DECC Global Calculator: Transport Sector Background Data and Methodology

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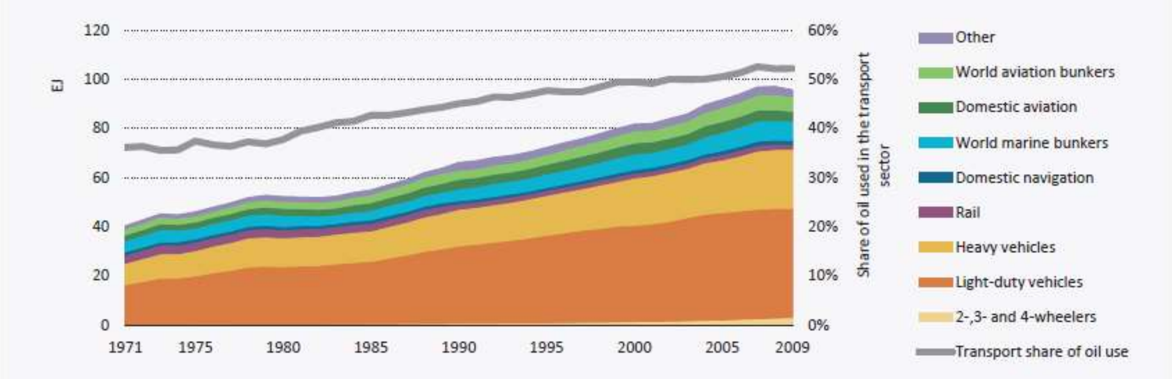
INTRODUCTION

For the expert reviewers: This document explains the approach to developing levels of ambition for the transport sector in the Global 2050 Calculator developed by the Department of Energy and Climate Change (DECC) in the UK. The Calculator is a multi-sectoral tool to compare CO_2 emissions in 2050 given different possible efforts in each sector. This document was developed to aid reviewers in understanding the data and assumptions used in for the Transport Sector and to encourage feedback on base year data, comments on framing of the sector, and expert judgment on levels of ambition. This is supported by a background worksheet for the Transport Sector which is used to illustrate each level in more detail.

The transport sector has four major levers: Passenger and freight demand, mode and occupancy, efficiency, and electrification. The transport modeling team has developed levels of ambition for each lever, which represent increasing effort towards reducing CO_2 emissions (not solely extending existing policies and trends): Level 1) existing trends or slightly worse than the baseline, Level 2) ambitious and likely, Level 3) ambitious and difficult, Level 4) maximum of what is possible to achieve in each lever.

To determine key areas for focus, it was important to understand the current and future contributions to CO_2 emissions from different subsectors of transport as well as regions and countries. Figure 1 shows that road transport makes up roughly 80% of energy use from the transport sector while aviation, marine, and rail modes use lesser amounts of energy. In order to develop levels of ambition, the focus of the transport sector is on those areas that can make the largest contribution to emissions reduction as well as having the most potential for change. Therefore road passenger transport has the greatest level of detail in the calculator. Ground freight also has more detail than longer distance freight, for example. Air travel and air freight are considered specifically because of their potential for significant growth as well as the larger contribution of planes to CO_2 emissions.

Figure 1: World transport energy use by mode



Notes: Light-duty vehicles are cars and light trucks (up to 3.5 tonnes); heavy vehicles are trucks and buses.
Source: Unless otherwise noted, all tables and figures in this chapter derive from IEA data and analysis.

Key point *The fastest-growing transport modes – light-duty vehicles (LDVs), trucks and aviation – are also among the most energy-intensive.*

Source: IEA 2012

The five categories of the transport sector used in the Global Calculator for passenger and freight demand, mode, and occupancy are:

- urban passenger transport
- non-urban passenger transport
- long-distance passenger transport
- ground freight
- long-distance freight.

The definition of each category is given in Part II of this document.

For efficiency and electrification, levels were developed by vehicle type categories:

- Light-duty vehicle
- Heavy-duty vehicle
- Ship
- Plane

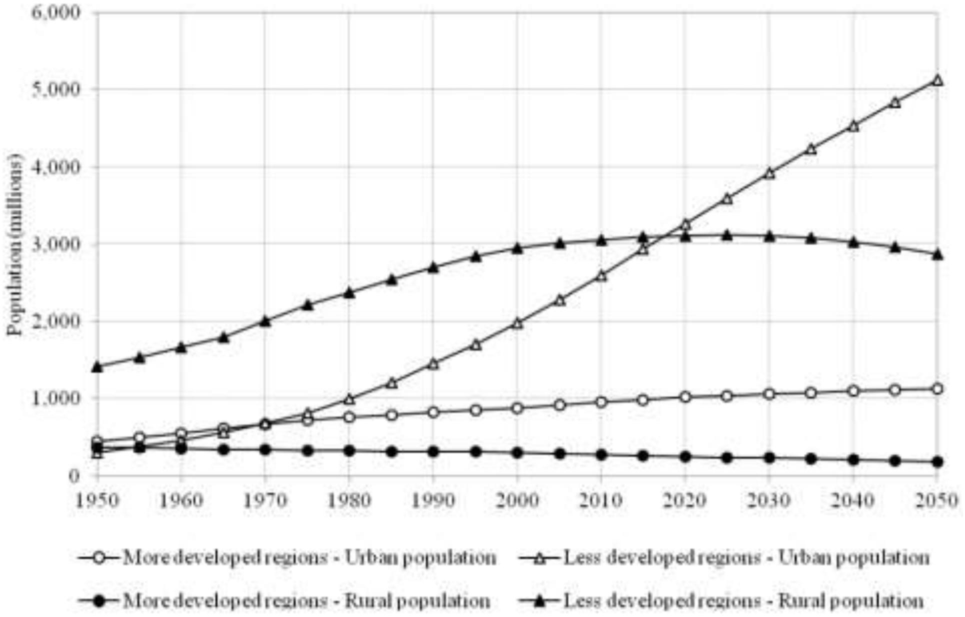
In practice, data in each country may not be available which match these categories exactly. For example, some countries collect data categorising by urban and rural areas; some collect totals for the country with more specific information on urban areas. Different segments of trips or types of trip might be collected separately, and even when data may match these categories and definitions directly, the data may not be publicly available. Therefore, building regional and global averages requires taking the existing data and adapting it to suit the categories as closely as possible. Often, approximations or estimations are needed to develop baselines and trends.

Part I is an in-depth discussion on how the urban passenger transport categories were developed. Part II describes the types of categories used, the rationale for and definitions of these categories. Part III shows how the different levels of ambition were developed based on these categories.

PART I: DEFINTION OF URBAN TYPOLOGIES/SUB-CATEGORIES

Similar to all global (transport) models (IEA – MOMO, ICCT – Roadmap, IIASA), we are adopting the UN definition of urban and rural (non-urban). The underlying projection of urban population was taken from the UN 2011 revision, which includes a breakdown of urban/rural from “more developed” and “less developed” countries. Urban populations are projected to reach 6 billion people (2/3 of the world’s 9 billion population) by 2050, with about 5/6 of this in the developing world (although at a lower rate of about 65% urban compared to about 90% urban in the developed world).
There are separate levers in the Global Calculator which allows users to choose their view of the global population in 2050 and the proportion of people living in urban areas.

Figure 2: UN Urban/rural population projections to 2050 by region



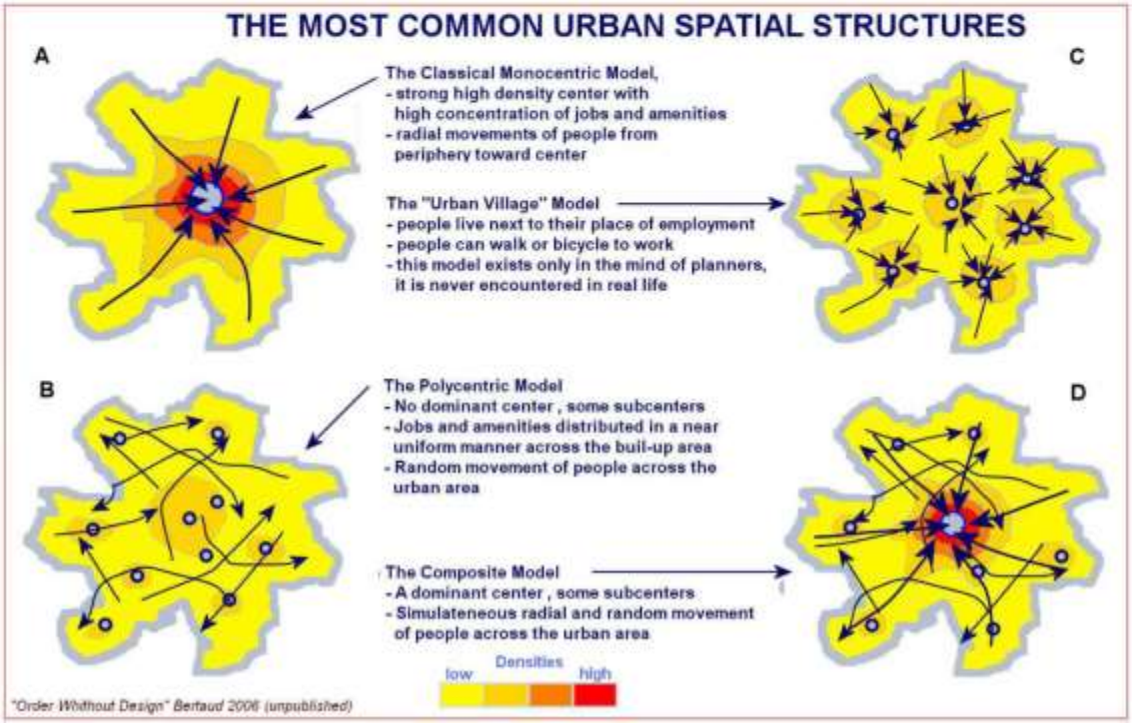
Source: UN Population projections, 2011 revisions

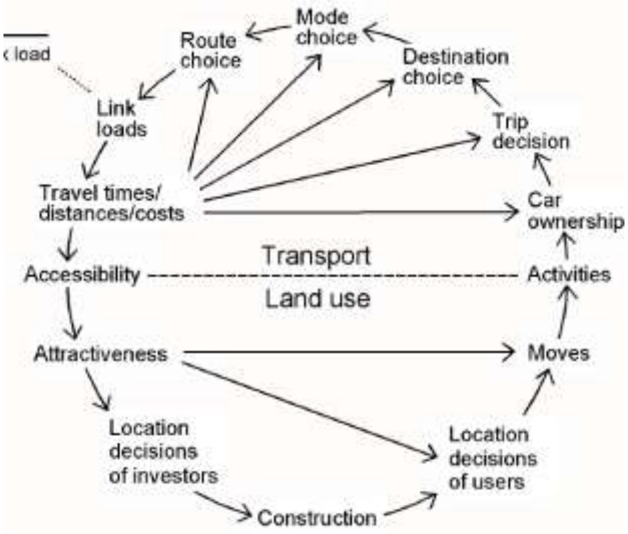
There are many trends that will influence future travel patterns in cities. Cities around the world are growing at vastly different rates and currently have very different travel behaviour. For the Global Calculator, we wanted to model at the regional level to build a global weighted average for each level of ambition which captures the potential differences in growth for different types of cities. For this we developed categories of cities which capture these different growth patterns.

