times higher.

Globally, the energy and CO₂ efficiency of rail freight operations improved by 18.1 percent and 19.0 percent, respectively, between 2005 and 2015 (IEA and UIC 2017). Over this period, the rates at which efficiency improved in India were similar to those in the United States but significantly below those in the EU and China. The IEA and UIC have not published comparable data for other LMICs.
Inhibiting Factors

The lower energy efficiency of trucking operations in LMICs can be attributed to numerous economic, infrastructural, vehicle-related, behavioral, and regulatory factors:

1. **Diesel fuel subsidies:** Although some countries have successfully reduced these subsidies in recent years, they are still widespread in LMICs. Subsidizing diesel fuel puts less financial pressure on truck operators to operate their vehicles efficiently. While there has been debate over the extent to which higher diesel prices will reduce truck energy consumption due to the low price elasticity of road freight demand for fuel (Park, Lee and Han 2021), the subsidies in some countries—such as India, Indonesia, Iran, and Egypt—are large enough to make them a significant factor (IEA 2021).

2. **Poor road infrastructure:** When the capacity of the road network is inadequate, the density of traffic prevents trucks from traveling at fuel-efficient speeds. Stop-start operations on congested stretches increases fuel consumption per kilometer steeply. Research in Germany established that regular traffic congestion reduced the fuel efficiency of freight delivery operations by 2.5 percent (Kellner 2016). It is likely to be significantly higher in LMICs. The standard of the road pavement and road geometry also strongly influences average fuel efficiency and is generally inferior in LMICs; these countries are typically at the lower end of global transport infrastructure rankings (Arvis et al. 2018).

3. **Old and under-maintained truck fleets:** Truck age is inversely related to fuel efficiency, as a Ugandan study by Namukasa, Namagembe and Nakayima (2020) has confirmed. In some LMICs, such as Niger and Benin, the average age of a truck is more than twice the average age of a European vehicle (ACEA 2022; Bove et al. 2018). The fuel performance of trucks also degrades more rapidly in LMICs because of poor maintenance and their operation on substandard roads. In intensely competitive haulage sectors, slim profit margins and under-capitalization make it difficult to shorten the vehicle replacement cycle.

4. **Lower levels of retrofitting with fuel-saving equipment:** Such equipment, which includes anti-idling devices and aerodynamic profiling, have been shown to offer a quick payback in financial and environmental terms when deployed in HICs. Small trucking businesses and owner-drivers in LMICs lack the resources to acquire this equipment. Also, in countries where poor and congested infrastructure constrains average truck speed, the cost and carbon benefits of aerodynamic profiling can be marginal (McKinnon 2015), as Karali et al. (2019) found in an analysis of fuel efficiency measures for Indian trucking operations. However, if infrastructure constraints are addressed, helping owner-drivers in LMICs raise the necessary capital to purchase this equipment could be a viable option for reducing fuel consumption and related emissions.

5. **Tires:** Partly because of the poor condition of the road pavements, many trucks still run on cross-ply tires in countries such as India (Balachandran 2015). In Europe and North America, radial tires are the norm, typically offering fuel savings of three percent to four percent compared with cross-ply tires. Truck operators in HICs are also transitioning to low-rolling resistance tires, which are slightly more expensive, but enhance fuel efficiency.
6. Lack of skills and training in fuel efficient driving: Numerous studies have shown driving ability is a major determinant of truck fuel efficiency, and that this ability is highly variable (AECOM 2016). Standards of driver training and testing are generally lower in LMICs with smaller numbers of drivers given specialist training in ecodriving. Furthermore, the older trucks they drive lack many of the driver assistance and fuel monitoring tools that are standard in the latest generation of European and North American vehicles.

7. Vehicle overloading: As discussed in previous chapters, a relatively high proportion of trucks in LMICs operate not only above legal weight limits, but also well above their optimal design weight. As a consequence, these overloaded trucks burn much more fuel than necessary. Research by Wahyudi et al. (2013) in Indonesia found that overloading increased truck CO$_2$ emissions by an average 70 percent to 80 percent. The total annual emissions per truck per annum were inflated by 22 tCO$_2$ to 54 tCO$_2$, depending on vehicle type and size, for every 10 percent increase in overloading.

