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Contents

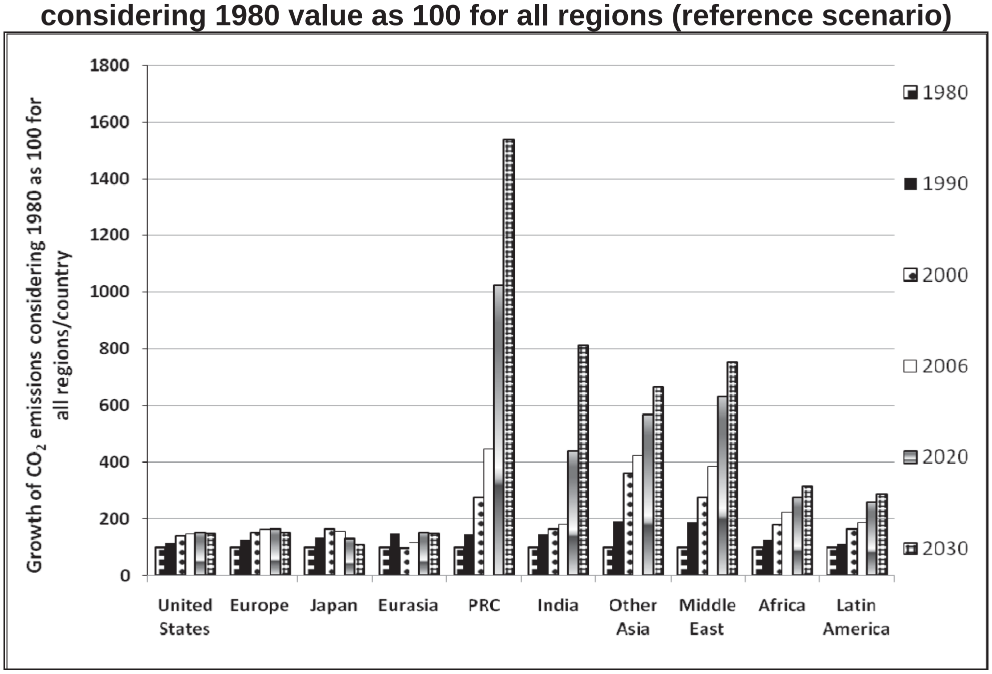
ACRONYMS AND ABBREVIATIONS

ASIF	activity-structure-intensity-fuel
BRT	bus rapid transit
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
EPA	Environment Protection Agency (US)
GHG	greenhouse gas
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
km	kilometer
LPG	liquefied petroleum gas
NAMA	nationally appropriate mitigation actions
NOx	oxides of nitrogen
PM	particulate matter
PRC	People's Republic of China
SMP	Sustainable Mobility Project
SUV	sport utility vehicle
UNFCCC	United Nations Framework Convention on Climate Change
VKT	vehicle kilometers traveled

Executive Summary

The transport sector contributed 23% of the total carbon dioxide (CO_2) emissions in the world according to the latest estimates of the International Energy Agency (IEA). Within road transport, automobiles and light trucks produce well over 60% of emissions, but in low- and middle-income developing countries, freight trucks (and in some cases, even buses) consume more fuel and emit more CO_2 than the aforementioned light-duty vehicles. Transport-related CO_2 emissions from developing countries will contribute in increasing proportion to global CO_2 emissions unless mitigating measures are implemented soon. This phenomenon can be understood by this figure (assuming a datum of 100 for all regions and/or countries in 1980 under reference scenario) which shows that the maximum growth in CO_2 emissions would be in developing countries of Asia. There is now a growing international consensus that future targets for CO_2 reductions in the post-2012 Climate Policy Framework will not be achieved unless CO_2 contribution from the transport sector in developing countries is appropriately addressed.

Transport sector energy-related CO_2 emissions growth considering 1980 value as 100 for all regions (reference scenario)



PRC = People's Republic of China.
Source: Modified from IEA. 2008. *World Energy Outlook.*

The steady increase of gross domestic product (GDP) per capita in many developing countries will continue to drive demand for mobility and vehicle ownership and use. And with the concentration of wealth around cities, an increasing share of light-duty vehicles are found in and around cities, clogging streets and adding to problems of air pollution, road safety, noise, and CO_2 emissions as well. A proper approach to dealing with the CO_2 emissions must be integrated with efforts to meet these other challenges. Gathering and analyzing the information required to do this is what we call “measuring carbon” from transport. “Measuring carbon” consists of three key tasks that link changes in vehicles, vehicle and transport activity, or vehicle fuel use to total fuel consumption:

- Analyzing and monitoring present transport activity, pollutant emissions, fuel use and CO_2 emissions;
- Projecting future transport activity as outcome of changes in the form of transport costs, incomes, land uses, and many other variables, and projecting resulting fuel use and CO_2 emissions levels;
- Evaluating the impact of policies aimed at both transport activities and CO_2 emissions.

Emissions (G) in the transport sector are a product of the level of travel activity (A) in passenger kilometers (or ton-km for freight), across all modes; the mode structure or percentages by mode (S); the fuel intensity of each mode (I), in liters per passenger-km; and the carbon content of the fuel or emission factor (F), in grams of carbon or pollutant per liter of fuel consumed. (The identity can be rewritten for vehicle, rather than travel or freight activity). Measuring carbon means being able to track all four of these parameters in a metro area, state, or at the national level whenever transport or carbon measures are implemented,

Today, authorities in developing Asian countries cannot adequately “measure carbon”. Existing aggregate data tell us only approximately how many vehicles of each kind have been at one time registered nationally or by state. In almost no Asian developing country are data collected or official estimates made of how far vehicles by type and fuel are driven in a year or how much fuel each vehicle-fuel combination consumes. There are also no regular national travel or commodity flow surveys. At the state or metropolitan level are occasional travel surveys and traffic counts but little reliable data on fuel consumption and almost no data on vehicle use.

Strategies to improve transport and improve vehicle fuel economy affect distances moved and fuel use per unit of distance. Present official data cannot address either the present situation in Asian countries or the changes that are expected to occur both from spontaneous growth and from policies or new technologies. And all that is reported officially to the IEA, the UNFCCC, or Asian regional agencies is sales of each fuel to the road sector at the national level. Using sales or consumption-based analysis of emissions is also called the top-down approach. This approach does not reveal the impacts of transport or CO_2-focused policies.

In transport, three kinds of “reduction” of CO_2 emissions from a baseline can occur. The first two act mainly on urban and rural development or transport systems, not on vehicles or fuels directly.

- Avoidance of growth in emissions through urban and rural development that maximizes access to housing, jobs, shopping, services, and leisure time without requiring traversing long distances in individual light-duty vehicles. Singapore in Asia and Curitiba in Brazil are two examples of urban areas whose development policies favored land uses and development patterns less dependent on automobiles than any of their regional neighbors.

- Shifting transport to modes with intrinsically low-carbon emission per unit of transport provided, e.g., from car or light truck to bus, rail, or metro, or maintaining high shares of those modes. Recent advances in bus rapid transit in Jakarta, for example, have shifted travelers from individual cars to faster buses.

- Improving (mitigating) emissions in existing and future vehicles and traffic by improving operational efficiency and traffic (transport measures), as well as by selecting different fuels, more efficient vehicle technologies and less powerful, lighter vehicles, which are true “CO_2” mitigation measures. The People's Republic of China’s (PRC) new fuel economy standards for light-duty vehicles, like those in Japan, lead to manufacturing and purchase of less fuel economic vehicles than otherwise.

“Measuring carbon,” as described, permits policy analysts to diagnose problems, carry out a number of steps important for reducing carbon emissions, and monitor the impact of those steps. Using a bottom-up approach permits estimation of the impact of changing parts of the complex transport system that affect CO_2 emissions, whether transport activity, fuels, or vehicles. This approach allows planning of technical and policy research on how to affect emissions from transport. The same approach allows estimation of how specific investments in new transport systems (e.g., metros or BRT) or technology (e.g., hybrid vehicles or signal timing systems) would affect emissions. A bottom-up approach allows policy analysts to isolate the impacts of various local and national policies such as fuel taxes, VKT taxes or congestion pricing from other changes. Finally, a bottom-up approach allows estimation of the impact of externally stimulated investments or incentives on transport, including the quantification of CO_2 “savings” from measured deemed eligible for NAMAs, CDM, or other external funding. Measuring carbon in transport cannot be carried out well in the majority of Asian countries because of the profound lack of data on vehicles, transportation activity, and fuel use by vehicle type.

Whatever combination of these types of measures, it is important to be able to measure and model not simply “before/after” measures, policies, or technologies are implemented but three specific cases:

- Business-as-usual or the base case projected forward with no policy measures,
- Modeled and predicted evolution of transport activity and emissions when policies and measures have been applied,
- Actual activity and emissions as measured or estimated to compare with both predicted outcomes and the business-as-usual case with no measures.

With this approach, it becomes possible to separate spontaneous evolution in transport activity and emissions driven by higher incomes and changing land uses. Armed with these data, analysts can estimate the impact of any particular mitigation measure over time against the background of growing emissions. In this framework, “savings” from a policy intervention will usually lead to lower fuel use or CO_2 emissions than would have occurred in a business-as-usual situation, i.e., without the actions implemented that would lead to changes in emissions.

The current methodology and terminologies employed by the IPCC in measuring emissions, we foresee a three-tiered approach for estimating transport emissions:

- Tier 1 would use international “default” parameters for fuel use/liter by vehicle type. Since these figures vary by a factor of two according to vehicle size and efficiency, Tier 1 is useful only for a first cut approximation.

- Tier 2 would correspond to taking actual national averages for fuel economy (fuel use/km) by fuel and vehicle type. Simulations of on-road (in-use) fuel economy are only useful if these have been validated by detailed comparisons of actual fuel use records.
- Tier 3 corresponds to using fuel economy data by vehicle that reflect actual vehicles in a project or affected by a project, i.e., in its zone of influence. Simulations may be used if they have been carefully validated for the types of vehicles in the project.

In most Asian countries and cities, the majority of information necessary to assess CO_2 and air pollutant emissions can be found only in individual projects, while even in these cases travel activity and characteristics are not sufficiently covered. The overriding focus in the short term is on coordination among public and private agencies at a given level as well as among levels of administration.

In the short term the following steps should be taken. A standard set of data can be developed, in three tiers much like the IPCC. This should lead to surveys of what data are and are not available in each country. A number of Asian countries should agree to carry out these surveys and to fill the most obvious data gaps, possibly with funding from an outside agency. This allows authorities to assess carefully what is known relative to what needs to be known. Building cooperation among agencies and private authorities assures that costs can be shared and new data collection can be coordinated with what is already collected.

At the same time, a clear message needs to go to governments that data collection requires funding in the long term. Funding needs to be structural and not project driven or dependent on foreign assistance apart from capacity building to strengthen local efforts. One financing scheme might involve a small tax on fuels and transport ticket sales or freight bills on overloading. Other funding sources can be explored, but funding should not be an issue when in fact only a very small fraction of the national transport bill (which itself is between 10% and 20% of most economic activity) is used for data gathering. Most of the data required are collected by developed countries to plan, implement, and monitor investments and operation of the transport system.

A clear challenge is selecting an agency or other institution to manage data collection, analysis and publication, including the analysis and publication of indicators. This must be an institution with a good background in both statistics and transport, as well as credibility in the transport community. We advocate that candidate institutions be selected as part of the task of analyzing existing data and determining data needs. A long-term commitment is required and the organization selected should have the required institutional mandates and operating budgets to conduct its work well.

In the medium term, the selected institutions in a number of countries should work with authorities to analyze data needs and field test surveys to determine what the real costs of the transport and fuel use surveys will be. With this information, authorities can determine the real costs of regular data gathering and processing. And governments can develop partnerships among national and local authorities to both share data-gathering costs and in the analysis with the host institution. International and local development (or academic) organizations can play an important role in strengthening the capacity to collect, analyze, and manage data required to arrive at well-chosen policies and programs to develop the transport sector in a sustainable manner and one which will slow down the growth of CO_2 emissions.

At the same time, a longer-term process must be started to appoint an international authority to coordinate data gathering and train national and local authorities much as the IEA has done for energy data. Regional authorities need to be established (or authority vested in an existing regional authority, such as the Economic and Social Commission for Asia and the Pacific (ESCAP) to work with countries and key cities in each geographic region.

1 Introduction

1. Growing urbanization coupled with increasing demand for mobility and personal motorization remains one of the key challenges in Asian cities. With the advent of cheaper and smaller cars like the Nanos in India, motorization is expected to continue to increase at an unprecedented rate. Most people in Asian cities have an increasing propensity to use light-duty vehicles (i.e., cars) and motorcycles as their main mode of daily commute partially because of disintegrated, unreliable, uncomfortable, and old public transport systems in Asian cities. Insufficient priority and investments of the government and private sector toward the urban public transport system have contributed to the continued decline of public transport patronage.

2. This increasing motorization and demand for mobility in Asian cities have contributed to air pollution, traffic accidents, congestion, as well as the increase of greenhouse gas emissions, in the urban area. National and local government authorities are caught off-guard on how to deal with these perennial problems. In some cases, the total number of vehicles has doubled in about 5–7 years in some Asian countries. In Ulaanbaatar, Mongolia, the city saw a 50% increase in the total number of vehicles. Still, in other cities, the growth of motorized two-wheelers has increased several folds.

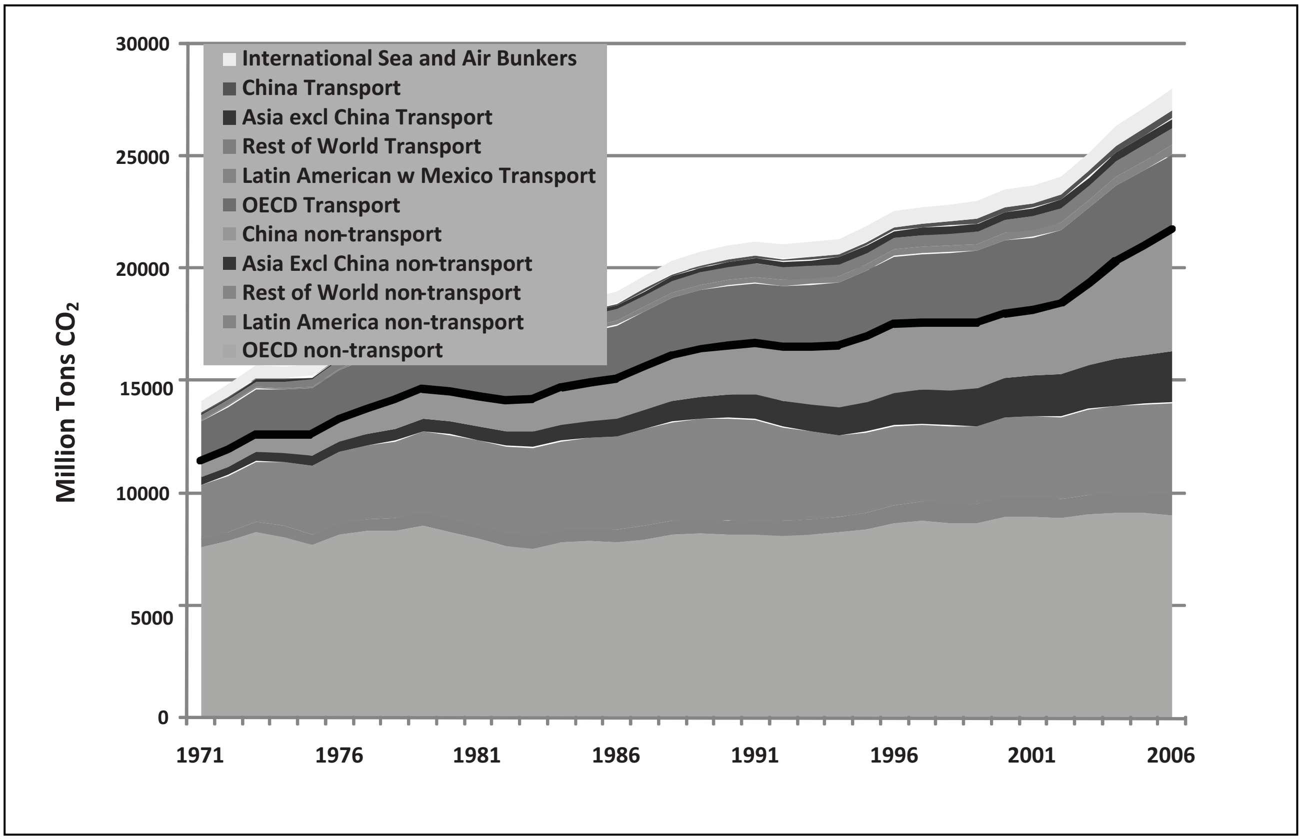
3. National and local government authorities, especially in Asia, are still struggling to better understand and measure the emissions of their current urban transport systems, and even more the formulation and implementation of policies and measures that can reduce and prevent future emissions of air pollutants and greenhouse gas.

4. This report provides a discussion on the relevance of measuring greenhouse gas emissions, particularly carbon dioxide (CO_2), as well as air pollution from the transport sector from various methodologies and using the activity-structure-intensity-fuel (ASIF) type model. It aims to guide authorities and researchers in Asia in measuring CO_2 emissions, as well as air pollutants from the urban transport sector. It also provides a discussion on the key parameters needed to be routinely collected by authorities to come up with an accurate estimate of the emissions.

2 Importance of the Transport Sector and Measurement of Transport Data

5. The transport sector contributes 23% of the total CO_2 emissions in the world according to the latest estimates of the International Energy Agency (IEA) (Figure 1). The transport sector's direct emissions from combustion fuels over the 1971 to 2006 represent a rising share of total global emissions. Road transport is responsible for the highest share of emissions globally. Within road transport, automobiles and light trucks produce well over 60% of emissions, but in low- and middle-income developing countries, freight trucks (and in some cases even buses) consume more fuel and emit more CO_2 than the aforementioned light-duty vehicles. Road transport is also associated with emissions of criteria air pollutants, such as carbon monoxide (CO) and oxides of nitrogen (NOx), as well as particulate matter (PM). These emissions have a high negative impact on human health, particularly in densely populated urban areas.

Figure 1: CO_2 Emissions from Transport and Other Sectors in Various Regions



Source: IEA.

6. An increasing share of CO_2 emissions is associated with road transport in and around cities. Many cities in Asia, which still has a high urbanization rate, will become a major source of CO_2 emissions in the future unless economic growth and urbanization are decoupled from the increasing demand for mobility, or if increased mobility can be decoupled from a growth in energy use. If this were to be done, the transport sector could be one of the key sectors where existing CO_2 emissions could be mitigated and, perhaps more importantly, future CO_2 emissions avoided.

3 What Existing Aggregate Data Tell Us

7. Figure 1 appears to give a great deal of information about CO_2 emissions from fossil fuel use. Unfortunately the figure is based on total reported aggregate sales of each fuel by sector (road transport, rail transport, etc, as well as major non-transport sectors). While the information provides a good summary or total of CO_2 emissions, it does not relate to the transport activities or vehicles in which the emissions arise.