Following Bertaud (Bertaud, 2001), we are defining “urban spatial structure” using two complementary components: 1) spatial distribution of the population and 2) spatial distribution of trip patterns of people when they travel between their homes and places where they either work or socialise.

This definition is highly consensual and well-used in the transport / urban literature (Gakenheimer, 1997; Zegras, 2007; Barter, 1999; Newman, Kenworthy, 1999; IPCCC).

Figure 3





Source: Wegener, 1994

The spatial structure of a city, in particular the relative location of homes, employment and amenities, has an impact on the number and length of trips (i.e. the *transport activity*). There is strong consensus in the literature that urban structure and modal shift are closely correlated (see Newman and Kenworthy, Zegras, Gakenheimer, Crutzig, IPCC4 and forthcoming IPCC5, etc.).

Building the transport module of the Global Calculator, we therefore faced an issue: *How to take into account and represent the diversity of urban structure around the world?*

A study by Kenworthy (2003) of 84 “global cities” provides valuable points of comparison and shows the extreme diversity of cities today. As a result, CO_2 emissions released by urban passenger transport systems vary by a factor greater than 100, ranging between extremes of 2,033 CKge per inhabitant and per year in Atlanta and 19 CKge for Ho Chi Minh City. As regards the share of public (versus private) transport in such emissions, it varies from over 70% in Manila or Dakar to less than 1% in Atlanta, but also in Riyadh.

Although the finding is unexpected, prosperity — measured in the annual GDP per capita — is not a factor which is highly correlated to the rate of private motorisation. Moreover, even with similar motorization rates, actual use of cars may vary considerably from one city to another (Kenworthy, 2003). As a result, energy consumption due to private transport related to wealth, measured in MJ/$1000 of GDP, does not increase systematically with GDP per capita. The highest levels are to be found in three groups of cities: African cities with 2,200 MJ/$1000 of GDP and cities in the United States and the Middle East with 1,900 MJ/$1000 of GDP. High-income cities in Western Europe and Asia perform best with only 489 and 303 MJ/$1000 of GDP respectively. Other regions average 1,364 MJ/$ of GDP, in between the two extremes.

As regards infrastructure, the length of urban expressway available per capita is particularly high in the United States (156 m/1000 inhabitants), Australia and New Zealand (83% of the American figure) and in Canada (78% of the American figure). In other regions, the urban expressway network is not extensive, particularly in Latin America and in China (2% of the American level). If, however, the expressway offer is related to wealth (instead of the number of inhabitants), the results are reversed: poor cities provide a little more urban expressway facilities than their high-income counterparts: 4.5 km compared to 4.1 km/$1000 of GDP. In fact, cities in Africa, Eastern Europe and the Middle East currently provide more expressway surface per $1000 of GDP than American cities.

The public transport supply, evaluated per annum as seats-km per capita is on average not very different in rich and poor cities: 3,336 in rich areas and 3,203 in poorer areas. As related to wealth, however, poor cities supply much more public transport facilities: 831 seats-km/$1000 of GDP compared to the offer of rich cities, i.e. 126 seats-km/$1000 of GDP.

This question needs to be addressed for at least 3 reasons:

1) *Science relevance*

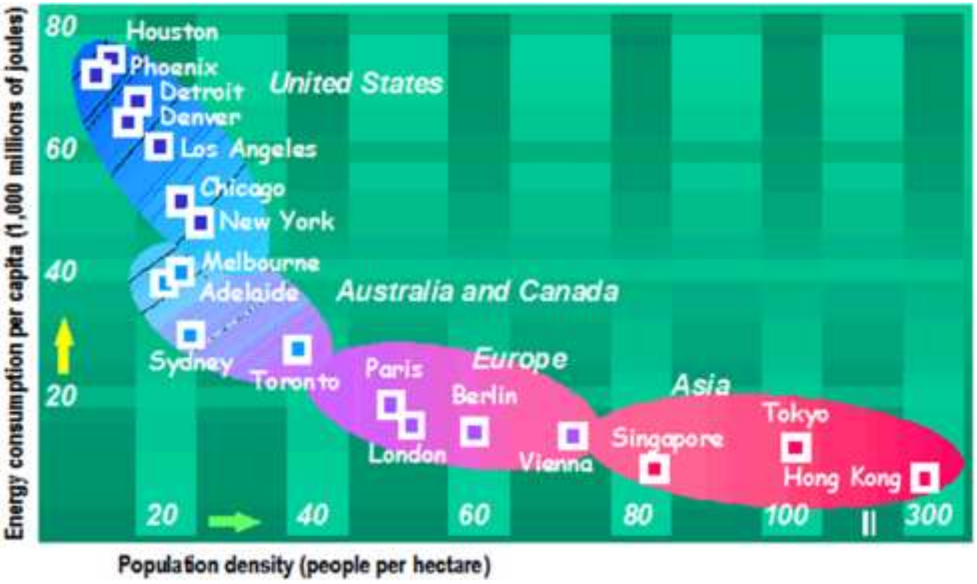
There is a strong consensus in the literature that urban structure, transport activity and modal share are strongly correlated.

Research in the last fifteen years by Newman and Kenworthy points out that there is a great deal of interaction between urban density and transport-related energy consumption. Newman and Kenworthy's famous hyperbola “Urban density and transport-related energy consumption” (cf below) shows a high correlation (R2 = 0.86) between average urban density and intra-urban transport-related energy consumption per capita. These results are due to density being highly correlated with modal distribution and the intensity of automobile use, as shown in the following table.

Following this work, Bertaud (2001, 2003, 2004) contends that the spatial distribution of population and employment densities and journeys within the urban area are much more important than average density to explain the number and length of these journeys and the energy they consume.

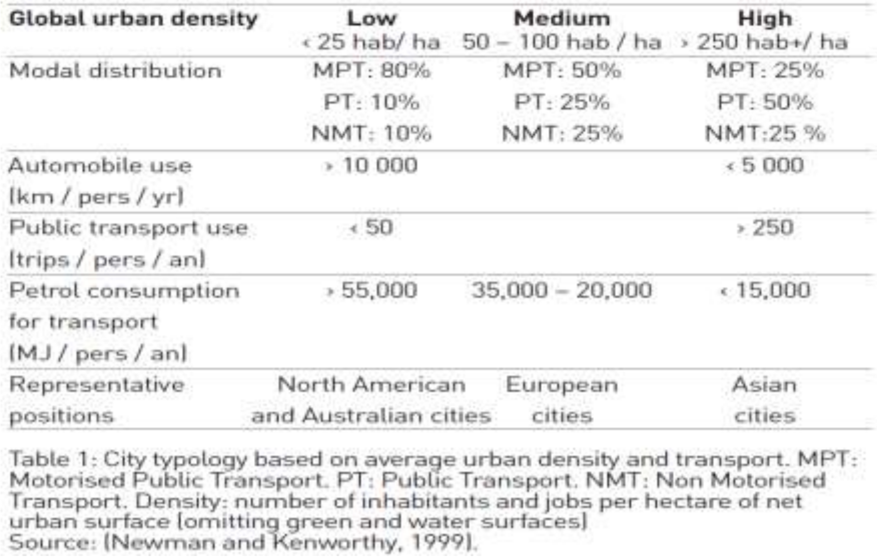
This is why all transport models (including IEA-MOMO, ICCT-Roadmap, IIASA-Message & Gains, etc.), working at a global level, even the simplest ones, represent this diversity of urban structure by differentiating and categorising the different situations.

Figure 4: hyperbola "Urban density and transport-related energy consumption"



Source: Kenworthy, 2003

Figure 5



Global urban density	Low ‹ 25 hab/ ha	Medium 50 – 100 hab / ha	High › 250 hab+/ ha
Modal distribution	MPT: 80% PT: 10% NMT: 10%	MPT: 50% PT: 25% NMT: 25%	MPT: 25% PT: 50% NMT:25 %
Automobile use (km / pers / yr)	› 10 000		‹ 5 000
Public transport use (trips / pers / an)	‹ 50		› 250
Petrol consumption for transport (MJ / pers / an)	› 55,000	35,000 – 20,000	‹ 15,000
Representative positions	North American and Australian cities	European cities	Asian cities

Table 1: City typology based on average urban density and transport. MPT: Motorised Public Transport. PT: Public Transport. NMT: Non Motorised Transport. Density: number of inhabitants and jobs per hectare of net urban surface (omitting green and water surfaces)
Source: (Newman and Kenworthy, 1999).

2) Policy relevance – definition of level of ambition in the Global Calculator 2050

Urban spatial structures are particularly resilient and path dependencies are strong. The spatial structure of a city therefore significantly limits possible future developments.
This of course also depends on the degree of consolidation (i.e. the percentage of 2050 urban area already built in 2010), also defined as the rate replacement / replenishment or rate of construction

(Dureau, 2000). This is why the low-carbon options and the spectrum of actions to reduce GHG emissions from the transport sector are i) dependent of the urban structure and its level of consolidation; ii) and therefore not the same in every city.

3) *User relevance*

One of the key areas of feedback (very explicit and unanimous) we received from the group of experts (January 2014) is that 1) first, at least for the levers *activity* and *modal shift*, users cannot easily discuss global numbers ("*the global urban passenger transport activity increase globally by x%, from y vehicle-km to z vehicle-km*" doesn't make immediate sense); 2) second, they are interested in differentiating scenarios by the type of cities.