In rail freight operations, the lower energy efficiency witnessed in LMICs is partly due to limited rail electrification, the age and poor maintenance of locomotives, and the poor standard of tracks that prevent locomotives from consistently reaching fuel-efficient speeds. In countries where passenger services are prioritized, freight trains are regularly diverted into sidings to clear a path for passenger trains, resulting in a substantial loss of energy due to slowing, stopping, and reaccelerating trains weighing many hundreds of tonnes. The idling of stationary diesel-powered locomotives can also account for a significant amount of rail freight CO$_2$, particularly in LMICs where this practice is common. Drivers of older, often under-maintained locomotives can be reluctant to switch off the engines because it can be difficult to restart them.

**Potential Enablers**

A range of technical, operational, and behavioral enablers can help overcome the barriers to improved fuel efficiency in both road and rail freight operations.

**Road Freight**

1. Driver training: Research and experience in Europe and North America has shown that training truck drivers to drive more fuel efficiently is one of the most cost-effective means of cutting CO$_2$ emissions from trucking. This method can help achieve average fuel and CO$_2$ savings of 5 percent to 15 percent, depending on the drivers’ experience and capability (Boriboonsomsin 2015; AECOM 2016). ‘Ecodriver training’ features prominently in the sustainable freight programs of the German Agency for International Cooperation (GIZ), the United Nations Conference on Trade and Development (UNCTAD), the Smart Freight Centre, among others, and has been shown to yield significant CO$_2$ savings in countries such as China, Thailand, Lao People’s Democratic Republic, and Vietnam (ADB 2016; Grütter and Dang 2016). The CO$_2$ benefits of driver training are potentially greater in LMICs than in HICs given the more difficult traffic conditions and much smaller parc of trucks with onboard driver assistance devices. This training also improves road safety, an important ancillary benefit in LMICs with high accident levels. Embedding fuel-efficient practices requires electronic monitoring of subsequent driving performance and follow-up guidance where necessary. The longer-term effectiveness of the training as a cost- and carbon-saving measure depends on carriers having the resources to equip their vehicles with these monitoring systems (Boodlal and Chiang 2014).
2. *Overhauling the vehicle fleet:* This can be done by shortening the vehicle replacement cycle, maintaining the vehicles more effectively, and retrofitting them with fuel efficiency devices. In theory, as trucks in LMICs have a longer working life, retrofitting should play a greater role in raising their average fuel efficiency. Smart-freight programs detail the full list of technical options and are broadly similar for all countries (UNCTAD 2021; CSRF 2015). Their uptake in LMICs, however, is constrained in several ways because:

- the lower proportions of articulated vehicles and lower average speeds reduce the relative fuel and CO₂ savings from aerodynamic profiling.
- longer stretches of uneven road surfaces can inhibit the switch to low-rolling resistance tires.
- lightweighting, which has been advocated as a CO₂-saving measure in Europe and North America, has less relevance in countries where managing overloading is a bigger priority.
- vehicle maintenance upgrades are often hampered by the shortage of skilled mechanics and spare parts, particularly for older, imported vehicles. Technical improvements to the fuel- and CO₂-efficiency of freight fleets in LMICs are heavily dependent on the quality of the road infrastructure, the availability of capital, and international supply chains for used vehicles and spare parts.

3. *Modifying operations:* LMICs can adopt the following three modifications that HICs are implementing in their road-based distribution operations to cut fuel consumption:

- **Rescheduling deliveries to off-peak periods:** This allows vehicles to operate closer to their most fuel-efficient speeds and deliver more reliably. In HICs, where many factories, warehouses, and shops operate 24/7, there is often sufficient flexibility in many supply chains to accommodate rescheduling; however, more research is required to assess its feasibility and carbon impact in LMICs. Most of the published studies on this subject have had an urban focus (e.g., Holguín-Veras et al. 2018). In several large Indian cities, such as New Delhi, Mumbai, and Kolkata; and Dhaka, Bangladesh, regulations confine truck movement to night hours to ease traffic congestion during the day. Opportunities for delivery rescheduling at interurban and interregional levels in LMICs and its potential carbon impact merit a fuller investigation.