8. The emissions shown in the figure are calculated using an Intergovernmental Panel on Climate Change (IPCC) method as applied by the IEA. The basic equation used in estimating greenhouse gases as prescribed by the IPCC Guidelines for National Greenhouse Gas

Inventories (2006) is: emissions = “activity data” x emission factor. In the case of transport, the national communications of governments submitted to the UNFCCC use fuel consumption as the activity data and the mass of CO_2 emitted per unit of fuel consumed as the emission factor. This equation can be regarded as a “Tier 1” method, which represents the basic level of methodological complexity. The Tier 1 method focuses on estimating emissions from the carbon content of fuels supplied to the country as a whole or to the main fuel combustion activities. From the foregoing discussions, this level of information is far too aggregate to be tied to changes in transport data. A Tier 2 method would involve emission calculation by source types, based on fuel use for each industry and sector of the economy, and a Tier 3 method uses source-specific data and could be used for only a small number of principal emission sources.

9. The IPCC approach is top-down, which is a measurement based on fuel use or fuel sales. However, a bottom-up approach is necessary to better understand the transport system, through gaining transport activity and characteristics data. This gives the link to transport policy, since transport policies may largely impact on CO_2 emissions through affecting total vehicle, passenger, and ton kilometer (km). Such policies could be the “nationally appropriate mitigation actions” (NAMAs), for which a key co-benefit will be lower CO_2 emissions. Tying changes in emissions to the outcomes of these NAMAs requires the bottom-up approach. Most transport policies will affect only part of total vehicle or transport activity, and usually relatively slowly. Without good transport activity observations and models, it is almost impossible to discern changes in activity caused by policies alone than from the overall changes in activity as economies grow.

10. The IEA calculations using the IEA approach represent a Tier 2 approach. They portray emissions by fuel and energy-consuming sector, based on the sales of fuel to each sector. In manufacturing, the detail is quite good because most countries maintain separate sales data on energy sales to iron and steel, nonferrous metals, paper and pulp, etc. A few even separate these sectors by primary versus secondary metals, paper making versus pulp, etc. These subsectors correspond to those for which physical and monetary output and employment are maintained. Thus, for these sectors it is possible to identify sectoral output as the activity factor and energy use or CO_2 emissions per unit of output as the energy or CO_2 intensity.

11. Unfortunately measuring changes in fuel sales cannot be used to impute changes in travel, freight, or vehicle activity because more than one type of vehicle uses each fuel. In Asian countries, for example, cars, some light trucks, motorcycles, and small buses use gasoline, while some cars, most buses, and trucks use diesel fuel. Small amounts of compressed natural gas and LPG may be used for smaller buses, larger buses, or cars. Because of this mix, there is no one-to-one correspondence between changes in fuel and changes in transport activity. No fuel is used uniquely by a given kind of vehicle, and in no country have the proportions of fuel type used by each vehicle type been consistent over time. Also in some countries fuel purchased at pumps may be used to run back-up diesel or gasoline generators, private boats, activities not included in road transport.

12. The basic problem is that while transport fuel data are collected by fuel and broad categories—road, rail, domestic water transport, domestic air travel, international marine bunkers, and international air bunkers—there is no official breakdown of road fuel use data by vehicle type, e.g., two-wheeler, car, sport utility vehicle (SUV), light truck, medium and heavy truck, bus, etc. For a majority of Asian countries, there are also no published data on vehicle-km or passenger and ton-km by the main modes, corresponding to the case of output for

manufacturing. Thus, it is not possible to associate CO_2 emissions to each major activity within the transport sector.[1]

13. Compounding this problem is that there is no meaningful measurement of transport activity at any level in the majority of Asian countries. “Vehicle activity” is measured in vehicle-km per vehicle and total vehicle km by vehicle type (i.e., two-wheeler up to large articulated truck or bus) and further distinguished by fuel type, e.g., vehicle-km/year for diesel, CNG, and gasoline cars. Passenger travel is measured in passenger km, and freight haulage in ton-km. While these data may be available for rail and air modes, they are almost never collected for urban transport, and only partly for road transport, usually for common carrier bus and trucking. These quantities are growing rapidly in most Asian countries, propelled both by greater numbers of vehicles in operation and in some cases greater km/vehicle per year.

4 Restraining CO_2 Emissions from Transport in a Growing World

14. Transportation activity typically increases with economic activity and increasing gross domestic product (GDP). Actions to slow and ultimately reverse that increase are warranted because of the need to mitigate local or national transportation problems, such as congestion, transportation-related air pollution, high accident rates, and high fatalities. Lower growth in vehicle kms traveled (VKT), particularly in individual vehicles, will reduce emissions because the CO_2 modal and vehicle intensities of light-duty vehicles (fuel use/km) are so high compared with all other motorized vehicles.

15. In transport, three kinds of “reduction” of CO_2 emissions from a baseline can occur. For each of these broad approaches, many estimates or observations of vehicles (road vehicles, trainsets, etc.) and transport activity (passenger or ton km, vehicle km by vehicle type and fuel, fuel use/km by fuel, and vehicle type) are needed to analyze the present situation and describe alternatives ex ante, analyze results ex post, and compare results with a counterfactual case without measures:

(i) Avoidance of growth in emissions through urban and rural development that maximizes access to housing, jobs, shopping, services, and leisure time without requiring traversing long distances in individual light-duty vehicles. Singapore in Asia and Curitiba in Brazil are two examples of urban areas whose development policies favored land uses and development patterns less dependent on automobiles than any of their regional neighbors.

[1] While aggregate energy sales by fuel to the road sector by fuel is known with reasonable accuracy, details are sometimes confused by fuel that is smuggled from low- to high-priced (or taxation) countries, and taxed fuel adulterated by untaxed or lower-taxed fuel.

(ii) Shifting transport to modes with intrinsically low-carbon emission per unit of transport provided, e.g., from car or light truck to bus, rail, or metro, or maintaining high shares of those modes. While Singapore, Curitiba, and Hong Kong, China,[2] achieved and maintained these high shares of public transport as a result of the development of their transport structures, most other developing cities have seen their public transport share eroded by either motorized two-wheelers or cars. New bus-based public transport systems such as TransJakarta (Jakarta), Metrobus (Mexico City), and Transmilenio (Bogota) have demonstrated that it is possible to attract some car drivers back to large buses, which have lower CO_2 emissions per passenger-km delivered.

(iii) Improving (mitigating) emissions in existing and future vehicles and traffic by improving operational efficiency and traffic (transport measures), as well as by selecting different fuels, more efficient vehicle technologies, and less powerful, lighter vehicles, which are true "CO_2" mitigation measures. In the developing world, only the People's Republic of China's (PRC) has so far promulgated fuel economy standards for new light-duty vehicles.

16. For each of these three approaches, imagine a counterfactual: Singapore (or Curitiba, Brazil) without the early government intervention that resulted in strong land-use planning, congestion pricing, and a clear departure from common transportation conditions found in other urban regions of Asia (or Latin American respectively); Jakarta, if so many lines of Trans-Jakarta had not been built to relieve some of the pressure from car use in main arteries; Brazil, if ethanol had not been introduced to replace about 25% of the automobile gasoline, or more recently the PRC, if fuel economy standards on new cars had not been introduced. In each case, how much higher would CO_2 emissions be in the absence of the measures cited? Quantifying the difference between actual and "counterfactual" is what in part "measuring CO_2 emissions" means. There is no doubt that a great deal of data, estimations, and modeling is required to answer this question.

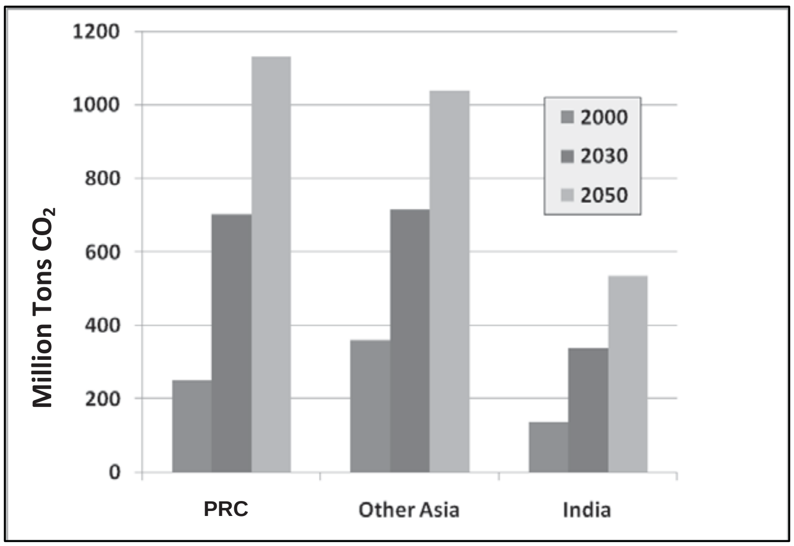
17. Measuring, modeling, or estimating the overall impacts of the first two kinds of transport changes (avoid future emissions and shift to the most efficient mode) requires a good set of data on transport conditions, data which today generally do not exist in majority of Asian countries. The same lack of data makes it difficult to estimate the specific CO_2 benefits of these strategies. But even measuring the impact of mitigation effects of technological interventions requires good data on CO_2 emissions per vehicle-km, data for which only exist for a few well managed fleets of trucks or urban buses in some Asian countries, e.g., Bangalore Municipal Transport Corporation. Since the majority of road-based emissions arise in private two-wheelers, cars, and trucks, most of the impact of either transport- or CO_2-focused measures cannot be seen, except in aggregate fuel sales. Thus, we cannot see the composition of CO_2 emissions in transport apart from a top-down manner based on all the fuel consumed in a country or city. Evaluating the real impact of fuel economy standards in the PRC is difficult

[2] Statistics from Hong Kong, China, shows increase in both vehicle population and public transport users (in 2007, there was an increase of 1.4% in public transport users). Detailed estimates from 2002 indicate 89% of motorized trips by public transport and intermediate public transport. Source: Hong Kong SAR Transport Department. Available: www.td.gov.hk/mini_site/atd/2008/s5_eng_1.htm and http://www.td.gov.hk/publications_and_press_releases/publications/free_publications/travel_characteristics_survey_2002_final_report/index.htm

because there are no real "data" on on-road fuel consumption of various kinds of cars, both from before the standards were enacted and after.[3]

18. The World Business Council for Sustainable Development (WBCSD) Sustainable Mobility Project (SMP) of transport and CO_2 foresaw a three- to fivefold increase in CO_2 emissions from transportation in Asian countries and regions in 2000–2030, as Figure 2 illustrates. This increase is driven principally by a six- to eightfold increase in the number of light-duty vehicles and large increase in the number of trucks. Despite improvements in reductions on fuel use of approximately 20%–25% for either mode, due to efficiency improvements, the overall growth in emissions is still very large. This growth is driven principally by the increased number of light-duty vehicles, which carry the largest share of growth in mobility. Looking at existing congestion levels in Asian cities, one wonders where the space will come from for this increased vehicle activity. This indicates that motorization in Asia is as much a general problem of transport and development as it is a CO_2 problem.

Figure 2: SMP Projections of CO_2 Emissions from Transport in Asian Regions 2000–2030



PRC = People's Republic of China, SMP = Sustainable Mobility Project.
Source: IEA.

19. The SMP projections for emissions are built bottom-up, i.e., from data and assumptions on vehicles, vehicle use, travel (in passenger-km), and freight (in ton-km) by mode. Vehicle fuel intensity by vehicle and fuel type, or fuel use/vehicle-km is used to connect vehicle activity to fuel consumption. Energy use per passenger-km or ton-km is called modal fuel intensity. This must be derived from information on vehicle fuel intensity and vehicle occupancy (persons or tons), which is related to load factor (persons or tons/maximum capacity in persons or tons). CO_2 emissions are derived from fuel intensities or total fuel use with coefficients provided by the IPCC.

[3] Schipper and Tax (1994) described the "gap" between the test fuel economy of vehicles and what is actually attained on the road, which may mean 25% higher actual fuel use than test.

20. Current transport in Asia, particularly road transport, faces profound congestion and capacity problems, with far fewer vehicles on the road than projected. Clearly a radical change in transport policy is called for (Leather 2009). Even in North America and Europe, the value of the CO_2 externality (at $85/ton CO_2) is still much less than the values of congestion, accidents, or local air pollution expressed per km of travel. Thus CO_2 itself cannot be seen as the main driver of transport policies (Parry, Walls, and Harrington 2007; Transport Canada 2008; Madisson et al. 1997). Policies that will restrain growth in transport activities should be implemented by local and national authorities. The co-benefits of such policies will gradually restrain the growth of CO_2 emissions, but can the impacts of such policies be measured?

5 How and Why Measure Carbon Emissions from the Transport Sector?

21. The SMP projections shown in the previous section are constructed from the best available estimates of the components of vehicle population, vehicle use, travel, freight, and fuel intensities. This connection from vehicles to carbon through vehicle use, travel or freight, and fuel intensity is what we mean by “measuring carbon.” The same data are related to traffic activity that gives rise to an increasing share of air pollutants. Yet few of these data are measured or estimated, collected, and published by Asian countries or specifically for cars, light trucks, other trucks and buses. In other words, despite recognition of the importance of CO_2 emissions, little is known about how much CO_2 is emitted by which kinds of vehicles while they are on the road.

22. “Measuring carbon” consists of three key tasks:

(i) Analyzing and monitoring present transport activity, pollutant emissions, fuel use, and CO_2 emissions;
(ii) Projecting future transport activity as outcome of changes in the form of transport costs, incomes, land uses and many other variables, and projecting resulting fuel use and CO_2 emissions levels;
(iii) Evaluating the impact of policies aimed at both transport activities and CO_2 emissions.

23. Unfortunately, none of these tasks can be sufficiently carried out with the present state of information available in the majority of Asian countries or large urban regions. The vast majority of developing countries in Asia only collect data on sales of fuels, and only a minority of countries support surveys and other data collection that pinpoint how far vehicles move and how much fuel they consume (and hence carbon they emit) per km of travel. Knowing only the aggregate sales of fuels is insufficient for measuring the impacts of policies because most policies will act on CO_2 only through changes in transport patterns. These changes cannot be measured or imputed from changes in aggregate fuel sales, and call for another definition of “measuring carbon,” connecting changes in transport activity and fuel use caused by specific policies or other interventions. Present data on road fuel use in Asia are too sparsely collected and aggregated to make this connection.

24. Because different kinds of vehicles use different fuels (gasoline and diesel, or CNG), there is no simple formula relating a vehicle type to aggregate fuel sales. And since vehicle fuel economy—usually defined as km traveled/liter of fuel consumed (km/l) or liters of fuel consumed/100 km—is often the target of policies, measuring both fuel consumption and

distance for each kind of vehicle-fuel combination is important for measuring policy outcomes and impacts. The number of vehicles may grow over time, the distance each vehicle travels may grow or shrink, and the fuel used per km may change. Understanding how these components change is called the "bottom-up" approach of measuring fuel use and carbon in transportation.

25. This bottom-up approach of measuring carbon in transport means linking vehicles and vehicle activity, and personal and goods mobility by mode to fuel used by vehicle and mode, from which CO_2 emissions are calculated. The main purpose of measurement is linking transport activity and energy use to each other and informing the policy process—diagnosis, options, cures, outcomes, corrections, and dissemination of results. It is important to understand the present circumstances with respect to transport activity and fuel use to get the underlying mobility and fuels/environmental policies right and propose appropriate measures like restraining fuel use and fuel-intensive modes.

26. "Measuring carbon" as described then permits policy analysts to carry out a number of steps important for reducing carbon emissions. Using a bottom-up approach permits estimation of the impact of changing parts of the complex transport system that affect CO_2 emissions, whether transport activity, fuels, or vehicles. This approach allows planning of technical and policy research on how to affect emissions from transport. The same approach allows estimation of how specific investments in new transport systems (e.g., metros or BRT) or technology (e.g., hybrid vehicles or signal timing systems) would affect emissions. A bottom-up approach allows policy analysts to isolate the impacts of various local and national policies such as fuel taxes, VKT taxes, or congestion pricing from other changes. Finally, a bottom-up approach allows estimation of the impact of externally stimulated investments or incentives on transport, including the quantification of CO_2 "savings" from measured deemed eligible for NAMAs, Clean Development Mechanism, or other external funding. As will be shown in the succeeding chapters, measuring carbon in transport or applying the bottom-up approach cannot at present be carried out sufficiently in majority of Asian countries because of the profound lack of data on vehicles, transportation activity, and fuel use by vehicle type.

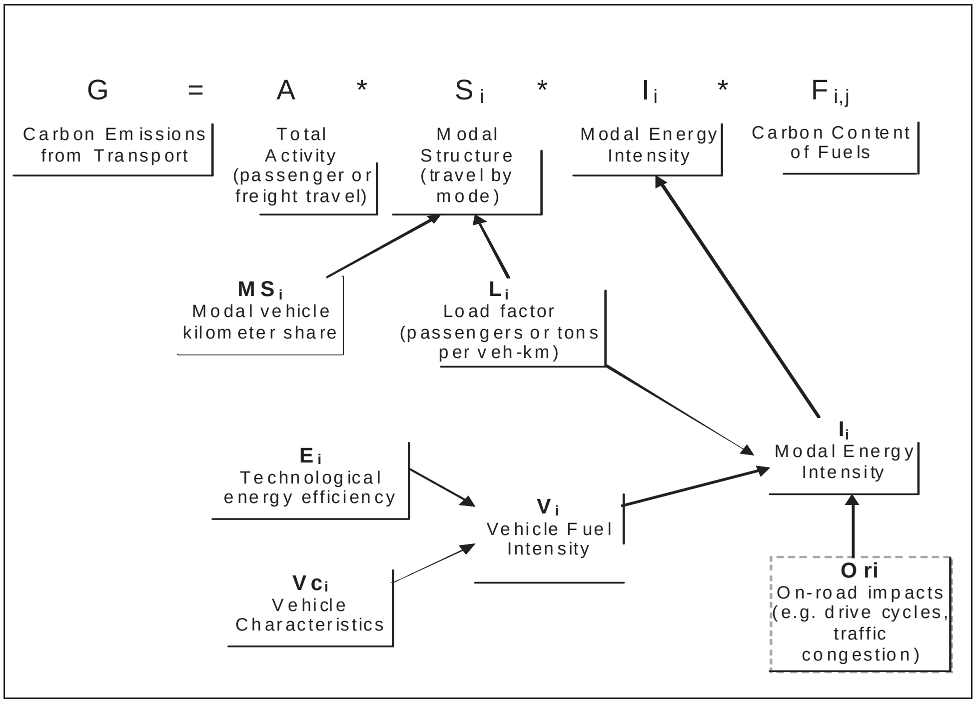
6 ASIF Approach – "Bottom-up"

27. The transport sector is comprised of a diverse set of activities, connected by their common purpose of moving people and goods. Broadly speaking, emissions (G) in the transport sector are dependent on the level of travel activity (A) in passenger km (or ton-km for freight), across all modes; the mode structure (S); the fuel intensity of each mode (I), in liters per passenger-km; and the carbon content of the fuel or emission factor (F), in grams of carbon or pollutant per liter of fuel consumed.