Figure 6

Relationship between spatial structure and the effectiveness of public transportation

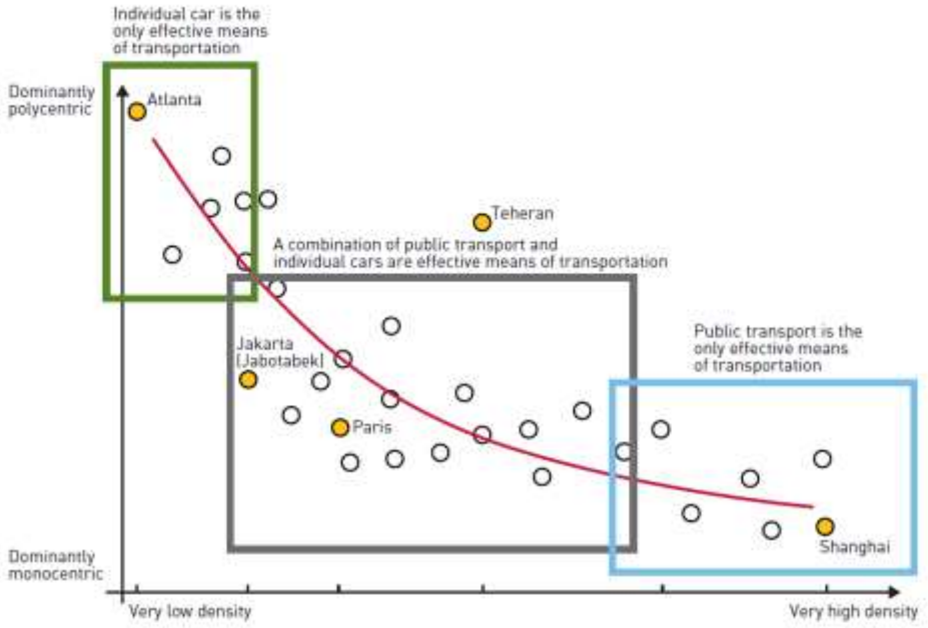


Figure 5. Relationship between Spatial Structure and the Effectiveness of Public Transport.
Source: (Bertaud and Malpezzi, 2003).

<u>Suggestion / principles to build an urban typology for the Global Calculator 2050</u>

- To use well-recognised consensual literature: Newman, Kenworthy, Barter, Bertaud, Fulton, Gakenheimer, Zegras, Shaeffer, Sims, Sperling, IEA, ICCT, Moving Cooler, UCCRN IPC3, IPCC, etc.
- To keep the typology very simple and straightforward in order
    - To respect the spirit and strength of the different (Global and National) 2050 Calculators
    - To ensure easy understanding and use for non-transport-experts

  This means that we will not be able to capture all the specificities of each city. We are working with a global perspective and it is therefore more important to capture the significant urban dynamics and trends than to ensure that each specific city finds its right sub-category.

- To have a generic definition of each type of urban structure
    - to help an easy visualization of what type of city
    - to avoid pointing to specific countries or regions
    - to keep global perspective
- to use this typology only for the levers *activity* and *modal share* (i.e. not for *vehicle technology* and *fuel technology*)
    - because the urban structure is strongly correlated to *activity* and *modal share* – less to *vehicle technology* and *fuel technology*
    - because the energy efficiency of each mode is already captured in the weighted energy efficiency used
    - to keep the global and simple approach of the Global Calculator 2050.

Suggested criteria to define the sub-categories for urban passenger transport in the Global 2050 Calculator

Spatial distribution of the population

Average density is of course a good candidate to represent the spatial distribution of the population – easy to measure, easy to understand, with data available – but as we discussed before, the relative location of homes, employment and amenities has a key impact on the number and length of trips. An analysis of average density is not sufficient to discuss transport-related energy consumption. The spatial distribution of population can therefore be represented in the form of a three-dimensional object: built-up urban area is shown on the XY plane and population densities within that area in dimension Z (see graph 1). To gain a better understanding of the impact of these urban spatial structures on transport-related energy consumption, an analysis of the geometrical properties of these three dimensional objects is required instead of just average density. One of these properties is the density gradient, i.e. the direction and speed with which density changes as it progresses from the centre to the periphery.

Figure 7:

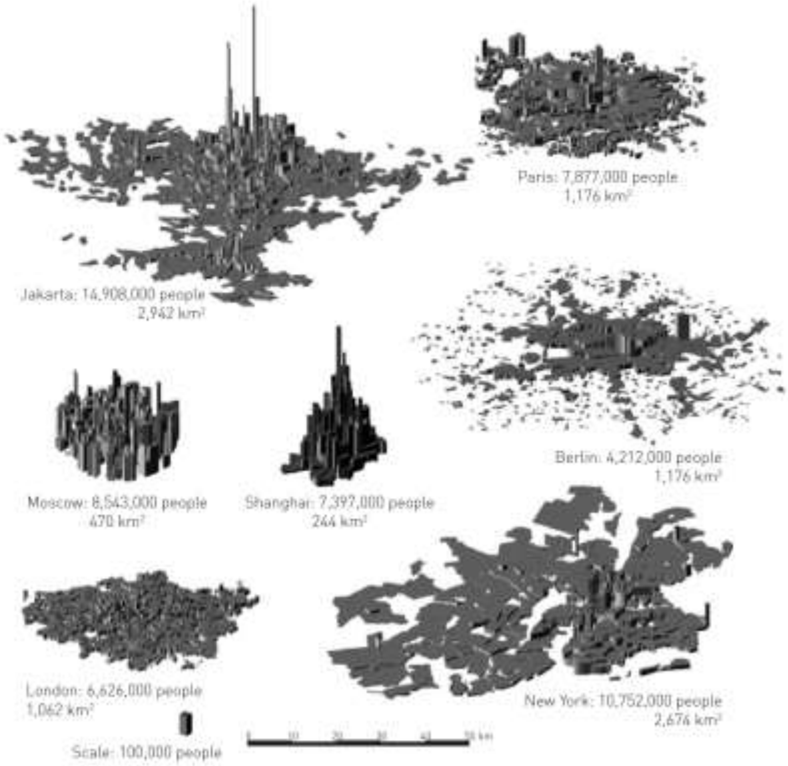
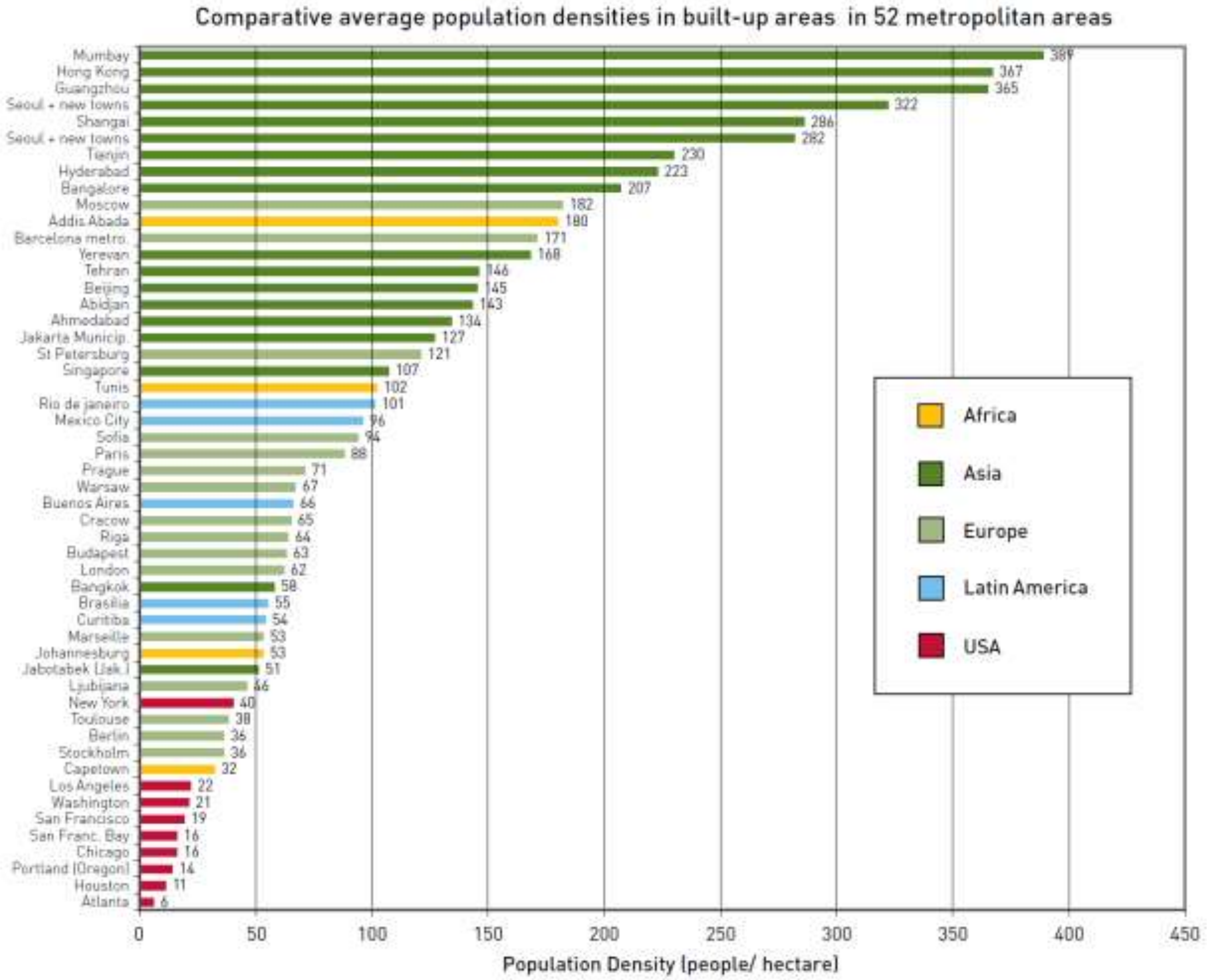


Figure 3. Residential density distribution in several cities. Source: [Bertaud, 2001].