- **Deceleration of road freight vehicles:** Some large trucking companies, such as Schneider in the United States and Geodis in Europe, have been reducing maximum truck speeds to save fuel and cut emissions (McKinnon 2016). Reducing the maximum speed of a U.S. class 8 truck from 75 miles per gallon (mpg) to 65 mpg, bringing it within its optimal speed range, cuts fuel consumption by an estimated 27 percent (Garthwaite 2012). This could be an effective decarbonization measure in LMICs with long stretches of high-capacity roads used by trucks traveling well above their optimal speed. Much of the road freight in LMICs, however, moves at speeds below the average fuel consumption ‘sweet spot.’ Under these circumstances, ‘down-speeding’ would raise, rather than lower, the carbon intensity while lengthening transit times and inflating the already high delivery costs.
More fuel-efficient routing: CVRS, as discussed earlier, is an option for reducing road tonne-kilometers, as it can minimize the distance traveled between delivery and collection points. This need not always translate to minimized fuel consumption and CO₂ emissions, as the system may direct vehicles onto inferior and heavily congested roads. Research in Germany has shown how vehicle-routing algorithms can be recalibrated to minimize fuel consumption and CO₂ and, in the process, reduce the total costs (Ehmke, Campbell and Thomas 2016). As CVRS becomes more widely adopted by carriers in LMICs, efforts could be made to maximize its carbon benefits.

Rail Freight

New technology has been increasing the energy efficiency of railway rolling stock hauled by diesel, electric, and hybrid locomotives. It is being incorporated in new rolling stock and retrofitted onto existing locomotives, many of which have an average life span of several decades and longer in LMICs. The adoption of this technology needs to be accelerated in LMICs. As in the road freight sector, the use of driver training and driver advisory systems (DAS), anti-idling devices, and improved maintenance can offer substantial energy savings. For example, potential rail energy savings from DAS can range from 5 percent to 20 percent (IEA and UIC 2019). These savings can be supplemented by enhancing rail infrastructure, particularly track and signaling upgrades and, in some countries, giving freight greater priority over lightly used passenger rail services in the allocation of track capacity.

Public Policy Interventions

Governments have many policy instruments at their disposal to improve the fuel efficiency of trucking and rail freight operations. These instruments fall into similar categories as those used for other decarbonization levers: regulatory, financial, infrastructural, and advisory.

1. Regulatory: Worldwide, the main regulatory measure that has been applied over the last decade to raise truck fuel efficiency is the imposition of fuel economy standards for new vehicles. As the International Council on Clean Transportation (ICCT) observes, “Fuel economy standards are one of the most cost-effective and politically-attractive carbon mitigation measures (Yang 2018).” In 2021, approximately 75 percent of all new trucks sales were subject to such standards, as these new sales were primarily in HICs (IEA 2022). HICs’ share of new sales is steadily rising as their fuel efficiency standards are tightening. Of the small number of LMICs with truck manufacturing industries, only India has so far introduced a fuel economy standard for heavy-duty vehicles (HDVs). Other LMICs that rely on imports of both new and used vehicles indirectly benefit from the fuel economy standards imposed in high-income exporting countries. But in the case of second-hand vehicles, they will realize the benefits only after a significant time lag and some degradation of the vehicles’ original fuel efficiency. LMICs relying heavily on used-vehicle imports can accelerate the indirect fuel and carbon savings they derive from fuel economy standards elsewhere by restricting the maximum age of these imported vehicles, as several countries already do, or by imposing their own fuel economy standards on imported HDVs at point of sale.
The fuel efficiency of existing domestic truck fleets can also be raised by tightening regulations on vehicle maintenance and overloading. South Africa has set a good example with the implementation of a road transport management system (RTMS). This is “an industry-led, government-supported, voluntary, self-regulation scheme that encourages consignees, consignors, and road transport operators to implement a management system (a set of standards) that demonstrates compliance with the Road Traffic Regulations and contributes to preserving road infrastructure, improving road safety and increasing productivity (Nordengen 2021).” To this list of benefits, reduced fuel consumption and carbon emissions can be added.

2. **Financial:** A phased withdrawal of diesel fuel subsidies and their gradual replacement with taxes puts road carriers under greater financial pressure to lower fuel consumption. While this can be politically challenging in countries where such subsidies are woven into the socioeconomic fabric, measures can be made more palatable when combined with other financial incentives such as scrappage schemes for older vehicles, financial support for driver training, and retrofitting vehicles with fuel saving devices.

3. **Infrastructural:** Investment in the capacity of the road network to ease congestion and improve pavement condition can result in truck fuel efficiency gains as well as a host of other benefits. There also need to be greater efforts to improve traffic management to help trucks operate at more fuel-efficient speeds. For example, countries can promote the rescheduling of deliveries to off-peak periods using advisory programs and ease access restrictions at industrial and logistical premises in the evening or at night where this does not pose a local noise problem.