28. The emission factors can be defined in several ways. A CO_2 emission factor can be calculated using the carbon content of the fuel and standard IPCC coefficients to convert fuel (or electricity) used back into carbon emissions. For other pollutants, emission factors can be measured in the laboratory, in a test station as occurs in many US states on a regular basis, on a test track, or using on-board or remote sensing equipment to examine vehicles in service in real traffic.

29. The relationship between these parameters is represented mathematically by the ASIF equation (Schipper and Marie 1999; Schipper, Gorham, and Marie 2000) (Figure 3).

Figure 3: ASIF Equation in Two Dimensions for Carbon Dioxide Emissions



Source: Schipper et al. (2000).

30. The relative importance of each component to total changes in emissions varies with location, income growth, etc. The transportation system is interconnected and interventions such as policies, programs, and projects can affect directly and indirectly one or more of these components. Measuring only how emissions have changed says little about how these components are changing, or how policies and measures can change the components and thereby total emissions.

<u>A</u> - Total transport activity. This can be passenger travel or freight (in ton-km). The specification could also be in vehicle km. Both tend to increase with increasing income. Land use and the form in which cities grow have a determining impact on travel distances. Local versus more distance production, imports and exports affect the volume of freight sent by rail, truck, and ship.

<u>S</u> - Modal structure represents the share of travel (in passenger- or ton km) in each mode, walking, cycling, and other nonmotorized transport; two-wheeler; car (including taxi) and light truck or SUV; urban, interurban bus, or minibus; urban rail (including metro), tram, or intercity rail; intercity air and ship (ferries between islands or across rivers, transport along rivers or coasts). Because fuel or emissions per passenger km (I) differ by more than a factor of 10 between a large loaded bus or train with a modern engine and an old, large car with only one occupant, shifts in travel or traffic from one mode to another have an important impact on overall emissions. Choices of mode are affected by the availability of transport modes (particularly car ownership and distance to trunk or rail lines), mode speed, and the resulting travel time between origin and destination. Other important factors affecting choice include prices of fuels and vehicles, legislative and fiscal policies in effect, speed and travel time provided by each mode, personal security, and social and

psychological dynamics. Care should be taken when conceiving public transportation systems as the actual impact on fuel and CO_2 emissions of measures favoring modal shifts are not always as effective as planned in terms of fuel savings and emissions abatement because of impacts on surrounding traffic, modal shift from nonmotorized to motorized transportation, etc. If **A** is specified in vehicle km, then **S** represents the share of vehicle km by vehicle type and fuel type.

Note that the number of vehicles of a given type and fuel, multiplied by the distance they are driven each year, times the occupancy factor “L” gives the total passenger km (or ton-km) produced by that vehicle type in a year.

I – the modal energy intensity is closely linked to income growth, changes in fuel prices (e.g., fuel taxes), vehicle standards, and public incentives, among others. Income growth may positively affect the energy intensity of vehicles as older units are replaced by newer, more efficient ones. Note the key parameter here is indicated as “L,” for vehicle load or occupancy. The higher the vehicle occupancy, the greater the passenger (or ton) km for each vehicle-km will be, and conversely the lower the modal energy intensity of a given travel or freight mode. Modal intensity must be derived from measured or estimated energy used by a mode divided by the number of people traveling by that mode. Modal intensity is very sensitive to the vehicle occupancy factor, which varies greatly from region to region or country to country. Therefore, modal energy intensities should not be “borrowed” from other countries or literature. They must be derived.

“V” is for road fuel intensity, or fuel/veh-km. In some countries (US, Japan), the inverse or fuel economy (fuel/km) is normally given. On-road fuel intensity or economy is affected by road conditions and congestion levels—worse congestion means worse fuel economy. This may in turn have effects on activity—a substantial reduction in congestion on a road, as observed in Mexico City’s Insurgentes BRT Corridor (Rogers 2006), could lead to enough speed increases that more car trips are made than otherwise.

Note that “V” is hardly a technological factor alone (denoted by “E”). Vehicle characteristics (Vc) and on-road conditions (Or), such as speed, congestion, and actual driver behavior) largely impact on fuel used per km.

F – the carbon content of fuels used has changed very little in most regions, except in Brazil, where sugar-cane based alcohol now accounts for 40% of automobile fuels. We do not consider this parameter any further in this paper, but it is becoming increasingly important to scrutinize with full fuel cycle analysis, as many so-called biomass fuels are associated with considerable amounts of CO_2 released in harvesting and preparation, often offsetting most or all greenhouse gas (GHG) emissions from the fuels replaced.

31. Each of these ASIF quantities can be affected by policies, as discussed elsewhere in this volume. In most Asian countries, trucks and cars/two-wheelers, then buses, then rail dominate CO_2 emissions from land transport in that order, but in a few countries domestic air travel has grown significantly as well.

7 Monitoring and Analysis of the Status Quo

32. This ASIF approach uses total emissions as an identity, the product of total activity, the share of each mode, the fuel used per passenger-km by mode, and the emissions per unit of fuel for each fuel and mode combination. Emissions per unit of fuel are related to emissions per vehicle/km by a number of further identities and definitions.

33. In a Ha Noi study conducted by EMBARQ, the World Resources Center for Sustainable Transport (Schipper et al. 2008), the total vehicle and passenger travel activity by mode (A and S in the ASIF formulation) were gathered for its analysis. In addition, vehicle activity and emissions coefficients or fuel use data have also been collected for this study. Table 1 shows what kind of data were collected for the Ha Noi model that served to estimate CO_2 emissions from changes in transport projects in the business-as-usual scenario.

Table 1: Example of an ASIF Matrix Reflecting the Business-as-Usual Scenario for Ha Noi in 2005

	A	**S**	**I**				**F**
Travel Mode	**Total Travel (million km)**	**Share of km (%)**	**Fuel Use/ Passenger-km (million l)**		**Fuel Efficiency (l/km)**		**CO_2 (tons)**
			Gasoline	Diesel	Gasoline	Diesel	
Walk	**1,045**	9					
Bicycle	2,237	19					
Motorcycle	6,608	57	165		0.025		261,937
Car	789	7	65	5	0.15	0.128	162,152
Truck	651	6	100	181	0.48	0.41	701,367
Bus	219	2	59	53	0.54	0.48	279,730

Source: Table adapted from Schipper et al. (2008).

34. For EMBARQ's India study (Schipper et al. 2009), an ASIF model was also developed to explicitly identify and quantify the key variables that give total fuel use and resulting CO_2 emissions levels. In the baseline scenario, the penetration of vehicles by fuel was used to estimate fuel consumption in 2000 and 2005. Vehicle penetration is then projected forward for future scenarios. Fuel intensities (fuel/vehicle-km) and distances (vehicle-km/veh/year) were estimated from Indian literature. The ASIF identity is satisfied for total fuel use as the product of vehicle activity, modal structure, and fuel intensity. Table 2 shows the different variables that helped construct the ASIF model for a business-as-usual scenario for India in 2000.

Table 2: Example of an ASIF Matrix Reflecting the Business-as-Usual Scenario for India in 2000

	A	S	I					F
Travel Mode	**Total Travel (billion pass-km)**	**Share of km (%)**	**Fuel Use/ Passenger-km (million l)**		**Fuel Efficiency (MJ/km)**			**CO_2 (Ktons)**
			Gasoline	Diesel	Gasoline	Diesel	CNG	
Car	196	7	171	46	3.1	2.79	2.55	15
Two-Wheeler	288	10	107		0.53			7
Three-Wheeler	78	3	46		1.21		0.68	4
Bus	1,485	50	28	352	9.42	9.51	14.29	28
Rail	457	15		47				4
Walking	222	7						
Cycling	260	9						

Source: Table adapted from Schipper et al. (2009).

8 Looking Forward: ASIF and Other Approaches to Projections and Forecasting

35. The ASIF formulation represents a simplified summary of the results of a good transport model based on activities that generate trips, trip distribution (origins and destinations) mode choice, and route choice over the network. If an entire origin–destination (O-D) matrix has been calibrated for small travel zones in an urban region against observations, surveys, and traffic counts, then these data can be aggregated to summarize activity for the entire region, with details kept separate. When such a travel model is coupled with an emissions simulation routine that estimates fuel use and local emissions for a given vehicle technology and vehicle type/fuel combination over the vehicle's trip as estimated by the transport model, the results are a simulation of CO_2 emissions. Averaged over an entire region, the average annual emissions can be simulated. More importantly, the model will show what key measurements can verify model predictions.

8.1 Changes in Transport Activity

36. The ASIF approach summarizes a detailed set of data and estimates used in transport planning and analysis, as well as traffic control and management. Table 3 summarizes these data and notes what data are required for authorities to collect, how to collect the data, or what means are available for collection. Trips and distance traveled, which are integral parts of origin–destination survey results, are sorted by modes taken. Routes may differ for a given mode choice. When the number of trips, the nominal distance, and the actual route taken are combined, the number of passenger kms by mode is known. The results then is distributed over the vehicles that provide those passenger kms, e.g., two-wheeler, car or light truck, bus, or some form of rail (air and long-distance rail are excluded). If the type of vehicle is known, then fuel consumption can be estimated, simulated, or in some cases measured from direct surveys or imputed from averages. Simulation may be necessary because actual driving conditions on a given route may be different from those that were the basis of previous estimates. Rogers (2006) showed that overall traffic conditions along the Insurgentes Corridor in Mexico City, where one lane in each direction was dedicated to BRT traffic, improved after implementing the BRT system because so many minibuses that made irregular stops were gone. The result was slightly shorter travel times and more even speeds for 60,000 cars per day, and thus, (from his simulation) a small reduction in fuel use for each car.

Table 3: Components of a Road Transport Model and ASIF Summary

Basic driving forces	**How many trips?** Transport Activities	**How many kilometers (km) traveled?** Vehicles	**How are km traveled?** Distance	**Routes** Fuels	**Distance travelled by fuel and vehicle characteristics**	**Fuel use and CO_2 emissions** CO2
What the step or term contains	Activities that join origins and destinations, giving, trips; For example, employment generates a trip from home to work in the morning and back in the evening. A stop for food shopping might be made on the way.	Separation of originations and destinations, but distance subject to actual route taken	Mode choices	Route, network conditions, speeds that give actual distances traveled and actual distances vehicles move	Changes in vehicle activity and speeds over routes by vehicle type and fuel	Changes in km traveled by vehicle type, and changes in fuel use/km by vehicle type, for each fuel
Driving Forces	Incomes, lifestyles, socio-demographic status	Profoundly affected by density and land uses, availability of modes, speeds	Choices affected by land uses, incomes, locations of "O" and "D," incomes, relative speeds and travel times, safety, and overall service	Relates to traditional traffic engineering and transport planning	Costs of a vehicle km (fuel, tolls, parking); traffic conditions, i.e., speed and congestion	Engine technology, driving style

Basic driving forces	**How many trips?** Transport Activities	**How many kilometers (km) traveled?** Vehicles	**How are km traveled?** Distance	**Routes** Fuels	**Distance travelled by fuel and vehicle characteristics**	**Fuel use and CO_2 emissions** CO2
Best Data Sources	Origin–destination surveys and commodity flow surveys for freight. For travel, should include purpose (e.g., to/from work, school, shops). Freight should include nature of commodity shipped	Same as previous. Should include non-motorized transport (with zero fuel or carbon intensity)	Same as previous, but also data from passenger and freight operators, on board surveys of travelers	Visual observations, traffic counts, speed measurements	Surveys of individual vehicle use; data from fleet operators (taxi, bus, truck)	Fuel use can be measured from surveys, estimated according to simulation models adjusted to local traffic conditions, or imputed from fuel sales, vehicles, and vehicle kilometers
Where in ASIF?	Combined, these data give passenger kilometers (or ton kilometers) by mode. Note that vehicle occupancy, which is part of the denominator of I (pass-km = veh-km times vehicle occupancy) is a nontechnical term affected by land uses, level of service and system management (for public transport), household size (for individual transport).				Do not appear directly in ASIF unless specified as a veh-km formula	Fuel use appears as numerator in “I,” fuel use multiplies carbon coefficient “F” gives the CO_2 emissions intensity by mode.

Source: Authors.

37. Table 3 also suggests how key driving forces can affect each component of transport activity and fuel use. These forces tend to increase total travel, total traffic and total emissions. Policies and measures aimed at counteracting these forces are discussed elsewhere in this volume. Measuring carbon means discerning the stimulating impact of higher incomes and other forces increasing transport activity from measures designed to restrain CO_2 emissions.

8.2 Measuring CO_2 Emissions from Changes in Transport Activity

38. The ASIF approach focuses on CO_2 generated in the combustion of fossil fuels in vehicles and in power plants supplying electricity to rail and other electric vehicles. Various analysts have shown that both petroleum-based fuels and their substitutes have important GHG emissions beside those associated with their final combustion in vehicles (Maclean and Lave 1998, Wu et al. 2007). This life cycle analysis has been applied more broadly to the investment and operation and maintenance of roads, bus, and rail systems in general (Chester 2008). For heavily utilized systems, the energy and CO_2 embodied in such activities may be small compared to that for operations, but rival that for operations in expensive rail and metro systems that are not heavily utilized. Life cycle analysis is also applied to understand the long-term CO_2 and GHG implications of some biofuels, whose production is land-intensive and may involve releases of GHG from soil. Equally important, some biofuels may indirectly cause large GHG emissions by displacing farmland, forcing cultivation of other less agriculturally promising land for food production.

39. The bottom row of Table 3 showed how the more complex transport modeling data are summarized by ASIF. In the ASIF disaggregated approach, multiplying the number of trips per day by the distance per trip gives the total distance a person travels. These must be disaggregated further by mode, with more than one mode possible for each trip. The total person-km traveled on each mode is then compared with the total fuel use and vehicle km that mode provides. Dividing fuel used in each mode by vehicle km in that mode gives the vehicle fuel intensity. Dividing fuel used by travel (passenger-km, freight in ton-km) gives the modal energy intensity of travel or freight by mode.

40. The best way to measure the transport-related components of CO_2 emissions if there is no detailed travel survey or origin–destination data is to survey both vehicle usages (distance traveled per year) and the movements of both passenger and freight from origin–destination travel surveys and commodity flow surveys. Alternative estimates can be made by surveys of passenger operators (urban bus, intercity bus, urban and intercity rail, taxi, and minibus operators) and freight carriers, as well as intercept surveys (truck weigh stations, passenger counts on different modes) and even visual observation of passenger car and light-duty truck occupancy.

8.3 From Transport Activity to Fuel Use and Emissions

41. In the section above, we outlined the importance of measuring transport and vehicle activity. Once the data for these measures of transport are established, various techniques and surveys permit estimation of fuel use by mode and vehicle type. Once this is known, then the fuel used can be converted into CO_2 (and potentially other GHGs) according to conventions established by the Intergovernmental Panel on Climate Change (IPCC).

42. The approach we have presented starts from transport activity, through vehicle choice and use to fuel use. Fuel use could be national averages; local averages; simulated, reported via surveys or measured. In addition to ASIF, other fuel use and emissions models have been used for conducting different on-road vehicle emissions inventories. Three common models are MOBILE, MOVES, and COPERT III. The first two models were designed by the US Environmental Protection Agency (EPA), while COPERT III was developed by the European Environment Agency. MOBILE Version 6 is an emissions factor program designed and released by the EPA in January 2002. It is the latest in a series of MOBILE models that started in 1978. The MOBILE series of emission inventories have been used to estimate total emissions from the highway motor vehicle fleet on a regional level. MOBILE is also used increasingly for other kinds of analysis ranging from estimating the national impacts of motor vehicle emissions control strategies to estimating human exposure to pollutants at a specific intersection. The emission factors calculated by MOBILE are then multiplied by an estimate of vehicle miles traveled to estimate total on-road emissions. The MOBILE family of models is for on-road vehicles, designed to predict gram per mile emissions factors of hydrocarbons, carbon monoxide (CO), oxides of nitrogen (NOx), CO_2, particulate matter (PM), and toxics from cars, trucks, and motorcycles under various conditions. Exhaust, evaporative, and refueling emission factors are also estimated in units of grams per mile.

43. The most recent version, MOBILE 6.2, is the most updated model in the MOBILE family of models, which has the new capacity to estimate PM[4] and mobile source air toxics emissions.[5]

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[4] Exhaust particulate matter (which consists of several components), tire wear particulate matter, brake wear particulate matter

MOBILE 6.2 includes CO_2 emission factors for gasoline-fueled and diesel highway motor vehicles, and for certain specialized vehicles, such as natural gas–fueled or electric vehicles that may replace them (US EPA 2007). This model calculates speed-sensitive emissions for hydrocarbons, CO, and NOx, specifically accounting for aggressive driving behavior that was not represented in older driving cycles.

44. The Motor Vehicle Emission Simulator (MOVES) is a new modeling system developed by EPA's Office of Transportation and Air Quality. This new system estimates emissions for on-road and non-road sources, covering a broad range of pollutants, and allows multiple scale analysis, from fine-scale analysis to national inventory estimation. When fully implemented, MOVES will replace MOBILE 6. The new system will not be a single piece of software, but will encompass the necessary tools, algorithms, underlying data, and guidance necessary for use in all official analyses associated with regulatory development, compliance with statutory requirements, and national and/or regional inventory projections. MOVES also includes speed correction factors for CO_2 emissions.

45. The latest version of COPERT, COPERT III, is a modeling program designed to calculate air pollutant emissions inventories from road transport. The development of COPERT was financed by the European Environment Agency, within the framework of the activities of the European Topic Centre on Air and Climate Change. COPERT was developed primarily to estimate on-road emissions to be included in the official annual national inventories for the European Union member-nations. This model allows for a transparent, standardized, and hence consistent and comparable data collecting and emissions reporting procedure in accordance with the requirements of European Union legislation (EEA 2007). COPERT estimates emissions of all regulated air pollutants (CO, NOx, VOC, PM) produced by different vehicle categories (passenger cars, light-duty vehicles, heavy-duty vehicles, mopeds, and motorcycles), as well as CO_2 emissions on the basis of fuel consumption. Emissions are additionally calculated for an extended list of nonregulated pollutants, including methane, nitrous oxide, ammonia, sulfur dioxide, heavy metals, polycyclic aromatic hydrocarbon, and persistent organic pollutants. The total emissions are calculated as a product of activity data provided by the user and speed-dependent emission factors calculated by the software. The speed-dependent emission factor formulas are developed empirically from multiple real-world tests on many urban drive cycles at different average speeds. These drive cycles are not of constant speed but involve stop-go city traffic and suburban driving cycles, and the speed-dependent emission factor curves are derived from the mean results of each distinct cycle.

46. Fuel use per km as used to evaluate projects may differ from national averages because vehicles or driving conditions are different. There is also a risk that traffic affected by projects may be affected by induced demand. Transport models should be used to estimate a zone of influence where a project will affect vehicle traffic and travel. Traffic and travel counts in that zone can be compared before and after a project or policy is implemented to see whether vehicle use, load factors on private or public transport, mode shift, or other expected effects really occurred. Changes in traffic activity in zones thought not to have been affected by a project or policy could be used as a control.