Figure 8



Conclusion:

In order to follow the principle of simplicity and to keep the typology straightforward for non-expert users, we will of course not take such a detailed approach to characterise all cities and then categorise them. **We will therefore primarily focus on the average density**. As we can see in figures 4 and 8, most cities in a particular region have a similar average density.

However we will keep in mind the three-dimensional representation and the density gradient when we consider the relation between spatial distribution of population, spatial distribution of trip patterns and dominant transport technology.

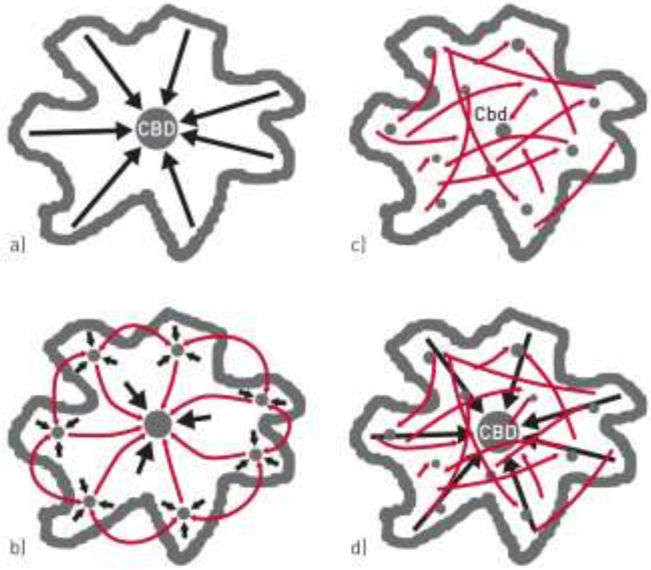
Spatial distribution of trip patterns

Four simplified and schematic models of the city help to describe the spatial distribution of trip patterns: The monocentric city. The labour market can remain unified since commuting from the suburbs to the centre is easily achieved along radial roads or using rail transport. (Figure 9.a). If land and real estate markets are almost or entirely free of regulation, density tends to follow the price of land and the density gradient has a negative slope from the centre to the periphery (London and New York in the previous figure).

The polycentric city “urban village” type (Figure 9.b). Some urban planners see this model as a kind of ideal with communities emerging around an employment cluster. These self-supporting “urban villages” will aggregate to form a sprawling polycentric city with a sometimes fairly low average density. Despite the sprawl, in such cities, trips are extremely short. Ideally, everyone can walk or cycle to work. These ideal conditions have never been observed in any city. And yet this Utopian vision is persistent in the minds of many urban planners (Bertaud, 2014). Stockholm, Seoul and Shanghai have supplied some interesting examples over the last 20 years: while housing construction is directly linked to satellite towns and the existence of local employment, in fact most of those living in these satellites commute to work in the city itself and city dwellers occupy the jobs available in the satellite towns. The result is a third type of city: the polycentric city with quasi “Brownian” type movements (Figure 9.c).

The mono-polycentric model type of city (Figure 9.d) is the result of a development in initially monocentric large cities whose structures have gradually evolved into a polycentric pattern. The CBD loses its primacy and activity clusters generating journeys are distributed throughout the built-up urban area. Mega-cities were not born polycentric, they gradually evolved to that formation.

Figure 9



a] The monocentric model
b] The polycentric model: The urban village version
c] The polycentric model: The random movement version
d] The mono-polycentric model: Simultaneous radial and random movements

In a polycentric city, each secondary centre generates travel from the whole urban area. Points of origin and destination are highly scattered for these trips; they are almost random. They tend therefore to be longer than in a monocentric city, all else being equal. It is also to be expected that polycentric cities have a negative slope density gradient centred on the “centre of gravity” of the urban area, which may or may not be the CBD. But the slope cannot be as steep as for a monocentric city, since proximity to the centre of gravity provides less accessibility to the entire set of destinations than is the case in a monocentric city. These theories are verified in cities such as Los Angeles and Atlanta.

Dominant transport technology

This criterion highlights the structuring effect of transport infrastructure on the evolution of the spatial design. It is based in particular on Zahavi's double constant (1980), giving prominence to the fundamental importance of the speed of transportation modes in city spatial operation and on the correlation between average urban densities and the modal distribution of journeys.

In a sample of world cities, Zahavi observed a double budget and time constant in urban mobility: on the one hand, the average time spent daily in transport is constant and equal to one hour; on the other hand, urban dwellers spend on average 11% of their budget on transport. As a result, the daily time budget devoted to transport remains constant despite developments in the speed of travel (Zahavi, 1980). Zahavi observes that if a transport system is faster and cheaper, city dwellers will use it to travel more and to cover a greater distance, not to save time or money. If transport infrastructure permits, users prefer to broaden their range of options rather than reduce the general cost of travel. The speed of transport systems then defines individual travel range. Since walking can cover 5 km/hour, and therefore permits a 2.5 km return journey to be covered in one hour, it gives access to a 20 km^2 range (a circle with a 2.5 km radius). Similarly, with car travel being on average 10 times faster, the accessible area is a hundredfold larger, i.e. 2,000 km^2.

Conclusion:

Building on Zahavi's conjecture, there is a consensus that the adoption of faster modes of transport profoundly changes the spatial organization of cities, i.e. the spatial distribution of trip patterns. The increase in average speed of a city's transport system calls for more space. The result is urban sprawl and reduced density. Dominant transport modes are therefore one of the determinants of urban structures. The increase in distance covered due to increased speed of travel and to urban sprawl leads to an increase in energy consumption.

Again, in order to follow the principle of simplicity and to keep the urban-passenger typology straightforward for non-expert users, we will of course not take such a detailed approach to characterise all cities and then categorise them. As we can see in figures 4 and 5, **we can again reasonably adopt a regional differentiation** here: North American or Australian low density metropolitan areas exhibit an almost total predominance of automobile use and total transport-related energy consumption is considerable (frequently more than 65,000 MJ/person/yr.). Asian and African high density metropolitan areas have a markedly more balanced tri-modal distribution with a clear emphasis on public transport (from 40 to 60% of travel). The total transport-related energy consumption is four to seven times less than in low density cities. European cities occupy an intermediate position as regards urban density: between 40 and 120 (inhabitants+jobs) net per hectare. Modal distribution is more balanced but cars are still very dominant, particularly in peripheral low density suburban areas. Total transport-related energy consumption is two to four times lower than in low density cities.

Population growth and margin for action – degree of consolidation

The literature define the degree of consolidation as the rate replacement / replenishment or rate of construction (Dureau, 2000), or in a more simple way as the percentage of 2050 urban area already built in 2010.

There is a basic but fundamental difference between the developed urban world and the emerging and developing one: in the emerging and developing world, the urban transition is happening now and is massive and extremely rapid. Almost all global population growth will be in the cities of the emerging and developing world, where population will double from two to four billion people. Taking in two billion new urban dwellers means building and providing for the equivalent each year of seven new cities of ten million inhabitants, that is seven “Shanghais” or “Jakartas”, or ten “Londons” per year. In emerging and developing countries, urban population growth is five to eight times faster than in industrialised countries (UN, 2007)[1]. Taking into consideration the life time of urban structures, the type of urban growth which will be found in the cities of the South in the next thirty years of exceptionally rapid urbanization will determine their energy consumption and their greenhouse gas emissions in the second half of the century.

Therefore we understand that **the margin for action to influence the 2050 urban structure is far more important in the developing and emerging urban world than in the developed one**.

Definition of each sub-category

The “Automobile City”

- relatively low population growth – urban structure mainly consolidated (it is estimated that around 80% of the 2050 urban area is already built)
- Low average density (<25 inhabitants/hectare)
- Spatial distribution of trip patterns is dominantly polycentric.
- Modal distribution dominated by motorized private transport (automobile mainly but could be 2-wheelers)

Activities are hardly mixed at all in the available space. Jobs are concentrated in the CBD and citizens live on the outskirts. Cars are the dominant means of transport and the intense segregation of activities in the available space does not allow for the use of slower modes. Public transport is marginalised and ends up being provided solely for the use of people who cannot drive or cannot afford to. The heart of the city is often entirely given over to a high density of commercial activities. Shops, services and industry are separate and scattered throughout the metropolitan area. Journeys cover long distances and are highly scattered

The “Transit City”

- Relatively low population growth – urban structure mainly consolidated (estimated that around 80% of the % 2050 urban area already is already built)
- Medium average density (50 – 100 inhabitants/hectare)
- Spatial distribution of trip patterns is mono-polycentric
- More balanced modal distribution (than the “automobile city”) between motorised private transport, transit transport and non-motorized transport, but with a clear dominance of the cars, particularly in peripheral low density suburban areas.

Cities spread over 10 to 20 km and are star-shaped around public transport lines which are also set out in a star-like configuration. Working and residential areas tend to settle around public transport lines. Centres of activity appear when they are accessible from the city centre. The heart of the city is still very

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[1] There is no precedent in history for such rapid growth, at least not on this scale: it took 130 years for London to grow from one to nearly eight million residents. It only took 45 years for Bangkok, 37 for Dhaka and 25 for Seoul to achieve the same demographic leap forward (UN-HABITAT, 2004).

dense and composite and journeys are short. There are frequent pedestrian pockets of medium density around railway stations. Journeys are radial over long distances.

The "Booming City"

- High population growth – urban structure mainly not consolidated
- High average density (>150 inhabitants/hectare)
- Spatial distribution of trip patterns is dominantly monocentric.

Balanced modal distribution between motorised private transport, transit transport and non-motorised transport, but with a clear dominance of the transit transport (between 40 and 60%).

PART II: TRANSPORT CATEGORY DEFINITIONS

This section gives a more specific definition for each of the five categories of transport and also discusses the data sources and challenges for each:

- urban passenger transport
- non-urban passenger transport
- long-distance passenger transport
- ground freight
- long-distance freight.

For each category, a global average figure for total passenger km or tonne km has been developed using background data. In order to develop different levels of ambition, each lever value is based on the major contributors to that category. For example, in terms of road transport, China, India, Europe, Latin American Countries (LAC), Africa and the US are expected to be the largest contributors to CO_2 emissions and/or population in 2050. Therefore, rather than looking at trends in all countries and regions, the levels of ambitions were produced by applying different trends to these countries and regions which are used as representatives for their categories.