4. **Advisory:** Governments can initiate or support green freight programs to advise shippers and carriers on a range of fuel-economy measures (see table 5.1 in the previous chapter). There has been a proliferation of such programs over the past 20 years, most of them providing online guidance on fuel efficiency. Governments can access this wealth of information and customize it to local needs. Governments can also play an important role in promoting industry-led green freight initiatives such as the Rango Verde (Green Range) in Argentina (Rodriguez 2017).
However, it is difficult to get the relevant messages across to the vast numbers of small carriers. The road freight sector is highly fragmented in most countries, not just LMICs. In Europe, half a million small- and medium-sized operators account for over 90 percent of road freight movement and require considerable advice and support for their decarbonization efforts (Toelke and McKinnon 2021). LMICs such as Mexico (TSTES and ITP 2013) have acknowledged the importance of engaging these small carriers. This engagement process can be assisted when the government agencies and the private sector emphasize environmental criteria during the procurement of freight services (e.g., Smart Freight Centre and WBCSD 2019).

**LMICs that rely on imports of both new and used vehicles indirectly benefit from the fuel economy standards imposed in high-income exporting countries. But in the case of second-hand vehicles, they will realize the benefits only after a significant time lag and some degradation of the vehicles’ original fuel efficiency.**

Government rail freight policies can also support fuel saving initiatives. Investment in track upgrades and rolling stock renewal, often motivated mainly by other policy objectives, cut fuel and CO₂ emissions per tonne-kilometer. Rail freight operations already benefit from fuel subsidies or preferential fuel duty rates in some countries. On the one hand, this helps keep rail services price competitive and promotes modal shift; but on the other, it eases the pressure on rail freight operators to improve fuel efficiency. This is an example of a public policy conflict between different freight decarbonization goals (discussed further in chapter 7).
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Switching truck and rail services to lower carbon energy sources is the only way to achieve complete decarbonization of domestic freight.
7. Carbon Content of Energy: Switching Logistics from Fossil Fuel to Lower-carbon Energy Sources

Current Situation and Trends

This final logistics decarbonizing lever—switching logistics to lower carbon energy sources—is the only lever that can potentially lower CO\textsubscript{2} emissions from domestic freight down to zero over the next few decades. While having the greatest promise, it is also the lever that currently is least applied in commercial freight and logistics operations. In the long-distance road freight sector, the main switch to low-carbon fuels so far has been in the blending of biodiesel, typically a 7 percent blend, with fossil diesel. Worldwide, in 2017, biodiesel represented only 1.6 percent of road freight fuel, most of it consumed in Europe, North America, and Brazil, but there has been significant use of B5–B7 blends in India, China, and several Association of Southeast Asian Nations (ASEAN) countries (IEA 2017). On a tank-to-wheel basis, a B7 biodiesel blend lowers CO\textsubscript{2} emissions by around 5 percent (DBEIS and DEFRA 2020). On a well-to-wheel (WtW) or lifecycle basis, emission savings depend on the feedstock used. For example, if the feedstock is recycled vegetable oil, the savings can be approximately 15 percent. Where biofuel crops are grown on deforested land, WtW GHG emissions can exceed those of the fossil diesel they are replacing (Transport and Environment 2021). In the major countries producing biodiesel, such as Indonesia, Malaysia, and Brazil, the main feedstock is palm oil but its farming practices raise questions about the actual reduction in GHG emissions. Efforts are being made, however, to certify the sustainability of biodiesel sourced from tropical plantations. The IEA (2020a) is projecting a 20 percent increase in biodiesel production in Brazil, 39 percent in Argentina, China, Malaysia, and Thailand, 48 percent in Indonesia, and six-fold in India. Some countries are planning to substantially increase biodiesel blends, for example to B30 in Indonesia (Searle and Bitnere 2018), though the high average age of much of the truck fleet in some LMICs is likely to constrain the viable maximum percentage biodiesel blend.