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[5] Sulfur dioxide (SO_2), ammonia (NH_3), six hazardous air pollutant (HAP).

8.4 Projection and Forecasting Issues

47. Forecasts show what you get if relationships among policy variables hold and the key drivers are known, but often results are conservative because forecasters do not have a good understanding of the issues including how vital data were obtained. One key issue is how poorly these relationships are understood. This is not only because of poor data but also because a limited number of Asian experts are set on the problem of understanding and measuring passenger and goods mobility and access, as opposed to counting vehicles and designing roads.

48. Forecasting or projecting overall emissions of CO_2 in transport is complicated. A top-down approach would project overall fuel use from prices and incomes, perhaps with vehicle stock information as well, as is done thoughtfully in the IEA *World Energy Outlook*. These are usually undertaken at the national level and aggregated to all of Asia. Such projections assume certain elasticities of fuel use with respect to fuel prices and incomes. With price and income assumptions, the projects are "finished." Or are they?

49. While such projections are useful in discussing overall directions of world energy markets, they are not well linked to the transportation activities that underlie them. Moreover, the presence of significant shifts in fuel use by different kinds of vehicles, i.e., fuel choices, as well as likely changes in fuel intensities caused not only by changing fuel prices but by fuel economy standards (Feng and Sauer 2004) or the likely entrance of new kinds of vehicles on the market (e.g. the Nano in India) or persistence of patterns of mobility built on two-wheelers (as seen in Ha Noi, Table 1) cannot be inserted easily into national projections because these imply changes not simply in fuel prices or income but rather changes in the price elasticity used to make the projections.

50. Table 4 below gives one of the major uncertainties that faces projections of transport CO_2 emissions, that of fuel and mode choice. For automobiles, but now also two- and three-wheelers, and in some countries urban buses, LPG and compressed natural gas are competing with gasoline and diesel. While CO_2 emissions do not differ greatly between major petroleum-based fuels, the introduction of electric drive and biofuels gives potentially large uncertainties. Moreover, the kinds of vehicles (e.g., a Nano versus a conventional car, or a two-wheeler versus a car) or choices between individual and collective modes have a large influence on fuel use per vehicle or passenger-km. In countries or regions with rapid changes in fuel choices, the vehicle stock or mode shares, or in any region or country designing policies to changes these choices and shares, a projection or scenario should have the details required to portray the choices, not simply the outcome as total fuel use and resulting CO_2 emissions.

Table 4: Fuel Type and Mode Choice in Asia

Vehicle/Fuel Type	Gasoline	Diesel	CNG	LPG	Others (Biofuels, Electricity)
Two-wheeler	Main			Some	60 million using electricity in the PRC
Three-wheeler	Main		Some	Some	Some electric *tuktuks* in Thailand, Nepal
Passenger car	Main	Up to 35% of fleet in Europe	10% of fleet in some Asian	Popular in Netherlands, Italy, to a	Bioethanol for cars in brazil and flexfuel cars in Sweden. Corn

Vehicle/Fuel Type	**Gasoline**	**Diesel**	**CNG**	**LPG**	**Others (Biofuels, Electricity)**
			countries; 1/3 of fleet in Argentina	lesser extent in other European countries	ethanol for approx 8% of fuel in US, etc. Some ethanol and biodiesel in Asia
Passenger SUV	Main	Increasingly diesel in Europe, Japan, increasingly SUVs			
Commercial/Freight Light truck or van	Main fuel in US, many Asian countries	Increasingly common in Europe for commercial light trucks. Passenger Vans in South Asia	Six passenger vans in India on CNG		
Urban Bus		Main fuel	Several thousand CNG buses in the PRC, tens of thousands in India, Bangladesh		Still several tens of thousands of electric trolleys globally, with the PRC being most important country in Asia. Ethanol-powered diesel engine buses in use in Stockholm.
Intercity and tourist bus		Main fuel			
Medium and heavy trucks	Very few still on gasoline	Main fuel			
Service vehicles (fire engines, cranes, etc.)		Main fuel			

CNG = compressed natural gas; LPG – liquefied petroleum gas; PRC = People's Republic of China.
Source: Authors.

51. Determining the numbers of vehicles by fuel, distance they run every year, and fuel use/distance is difficult enough. Data issues include:

(i) Fuels: (a) quick allocation of gasoline, diesel by vehicle type and by urban vs. rural, (b) splitting motorcycles and other gasoline users from cars, and (c) diesel cars from other diesel uses;

(ii) Vehicles: (a) lack of decent breakdown by mode type and engine technology (e.g., Euro 1 or Euro 2 compliant, etc.), (b) limited data on active vehicle fleet;

(iii) Vehicle activity: (a) limited data and inconsistent methodologies on vehicle-km traveled, passenger-km traveled, and tons-km; (b) limited data on fuel consumption per km traveled on various transport modes; and (c) limited data available on type of roads used whether national highways, expressways, urban arterials, urban local, urban collector, etc.; and

(iv) Emission factors: (a) lack of locally representative emission factors for existing vehicle fleet

52. Scenarios permit connecting stories and reasoning to illustrative, but not definitive quantities. Often the results are surprising because scenario builders get caught up in describing the phenomenal increase in motorization. The EMBARQ scenarios for the PRC, India, and Viet Nam were built to force decision makers to think outside the box, rather than just validate existing forecasts and beliefs (Annex 1).

53. A good example is that of the “Road Ahead” in the EMBARQ PRC scenarios. The “Road Ahead” scenario demonstrates a set of business-as-usual assumptions, that if car ownership and use are unconstrained, oil consumption will continue to increase rapidly as the number of automobiles increases in the PRC. Oil consumption comprises most of the transport energy use in “Road Ahead” at 450,000 barrels per day (kbpd) in 2010 and 2,500 kbpd in 2020. Carbon emission from cars in the PRC in 2003 was estimated to be 8.8 million tons of carbon (MtC). Yet emissions grow to 20 MtC in 2010 and 102 MtC in 2020 in “Road Ahead,” with the assumptions that no additional policies other than existing fuel economy regulations will be implemented. The only condition for this base case is imposed by the existing fuel economy standards.

54. Common pitfalls are found in the base case and data set used for creating the vehicle and emissions forecast and scenarios. For one thing, are the forecast, projected or otherwise, chosen values of the components of ASIF consistent with each other? By how much do they differ from present day values, and are the differences realistic over the period the scenarios or projections cover? Are the high rates of growth in car use realistic? Can cities in the PRC (where most of the growth in car ownership and use is taking place) absorb nearly 150 million cars by 2020? And are the projected improvements in fuel economy realistic, given the crowding and congestion already experienced all across Asia? The present rapid growth and these uncertainties are probably larger than the impacts of any particular transport or energy efficiency measure, hence the effort required to identify impacts, i.e., “measure carbon.”

9 Looking Backward: Measuring Policy and Other Impacts

55. Policies and measures are designed to influence the way the transport system changes and evolves and how vehicles in it emit CO_2. Therefore, the goal of measuring CO_2 in transport is really one of measuring changes from a moving (usually growing) baseline. This goal can only be satisfied by a bottom-up approach because policies typically aim at only some of the many variables related to CO_2 emissions. A policy, such as a carbon tax on fuels, can have one impact on travel, another on vehicle activity, and a third on the CO_2 emissions per km of vehicle travel. Understanding each of these changes is important for policy analysis.

56. It has been stated earlier that there are three ways to reduce CO_2 emissions from transport: (i) avoidance through development, (ii) shifting away from high CO_2 modes (automobiles) or keeping their share low, and (iii) improving the carbon intensity of vehicles.

Whatever combination of these types of measures, it is important to be able to measure and model not simply "before/after" measures, policies, or technologies are implemented but also three specific cases:

- business-as-usual or the base case projected forward with no policy measures,
- modeled and predicted evolution of transport activity and emissions when policies and measures have been applied, and
- actual activity and emissions as measured or estimated to compare with both predicted outcomes and the business-as-usual case with no measures.

57. With this approach, it becomes possible to separate spontaneous evolution in transport activity and emissions driven by higher incomes and changing land uses. Armed with these data, analysts can estimate the impacts of any particular mitigation measure over time against the background of growing emissions. Many outcomes that reduce the carbon footprint of transport slow the growth rate but do not necessarily reduce the absolute level of emissions. Consequently, good transport activity data and fuel use data are both needed to be able to distinguish what happened because of a policy from what "would have happened" without the policy. These data permit evaluation of how each component of ASIF changed against both prediction and under the influence of other forces.

58. Over time, every country and region have experienced the same evolution of transport activity as income levels have grown, resulting in increases in trip distances and travelers shifting from feet/pedals/animal power to collective transport and ultimately to private cars. In the PRC, private car trips in cities still account for less than 10% of trips and 20% of travel in major cities (Tsinghua 2007), while in the US in 2001, car trips accounted for almost 90% of trips and roughly the same share of distanced traveled (NHTS 2003). The increase in distance traveled, in part facilitated by car use, increases the total distances traveled. This is because in uncongested parts of the city, car travel is faster than by other modes, facilitating longer trips in a given amount of time. Thus, if transport planners in developing countries respond to increased congestion by expanding the road network toward outer areas, these will appear decongested at first, but, history as a guide, these expanded road network will eventually fill up, as Beijing and most other Asian cities with large car populations have experienced. Slowing, stopping, or reversing this trend requires both good land use planning and deft political moves, which is probably why most Asian cities appear to be expanding in car-oriented ways. The resulting lower population densities both reduce boardings/km on buses and increase trip lengths, which further encourages car use.

59. In countries of the Organisation for Economic Co-operation and Development, increased car ownership and shifts of travel in other modes to cars together account for almost all the increase in per capita fuel use and CO_2 emissions for travel (Schipper and Marie 1999). And shifts toward motorized transport and cars raise the fuel use per passenger-km traveled. The same is true for developing countries (WBCSD 2003). Business-as-usual projections foresee continuation of these trends, as individual automobile ownership is made possible by higher incomes (or falling costs for owning and using cars). Thus, if Asian cities continue to sprawl, the results will be both a higher share of automobiles in total travel (in passenger-km) and a high

share of that travel in high-carbon modes.[6] It is against this baseline evolution that "measuring carbon" must occur.

60. In this framework, "savings" from a policy intervention will usually lead to lower fuel use or CO_2 emissions than would have occurred in a business-as-usual situation, i.e., without the actions implemented that would lead to changes in emissions. Figure 4 illustrates the kind of comparison to make. The diagram could symbolize a specific transport corridor, a part of a city, or an entire metro region.

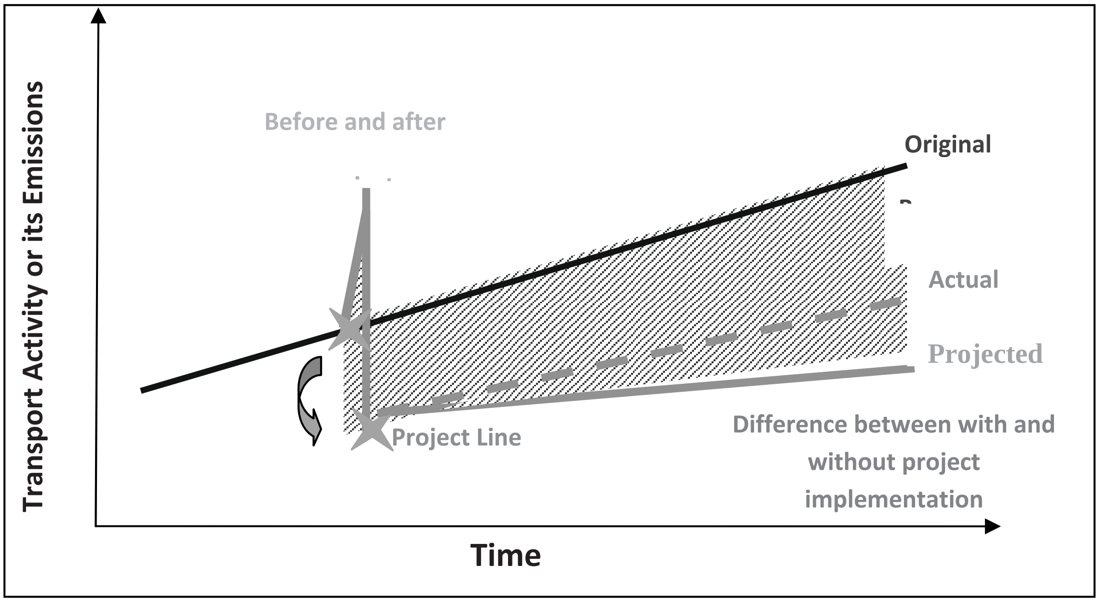
61. In Figure 4, a moving baseline depicts a business-as-usual scenario and a project outcome. The solid line represents transport activity or emissions as projected under a business as usual baseline, i.e., no new projects or policies. This baseline is calculated bottom-up using ASIF. Fuel intensity estimates or measures transform vehicle movement to fuel use. The spike where the project is initiated illustrates what often happens when projects themselves cause temporary disruptions during construction or during their initial phase. The bottom-up approach requires the analyst to specify how many vehicles, of what type, travel how far, and using how much fuel. Some vehicles counted may not be used if travelers switch to another mode. It is this level of detail that is required for the immediate before/after analysis.

62. Cities, regions, and countries are not static. Emissions rise over time when incomes and population rise, more individuals use cars, traffic worsens, and the urban region itself may expand (increasing trip lengths).

63. A project or intervention can quickly change both the absolute level of emissions—the "project line" shown in Figure 4—and the slope of the change in emission over time. What is illustrated in Figure 4 has been exaggerated to differentiate the baseline from the actual development because of a project or policy. Note, however, that the slope of the project line has been drawn to be less than the slope of business as usual. This illustrates another—perhaps more important—outcome, namely, projects and policies slow the rate of growth of CO_2 emissions relative to the rate of growth in the business-as-usual case. Some projects might lower the absolute level of emissions briefly, only to see growth return at the same rate as before. The bottom-up data described previously are required to calculate how much "less than otherwise" measures saved. This is true whether the measures are imposed as national policies or locally, and whether the measures are broad, such as taxes and fees, or specific transport projects. Quantitative understanding of vehicles, vehicle use, flows of people and goods, and vehicle fuel use is also necessary.

[6] For example, Bangalore statistics show constant reduction in bus trips mode share: 60.19% in 1994 (ILFS); 48.91% in 2002 (RITES); and 35% in 2008 (MOUD). Meanwhile, the two-wheeler ownership motorization levels (two-wheelers per 1,000 people) increased from 124 in 1995 to 247 in 2005. To combat decrease in share, Bangalore doubled the number of buses in 7 years (2001–2007) but, owing to the growth in city size, the average trip length increased by 2.5 km and per capita land transport energy consumption increased from 3.59 Megajoules/Day (MJ/day) to 9.67 MJ/day. See www.cleanairnet.org/caiasia/1412/article-73353.html for more discussion.

Figure 4: Transport Activity and Emissions Over Time With or Without Transport Policy or Project



Source: Rogers and Schipper. (2005); Schipper, Cordeiro, and Ng (2007).

64. The reason bottom-up data are so important is that most transportation measures affect how people and goods move, and thereby how fuel use changes. Fuel sales data are too aggregate to reveal how transportation activities changed from specific measures. If one examines the US NEMS model, the total for national transport fuel use or emissions is modeled bottom-up from a dozen modes of travel and freight and even more technology-fuel combinations. If a policy intervention or project affects a particular mode, fuel, or region, its impact is unlikely to be discernible within the aggregate fuel sales. And without a reasonable accurate business-as-usual projection, there is nothing with which to compare the outcome of imposing such policy intervention or project to.

65. Another reason a bottom-up model and approach is desirable is to be able to account for effects of economic recession or boom, increases in total population or its distribution, and other effects within either an entire country or just an urban region. While the 1997–1978 Asian recession or the current worldwide slowdown has apparently lowered transport activity, congestion, and fuel use, more detailed information is needed to separate the macro effects from changes in transport activity that might signal impacts of policies or other transport-oriented interventions.

66. Consider now the various kinds of interventions related to CO_2. A project only aimed at public transport vehicles' fuel type or consumption would in principle be easy to monitor if the operators were cooperative. Comparing actual activities with a counterfactual would be straightforward. Unfortunately, such a project would only have a small impact on a region or country's emissions because the public transport sector represents such a small share and diminishing share of total emissions.

67. A project such as a new BRT line aimed at shifting car users to buses could also be relatively straightforward to monitor in terms of methodology. A good database on fuel use in buses and private cars would be necessary. On-board surveys could establish which bus riders used to travel by car and determine how far they used to drive. Over a number of years, however, a model of “business-as-usual” without the project would be needed to see if the overall results tend to increase or decrease over time. Whether the project was a CDM, NAMA, or financed in part by the Global Environment Facility or another international mechanism, the process of estimating CO_2 savings does involve many steps, as Rogers’ work for the Mexico City BRT line shows (Rogers 2004).

68. The most important projects in terms of potential CO_2 savings must aim at restraining the growth of the use of private cars and reductions in the emissions/km of all vehicles. To measure these impacts, both national and regional models of traffic and transport activity are needed, as well as good measures of real fuel economy of all road vehicles. This is more complicated and time-consuming than previous examples of interventions.

69. Considering the discussions above and building on the current methodology and terminologies employed by the IPCC in measuring emissions, a parallel scheme could be used for transport energy and emissions. Tier 1 would then use international “default” parameters for fuel use/mile by vehicle type. Since these figures vary by a factor of two according to vehicle size and efficiency, Tier 1 is useful only for a first-cut approximation. Note that per passenger or ton-km of travel or freight, the variation is closer to a factor of five, so there can be no substitution of numbers. Local vehicle activity or travel/freight estimates must be made, as there are no “default” parameters.

70. Tier 2 would correspond to taking actual national averages for fuel economy (fuel use/km) by fuel and vehicle type. Simulations of on-road (in-use) fuel economy are only useful if these have been validated by detailed comparisons of actual fuel use records.

71. Tier 3 corresponds to using fuel economy data by vehicle that reflect actual vehicles in a project or affected by a project, i.e., in its zone of influence. Simulations may be used if they have been carefully validated for the types of vehicles in the project.

10 Data Requirements: A Three-Times-Three-Tiered Approach?

72. Data required for monitoring transportation and local emissions, data required for evaluating the impacts of transport and CO_2 policies on CO_2 emissions, and data required for good transport forecasts are similar. This makes one group of three-tiered components.

73. The other set of tiers that maps into these uses are the data themselves. Almost no developing countries in Asia have or use data at present that provides a thorough understanding of the transport sector. What is published is total transportation fuel use; by fuel type; and whether the usage is for road transport, rail, domestic waterborne shipping, passenger traffic, or domestic air traffic. We define “data” as information generated regularly by surveys bottom-up or by top-down tabulations where possible. There are many one-time, disaggregated estimates of vehicle activity, passenger and freight activity, and energy use made for studies but these are rarely repeated in any consistent way. Hence, leaders and planners in developing

Asian countries cannot easily see the connection between transport and CO_2 emissions. They can only measure emissions arising from aggregate fuel sales by the type of fuel.