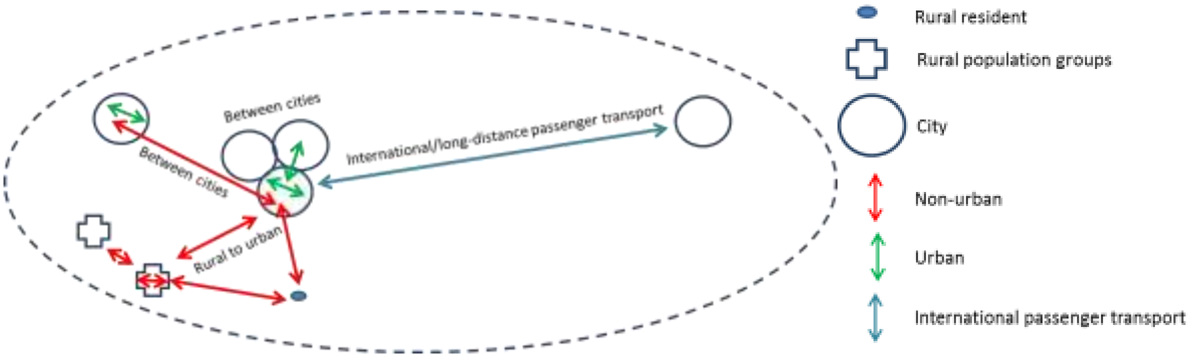
Urban Passenger Transport

This category only refers to ground transportation. It represents all travel within an urban agglomeration, which can either be a single city or a group of cities with coinciding borders. A trip that starts and ends within the urban area is considered an urban trip. Due to differences in data collection, allocation of person-km for trips 'between cities' and trips from 'rural to urban' areas will not adhere strictly to a geographical urban boundary. In general, trips where more than 50% of the trip takes place in a rural area will be counted as a rural trip. The urban category will focus on capturing trips that take place within the urban boundaries.

Ideally, each trip would be split into an urban and rural portion, however how a trip is counted will depend on the datasets that are used. A commuting trip which begins in a rural area and ends in a city will have a portion that is urban and a portion that is rural. At a national level, each trip (from origin to destination) is often given one mode and one sub-category (urban or rural). The trip will be assigned a mode and sub-category based on the mode and sub-category that make up the largest portion of the trip (NHTS US 2011). However, city level information will give data only on the urban portion of trips. City level data also may not count

For example, a commuting train trip beginning in a rural area into London, followed by an underground trip to an office site. While at the national level this may be considered one train trip, and the largest portion of the trip will be made on the train, the city level data will not capture the train trip as part of the urban travel pattern, but will capture the underground trip from the train station. Similarly, a trip made between two cities, either by train or car, may not be captured in the urban travel patterns, but will likely appear in national level data. Therefore, the urban boundary for data collection may not be as strict in the geographical sense but does capture travel using the urban transit system or infrastructure.

Figure 2: Categorization of trip types



What this represents: The data we are using in the calculator is per capita person-kilometres travelled by mode for each urban typology. To develop values for each of our three urban typologies required determining the major contributors to each region. This is also compared to the expected CO_2 contribution to road transport from each country or region in 2050. For example, though Africa makes up a large proportion of the population in region 3, it only contributes 6% of expected 2050 emissions in Region 3 (see table 1). Because the calculator is using per capita kilometres traveled per region, population will be used to develop a weighted average within each region as well as a weighted average of the regions combined for the urban passenger transport category. The countries/regions of main focus are in bold.

Countries/regions used to develop Global Calculator Regional trends:

Automobile City: US and Mexico
Transit City: Europe and Latin American Countries (LAC)
Booming City: China, India, Africa

Table 1: Population and CO_2 eq. tonnes (2050) in millions of contributors and percentage of region

1	Population		Emissions		2	Population		Emissions		3	Population		Emissions	
US	**317**	**64%**	**1509**	**75%**	**Europe**	**740**	**52%**	**1135**	**48%**	**China**	**1361**	**27%**	**2245**	**37%**
Mexico	**120**	**24%**	**271**	**13%**	**LAC**	**495**	**35%**	**684**	**29%**	**India**	**1240**	**24%**	**1897**	**31%**
Canada	35	7%	145	7%	Japan	130	9%	437	18%	**Africa**	**1033**	**20%**	**374**	**6%**
Australia	24	5%	^{100}	5%	S. Korea	50	4%	124	5%	Southeast	762	15%	*633	10%
Total	**496**		**2025**		**Total**	**1415**		**2380**		Baltic/Mid	303	6%	^907	15%
										Central Asi	318	6%		
										Other Asia	61	1%		
										Total	**5078**		**6056**	

Emission data from IEA ETP 6 Degree scenario (*ASEAN only, ^Middle East only, $^+$Australia and New Zealand)

Data: Data sources and format vary for each of the countries or regions chosen. For the US, data from the National Household Transportation Survey was used, which gives detailed information for travel modes and locations (urban and non-urban). For each location, data is available on trip length, the breakdown of modes and vehicle types, number of trips per day, and various related information. European data is similarly accurate. There is good data available for cities as well for China, India, and LAC, though the same level of data disaggregation is not readily available. This data is more often available as an aggregate mode share or total VKT by mode. (See Urban Transport Appendix)

Challenges: The challenge in this section is that the definitions and data collection approaches are different for each country. Assumptions and estimations are required to have inputs similar to those which are available from the US data set.

Non- Urban Passenger transport

Description: This category only refers to ground transportation. It represents all travel outside of urban areas. If a trip takes place between two cities, any portion that passes through a rural area would be considered non-urban travel. This includes: trips that begin and end in rural areas, commuter trips starting in rural areas and ending in cities where the largest portion of the trip is made in a rural area, and trips between cities which require passing through a rural area.

What this represents: This category is divided into two regions: developed and developing. This is done for similar purposes as the regional split for urban passenger transport. Rural areas in developed and developing countries have different baselines in terms of quality of infrastructure and mode split. The potential for growth, shifting, and possible mitigation actions are different for these two regions.

Data: Data sources and format vary for each of the countries or regions chosen. For the US, data from the National Household Transportation Survey was used which gives detailed information for travel modes and locations (urban and non-urban). European data is similarly accurate. There is much less data available on rural areas in China, India, and Latin America. However, total passenger-km data in urban and non-urban areas is available through IEA data sources. There is less accuracy in mode share and trip length data, though some assumptions can be made by looking at urban data and rural data in the US and Europe. There is particularly much lower accuracy for non-motorised modes and travel by two and three wheelers. Additional research and assumptions are used to develop values for these modes.

Long-distance Passenger transport

This category was made to capture the growing contribution of air travel (CTA/PEW 2009). It is separated from ground transport because different trends are impacting growth in this sector compared to ground transport; this impact is also different in developing and developed countries. There are also different actions for mitigation. The baseline year looks at all air passenger-km. Subsequent years, or different levels of ambition, include some of this air travel which could have shifted to rail.

What this represents: This is divided into two main regions, developed and developing, to represent different trends. This is because expected growth rates in air travel in these two regions are very different. Within the region, flights are divided into short-haul and long-haul representing those that could potentially be shifted to rail or bus and those that are too long to be made by a mode other than air.

Data: Total air travel is tracked by governments as well as businesses. The baseline data is a combination of these sources, as are the future projections. Information regarding shifting to high-speed rail is based on policies in Europe as well as evidence of this taking place in China.

Challenges: In this category it is important to distinguish between trips that are made by rail in the base year and those trips with the potential to be shifted from air to rail. Base year rail trips are captured under urban or non-urban travel. The rail trips in long-distance passenger travel are only those which can potentially be shifted from current day or projected air trips. This distinction is made in the modeling in order to capture the characteristics of long-distance trips, in both demand and distance, which can be different than trips that are currently made by rail.

Ground Freight

This category covers all ground freight in the base year – rail and road, in terms of tonne-km. Because inland waterway freight has a very small contribution to total transport emissions, it is not currently considered in the baseline scenario. However, for different levels of ambition, the ability to switch some freight transport away from road and to either water or rail is considered.

What this represents: The approach taken is similar to that of the urban transport approach. Total demand and mode share is determined by considering the major contributors to freight tonne-km. In this case, the major contributors are the US, Europe, China, and Russia. India is also considered since it will be a major contributor in the future. Different growth rates are applied to each of these contributors to develop different levels of ambition.

Data: Data is available by country or region on freight tonne-km. There are many sources of data and analysis of ground freight (IEA, ITF, WBCSD, etc.). They all provide similar base year numbers, however they provide different growth rates for different scenarios.

Challenges: The major challenge in this category is understanding the future of manufacturing and how this will impact freight. While freight projections are often tied to GDP growth, technology and costs may change where and how goods, especially low-cost/low-risk goods, are manufactured.

Long-distance freight

This category is treated at a global level as much of the travel does not take place within a specific country. This category captures only the freight that must be moved by air or ship and cannot be or is very unlikely to be substituted for ground transport. Though this is a small category of total emissions, there is a lot of potential for growth and increase in CO_2 emissions, and the potential for new technologies is significantly different from ground freight. The Appendix has details on estimates used for background information.

What this represents: This is divided into two areas: Ship and Air. We are not assuming that by the nature of what is shipped, there is little potential that any of this will shift to ground transport, however the growth rates for ship and air freight may change.

Data: There are a variety of reports that address the growth in this sector at the global level.

Challenges: Along with a need to understand changes in manufacturing, a major uncertainty for this category is the potential for new technologies. The fleet turnover rate is much lower for these vehicles, so even new technologies may not take hold within the current projections of the calculator.

PART III: BASE YEAR DATA AND LEVEL ASSUMPTIONS

Data and projections for all regions were supported by ETP 2010 (IEA), Global Transportation Energy and Climate Roadmap (ICCT 2012), ITF Transport Outlook (2012), and ITF Statistics Brief: Global Transport Trends in Perspective (2013). The following discussion of levels is based first on a literature review looking at rates of possible growth, then on understanding what that growth means potentially from a bottom-up perspective. Many different scenarios could meet the assumed growth; these examples are given to illustrate how that growth could be met.

Urban Passenger transport

Base year: The base year was developed by looking at current data for countries or regions that make up the largest portion of our dedicated "regions." Data was used from multiple sources and formats. A weighted average for each region was developed based on the contribution of its population to the total population.