In the truck fleets of LMICs, other lower-carbon fuels such as biomethane (a gaseous fuel produced by the anaerobic digestion of food and agricultural waste) and Hydrotreated Vegetable Oil (HVO), also known as 'renewable diesel', have not found significant uptake. The high price of gas-powered vehicles, lack of gas refueling facilities, and limited supplies of sustainable biomethane constrains its use in the road freight sectors of these countries. HVO is a diesel ‘drop-in’ fuel that can be blended to much higher levels than biodiesel without engine modifications. It is produced mainly from waste and residues and consumed in trucks in Europe and North America mostly. Neither of these lower-carbon alternative fuels are expected to capture a significant share of the road freight markets in LMICs, at least in the short term. India may be a notable exception, given the country’s “ambitious plans to expand the use of biomethane in transport, targeting the build-out of 5,000 bio-CNG stations by 2025 (IEA 2020b)."
In Europe and North America liquid and gaseous biofuels are mainly seen as transitional, helping to decarbonize trucking in the short to medium term until a new generation of electric vehicles becomes available, powered with what will, by then, be low-carbon electricity. Most LMICs are at an earlier stage of this transition. The duration of the transition, and in some countries, its viability, will depend on the speed with which electric powertrain technology diffuses globally mainly from Europe, North America, and China.

While the electrification of road freight will be a relatively slow process, the electrification of rail freight operations is already prevalent worldwide (IEA and UIC 2019). The percentage of rail track electrified varies widely across countries, with corresponding variations in the proportions of electrified freight haulage. Countries with extensively electrified rail freight services will be well placed to decarbonize them as the carbon intensity of their grid electricity reduces. For many LMICs, this will require parallel and concerted effort in reducing the average carbon intensity of grid electricity (see figure 7.1).

The use of biodiesel as a transitional option for cutting CO$_2$ emissions has been much more limited in the rail sector than in road freight, even though it can be similarly blended. Stead et al. (2019) partly attribute this to locomotives having much longer lives and hence, potentially longer-term, biodiesel-related maintenance problems. The higher cost of biodiesel may also be discouraging its use in the rail sector, particularly as some countries already subsidize the fossil diesel consumed in rail freight operations. If these technical and economic issues could be resolved, biodiesel-blended fuel could help with the decarbonization of diesel-powered rail freight services, particularly in those LMICs in which biodiesel production is forecast to rise steeply over the next few years, particularly Indonesia, Brazil, and India (IEA 2021).

**Figure 7.1. Average Carbon Intensity of Electricity Generation, 2010-2018**

![Figure 7.1](source: IEA 2022.)
Future Prospects

In reviewing factors affecting the adoption of lower-carbon energy sources for road freight, it is helpful to distinguish the short- to medium-term prospects prior to the transition to electric vehicles, as well as the longer-term prospects once electric vehicles have achieved mass adoption in LMICs.

Short- to medium-term

In the next 10 to 15 years, the increased blending of diesel with sustainable biodiesel will offer the easiest option for the decarbonization of road freight vehicles in LMICs. However, the adoption of this measure will be constrained by the age and engine tolerances of the truck fleet. As fleets are renewed, the uptake of B7 and higher blends could be substantially increased, as long as sufficient quantities of genuinely low-GHG biodiesel can be produced. LMICs must avoid the situation in the EU, where a large proportion of the biodiesel consumed in road transport emits substantially more GHG than fossil diesel on a lifecycle basis because of its high-carbon feedstocks (Valin et al. 2015). In most LMICs, HVO production has to be end-to-end and producers must find a scalable supply of waste material as feedstock. Developing biomethane production and distribution systems at scale would present even greater challenges for many countries and require a switch to gas vehicles, which few carriers in LMICs can afford.
Longer-term

There is general agreement that complete decarbonization of long-haul trucking will be achieved by electrification, but there is continuing uncertainty about the use of the three different methods of powering vehicles with low-carbon, and eventually, zero-carbon electricity. This can be done using batteries, hydrogen fuel cells, highway electrification, and various combinations of these technologies. Battery-powered vehicles, for example, can have hydrogen fuel-cell range extenders, while trolley trucks drawing electricity from overhead catenaries will need batteries to access premises off the electrified highway network. It is likely that all three technologies will coexist in varying degrees by country and road-haulage duty cycle.

LMICs with truck manufacturing capability, such as India, Thailand, and Brazil, will be in a stronger position to shape the future mix of these technologies, compared to countries relying on imports, particularly of second-hand vehicles. Global supply chains for new and used vehicles connect individual LMICs to the truck markets and production systems of one of four truck manufacturing hubs - the EU, North America, China, and Japan. These allegiances are likely to influence individual LMICs’ truck transition from diesel to low-carbon electrical power. This shift is likely to be more difficult and longer in LMICs than in HICs for several interrelated reasons:

1. **Limited supply of new low-carbon vehicles**: Global truck manufacturing capacity is concentrated in HICs as their trucking sectors are better resourced and their governments are more ambitious in setting carbon reduction targets. Production capacity is likely to be channeled towards meeting these countries’ demands in the short to medium term.