74. In most Asian countries, information and data collection related to transportation generally fall within the jurisdiction of the ministries of transport and energy. In some instances, the ministry of environment also collects information related to transport. Needless to say, the regularity and consistency of data collection mostly, if not at all, are not present. Categories are not carefully defined and in some cases sources or years applicable are not even given.

Table 5: Planning, Monitoring and Evaluation of Policies Related to the Transport-CO_2 Link: Data Required for a Three-Tiered Data Collection Approach

Data Category	Tier One: Known Today	Tier Two: National Bottom Up	Tier Three: Urban Region or Project-Specific	Best Practices for information gathering	Complementary Data Sources
	Little information except slowly changing averages	Allows estimation of social and regional impacts of policies	Allows estimation of impact of local project on regional areas		
Vehicles	Total registrations by country and state, sometimes by city or metro region	From surveys, stratified by where vehicle is garaged, socio-demographic characteristics of private owner or characteristics of firm		Annual survey for vehicle owners coupled to vehicle registry	Household income surveys; business surveys
Vehicle use		From surveys, stratified by where vehicle is garaged, socio-demographic characteristics of private owner or characteristics of firm	From surveys, stratified by where vehicle is garaged, socio-demographic characteristics of private owner or characteristics of firm	Annual survey of vehicle owners; reading of odometers and other sources of data	Household survey; Police and insurance data on accidents; Collect at time of resale of vehicle
Passengers or freight output by mode	Some data intercity common carrier of road freight and bus; Good data on intercity rail; Poor data on urban travel (in passenger/km) by mode; No	Complete specification of passenger and freight mobility by mode and distance interview, i.e., trips by length of trip	Complete specification of passenger and freight mobility by mode and distance interview, i.e., trips by length of trip.	National and local travel survey (trips by distance, mode, and purpose); truck utilization survey and commodity flow survey over all freight	Common carrier operators' own data on passenger-km for intercity rail, bus, and urban modes.

Data Category	Tier One: Known Today	Tier Two: National Bottom Up	Tier Three: Urban Region or Project-Specific	Best Practices for information gathering	Complementary Data Sources
	data on car or motor cycle			modes	
Fuel use/km by vehicle type to get CO_2 emission per kilometer and per passenger and ton-km	Unknown; Multiplicity of fuels (e.g., diesel used for cars, vans, buses, and trucks) invalidate any common rules of thumb.	Fuel use/km for each kind of fleet vehicle		Vehicle use and fuel consumption survey	Trade associations for urban bus, intercity bus, taxi, trucking; Electric utility for sales to electric traction customers (trolley bus, urban and intercity rail)
Total fuel use for a given vehicle type to get total CO_2 emissions by mode	Unknown	Each fuel for each vehicle, e.g., gasoline, diesel, CNG, LPG for passenger cars, other light-duty vehicles, etc.			
Best practices		Bottom-up survey "Australian Transport Task"; Mixed surveys and top down: MLIT and METI transport and energy data; Canadian vehicle use and fuel consumption survey	Occasional metro household travel surveys, e.g., Ha Noi 2003; vehicle activity survey in Pune, 2003		

CNG = compressed natural gas, CO_2 = carbon dioxide, LPG = liquefied petroleum gas.
Source: Authors.

75. In Table 5, "best practices" refers to survey-based data gathering aimed at quantifying ex ante the impacts of a project, rather than applying data from a larger part of the urban region or country as an approximation to a zone, where a project is expected to have an impact. In Rogers (2006), for example, films of the cars using the Insurgentes corridor were used to identify the differences between those cars and the "average" vehicle in the Mexico City region. "Best practices" may be expensive if used for a single transport project, but inexpensive if based on a wider set of data or observations gathered to improve transport planning (vehicle use) and environmental monitoring (vehicle emissions).

76. For Asian countries, Japan has the most thorough approach to collecting and analyzing data on all branches of transport, with particular emphasis on road transport data. The information on each mode of road transport (vehicles, vehicle-km/year, passenger-km per year, fuel use by fuel, fuel use per passenger, and vehicle km) contributes to a bottom-up picture of road transport. Similar information is available for passenger and freight rail, domestic air travel, and domestic (e.g., coastal and interisland) shipping, including ferries. Australia has a similar system with even more details published. Unfortunately, these are the most complete data collection and publication efforts in the greater Asia and Pacific region.

77. Many countries in Asia have not institutionalized data collection, management, and the updating process. For example, in India, the Ministry of Shipping, Road Transport and Highways maintains the database on registered vehicles. They collect data from various regional transport authorities, but since vehicle registered data is neither updated periodically nor categorized by fuel use, it cannot be used for the ASIF methodology. Activity level data are collated generally at corridor level and are maintained by the national highways agency. These data represent vehicle volumes, not vehicle-km/vehicle that can be used for annual averages. Data at city levels are collected, processed, and maintained at city and regional levels without having these compared or cross-checked with data at the national level. In addition, the Ministry of Urban Development conducts periodic surveys in big cities to capture some of the important activity and trip patterns. Almost no data on freight, passenger travel, or vehicle km traveled by private trucks, cars, or two-wheelers in urban regions are collected regularly.

78. In the PRC, the main source of data is the National Bureau of Statistics, which acts as the common repository of data from various agencies. It has the passenger level estimates, freight ton estimates, average distance traveled, etc. But the number of vehicles is not categorized by mode and fuel type. Data at city levels are often available at research agencies and not related to the national government. The PRC data situation is similar to the situation in most other developing Asian countries. For Indonesia, Republic of Korea, Pakistan, and Thailand, the main source of data is the statistics division, which collates the vehicle registration database. But again, it has the disadvantages of not maintaining the vehicle registration database and the failure to collect more specific data on vehicle activity and fuel type.

79. In Bangladesh, Malaysia, Nepal, Philippines, and Sri Lanka, the transport ministries and research institutions act as main repositories of the transport database. They have the vehicle registration accounts, which are updated regularly for a few countries such as the Philippines but for some, such as Nepal, it is rarely done. They again do not collate information at the corridor level, activity, and fuel type.[7]

80. The national centers of statistics or census clearly play a major role as some parameters that are routinely collected over a period benefits the analysis of the transport sector.

81. The main issues relating to the collection and maintenance of data necessary for measuring CO_2 emissions from the transport sector are (i) dedicated institutions and capacity conducting the measurement, surveying, and analysis; (ii) the parameters collected; and (iii) the means of publication and sharing among agencies. Since transport and energy data tend to

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[7] For example, the last time Metro Manila had detailed city level trip characteristics surveys was during the 1996 Metro Manila Urban Transport Integration Study. Latest vehicle registration information available at the Ministry of Shipping, Road Transport and Highways of India website is 2004.

involve a number of national authorities (e.g., ministries of communication and/or transport, energy, environment) and major regional/local authorities with similar responsibility, weaving together a working group with agreed-upon periodic information exchange is complicated, as experience in OECD countries has shown.

82. It must be emphasized that the main data collection focus at both the local (i.e., metro) and national levels is on transport data, i.e., vehicles, traffic flows and speeds, vehicle usage, travel and freight activity. These are the basis of traffic and transport planning at all geographical and administrative levels. Collecting these data is in the direct interest of transport and traffic safety authorities, who should shoulder the main cost burdens. Environmental authorities have an interest in local emissions and global emissions from different vehicle types. Energy authorities have an interest in monitoring how fuels are used for different classes of road vehicles. Thus, even if there were no interest in CO_2 reduction, each nation's authorities should share in the overall costs of gathering and maintaining these data as a way of monitoring the transport system, air pollution, and fuel use. Further, the private sector (transport providers, automobile manufacturers, etc.) should also have a direct involvement as stakeholders.

83. OECD country experience shows it takes several years to set up the required vehicle, passenger and freight surveys, fund data collection and analysis, and maintain the surveys over a long period. Once a data system has been established, it needs to be maintained. Recently, in the US, the Vehicle Inventory and Utilization Survey, which covered all trucks (including household SUVs and pickups) was discontinued after 2002, leaving the US, the largest road fuel consumer in the world, with no instrument measuring how its vehicles consume fuels. Because action to reduce emissions from transport will take place in small steps over many years, it is important that national authorities understand the criticalness of securing funding for a long-term effort.

11 Testing ASIF and Available Data for Estimating Emissions in Asian Countries

84. Given the ASIF model and data requirements, the authors assessed the current vehicle fleet and forecasted the vehicle numbers from 2005 up to 2035 using data collected by Segment Y Ltd. and through various government data in selected Asian countries. Vehicle fleet data for the PRC, India, Indonesia, the Philippines, Thailand, and Viet Nam were sourced from Segment Y Ltd and cross-checked with available public data. The data obtained from Segment Y Ltd included detailed breakdown of existing vehicle fleet by fuel and mode type, including compliance with Euro standards.

85. Vehicle activity data, i.e., annual VKT, from many Asian countries are not aggregated at the national level. To obtain the best possible numbers on emissions and existing vehicles under the present circumstances, vehicle registrations, operation, and activity data were culled from various existing studies available on the web. Selected national government agencies and key stakeholders were also contacted for data collation. In some cases where vehicle activity data was not available, data from various published research papers published were used. It is acknowledged that vehicle activity data are uncertain. Yet by putting terms for activity in each projection in a transparent way, experts and authorities can see the role of the number of vehicles and vehicle utilization, as well as the assumed fuel use/km and carbon content of fuel figures in this ASIF-based approach to projections.

86. Long-term forecasting of vehicles is complex as travel behavior constantly changes with respect to the economic, social, and environmental influences. To have the long-term forecasting for Asian vehicles, it was decided to observe the past trend of vehicle registrations available from the past two decades and establish the current growth rates. These growth rates were compared with the growth rates established by the short-term econometric regression of vehicles and GDP. The time-series growth rates were found to be more conservative in nature and, thus, adopted for many countries. There is a need to modulate the growth rates as per the economic growth during the later years in long-term forecasting. The authors with an intention of restricting the projections based on the concept of "saturation limits" adopted the research by Dargay et al. (2007) to limit the motorization levels. This research is based on the concept that motorization levels in a country have maximum saturation levels that cannot be exceeded at a certain point of time. The motorization projections were modulated by keeping the saturation limits on vehicle shares. When the time-series growth outpaced the saturation level, the growth of that particular mode will stop, thus restricting the numbers during the later years.

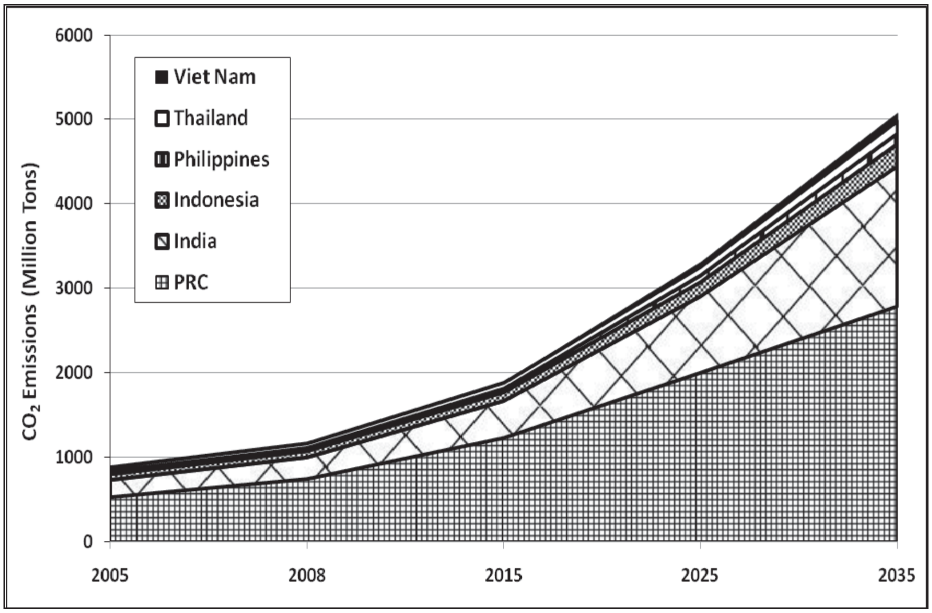
87. Whenever locally developed emission factors are available from relatively reliable sources, they were used. Emission factors were also used from various studies in some Asian countries, such as the emission factors developed for Bangkok, Thailand, under the Developing Integrated Emissions Strategies for Existing Land (DIESEL) Transport project of the World Bank.

88. Figures 5 and 6 show CO_2 estimates generated for this paper. As explained above, the estimates are business-as-usual projections, with many limitations. Estimates from the PRC do not include the possible impacts of current strengthening of fuel economy measures for example. It is not known what present on-road fuel economy levels actually are, nor how the fuel economy standards (which apply to 15 classes of light-duty vehicles by weight) play out in terms of vehicles sold nor what the sales weighted average fuel economy means in real traffic. Without knowing these quantities and the rate at which new cars replaced older ones, one cannot measure the future impacts of the standards. The same limitations apply to projections in other countries. Even without standards, fuel economy is likely to change. But by how much, and what is the present value for each kind of vehicle?

89. These uncertainties notwithstanding, the estimates suggest 6.4% annual growth in fuel consumption until 2035 on account of increased motorization. The analysis shows that contrary to developed nations, passenger transport share among developing Asian countries are lower than freight transport share. The LCV share in many countries includes intermediate public transport vehicles used for passenger movement. However, the estimates have to be considered with the policies and current motorization levels. Countries like Viet Nam show increase in share of road transport freight emissions due to heavy investment of roads. However, the estimates are dependent on current technology and trip patterns. Increase in mobility and motorization in future can counterbalance the gains in the fuel economy of vehicles and this aspect needs to be considered in the future with analysis of improved data and assumptions.

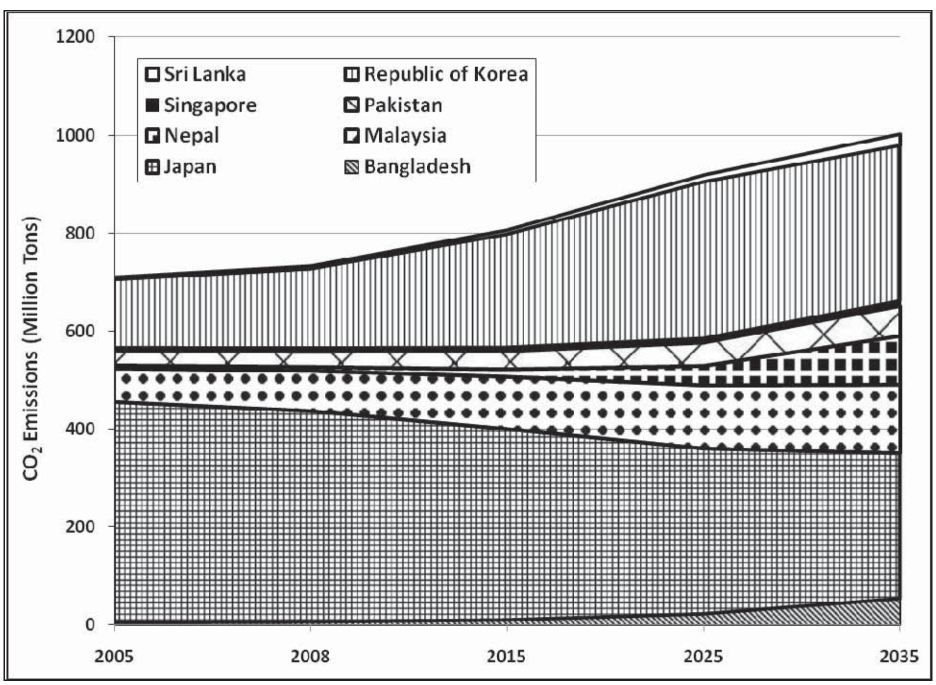
90. Using the same vehicle activity and fleet data, PM emissions were also estimated with the appropriate emission factors. Estimates showed gradual reduction of PM emissions on account of strengthening of emission standards, and as such reflected in the vehicle fleet forecasts. Since the emission standard road maps are not clear and were seen to stop at Euro 3 in some countries, PM emissions showed an increasing trend after a decade.

Figure 5: Road Transport CO_2 Emissions (Million Tons) Using Segment Y Ltd. Data



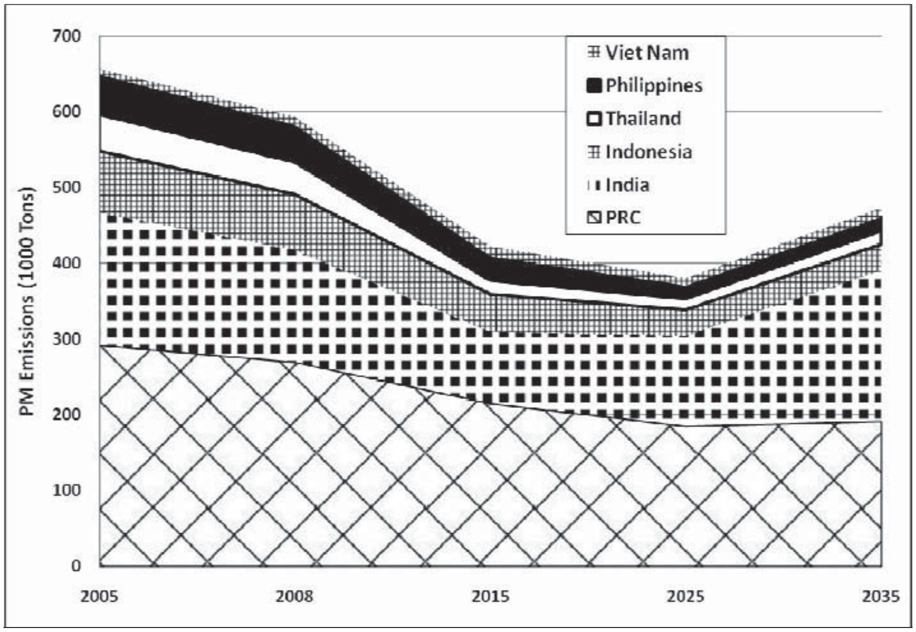
PRC = People's Republic of China.
Source: Authors.

Figure 6: Road Transport CO_2 Emissions (Million Tons) for Other Asian Countries



Source: Authors.

Figure 7: Road Transport PM Emissions (1,000 tons) for Asian Countries Using Segment Y Ltd. Data



PRC = People's Republic of China.
Source: Authors.

91. This exercise has verified the difficulties identified in the earlier chapters in using the ASIF bottom-up methodology with existing data. In the absence of a good data set on vehicle fleet, activity, and operations, several assumptions were used. Although all data have come from existing published studies, it still raises the issue of the accuracy and representativeness of the data in local conditions.

12 Summary and the Way Forward

12.1 Bottom-Up and Top-Down

92. The bottom-up, ASIF approach permits estimation of the impact of changing parts of the complex transport system that affect CO_2 emissions, whether transport activity, fuels, or vehicles. This approach allows planning of technical and policy research on how to affect emissions from transport. The same approach allows estimation of how specific investments in new transport systems (e.g., metros or BRT) or technology (e.g., hybrid vehicles or signal timing systems) would affect emissions. Since CO_2 emissions depend on emissions per vehicle km or emissions intensity and distance traveled, relating the impact of transport policies to CO_2 emissions requires good knowledge of these activity parameters.