Regions

Automobile City:

The US and Mexico were used to develop the base for region 1. Data on the US came from the US National Household Transportation Survey (2009). This includes both raw data and related reports. The data for Mexico came from Encuesta Annual de Transportes 2011 (INEGI, Datos 2010), MEDEC Reporte Final (CTS-EMBARQ Mexico, 2009), and Observatorio de Movilidad Urbano (IDB 2010), with additional information from 'La importancia de reducción del uso del automóvil en Mexico' (ITDP2012).

	Mode split	Average distance by mode
Car	**64%**	**13.5**
Bus	**18%**	**12.3**
Rail	**2%**	**10.8**
2-3 W	**1%**	**14.0**
Bike	**1%**	**3.7**
Walk	**14%**	**1.1**

Transit City:

Europe and LAC were used to develop the base for region 2. Data on the Europe came from' EU transport in figures Statistical Pocketbook '(2013) and 'Calculating the Economic Benefits of cycling' (ECF 2013). The data for the LAC region came from Observatorio de Movilidad Urbano (IDB 2010) and Cycling in LAC (IDB 2013).

	Mode split	Average distance by mode
Car	**45%**	**9.9**
Bus	**20%**	**10.9**
Rail	**4%**	**18.9**
2-3 W	**4%**	**13.0**
Bike	**6%**	**3.7**
Walk	**21%**	**1.9**

Booming City:

China, India, and Africa were used to develop the base for region 3. Data for China came from the 2050 China calculator. Data for India came from Study on Traffic and Transportation Policies and Strategies in Urban areas in India (WSA 2008). Data for Africa came from 'Stuck in traffic: Urban transport in Africa' (AICD, WB 2008). For all countries, additional data was used to develop values for 2-3 Wheelers including: 'Managing 2&3 wheelers in Asia' (PCFV, CAI), 'The case of Electric Bike diffusion in China' (Thesis, Dror, 2011).

	Mode split	Average distance by mode
Car	**15%**	**9.1**
Bus	**23%**	**9.9**
Rail	**4%**	**7.1**
2-3 W	**12%**	**6.6**
Bike	**14%**	**3.6**
Walk	**33%**	**1.9**

2050 Levels: Additional information for developing the levels include Peak Cars Webinar by Navigant Research (2013), Mobility 2030: Meeting the challenges to sustainability (WBCSD 2004), Electric Motorcycles and Scooters (Pike Research 2011), Passenger Transport Mode Shares in World Cities (LTA Academy 2011).

Level 1: This scenario assumes 3.2% growth annually in total urban and rural VKT. The total growth is split between regions and between urban and non-urban travel.

Automobile City:

A large portion of the population in this region is nearing peak demand. Though total passenger-km travelled (PKT) is expected to increase, it is a small increase compared to growth in Booming Cities. From the base year, trip mode shares and distances will remain mostly the same. There is some shift from walking to 2-3 wheelers to reflect growth in Mexico. The rest of the growth comes from an increase in the number of trips people make.

	Mode split (number of trips)	Average distance by mode (km)
Car	68%	14
Bus	14%	11.5
Rail	3%	20.2
2-3 W	2%	14.0
Bike	1%	3.7
Walk	12%	1.1

Transit City:

Because there is still significant room for growth in vehicle travel in LAC, this level shows an increase in trips by mode as well as an increase in trip distances to match North American standards. This increase in trip distance would be due to sprawled development taking place in LAC countries, as well as more Europeans commuting longer distances by car.

	Mode split (number of trips)	Average distance by mode (km)
Car	60%	11.9
Bus	16%	10.4
Rail	2%	18.9
2-3 W	3%	13
Bike	5%	3.7
Walk	14%	1.9

Booming City:

In this region, the percentage of trips by car triples from 2011 and the average distance by mode also increases for all modes due to more sprawling development. This increase is also due to a large shift away from walking and biking modes which will go primarily to automobiles and 2-3 wheelers. Public transit will continue to be a significant mode.

	Mode split (number of trips)	Average distance by mode (km)
Car	55%	10.6
Bus	17%	11
Rail	1%	10
2-3 W	14%	10
Bike	1%	3.5
Walk	12%	1.9

Level 2: This scenario assumes 2.7% growth annually in total urban and rural VKT. The total growth is split between regions and between urban and non-urban travel.

Automobile City:

Due to more transit-oriented development and improved transport services, fewer trips will be made by car, more trips will be made by transit and walking than in Level 1. This is also assuming that because of improved planning, vehicle trip distances will decrease by 10% for each mode.

	Mode split (number of trips)	Average distance by mode (km)
Car	59%	12.1
Bus	17%	9.4
Rail	4%	18.2
2-3 W	3%	12.6
Bike	3%	3.7
Walk	14%	1.9

Transit City:

The Transit Cities will essentially maintain their current mode share and trip distances as with the baseline scenario. There will be slightly less walking with a shift towards cycling and 2-3 wheelers.

	Mode split (number of trips)	Average distance by mode (km)
Car	49%	11.0
Bus	21%	10.9
Rail	2%	18.9
2-3 W	5%	13.0
Bike	6%	3.7
Walk	17%	1.9

Booming City:

Due to improved development patterns, trip distances will remain the same throughout the region for most modes, while 2-3 wheeler distances will grow to similar distances as in the other regions. There will still be a significant reduction in walking and cycling, but growth of 2-3 wheeler trips will be inhibited by policies on emissions restrictions and safety. Most of the vehicle growth will be met by cars.

	Mode split (number of trips)	Average distance by mode (km)
Car	41%	10.6
Bus	22%	11
Rail	1%	11.5
2-3 W	15%	9.5
Bike	6%	3.5
Walk	15%	1.9

Level 3: This scenario assumes 2.2% growth annually in total VKT. The total growth is split between regions and between urban and non-urban travel.

Automobile City:

Though much of the urban development pattern is already established in these cities, significant effort is made to shift trips to walking, biking and transit. Mixed use development will also further reduce the vehicle trip distances to those comparable with Europe today.

	Mode split (number of trips)	Average distance by mode (km)
Car	52%	12.3
Bus	20%	11
Rail	5%	20.5
2-3 W	5%	13.0
Bike	3%	3.7
Walk	15%	1.9

Transit City:

Because of a push towards transit-oriented development, particularly in the LAC region, the percent of trips made by car are reduced from the base year. The walking percentage remains high, with some growth in cycling and transit. Trip distances remain the same as the base year.

	Mode split (number of trips)	Average distance by mode (km)
Car	37%	9.9
Bus	26%	10.9
Rail	3%	18.9
2-3 W	8%	13.0
Bike	7%	3.7
Walk	19%	1.9

Booming City:

Planning focuses on meeting the needs of citizens, reducing the distances between amenities, rather than encouraging car growth. While car growth continues, a larger effort is made to increase transit options. Also, mixed use and transit-oriented development are able to maintain a higher portion of walking and cycling trips while providing greater access to jobs and services.

	Mode split (number of trips)	Average distance by mode (km)
Car	34%	10
Bus	25%	10.9
Rail	2%	12.0
2-3 W	16%	9
Bike	7%	3.5
Walk	16%	1.9

Level 4: This scenario assumes 1.6% growth annually in total VKT. The total growth is split between regions and between urban and non-urban travel.

Automobile City:

Due to both planning and external forces, such as the price of fuel, car use drops significantly from the base year scenario. A significant increase in transit is due to increased funding for these modes. Also, mixed use developments allow for increased cycling and walking to access jobs and services.

	Mode split (number of trips)	Average distance by mode (km)
Car	39%	10.9
Bus	24%	11.0
Rail	5%	21.0
2-3 W	7%	13.0
Bike	7%	3.7
Walk	18%	1.9

Transit City:

Due to planning and policies that reduce vehicle use, urban areas throughout Europe and LAC develop similarly to cities like London, Amsterdam and Copenhagen with large transit and cycling and walking shares.

	Mode split (number of trips)	Average distance by mode (km)
Car	30%	9.0
Bus	28%	9.8
Rail	4%	16
2-3 W	10%	9.5
Bike	8%	3.7
Walk	20%	1.9

Booming City:

Taking advantage of the fact that much development will still take place in these cities, a concerted effort is made to meet the needs of citizens rather than encourage car growth. There is limited growth in the use of cars, significant growth in transit, and walking and cycling mode shares remain high while providing access to good jobs and services.

	Mode split (number of trips)	Average distance by mode (km)
Car	20%	9.0
Bus	28%	9.8
Rail	2%	12.0
2-3 W	20%	8
Bike	10%	3.5
Walk	20%	1.9

Non- Urban Passenger transport

Base year: The base year was developed by looking at current data for countries or regions that make up the largest portion of our dedicated "regions." Data was used from multiple sources and formats. A weighted average for each region was developed based on the contribution of population to the total population. For non-urban transport, or rural transport, less concrete data was available so more estimates were made, especially for biking, walking, and use of 2-3 wheelers.

Developed:

The US and Europe were used to develop the base for region 1. Data on the US came from the US National Household Transportation Survey (2009). This includes both raw data and related reports. Data for Europe included 'EU transport in figures Statistical Pocketbook '(2013)

	Mode split (number of trips)	Average distance by mode (km)
Car	**82%**	**17.6**
Bus	**7%**	**15**
Rail	**4%**	**26.9**
2-3 W	**1%**	**22**
Bike	**1%**	**1.3**
Walk	**5%**	**3.0**

Developing:

Mexico, LAC, China, India, and Africa were used to develop the base for 'Developing'. The data for Mexico came from Encuesta Anual de Transportes 2011 (INEGI, Datos 2010), MEDEC Reporte Final (CTS-EMBARQ Mexico, 2009), and Observatorio de Movilidad Urbano (IDB 2010), with additional information from 'La importancia de reducción del uso del automóvil en Mexico' (ITDP2012). Data for China came from the 2050 China calculator. Data for India came from 'India: Inter-City Passenger Transport – Trends And Issues' (Dayal 2011), 'Impacts of Motorization in China and India on Global Warming' (Marwah 2005), and estimations on cycling and walking. Data for Africa came from 'Rural Transport Services in Africa' (Starkey 2007). For all countries, additional data was used to develop values for 2-3 Wheelers including: 'Managing 2&3 wheelers in Asia' (PCFV, CAI), 'The case of Electric Bike diffusion in China' (Thesis, Dror, 2011).