2. **High capital cost of the low-carbon vehicles**: In 2030, battery-powered HDV tractor units could be approximately twice as expensive as current diesel-powered tractor units. Although their much lower lifetime energy and maintenance costs could enable them to achieve total cost of ownership (TCO) parity by the early 2030s, their high capital cost will present a major barrier in the undercapitalized trucking sectors of most LMICs. This will limit the demand for new low-carbon vehicles in LMICs. This constraint can be eased with vehicle leasing schemes and the infusion of more climate finance into the decarbonization of global truck fleets.

3. **Increased supply of diesel trucks to LMICs**: As low-carbon vehicle rollouts accelerate in Europe and North America, possibly shortening previous replacement cycles, the supply of used diesel vehicles for export to LMICs is likely to increase. This could reduce the price of diesel trucks in international markets. A surge in the import of second-hand diesel HDVs will help rejuvenate fleets in LMICs with more fuel-efficient, cleaner vehicles, but in the longer term, delay the transition to low-carbon trucks.

4. **Global market for used low-carbon trucks**: At present, used diesel trucks typically enter the export market after 5 to 8 years. The electric motors of HDVs are expected to have a much longer life than diesel engines, with initial battery lives of around 7-10 years depending on the duty cycle (NACFE 2021). Some of these truck batteries are expected to be reconditioned for a second life in a non-transport role, while others will have their materials recycled for reuse in new batteries. Separate value chains may develop to supply new or reconditioned batteries for the used electric trucks imported by LMICs.
5. **Supporting infrastructure:** The transition to low-carbon vehicles will be slow, delaying the rollout of new recharging and refueling systems, which, cyclically, is likely to discourage uptake. The electricity grids of LMICs will also have to be upgraded to reliably meet the power demands of these vehicles. Also, in many LMICs, their decarbonization impact will depend on the carbon intensity of grid electricity dropping steeply from its current level by the time the main vehicle power-shift gets underway.

6. **Forecast growth of road freight traffic:** In many LMICs, road freight traffic is predicted to grow sharply over the next few decades and truck fleets will need to expand to accommodate this growth (ITF 2021). The demand for electrified vehicles and the low-carbon electricity needed to power them could increase rapidly in LMICs in the 2030s and 2040s, possibly exceeding the available supply.

However, in some LMICs, efforts are already underway to prepare for the transition to low-carbon trucks. India, in particular, has ambitious plans to electrify its truck fleet, mainly with batteries, though the government is also exploring the electrification of lanes on the 1,300 kilometer Delhi–Mumbai expressway for trucks and buses (Mohanti 2021). India also has the advantage of having a large truck manufacturing sector and is much less dependent on new and second-hand vehicle imports but even in such a country, the ‘defossilization’ of the truck fleet could be relatively slow. In its “high ambition” forecast, the ICCT expects only 60 percent of medium- and heavy-duty trucks to be electrified by 2050, while several other organizations project a slower uptake (Kumar 2021). The task of electrifying India’s truck fleet is made all the more formidable by the forecast 7 percent compound annual growth rate for road freight from 2025 to 2050 (Stranger and Lakhina 2021). Given this growth rate, “the impact of India transitioning to zero-emissions trucks would be globally significant from an emissions perspective but would also create a powerful example” for other LMICs (Stranger and Lakhina 2021).

Recharging the new generation of battery-powered vehicles can be internalized within the logistics sectors of LMICs to some extent. The long hours of intense sunlight that many of these countries experience can help recharge truck batteries either directly from solar panels on the rooftops of articulated trailers or indirectly from panels on warehouse and factory roofs. The cost of solar power has dropped sharply in recent years, greatly improving the economics of covering the roofs of logistics buildings and trailers with panels and micro-generating renewable energy within the logistics system. Rooftop solar power is already developing rapidly in China, India, Mexico, and Brazil (IRENA 2019). Where weather conditions are favorable, the installation of wind turbines at warehouse and terminal sites can extend the range of micro-generation options.