93. At the same time, reductions in emissions/km are also expected through a number of improvements in technology and improvements in traffic conditions themselves. Measuring these improvements requires knowledge on which vehicles consume which fuels and how far they are driven. The possibilities of switching to fuels that emit both less CO_2 when burned and processed such as biofuels. While not a transport measure by itself, this information also

requires knowledge on how far vehicles go and how much fuel/km these vehicles emit. Such data will then enable a comparison of emissions from vehicles using the different fuels—the distances the vehicles are driven before and after fuel changes are not the same, as a comparison of diesel and gasoline cars in Europe has shown (Schipper 2009; Schipper, Fulton, and Marie 2002).

94. Forecasting or projecting overall emissions of CO_2 in transport is complicated and requires a good understanding of the business-as-usual in the vehicle fleet, activity, and operations data. A top-down approach would project overall fuel use from prices and incomes, perhaps with vehicle stock information as well, as is done thoughtfully in the IEA *World Energy Outlook*. But it may not provide a good understanding of the problems and interlinkages of various parameters like VKT, fuel type, and fuel intensity when a bottom-up methodology like the ASIF is not used.

12.2 Data

95. The current state of information on how people, vehicles, and freight move within countries and their major urban areas in developing Asia is poor. The available information does not permit the discerning of how much fuel vehicles, people, or goods are required to use over a given distance. The broad information available in fuel sales is not tied to the vehicles that use the fuels. This means that the impacts of policies designed to influence transport, including NAMAs, as well as policies aimed directly at fuel use and CO_2 emissions, such as fuel economy standards, cannot be measured with any accuracy against the background of rising aggregate transport activity and fuel use. While blunt instruments like large price increases or strict fuel economy standards will show up in national aggregate fuel statistics, most key measures that affect CO_2 emissions will act through impacts on transport activity, vehicle use, and only secondarily on direct fuel consumption.

96. What is needed is a broad program of capacity building to increase the ability to collect and analyze data on transportation activity, fuel use, and the resulting CO_2 emissions. Countries need to assess what they do know at present, what gaps can be filled by using available information, and what new information needs to be gathered on a regular, accurate, reliable, and transparent basis. Such capacity building efforts need to be linked to a better institutional framework that defines the responsibilities for data collection and sharing, analysis, and dissemination.

97. In most Asian countries and cities, the majority of information necessary to assess CO_2 and air pollutant emissions can be found only in individual projects, while even in these cases travel activity and characteristics are not sufficiently covered. Those parameters, which cover predominantly vehicles, vehicle activity, transport activity, and fuel use associated with each kind of vehicle/fuel combination, must be gathered as part of regular surveys undertaken by transport, energy, environment, and commercial authorities at the national level. Since the same data are required for good regional and/or local transport policy and environmental policy, we recommend that local authorities also work together to collect such data. The data currently collected by the Ministry of Land, Infrastructure and Transport in Japan form a good starting point (MLIT 2008), and the details on vehicles and usage as collected for Australian authorities form an even more detailed approach that is laudable. These must be supplemented by personal travel surveys that measure how people, not vehicles, move, and commodity flow surveys that show how goods move in the economy.

98. Public and private authorities and stakeholders in each country have to ask certain key questions:

- What level of accuracy is required to “measure carbon”? In general, the sample size and measurements should permit enough accuracy to resolve at least 10% of the current or expected growth in transport emissions. This level is about what is required to discern a single year change in new vehicles because of fuel economy standards or changes in vehicle use if there is a sizable increase in fuel prices. To measure the impacts of local transportation policies accuracy may need to be greater but, as Rogers (2006) suggests, the focus can be in a zone of influence where the impacts of those measures is expected.

- What level of accuracy, how periodic, what is ideal and workable? This depends on how fast a country’s transport activity is growing and to what extent a country wants to use these data to validate measures that will affect transport and thereby restrain CO_2 emissions. If surveys are only carried out every 5 years, then the most current information at hand when policies and measures are enacted will be 3–4 years old on average, given the delay to process data. At current rates, the PRC’s private car fleet doubles in that period of time, so data will be “old” when they are available.

- How much funding is required to collect the ASIF parameters of vehicles, vehicle movement, person and goods movement, and fuel use for each vehicle/fuel type combination? This can only be answered in detail by each national or local authority.

- How can costs be shared among different branches of government? How can surveys be combined and sample frames be shared? As an example, why not put certain questions in at least a subsample of the national census? The best approach considers together vehicle, traffic, transport, fuel, and emissions data and develops a systematic approach with costs shared among authorities and coordination of frequencies, etc. so that the efforts of different authorities, the data collection and processing itself, and analysis all takes place in a coordinate fashion.

- Since most Asian countries will be interested in third-party funding for transport-related projects, countries should realize that good baseline data need to be collected in advance not when a project appears on the horizon. Fortunately most data required for good transport/CO_2 monitoring are important to transport planning, environment assessment, and energy planning as well. We recognize that national statistical agencies have traditions or well-established national practices. However, the IEA has demonstrated with its collection and harmonization of energy data that such harmonization can occur.

- One step that could be taken almost immediately is to provide some seed grants for selected Asian countries to begin the careful steps to develop data collection, not on a project-by-project basis but as a long-term responsibility of each government. Having such data developed could then be a prerequisite for all transportation-related assistance after a number of years.

- The most important step toward harmonization would be increased transparency of present national data sets. For example, when authorities publish passenger km or road transport data, the definition of what is included should be presented clearly. As far as we can ascertain, this is not the case for the majority of Asian countries.

- Additional efforts could be led by the International Transport Forum, the International Road Federation, the Global Road Safety Partnership, and other authorities to harmonize definitions, weight and power classes and other vehicle characteristics so stocks, sales, and vehicle activity are truly comparable across countries and between Asia, Latin America, and other regions.

12.3 Way Forward

99. In the short term, the following steps should be taken. A standard set of data can be developed, in three tiers much like the IPCC. This should lead to surveys of what data are and are not available in each country. At the same time, a clear message needs to go to governments that data collection requires funding. Funding needs to be structural and not project driven or dependent on foreign assistance apart from capacity building to strengthen local efforts. One financing scheme might involve a small tax on fuels and transport ticket sales or freight bills of lading. Other funding sources can be explored, but funding should not be an issue when in fact only a very small fraction of the national transport bill (which itself is between 10% and 20% of most economic activity) is used for data gathering.

100. A clear challenge is selecting an agency or other institution to manage data collection, analysis, and publication, including the analysis and publication of indicators. This must be an institution with a good background in both statistics and transport, as well as credibility in the transport community. We advocate that candidate institutions be selected as part of the task of analyzing existing data and determining data needs. A long-term commitment is required and the organization selected should have the required institutional mandates and operating budgets to conduct its work well.

101. In the medium term, the selected institutions in several countries should work with authorities to analyze data needs and field test surveys to determine what the real costs of the transport and fuel use surveys will be. With this information, authorities can determine the real costs of regular data gathering and processing. And governments can develop partnerships among national and local authorities to both share data gathering costs and in the analysis with the host institution.

102. International organizations and development institutions can play an important role in strengthening the capacity to collect, analyze, and manage data required to arrive at well-chosen policies and programs to develop the transport sector in a sustainable manner and one which will slow down the growth of CO_2 emissions.

103. At the same time, a longer-term process must be started to appoint an international authority to coordinate data gathering and train national and local authorities much as the IEA has done for energy data. Regional authorities need to be established (or authority vested in an existing regional authority, such as ESCAP) to work with countries and key cities in each geographic region.

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Appendix 1: Review of Key Land, Transport, Carbon Dioxide Emissions Forecast Models and Scenarios

1. This appendix provides a general introduction of transport and energy models and what they can or cannot tell. One of the important elements of projections include baseline that reflects expectations, known relationships among variables, connection between exogenous or surprise variables and endogenous or policy variables.

2. There have been several land use, transport, and carbon dioxide (CO_2) emissions forecast models developed over the past few years, attempting to project energy use and CO_2 emissions from the transport sector. Some models are wider in scope than others, focusing on global transport trends, while some are specific country studies. This section provides a review of existing land, transport, and CO_2 emissions forecast models. The US DOE NEMS model is a large, multisector, US-focused modeling system, and its comprehensive approach could be studied and applied to other regions. The IEA/SMP and both EMBARQ's India and the PRC models are similar in structure, as all three are heavily based on the ASIF approach. However, the IEA/SMP model has a global scope and includes a safety component, while EMBARQ's models are country specific and only focused on road transport.

3. The energy demand model developed by the McKinsey Global Institute covers most regions globally, and analyzes policy options, such as removing fuel subsidies, tightening fuel-economy standards, and providing subsidies or tax credits for companies implementing certain energy conservation technologies. Although it has a global scope, it also includes an in-depth PRC case study.

A. US DOE NEMS Model

4. The National Energy Modeling System (NEMS) is a computer-based energy-economy modeling system of the US energy markets for the midterm period through 2025. NEMS projects the production, imports, conversion, consumption, and prices of energy, subject to assumptions on macroeconomic and financial factors, world energy markets, resource availability and costs, behavioral and technological choice criteria, cost and performance characteristics of energy technologies, and demographics annually. Congress and other federal agencies have used NEMS to evaluate energy and transportation policies. The model has been peer reviewed by the US transportation community including the Department of Energy, Department of Transportation, Environment Protection Agency (EPA), the Office of Management and Budget, the Government Accountability Office, and the National Academy of Sciences.

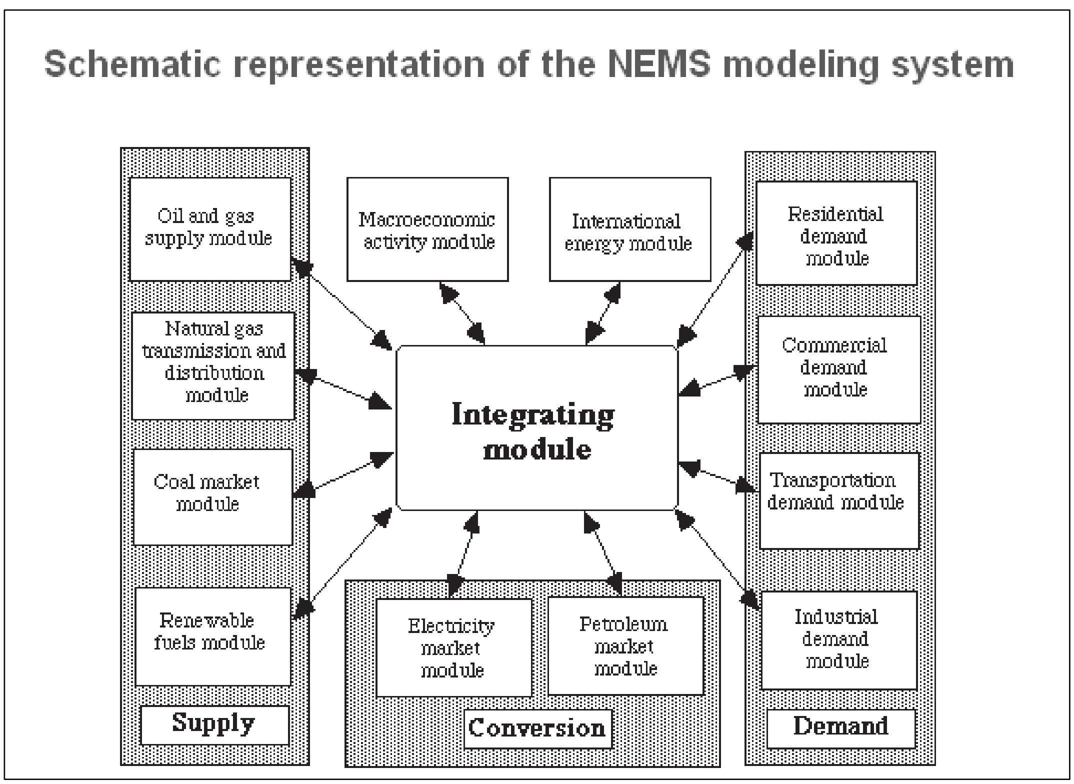
5. The structure of NEMS consists of an integrated modeling system representing all demand sectors of the economy (residential, commercial, industrial, and transportation), including a macroeconomic component and all energy supply sources (i.e., crude oil supply; oil refinery; oil distribution; natural gas including exploration, drilling, and distribution; electricity including nuclear, coal, natural gas, residual fuel, and small generators like wind and solar; coal; and renewable fuels). The NEMS Transportation Demand Module (TRAN) provides wide coverage of the aggregate transportation system including the following submodules: light-duty vehicles, aviation, freight transport (truck, rail, waterborne), miscellaneous (transit, recreational boats, aviation gasoline), and emissions. This module is further divided into sub-modules that include light-duty vehicles, aviation, freight transport, rail and waterborne, as well as

miscellaneous sub-modules. The latter includes mass transit, which covers six transit modes: three types of passenger rail—transit, commuter, and intercity; and three types of passenger buses—transit, intercity, and school. Travel is estimated for all six transit modes as a function of the relative historical growth rate of passenger-miles of travel relative to light-duty vehicle passenger-miles. Growth rates of efficiency improvements are calculated based on the growth rates of similar technology modes. This assumes that technology advancements will parallel those in modes using the same vehicles.

6. The Transportation Demand Module also has a module that forecasts emissions of the criteria pollutants sulfur oxides (SOx), nitrogen oxides (NOx), hydrocarbons, carbon (CO), and CO_2. Most recently, TRAN incorporated the EPA Mobile 6.0 model, which is used by EPA and several state governments to calculate regional emissions. CO_2 and total CO emissions can be calculated by fuel type and by transportation mode, which allows the user to associate various policies or investments with an increase or decrease in carbon emissions.

7. A unique feature of this model is that it incorporates an economic component, captured by the Macroeconomic Activity Module (MAM), which consists of the Global Insight Model of the US economy, the Industry Model, the Employment Model, and the Regional Model. The Macroeconomic Activity Module uses the input–output (I-O) National Accounts data (from the Bureau of Economic Analysis of the US Department of Commerce). The module is a key element for measuring the impacts of potential GHG strategies on the economy. This makes it one of the most important components of NEMS, as it is essential to the convergence process and it fully integrates the economy with the modeling process.

Figure A1-1: Schematic Presentation of the NEMS Modeling System



Source: http://enduse.lbl.gov/Projects/NEMS.html

8. The limitations of the NEMS model are based on the fact that it operates at a census region and census division level. Therefore, extrapolation and interpolation are needed to subdivide the estimates down to the state level. Local- or county-level forecasts are not applicable to the model. TRAN does not explicitly account for modal switching (shifting from one mode to another), hence, policies designed to shift ridership from one mode to another are currently not measurable or easy to implement.

9. The current NEMS model at EIA employs about 40 full-time employees and four full-time contractors. Therefore, enhancing, updating, and maintaining the model requires significant more resources.

B. IEA/SMP (Mo Mo) Transport Model

10. In 2004, the IEA, together with the WBCSD's Sustainable Mobility Project (SMP), had developed a global transport spreadsheet model that can be used for conducting projections and policy analysis. The IEA/SMP Transport Spreadsheet Model includes all transport modes and most vehicle types. It can be used to conduct projections of vehicle stocks, travel, energy use, and other indicators through 2050 for a Reference Case and for various policy cases and scenarios. The structure of this model is based on bottom-up modeling and assumes the penetration of alternative fuels and vehicle technologies. It uses the ASIF approach as follows, and does not include any economic or cost analysis.

- Activity (passenger and freight travel)
- Structure (travel shares by mode and vehicle type)
- Intensity (fuel efficiency)
- Fuel type = fuel use by fuel type (and CO_2 emissions per unit fuel use)

11. Various indicators are tracked and characterized by coefficients per unit travel, per vehicle, or per unit fuel use as appropriate. Apart from energy use, the model tracks emissions of CO_2, and CO_2-equivalent GHG emissions (from vehicles as well as upstream), particulates (PM), NOx, hydrocarbons, CO, and lead (Pb). Projections of safety (fatalities and injuries) are also incorporated.

12. Although the model emphasizes on light-duty vehicles (cars, minivans, SUVs), it also includes other sectors/modes, such as medium trucks, heavy-duty trucks, minibuses, large buses, two- and three-wheelers, aviation (domestic and international), rail freight, rail passenger, national waterborne, and international shipping. Vehicles technologies and fuels considered included gasoline, diesel, LPG-CNG, ethanol, and biodiesel for internal combustion engine, as well as hybrid-electric and fuel-cell vehicles. Since fuel data for most regions are not available, the model has used estimates from various sources. For OECD regions, estimates of new car fuel efficiency from the WEO 2002 and IEA's *Annual Energy Outlook 2002* were used. For non-OECD countries, estimates were derived from the World Energy Council 1999 study.

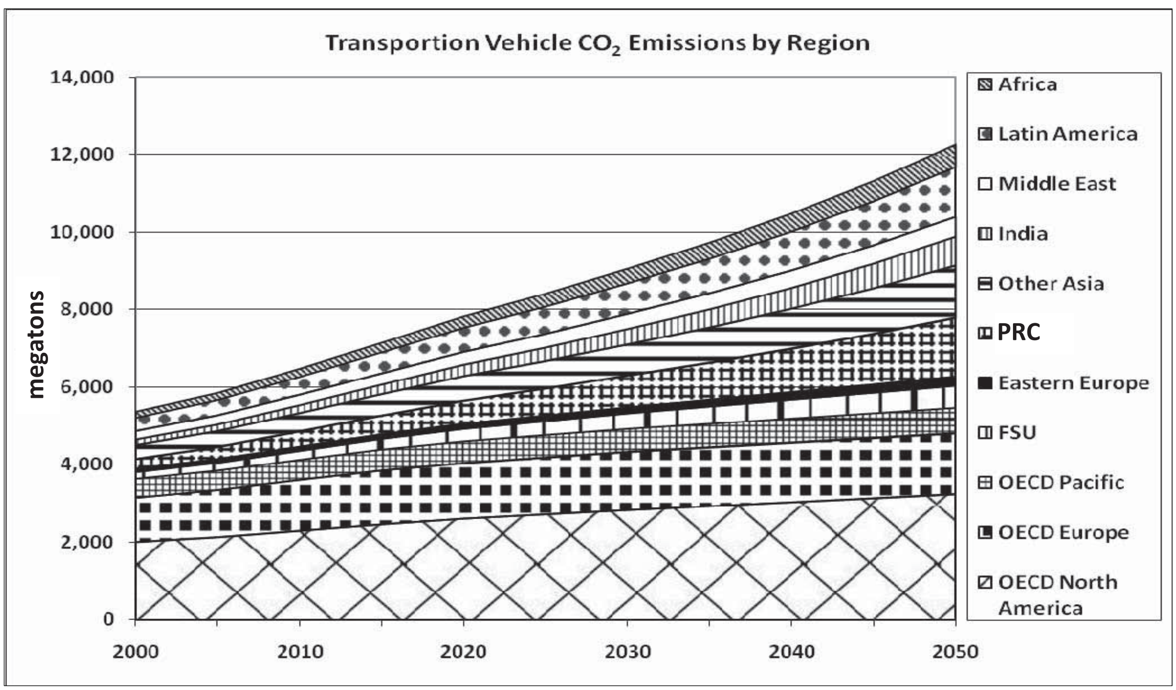
Projections:

13. Under reference case projections, global transportation fuel use increases by a factor of 2.5 between 2000 and 2050. Gasoline and diesel fuel will remain dominant in the market and their use will grow significantly, while alternative fuels and vehicles are not projected to hold a large market share. Total fuel use will grow substantially for all modes except buses. Light-duty

vehicles, freight trucks, and air travel will have the largest growth. Similarly, transport CO_2 emissions are projected to increase from 4.6 gigatons in 2000 to 11.2 in 2050. CO_2 emission increases will concentrate in non-OECD countries, which is a phenomenon also projected for fuel use increases.