	Mode split (number of trips)	Average distance by mode (km)
Car	**11%**	**17.8**
Bus	**9%**	**12.2**
Rail	**9%**	**19.1**
2-3 W	**11%**	**17.6**
Bike	**25%**	**4.5**
Walk	**35%**	**1.4**

Level 1: This scenario assumes 3.2% growth annually in total urban and rural VKT. The total growth is split between regions and between urban and non-urban travel.

Developed:

With well-established development and transit corridors, mode share remains roughly the same as the base year with a slight growth in 2-3 wheelers. This also assumes some decrease in trip distances while the number of trips people take increases.

	Mode split (number of trips)	Average distance by mode (km)
Car	**86%**	**19.3**
Bus	**4%**	**16.5**
Rail	**4%**	**29.6**
2-3 W	**1%**	**24.2**
Bike	**1%**	**1.4**
Walk	**5%**	**3.3**

Developing:

Without significant investment in transit or to provide services in rural areas, there will be major growth in car and 2-3 wheeler trips. Trip lengths may also grow along vehicle and road improvements which will make longer distance traveling more comfortable.

	Mode split (number of trips)	Average distance by mode (km)
Car	**50%**	**22.2**
Bus	**9%**	**15.2**
Rail	**8%**	**23.9**
2-3 W	**23%**	**21.9**
Bike	**2%**	**5.7**
Walk	**8%**	**1.8**

Level 2: This scenario assumes 2.7% growth annually in total urban and rural VKT. The total growth is split between regions and between urban and non-urban travel.

Developed:

By increasing transit options and providing services in rural areas, more trips are possible by biking, walking, and transit. Provision of better services also leads to a reduction of trip distances by 15%.

	Mode split (number of trips)	Average distance by mode (km)
Car	**75%**	**17.9**
Bus	**8%**	**16.5**
Rail	**9%**	**28**
2-3 W	**4%**	**21.8**
Bike	**1%**	**1.3**
Walk	**5%**	**3.0**

Developing:

By increasing transit options and providing services in rural areas, more trips are possible by biking, walking, and transit. Provision of better services also leads to a reduction of trip distances by 15%. This reduces growth in car and 2-3 wheeler travel.

	Mode split (number of trips)	Average distance by mode (km)
Car	**45%**	**21**
Bus	**11%**	**15.2**
Rail	**8%**	**22**
2-3 W	**18%**	**20.2**
Bike	**8%**	**5.2**
Walk	**10%**	**1.6**

<u>**Level 3:**</u> This scenario assumes 2.2% growth annually in total urban and rural VKT. The total growth is split between regions and between urban and non-urban travel.

Developed:

A significant increase in transit as well as an increased provision of services in rural areas help to reduce car travel. Inter-city travel may also decrease as policies encourage smarter travel choices in for businesses, for example. This may also further reduce the average distance traveled per trip.

	Mode split (number of trips)	Average distance by mode (km)
Car	**67%**	**17**
Bus	**12%**	**14.9**
Rail	**11%**	**25.2**
2-3 W	**3%**	**19.6**
Bike	**2%**	**1.2**
Walk	**5%**	**3.0**

Developing:

Providing much more transit in the form of both bus and rail will shift growth away from cars and 2-3 wheelers. Providing access to jobs and services in rural areas will also help to maintain large shares of bike and walking modes.

	Mode split (number of trips)	Average distance by mode (km)
Car	**33%**	**21**
Bus	**20%**	**15.2**
Rail	**10%**	**22**
2-3 W	**12%**	**20.2**
Bike	**10%**	**5.2**
Walk	**15%**	**1.6**

Level 4: This scenario assumes 1.6% growth annually in total urban and rural VKT. The total growth is split between regions and between urban and non-urban travel.

Developed:

Major shifts in policies to fund rail and bus travel between cities and in rural areas help to reduce car travel. Providing local services and amenities, as well as access to jobs, also allows for walking and biking increases.

	Mode split (number of trips)	Average distance by mode (km)
Car	**55%**	**16.5**
Bus	**18%**	**14.1**
Rail	**11%**	**23.9**
2-3 W	**1%**	**18.6**
Bike	**4%**	**1.3**
Walk	**8%**	**3.0**

Developing:

Major shifts in policies to fund rail and bus travel between cities and in rural areas will shift growth away from cars and 2-3 wheelers. Providing access to jobs and services in rural areas will also help to maintain large biking and walking shares.

	Mode split (number of trips)	Average distance by mode (km)
Car	**26%**	**20.0**
Bus	**24%**	**14.0**
Rail	**12%**	**20.0**
2-3 W	**9%**	**18.0**
Bike	**12%**	**4.5**
Walk	**17%**	**3.0**

Long-distance Passenger transport

Base year: Because air passenger data is tracked very concretely by industry, governments, and airlines, the data for both Slow-growth and Fast-growth regions is based on ETP 2012 data (IEA). These values are also confirmed by Boeing (2013) and Lufthansa (2013) reports. The data is also split between short-haul and long-haul flights.

Slow-growth:

This is made up of OECD countries which are expecting to see growth in air travel but less than non-OECD countries. In general, many of these countries could shift a lot of air travel to rail. The current share of short-haul flights worldwide is 36%.

Slow-growth	Total passenger-km (billions)	% of all pkm
Short-haul	**1425**	**36%**
Long-haul	**2550**	**64%**
Rail	**0**	**0%**

Fast-growth:

Non-OECD countries are expected to have a significant increase in air travel as incomes and businesses grow. Besides China, there may be limited capacity or ability to shift air travel to rail. The current share of short-haul flights worldwide is 36%.

Fast-growth	**Total pkm (billions)**	**% of all pkm**
Short-haul	**475**	**36%**
Long-haul	**850**	**64%**
Rail	**0**	**0%**

2050 projections: Additional information included Current Market Outlook 2013-2032 (Boeing 2013), Global Market Forecast 2013-2032 (Airbus 2013), Air Passenger Market Analysis (IATA 2013), 'EU could ground short-haul flights in favour of high-speed rail' (Guardian 2011).

Level 1: This level assumes a 4.5% growth annually in passenger kilometres traveled. This is higher than the 'high baseline' estimated from IEA (ETP 2010). Travel in the OECD areas will continue to expand while significant growth will take place in non-OECD countries. Over ~55% of growth will be in non-OECD countries as their economies grow, and ~45% growth in OECD countries.

Slow-growth: Air travel growth continues as usually with approximately 2.4% growth per year and no change in modes is anticipated.

Slow-Growth	**Total pkm (billions)**	**% of all pkm**
Short-haul	**3,593**	**36%**
Long-haul	**6,430**	**64%**
Rail	**0**	**0%**

Fast-growth:

Air travel grows rapidly at roughly 6.4% per year and no change in modes is anticipated.

Fast-growth	**Total pkm (billions)**	**% of all pkm**
Short-haul	**5,338**	**36%**
Long-haul	**9,553**	**64%**
Rail	**0**	**0%**

Level 2: This level assumes a 3.1% growth annually in passenger kilometres traveled. Slower growth can be due to increased cost (possibly due to carbon pricing) or policies to reduce growth.

Slow-growth: Air travel growth slows slightly approximately 1.8% growth per year and no change in modes is anticipated.

Slow-growth	**Total pkm (billions)**	**% of all pkm**
Short-haul	**2000**	**25%**
Long-haul	**5000**	**64%**
Rail	**860**	**11%**

Fast-growth:
Air travel grows rapidly at roughly 5.4% per year and no change in modes is anticipated.

Fast-growth	Total pkm (billions)	% of all pkm
Short-haul	2400	25%
Long-haul	6000	63%
Rail	1200	13%

Level 3: This level assumes a 1.9% growth annually in passenger kilometres traveled. This is similar to the amount of growth predicted in the IEA ETP BlueShifts scenario.

Slow-growth:
Air travel growth slows to approximately 1.1% growth per year. Some short-haul flights are shifted to existing rail.

Slow-growth	Total pkm (billions)	% of all pkm
Short-haul	1100	20%
Long-haul	3500	63%
Rail	1100	18%

Fast-growth:
Air travel grows rapidly but at a slower rate than other scenarios at 3.8% growth per year. Some short-haul flights are shifted to existing rail.

Fast-growth	Total pkm (billions)	% of all pkm
Short-haul	1030	18%
Long-haul	3500	62%
Rail	1000	18%

Level 4: This level assumes a 0.5% growth annually in passenger kilometres traveled. As long-distance travel becomes more expensive and alternatives such as telecommuting/video-conferencing are increasingly sophisticated, fewer long-distance passenger trips are needed.

Slow-growth:
Long distance travel decreases 25% from the base year. A large portion of short-haul flights are shifted to increasingly available high speed rail lines.

Slow-growth	Total pkm (billions)	% of all pkm
Short-haul	269	8%
Long-haul	1939	60%
Rail	1000	31%

Fast-growth:

Long-distance travel continues to grow at a rate of 2.4% per year. However, a large portion of investment goes towards providing new and improved rail throughout these countries.

Fast-growth	Total pkm (billions)	% of all pkm
Short-haul	230	7%
Long-haul	2000	62%
Rail	1000	31%

Ground freight

Base year: Ground freight base data is from ETP 2012 data (IEA), ITF Statistics Brief (2013), Railway Handbook (IEA UIC 2014). It is split between slow-growth and fast-growth countries as well as between road and rail.

Slow-growth:

OECD countries

Slow-growth	million tonne-km	Mode Split (%t-km)
Road	4,478,000	54%
Rail	3,311,921	40%
Waterborne	500,000	6%

Fast-growth: Non-OECD countries

Fast-growth	million tonne-km	Mode Split (%t-km)
Road	4,609,166	35.3%
Rail	6,133,761	47%
Waterborne	2,300,000	17.6%

Projections: Additional information for projections included Railway Handbook (IEA UIC 2014), Freight Facts and Figures (FHWA 2013), Impact of High Oil Prices on Freight Transportation: Modal Shift Potential in Five Corridors (MARAD 2008), Freight Rail Bottom Line Report (AASHTO), Short-Sea Shipping in Europe (OECD 2001).

Level 1: This business as usual scenario extends existing trends to a 2.8% growth in tonne-km worldwide annually. If freight growth remains tied to GDP growth, and GDP growth continues, this is a likely scenario (ITF Outlook 2012). This means that both demand and distance traveled of goods is growing. The quantity and distance of rail freight would not be expected to change as it can be more difficult and costly to provide infrastructure, and logistically coordination is needed to maximise use of rail potential.