**Public Policy Interventions**

Public policies in support of this logistics decarbonization lever are likely to diverge to a greater extent between LMICs as a result of national differences in several key parameters such as:

- country size, geography, and climate
- carbon intensity of the electricity supply in the short, medium, and long term
presence of a truck manufacturing capability
sourcing of new and imported vehicles
financial state of the trucking industry
spatial pattern of freight flow
freight modal shift potential

At one end of the spectrum would be a small country, with:
very low carbon electricity
heavy or total dependence on road freight, much of which is channeled along a few corridors
hauliers earning relatively healthy margins and regularly replacing their vehicles.

Such a country would be well placed to promote a rapid switch to electrified haulage and would achieve a substantial reduction in the GHG.

At the other end of the spectrum is a large country with:
electricity that has a high and slowly declining carbon intensity
heavy dependence on road freight but with long dispersed freight flows
hauliers that earn low margins and run old vehicles

The decarbonization of such a country’s road freight sector will be more protracted and so, in the meantime, it would be advisable to focus policy attention on other decarbonization levers, mainly levers three and four, and explore opportunities for using sustainable biofuels as an interim measure.
Other countries fall in between these extremes. Those most favorably disposed to the switch to low-carbon trucks could adopt a wait-and-watch approach and learn from the experience of commercial trials ongoing in HICs before choosing a particular combination of powertrain technologies. The European Commission and the UK government, for example, are currently adopting a position of technological neutrality until they see how the new low-carbon truck market evolves. The governments of LMICs, however, should guard against a possible flood of used diesel truck exports from HICs by tightening controls on the import of these vehicles by age and fuel economy standard.

Wherever a country is on the truck decarbonization spectrum, phasing out diesel fuel subsidies and/or transferring them to greener alternatives will help push the freight sector toward non-fossil power. Biofuel mandates and tax incentives can also be used to promote the use of biofuels in the freight sector, but these incentives should be reserved for only biofuels which, on a verifiable lifecycle basis, offer net GHG reductions. Financial incentives can also be used to encourage the purchase of biogas vehicles, the installation of biogas refueling systems, and the development of in situ renewable energy systems using solar or wind power.

For LMICs with electrified rail freight networks, the public policy options are more straightforward. Extensions to the electrified network can improve the energy efficiency of rail freight operations and improve its access to decarbonizing electricity. Often, targeted extensions to the electrified network can plug gaps in rail freight routes that permit a switch from diesel to electric haulage across the entire route. When this applies, potential carbon savings per kilometer of newly electrified line can be disproportionately high. Governments could further investigate alternative methods of rail electrification involving batteries and hydrogen fuel-cells (e.g., SINTEF 2017) and their applicability for LMICs where:

• Diesel rail haulage is the norm

• Only a limited section of the network is electrified

• The carbon intensity of the electricity is relatively low

It will also be important to learn from pilots under way in HICs, such as the United States (Luvishis 2021).

LMICs with truck manufacturing capability, such as India, Thailand, and Brazil, will be in a stronger position to shape the future mix of technologies, compared to countries relying on imports, particularly of second-hand vehicles.
References


Conclusion

Freight modal shift, optimized vehicle loading, and increases in truck fuel efficiency emerge as the most promising measures for logistics decarbonization in low- and middle-income countries in the near- to medium-term.
8. Conclusion

This paper has examined the challenges of decarbonizing logistics in LMICs by considering how the five main sets of carbon-reducing measures—the decarbonization ‘levers’—could be adapted to their needs and circumstances.

A broad overview of the subject has its limitations. The distinction between HICs and LMICs is unrefined as countries vary enormously in their levels of economic and logistical development. Generalizations about LMICs have been particularly difficult due to their geographical, economic, and political heterogeneity. However, the report has uncovered some general takeaways that should be of interest and value to policy makers, managers, and researchers. An application of the framework to the decarbonization of logistics in South Africa (Terblanche 2019) illustrates how it can be adapted to national circumstances. In this case, for example, the country-specific road transport management system (RTMS) initiative and poor adherence to delivery slot times were found to exert a significant influence on road freight emissions.

Over the next three decades, CO\textsubscript{2} emissions from domestic freight transport are likely to increase substantially in countries outside the OECD (ITF 2019). It is imperative, therefore, that these countries try to contain, arrest, and eventually reverse this trend. This report has discussed how LMICs might do this by maximizing the decarbonization leverage gained from a broad range of trends and initiatives.