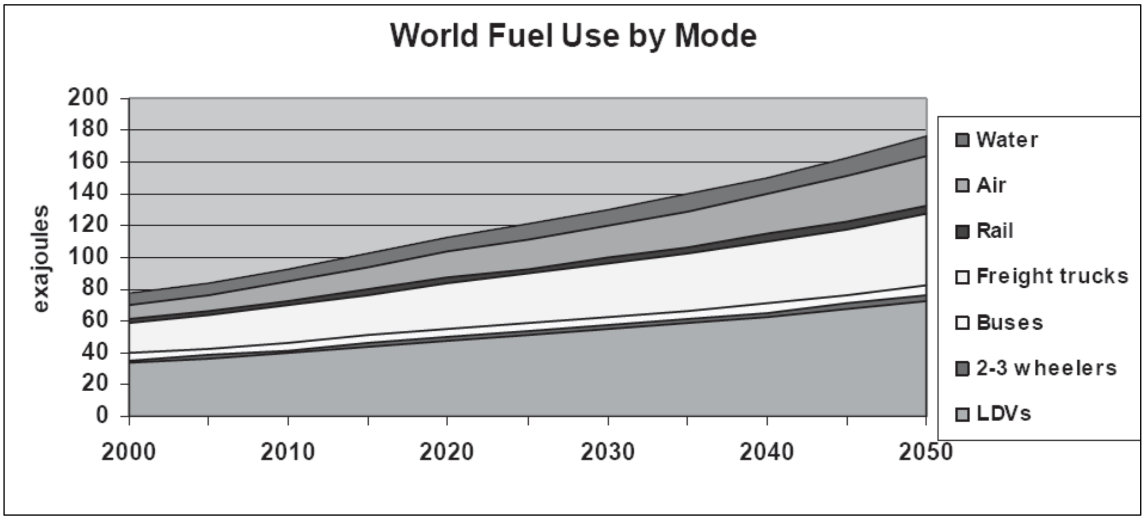
14. On the other hand, vehicle pollutant emissions, including PM-10, NOx, volatile organic compounds (VOC), carbon monoxide (CO) and Pb, are projected to decrease significantly in both OECD and non-OECD regions. All vehicle pollutant emissions, other than lead, are estimated as a simple function of vehicle km of travel multiplied by average emissions per kilometer. These projections are based on two major assumptions: (i) all developing countries will adopt OECD-level fuel and vehicle emissions standards, and (ii) vehicles will be well maintained in developing countries. However, emissions are assumed to increase twice as much in non-OECD regions than in OECD regions. Since leaded fuel is expected to be fully phased out in nearly every country in the world by 2015, lead emissions will decline considerably over the next few years.

Figure A1-2: Reference Scenario Showing Transportation Vehicle CO_2 Emissions by Region Using the IEA/SMP Transport Model



PRC = People's Republic of China; FSU = Former Soviet Union; OECD = Organisation for Economic Cooperation and Development.
Source: IEA/SMP Transport Model.

Figure A1-3: Projection of World Fuel Use by Mode
Using the IEA/SMP Transport Model



LDV = light duty vehicle.
Source: IEA/SMP Transport Model.

C. Applying the ASIF with Available Data in Selected Asian Countries

15. EMBARQ, the World Resources Institute Center for Sustainable Transport was supported by the Japan International Transport Institute in 2006 to review India's motorization trends and challenges, and to suggest policies and measures that should be implemented to reduce transport CO_2 emissions. A transport model with four different scenarios was developed for future Indian urban road passenger transport in 2020 and 2030, where different assumptions were made for modal shares. Each scenario provides different projections of energy use and CO_2 emissions.

India Transport Scenarios:

16. Four transport scenarios are developed to reflect different modal shares that could be caused by different policies and measures for 2005, 2010, and 2030.

1. **Business-as-usual (BAU)**
   This is the baseline scenario where private passenger vehicles continue to increase, while public transport will not be further developed. No vehicle constraints or regulations are imposed and private vehicles are encouraged to grow, driven by a booming economy and population growth. This scenario assumes that energy, infrastructure and financial constraints do not hinder expansion of transport activities.

2. **Fuel Efficiency (FE)**
   High efficiency and alternative fuels, such as biofuels, are assumed to be widely adopted as a result of different fuel policies. This scenario reflects a policy focus aimed at oil saving and renewable fuels in all transport modes, in a world driven by energy security concerns.

3. **Clean Two- and Three-Wheelers (TWW)**
   Two- and three-wheelers are assumed to be dominating the motor vehicle market in this third scenario. The trend toward cleaner fuels and motors, as well as two- and three-wheelers accelerates, while four-wheeled cars are not the basis for individual mobility in India.

4. **Sustainable Urban Transport (SUT)**
   This scenario shows an integrated transport system with high public transport supply and demand. Efficient public transport networks are assumed to be developed. Bus rapid transit (BRT) systems are assumed to be integrated with other types of transport modes, and nonmotorized transport modes will continue to be significant.

Projections:

Vehicle Ownership

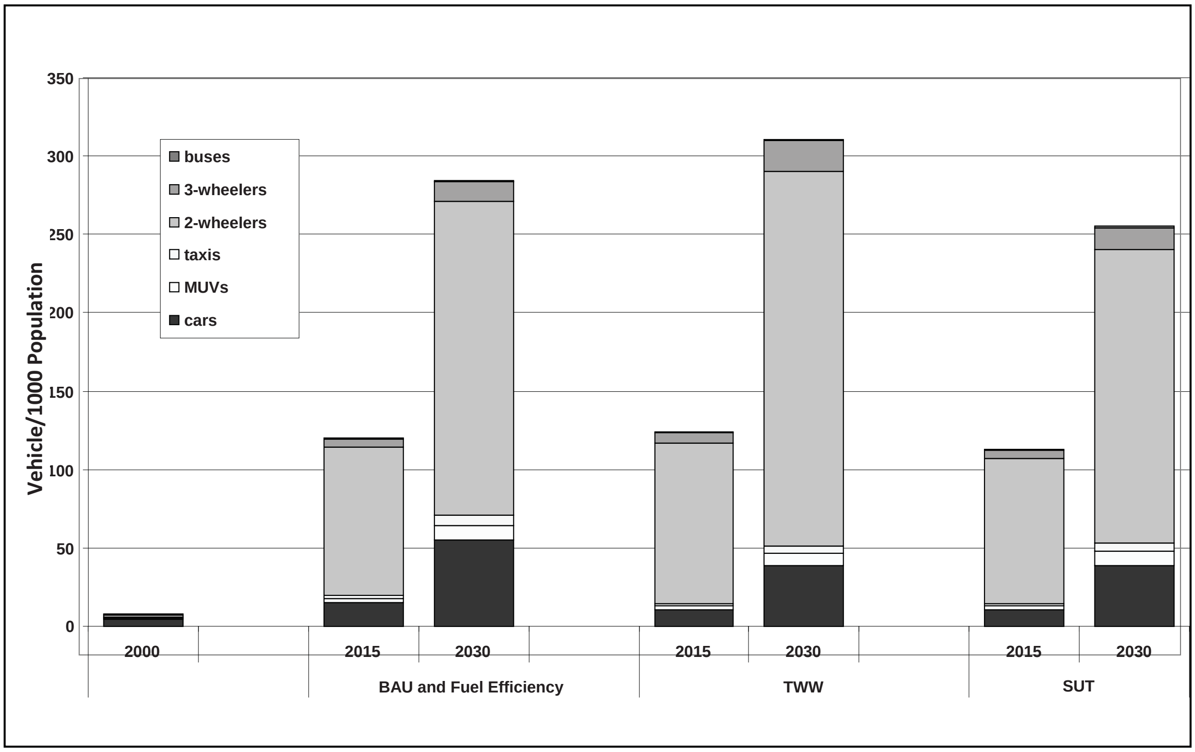
17. In the BAU scenario, the level of cars projected for India is 70 per 1,000 population, and 200 two-wheelers per 1,000 people. In the FE scenario, the motorization rates are the same as in BAU. In the TWW scenario, the number of cars only grows to slightly more than 50 per 1,000 population, but two-wheelers grow to nearly 240 per 1,000 population, 20% higher than in BAU.

18. Since SUT is designed to prevent the gridlock already present in India's largest cities, not only will there be less cars than in the BAU scenario but these cars will also travel less. There are more two-wheelers than in the base case, but fewer than in TWW, which reflects their relative importance connecting bus and rail. In addition, there are also more three-wheelers as they provide a vital for-hire link between trunk routes of mass transit and areas farther from these routes. The big change for this scenario is enhanced BRT and rail connections in cities.

Vehicle Use

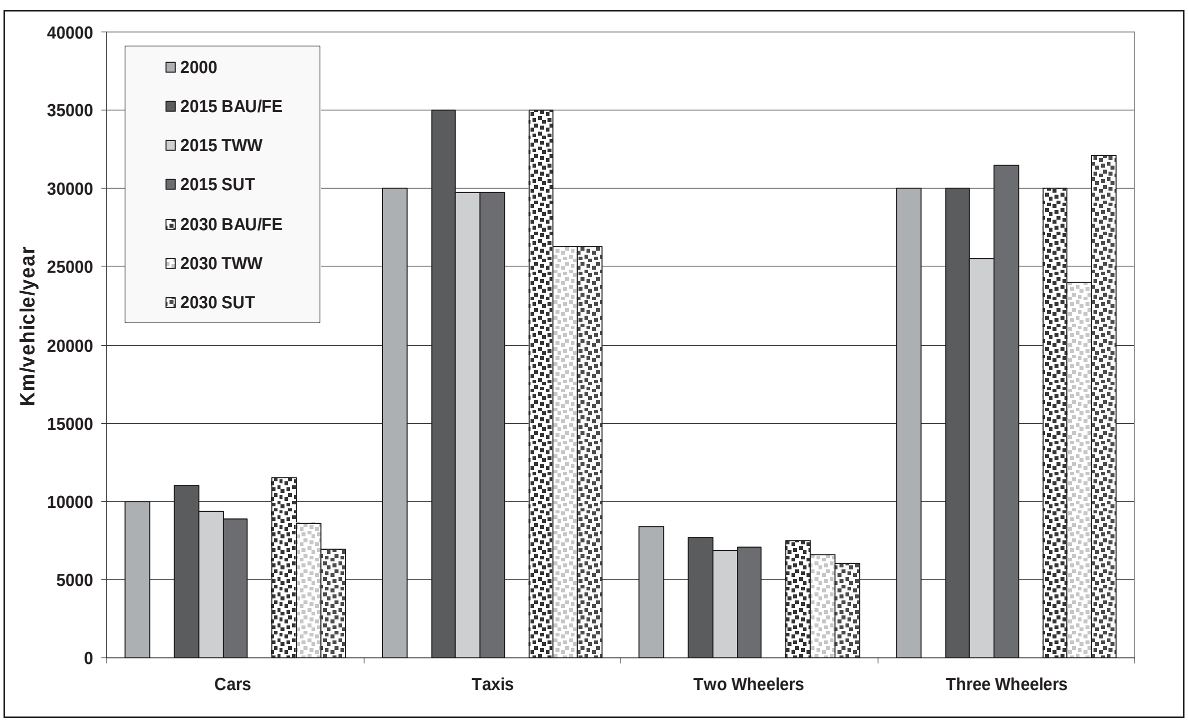
19. Car utilization is highest in BAU and lowest in SUT, with TWW in the intermediate level. Motorcycles are driven the farthest in BAU, and about the same in SUT and TWW, although the much higher numbers in TWW mean the share of total mobility provided by motorcycles in that scenario is highest of all. Because of their high numbers, two-wheelers dominate total VKT on the roads in India in all scenarios.

Figure A1-4: Per Capita Vehicle Ownership Shows the Number of Vehicles, Expressed on a Per Capita Basis



Source: EMBARQ-WRI.

Figure A1-5: Vehicle Use by Vehicle Type in the Three Scenarios in 2015 and 2030

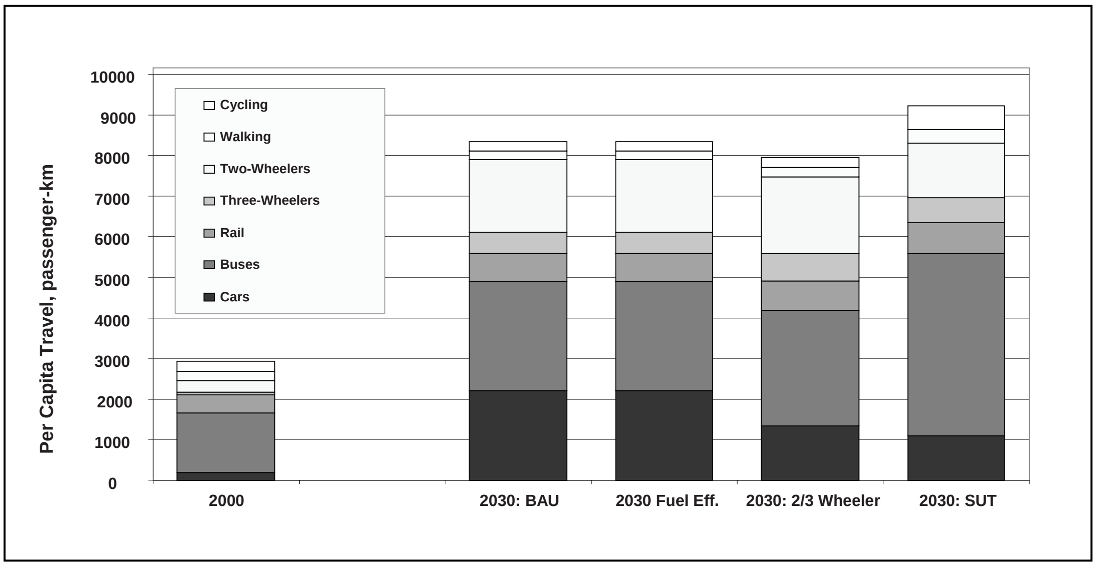


Source: EMBARQ-WRI.

Total Mobility

20. Total mobility is calculated as the distance every vehicle is driven multiplied by the number of people per vehicle, or load factor. These load factors start at 2.7 for cars and 1.5 for two-wheelers and fall slowly with rising numbers of vehicles (and to some extent the demographic shrinking of households). This has been observed in Japan, Europe, and the U.S. over the past 50 years, where load factors are now roughly 1.5 per car. For buses, load factors are highest in the SUT scenario, reflecting large BRT buses.

Figure A1-6: Per Capita Mobility for Different Travel Modes and Scenarios



Source: EMBARQ - WRI.

21. The results of these scenarios leave Indians much more mobile in 2030 than today. Average travel in 2000 was put at slightly under 3,000 km/capita. This rises to over 8,000 km/capita in the first two cases, slightly less in TWW and over 9,000 km/capita in SUT. In every case automobile mobility rises the most in relative terms, from a very low level. But while two-wheelers lead in their scenario, buses and rail are the dominant form of mobility in SUT. The key difference with more mature Asian countries (Japan, Republic of Korea) is that it is relatively easier to move about in very popular two-wheelers. Without those vehicles it is hard to see how Indians could be very mobile.

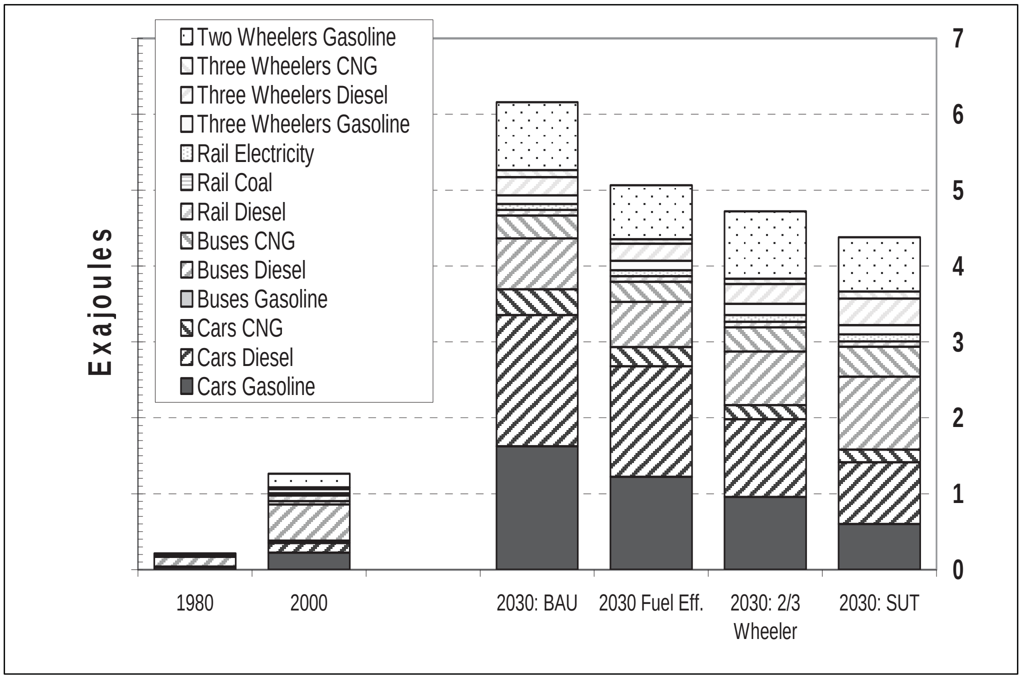
22. In TWW, car travel is significantly lower than in BAU, but two-wheeler mobility is slightly higher as is bus use. Two-wheeler travel is lower in SUT because of buses and transit covering longer distances effectively, but still serves a key role in shorter trips. Car travel is lower in TWW and lowest in SUT because cars are simply more difficult to use. The high speeds of urban buses, as well as the utility of two- and three-wheelers to cover areas where fast urban transit does not reach outpaces cars, which are continually mired down by each other.

Fuel Mix

23. Fuel mix was varied based on important trends in India, namely, the appearance of CNG cars, three-wheelers, and buses. Also diesel cars have made some headway in recent years.

Behind some of these trends is the low price of CNG or diesel, or incentives for three-wheelers to convert to CNG. CNG has lower GHG emissions than gasoline and is about even with diesel, depending on the exact measurement of various parts of the full fuel cycles.

Figure A1-7: Fuel use by vehicles of each travel mode in different scenarios



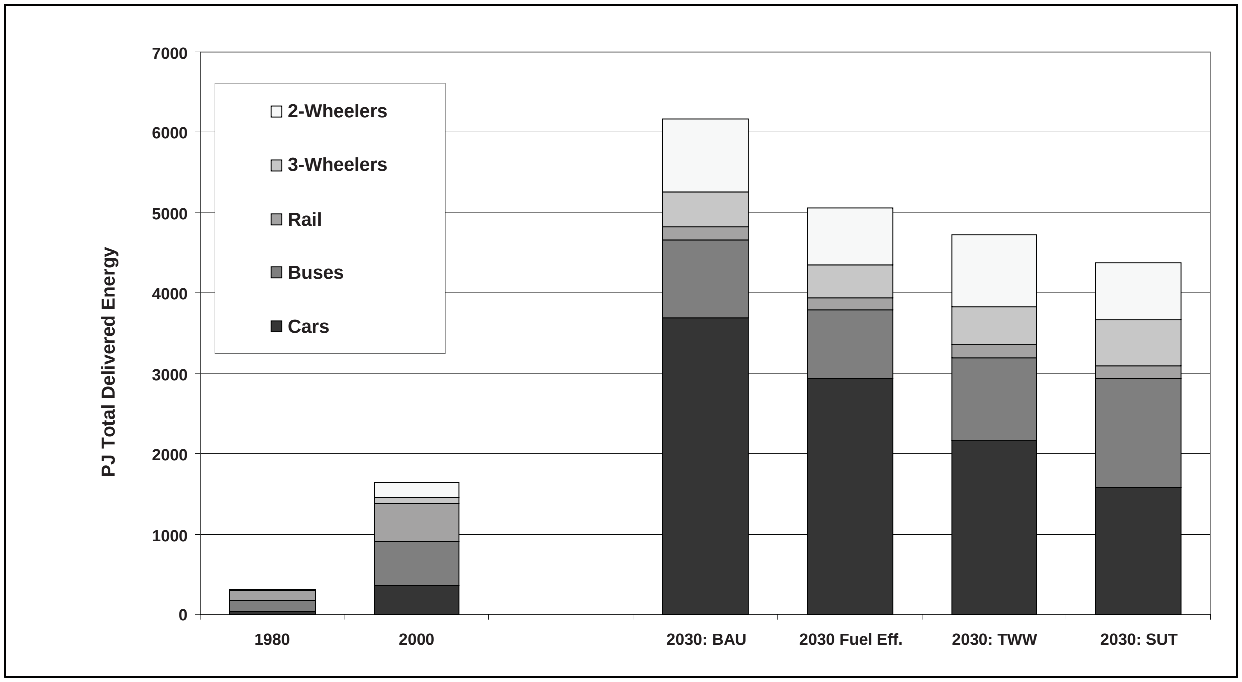
Source: EMBARQ-WRI.

24. As the most energy-intensive mode, fuel use for cars dominates the BAU and FE scenarios, and still represents the largest single modal share in TTW. Only in SUT does their share fall below that of buses, which provide more than four times the total mobility as cars do in SUT.

Total Fuel

25. Total fuel use is calculated in a straightforward manner from average fuel/km multiplied by km over each fuel and vehicle.

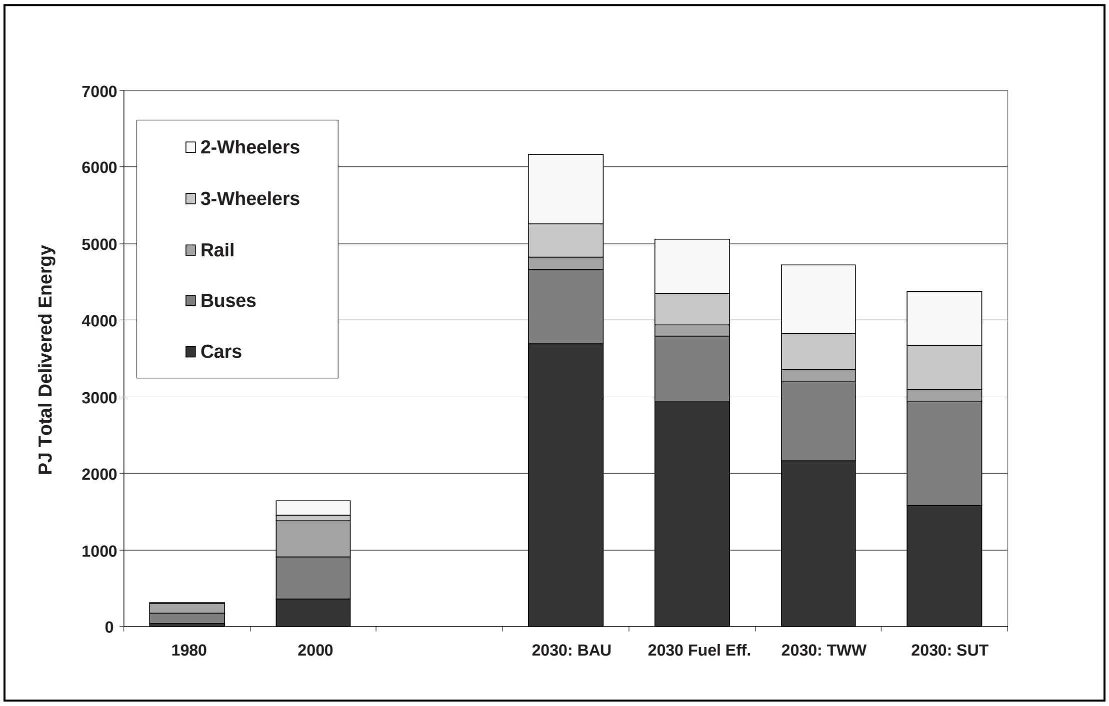
Figure A1-8. Total Fuel Use by Scenario



Source: EMBARQ-WRI.

26. Total CO_2 emissions are calculated in a straightforward matter from fuel use. The modest contribution from electricity is counted at the average ratio of emissions to kWh delivered to the Indian economy as estimated by the IEA in its *World Energy Outlook*. In every case the conversion from fuel to CO_2 is done in a straightforward linear way using IPCC coefficients. Diesel has higher GHG per unit of energy than gasoline, but diesel light-duty vehicles tend to be somewhat more efficient than their gasoline counterparts, so the two effects more or less cancel. In calculating the emissions from CNG, we have taken into account only the direct emissions from combustion, not the indirect emissions from the combustion (and leakage) of natural gas used in pipeline pumping and compression where vehicles are filled. A full fuel cycle analysis might add 10%–15% overheads to the emissions from oil and 15%–20% to those of natural gas.

Figure A1-9. Total CO_2 Emissions by Mode



Source: EMBARQ-WRI.

27. The most striking element of these scenarios is the huge rise in total emissions in all of them. Our assumptions were conservative - numbers of vehicles, distances, fuel economy, and modal shares are well within the experience of Asian countries and even to some extent OECD countries.

28. What propels this growth in CO_2 is the assumption that India will continue to motorize from a low level of 2000. Exactly how much of that growth continues on two-wheelers (or continues to shift to cars) is what the scenarios capture. And how much the real fuel intensity of vehicle use can be pushed down illustrates the real potential for near term improvements in vehicles and fuels.

29. The greatest uncertainties in these scenarios arise from the combined factor vehicles and distance/vehicle. Lacking a great technological breakthrough, on road fuel intensities are not likely to fall by more than 25%–30% over their estimated values for 2000, which is reflected in our work.

Appendix 2: What Kind of Data are Available? What are the Gaps? What are the Current Policies? Using the People's Republic of China and Japan as Examples

1. The type of data collected in Asia varies according to country, as well as existing policies in each region. There are sophisticated and mature data collection systems found in certain Asian countries, yet many databases are still lacking key datasets. The People's Republic of China (PRC) and Japan are used in this study to show how each country's data collection practice is different from one another, and what they could learn from each other. Japan's system uses inputs from several ministries, who have to work together to produce a database that is useful for policy-making processes. The PRC has a relatively young system compared to Japan's, but has been producing consistent sets of data over the past decade, even though not much has been collected in great detail from the transport sector.

2. The *PRC Statistical Yearbook* is compiled by the National Bureau of Statistics of the PRC, and is one of the widely accepted publications that show transport-related data. However, transport is listed together with storage, post and telecommunication services as a sector. Therefore, energy and fuel consumption data for the PRC is not listed for the transport sector alone in the *PRC Statistical Yearbook*. Since the statistical yearbook lists transport, storage, post and telecommunication services as a sector, there is a chapter specially dedicated to it every year. In this chapter of the yearbook, transport statistics include freight and passenger transport, and reviews railways (national, joint venture, and local), highways, waterways, and ports data. Data on civil motor vehicles, as well as the number of drivers, are also provided. Such data are obtained from the vehicle management department in the traffic management bureau at the Ministry of Public Security. Data on freight and passenger highway and waterway transport are collected from the Ministry of Communications and the National Bureau of Statistics, through different reporting systems. Civil aviation transport includes civil aviation transport flights, flights for general purpose and airports for civil aviation, excluding foreign companies' flights within PRC territory. The statistical yearbook covers air lines, length and transport volume of domestic transport, as well as transport between mainland PRC and Hong Kong, China; Macau, China; and Taipei,China.

3. Transport data are obtained from the Department of Industrial and Transportation Statistics at the National Bureau of Statistics, Ministry of Railway, Ministry of Communication, PRC Civil Aviation Administration, Ministry of Public Security, the PRC Petroleum Corporation Group, and Statistical Bureaus of provinces, autonomous regions, and municipalities directly under the Central Government. The *PRC Statistical Yearbook* is one of the most comprehensive national yearbooks circulated around, but specific transport data could also be found on provincial or city levels. Data on passenger activity appear to exclude urban transport by any mode. There is no evidence that any passenger-km data for cars/vans/light trucks or two-wheelers are present.[8]

[8] Official data for "road transport" show a curious slowing of growth after 2000. The beginnings of the boom in cars would suggest the opposite, unless these data only cover bus traffic, which slowly will yield share to cars.

4. As shown in Table A2-1, the *PRC Statistical Yearbook* includes freight and passenger transport data. Freight and passenger transport volume is carried by a particular form of transport mode during a given time period over a specific distance. The number of civil motor vehicles is defined as the total number of registered vehicles and those that have received license tags according to the work standard for motor vehicles registration and estimated by the Transport Management Office within the Department of Public Security. Such data are divided into the type of motor vehicles, including passenger vehicles, trucks and others, as well as private vehicles that are further broken down by size.

Table A2-1: Summary of Transport Data in the PRC Statistical Yearbook

Transport Mode	Vehicles	Activity	Fuel Use	Method
Cars	Number of civil vehicles owned by size (mini, small, medium, large) and type (passenger vehicles or trucks); number of privately owned vehicles by size and type	Vehicle kilometers (km). Not listed specifically for cars but for "roadways"	Energy use in road transport by type of energy, but not by vehicle type (scattered)	Total numbers of vehicles that are registered and have received vehicle license tags according to the work standard for motor vehicles registration in the Department of Public Security
Buses	Included in cars as "passenger vehicles" until 2002	Intercity bus traffic is probably what is called "road transport passenger-km" in some Chinese data.		
Rail	By fuel type (steam, diesel and electric) and model	Passenger traffic (persons); passenger-km; freight traffic (tons); freight ton-km; average passenger transport distance (km); average transport distance of freight (km); passenger traffic by region; passenger-kilometers by region	Number of railway vehicles by fuel type; No attempt to split into passenger and freight activity; Unlikely that urban rail and metro is included here	Freight (passenger) traffic density = [freight ton-km (passenger-km)]/ (length of route in operation) measuring unit: ton-km/km (or person-km/km)
Domestic Air	Number of civil aviation routes and civil aircrafts by type; civil aviation traffic and flying time of general	Passenger traffic (persons); passenger-km; freight traffic (tons); freight ton-km; average	Aviation gasoline use and turbo fuel	Likely direct queries of airline companies and sales statistics of fuel providers

Transport Mode	Vehicles	Activity	Fuel Use	Method
	aviation by passenger/freight traffic, by distance traveled (passenger-km and freight ton-km)	passenger transport distance (km); average transport distance of freight (km); passenger traffic by region; passenger-km by region		
Domestic Maritime – coastal, ferries, rivers	Number of civil and private-owned transport vessels by region, weight (ton), passenger capacity (seat), and drawing power (kw)	Passenger traffic (persons); passenger-km; freight traffic (tons); freight ton-km; average passenger transport distance (km); average transport distance of freight (km); passenger traffic by region; passenger-km by region; volume of freight by type (tons)	Can be identified by type (heavy diesel) and price, which distinguishes it from road diesel and railway diesel; How distinguished from fishing and agriculture uncertain	

Source: National Bureau of Statistics of China.

5. The *Japan Statistical Yearbook* is the most comprehensive and systematic summary of basic statistical information of Japan covering a wide range of sectors, published annually by the Statistics Bureau under the Ministry of Internal Affairs and Communications. Transport activity is surveyed and transport-related data collected by various agencies, including the Transport Research and Statistics Division, Information and Research Department, Policy Bureau, and the Ministry of Land, Infrastructure and Transport (MLIT). Summary documents published by MLIT every year (and available on the web) provide vehicle km, passenger or ton-km, and fuel use for several kinds of buses, trucks, and cars (mini cars, taxis, and ordinary cars). Thus, a complete bottom-up description of Japan's land transport is available that complements the detailed data on rail, aviation, and interisland shipping.

6. A chapter is dedicated to transport alone in the *Japan Statistical Yearbook* that includes the indexes of transport, traffic volume by type of transport and facilities related to transportation. Data on land transport are obtained mainly from the *Statistical Yearbook of Railway Transport*, *Statistical Yearbook of Motor Vehicle Transport*, *Statistical Handbook of Land Transport*, and *Motor Vehicles Owned* (monthly report) compiled by the Ministry of Land, Infrastructure, Transport and Tourism; and, with respect to the conditions of roads, *Annual Report of Road Statistics* by the Ministry of Land, Infrastructure, Transport and Tourism. Data on marine transport are supplied mainly by *Statistical Survey on Coastwise Vessel Transport*, while air transport data are obtained from the *Annual Statistical Report on Air Transport* also by the Ministry of Land, Infrastructure, Transport and Tourism.

7. The Ministry of Land, Infrastructure, Transport and Tourism conducts a survey of railway transport monthly. It covers railway and tramway enterprises throughout the country and measures passenger operation-km, passengers carried, passenger-km, revenue from passenger transport, freight operation-km, freight volume, ton-km and revenue from freight transport. Data for motor vehicle transport are obtained from the *Statistical Handbook of Land Transport* and *Statistical Yearbook of Motor Vehicle Transport* published annually by the Ministry of Land, Infrastructure, Transport and Tourism. The former publication collects information on the activities of all land transport including statistics on land transport by railways and motor vehicles as well as those on related businesses such as freight transport.

8. Data on motor vehicle ownership are published monthly by the Ministry of Land, Infrastructure, Transport and Tourism. This data category includes registered motor vehicles entered in the motor vehicle registration files in compliance with the Road Transport Vehicle Law, together with legally registered light two-wheeled vehicles and light motor vehicles. Registered motor vehicles are classified into buses, trucks, passenger cars, special use vehicles and heavy special vehicles.

9. Statistics on marine transport and coastal passenger transport are compiled from reports showing actual operation activities submitted at regular intervals by shipping enterprises to the Ministry of Land, Infrastructure, Transport and Tourism in compliance with the Sea Transportation Law. Reports on coastal passenger transport are submitted annually and published in the *Domestic Transportation Statistics Handbook*. Aviation data are derived from aviation transport survey, which has been conducted monthly since 1957 by the Ministry of Land, Infrastructure, Transport and Tourism. It includes the Survey on Aircraft Operation, Survey on Air Transport, Survey on Airlines Utilized, and Survey on Businesses Utilizing Aircraft. In each survey, questionnaires are sent via mail and internet to the air transport companies and airplane service companies. Table A2-2 gives a summary of all transport-related data collected by the Japan MLIT.

Table A2-2: Summary of Japanese Transport Data

Transport Mode	Vehicles	Activity	Fuel Use	Method
Cars	Number of cars by fuel type: private conventional cars, taxis, minicars	Km/car by fuel and type; passenger km by car type	Fuel use/km by fuel and car type	Random sampling; Survey method: Enumerator survey (partially by mail) (self-entry).
Buses	Transit buses; intercity buses	Vehicle kilometers and passenger-kilometers	Fuel use by type	
Rail	Intercity rail; urban and commuter rail	Freight by type; cargo transport volume by operational mode and by vehicle type (transport tonnage/tons-km); passenger transport volume by operational mode and by vehicle type (number of passengers/passengers-km), transport frequency, and distance.	Fuel consumption	Survey of passenger traffic receipt; survey of freight volume

Transport Mode	Vehicles	Activity	Fuel Use	Method
Domestic Air	Number of units handled for transport and operating hours of aircraft	Weight; capacity; number of passengers; number of passengers transported; weight of passengers transported; number of flight services; cargo weight; utilization of capacity; transport ton-kilometers	Fuel consumption	Complete enumeration using survey method by mail or on-line application (self-entry)
Domestic Maritime (coastal, ferries, rivers)	Number and gross tonnage of incoming vessels,	Passenger km Number of passengers, marine incoming and outgoing freight; land incoming and outgoing freight.	Fuel use/passenger km	Survey on Ports and Harbor; Land Incoming and Outgoing Freight Survey by using enumerator survey (self-entry)

Source: Japan Statistical Yearbook.

10. Overall, Japan follows a more systematic way of data collection when compared with other Asian countries. There are also laws and regulations that different private and public entities have to follow when collecting, compiling, and submitting data of their respective sectors. This practice is still uncommon in other Asian countries, most possibly because of the lack of priority and importance placed upon comprehensive data collection systems.

Transport and Carbon Dioxide Emissions: Forecasts, Options Analysis, and Evaluation

Transport accounts for 23% of worldwide energy-related carbon dioxide emissions (CO_2), according to the latest estimates of the International Energy Agency, and 19% of these transport-related emissions come from Asia. Asia's share in total worldwide transport–related CO_2 emissions is expected to increase significantly, accounting for more than 50% of the sector increase and growing from 1 billion tons of CO_2 in 2006 to 2.3 billion tons by 2030. This paper discusses the relevance of measuring greenhouse gas emissions, particularly CO_2, from transport and presents a simple methodology for measuring CO_2 emissions from the sector. It aims to guide transport authorities in Asia with a better understanding of the available tools and methodologies for measuring CO_2 emissions and thus strengthen formulation and implementation of policies and measures that can reduce and prevent future emissions of air pollutants and greenhouse gas.

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ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries substantially reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to two-thirds of the world's poor: 1.8 billion people who live on less than $2 a day, with 903 million struggling on less than $1.25 a day. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

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