For many LMICs, freight modal shift (lever 2), optimised vehicle loading (lever 3), and increases in fuel efficiency (lever 4) offer the greatest potential, though each lever requires much stronger action such as:

- building intermodality into company supply chains
- curbing truck overloading
- phasing out fuel subsidies
- rejuvenating truck and locomotive fleets
- convincing the logistics workforce to adopt energy-efficient practices

Many measures with relatively low or negative carbon mitigation costs could be implemented in the short to medium term. ‘Collectively they can significantly reduce the amount of energy that will ultimately need to be ‘defossilised’ by the application of the fifth decarbonization lever

Constraining the growth of freight demand (lever 1) is a more difficult and risky option to pursue in countries at an earlier stage in their economic development. As outlined in chapter 3, LMICs have options to help avoid locking themselves into transport- and carbon-intensive macrologistics systems, as many HICs have done. LMICs, for example, can exploit digitalization, which gives businesses greater flexibility to configure their logistics systems in ways that reduce carbon emissions.
The shift from fossil to renewable energy (lever 5), which will ultimately deliver zero carbon freight distribution, also presents challenges due to LMICs’ heavy reliance on imported trucks, underfunded trucking industries, and relatively carbon-intensive electricity. Here too, however, LMICs have a potential advantage in the microgeneration of solar energy from the vast photovoltaic footprint of warehouses, factories, freight terminals, and trailers.

LMICs can also benefit from the transfer of advice, good practice case studies, and training in sustainable logistics from HICs. Recent research in Nigeria (Orji et al. 2019) on barriers to the adoption of ecological innovations in logistics highlights the need for such advisory services. Much of this is already being channeled through global, regional, and national green freight programs to managers and policy makers in LMICs (CCAC 2015; Hernandez and Façanha 2017). Large logistics providers, freight forwards, and shippers with global operations can also play an important role in both disseminating information about decarbonization and procuring freight transport services in ways that incentivize local carriers to cut emissions. Another encouraging trend has been the creation of regional alliances to promote the decarbonization of transport, which focus much of their attention on freight and logistics (Bakker et al. 2017). These multinational initiatives, among other things, create new opportunities for freight modal shift, improved truck utilization on cross-border routes, and joint initiatives on the supply of low-carbon fuels.

The report outlines a series of public policy interventions for each of the decarbonization levers. Table 8.1 consolidates them into a logistics decarbonization toolkit, indicating their likely impact on each of the levers. Table 8.1 shows how the same policy instrument can exert pressure on several decarbonization levers and that these pressures are not always in complementary directions. There has been limited research on the net impact of these policy tools in different LMIC settings and the related trade-offs with other economic and social policy goals. As experience and knowledge builds on this subject, the governments of LMICs will be able to play a more active and targeted role in the logistics decarbonization process.
Table 8.1. Range of Public Policy Initiatives and Impacts on Five Logistics Decarbonization Levers

<table>
<thead>
<tr>
<th>Public policy measure</th>
<th>Freight transport intensity</th>
<th>Share of freight on lower carbon modes</th>
<th>Freight capacity utilization</th>
<th>Freight energy efficiency</th>
<th>Carbon intensity of freight energy</th>
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<td>Incentives to accelerate truck replacement rate</td>
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<td>Raising environmental standard for imported vehicles</td>
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<td>Tax incentives for low-carbon fuels and vehicles</td>
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<td>Support for ecodriving training schemes</td>
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<td>Grants and revenue support for freight modal shift</td>
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<td>Phased internalization of environmental costs (in fuel pricing, for example)</td>
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<td><strong>Regulatory</strong></td>
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<td>Introducing/tightening truck fuel economy standards</td>
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<td>Tougher regulation on vehicle maintenance</td>
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<td>Removal of regulations constraining vehicle loading</td>
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<td>Tighter enforcement of truck overloading regulations</td>
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<td>Relaxation of truck size and weight limits</td>
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<td>Lowering of speed limits for road freight vehicles</td>
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<td>Legalization of supply chain collaboration initiatives</td>
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<td>Easing constraints on off-peak freight delivery</td>
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<td>Liberalization of the rail freight market</td>
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<td>Public policy measure</td>
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<td><strong>Infrastructural and land use planning</strong></td>
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<td>Expansion of rail and waterway network capacity</td>
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<td>Investment in rail network electrification</td>
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<td>Grants for rail sidings and intermodal equipment</td>
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<td>Promoting development of freight villages</td>
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<td>Linking planning permission to rail and waterway access</td>
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<td>Applying low-carbon logistics land use strategies</td>
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*Source: Original table produced for this publication.*
References