Slow-growth:

In OECD countries, growth is expected to be slightly slower, so this roughly equivalent to an increase of 150% in tonnes of road freight, as well as 50% increase in the distance traveled of road freight.

Slow-growth	million tonne-km	Mode Split (%t-km)
Road	11,754,750	68%
Rail	4,967,882	39%
Waterborne	500,000	3%

Fast-growth:

For non-OECD countries, it is also roughly equivalent to a 50% increase in distance of road freight as well as 200% increase in tonnes of road freight.

Fast-growth	million tonne-km	Mode Split (%t-km)
Road	15,555,935	58%
Rail	9,200,642	34%
Waterborne	2,300,000	8.5%

<u>**Level 2:**</u> This scenario includes a 2.1% growth in tonne-km worldwide annually. This means that both demand and distance traveled of goods is growing. The quantity of rail freight increases to provide as logistically coordination improves to maximise rail potential for transport.

Slow-growth:

In OECD countries, growth is expected to be slightly slower. This is roughly equivalent to an increase of 75% in tonnes of road freight, as well as a 50% increase in the distance traveled of road freight. It is also a roughly 50% increase in rail freight.

Slow-growth	million tonne-km	Mode Split (%t-km)
Road	8,396,250	61%
Rail	4,967,882	36%
Waterborne	500,000	4%

Fast-growth:

For non-OECD countries, it is also roughly equivalent to a 50% increase in distance of road freight as well as 125% increase in tonnes of road freight. It also assumes a 50% increase in rail freight.

Fast-growth	million tonne-km	Mode Split (%t-km)
Road	13,136,123	53%
Rail	9,200,642	37%
Waterborne	2,300,000	9%

Level 3: This scenario includes a 1.4% growth in tonne-km worldwide annually.

Slow-growth:

In OECD countries, growth is expected to be slightly slower, so this is roughly equivalent to an increase of 25% in tonnes of road freight, as well as a 25% increase in the distance traveled of road freight. It also assumes a 50% increase in rail freight. Some of the new growth will also be shifted to waterborne shipping.

Slow-growth	**million tonne-km**	**Mode Split (%t-km)**
Road	**6,717,000**	**46.6%**
Rail	**6,292,650**	**43.7%**
Waterborne	**1,392,000**	**9.7%**

Fast-growth:

For non-OECD countries, it is roughly equivalent to a 60% increase in tonnes of road freight. It also assumes a 50% increase in rail freight. Some of the new growth will also be shifted to waterborne shipping.

Fast-growth	**million tonne-km**	**Mode Split (%t-km)**
Road	**7,374,666**	**39%**
Rail	**9,200,642**	**48.6%**
Waterborne	**2,345,000**	**12.4%**

Level 4: This scenario includes a 0.2% growth in tonne-km worldwide annually.

Slow-growth:

This represents an increase in tonnage over the base year, but having policies geared towards local freight and away from long distance. In OECD countries, growth is expected to be slightly slower, so this assumes an increase of 10% in tonnes of road freight, as well as 25% reduction in the distance traveled of road freight. It also assumes a 25% reduction in the distance of rail freight. Some of the new growth will also be shifted to waterborne shipping.

Slow-growth	**million tonne-km**	**Mode Split (%t-km)**
Road	**2,686,800**	**32.6%**
Rail	**4,523,301**	**54.8%**
Waterborne	**1,044000**	**12.6%**

Fast-growth:

For non-OECD countries, there is assumed to still be a significant growth in total freight. This would be equivalent to an increase of 30% in tonnes of road freight, as well as a 25% reduction in the distance traveled of road freight. This assumes an increase of 35% in tonnes; it also assumes a 25% reduction in the distance of rail freight. Some of the new growth will also be shifted to waterborne shipping.

Fast-growth	**million tonne-km**	**Mode Split (%t-km)**
Road	**4,347,000**	**28.9%**
Rail	**9,149,250**	**60.7%**
Waterborne	**1,566,000**	**10.4%**

Long-distance freight

Base year: Long-distance freight is one category since there is a large global component. This data is based on IEA ETP (2012), ITF (2013), Review of Maritime Transport (UNCTAD 2013).

All	**million tonne-km**	**Mode Split (%t-km)**
Air	**160,000**	**0.2%**
Ship	**64,626,000**	**99.8%**

2050 Projections: Additional information for projections includes Review of Maritime Transport (UNCTAD 2013), International Shipping Facts and Figures – Information Resources on Trade, Safety, Security, Environment (IMO 2012), Scenarios for Fulfilling Climate Targets for 2050: Shipping's Share of the Burden (IMSF 2011).

Level 1:

This scenario assumes a 5.1% annual increase in air and 3.8% in maritime tonne-kms. This is greater than the estimate from ITF (2008 or 2012) based on extension of current annual growth rates for the air freight and shipping sectors. It is roughly equivalent to increasing total tonnes shipped by air 8 times and total tonnes shipped by sea 6 times, as well as increasing the shipping distance by 25 percent.

All	**million tonne-km**	**Mode Split (%t-km)**
Air	**480,000**	**0.3%**
Ship	**161,565,000**	**99.7%**

Level 2:

This scenario assumes a 3.8% annual increase in air and 2.7% in maritime tonne-kms. It is roughly equivalent to increasing total tonnes shipped by 3 times from present shipped tonnes.

All	**million tonne-km**	**Mode Split (% t-km)**
Air	**400,000**	**0.3%**
Ship	**133,775,820**	**99.7%**

Level 3:

This scenario assumes a 2.1% annual increase in air and maritime tonne-kms. It is roughly equivalent to increasing total tonnes shipped by 2 times from present shipped tonnes and reducing the distance shipped by 10 percent.

All	million tonne-km	Mode Split (%t-km)
Air	400,000	0.2%
Ship	116,326,800	99.8%

Level 4:

This scenario assumes a 0.5% increase in tonnes shipped by air and 1.1% annual increase in tonnes shipped by sea. It is roughly equivalent to increasing total tonnes shipped by 4 times for air and 2 times for sea from present shipped tonnes and reducing the distance shipped by 40 percent.

All	million tonne-km	Mode Split (%t-km)
Air	192,000	0.2%
Ship	93,061,440	99.8%

Efficiency Improvements

Efficiency improvements for vehicles refer to the reduction in energy use of the vehicle. The vehicles are currently in four different categories: Light-duty vehicles, heavy-duty vehicles, ships, and airplanes. Data for light and heavy-duty vehicles is based on the ICCT Energy Roadmap. The report shows that 1 to 2% annual increases in efficiency are projected through 2030. Data for shipping and airplane efficiency is based on the CTA/PEW study, Greenhouse Gas Emissions from Aviation and Maritime Transportation: Mitigation Potential and Policies, which considers logistical as well as technological improvements.

Annual Energy Intensity Reduction

	Level 1	Level 2	Level 3	Level 4
Light-Duty Vehicles- ICE	0.8%	1.0%	1.3%	1.5%
Light-Duty Vehicle- Electric	0.2%	0.3%	0.5%	0.8%
Heavy-Duty Vehicles	0.5%	1.0%	1.2%	1.4%
Air	0.5%	0.8%	1.2%	1.5%
Ship	0.1%	0.8%	1.6%	1.8%

Vehicle Types: Hybrids, Electric and Hydrogen

The Global Calculator looks at energy demand from all sectors together. It is important, therefore to determine the amount of fossil fuel versus electricity demand for the transport sector. This is done by estimating the percentage of the total fleet that will use different fuel sources. Because the take up rate of electric and hydrogen vehicles is not clear, a variety of sources informed the levels. For LDVs and HDVs, the IEA ETP 2012 data on vehicle types was used to estimate the percentage of the fleet that could be electric or hydrogen under different scenarios. Data for shipping and airplane fuel sources is based on the CTA/PEW study, Greenhouse Gas Emissions from Aviation and Maritime Transportation: Mitigation Potential and Policies.

	Level 1	Level 2	Level 3	Level 4
Urban Light-Duty Vehicles	5% hybrids, 2% electric	10% hybrids, 10% electric	20% hybrids, 20% electric; 15% hydrogen	33% hybrids, 35% electric; 20% hydrogen
Urban 2-3 Wheelers	40% electric	60% electric	70% electric	80% electric
Heavy-Duty Vehicles	5% hybrids	10% hybrids, 5% hydrogen	15% hybrids, 15% hydrogen	20% hybrids, 30% hydrogen
Ship	0% hydrogen	0% hydrogen	5% hydrogen	10% hydrogen
Air	0% hydrogen	0% hydrogen	5% hydrogen	10% hydrogen

Vehicle Ownership:

The Global Calculator allows users to choose the vehicle ownership rate. While the total number of vehicle kilometres traveled will be based on other user selections, globally, the number of vehicles we need in order to cover that distance can vary. If more people buy cars but use them less frequently, we will need to produce more cars. This would be the case for example, if congestion is very bad and people use cars more often as luxury items than for everyday purposes. If fewer cars are needed, which could be possible with extensive car-sharing or self-driving vehicles, fewer cars may need to be produced. While there will not be a large impact on CO_2 emissions from the transport sector from this lever (because of the modeling approach) this will impact manufacturing CO_2 emissions and costs.

A couple of examples demonstrate typical vehicle use in the US:

19,100 km per vehicle annually in the US in 2010 (FHWA 2010)

The typical taxi travels 70,000 miles (113,000 km) per year (NYC Taxi Factbook 2014)

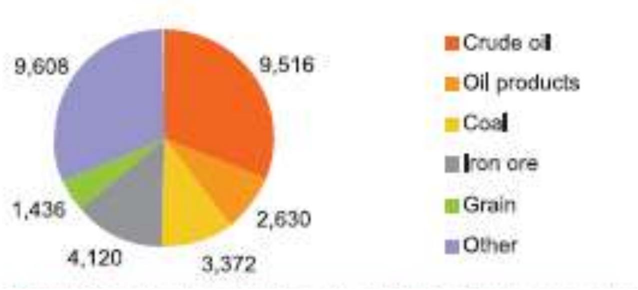
		Urban	Rural
Level 1	Ownership is high but usage per vehicle is low, 20% less per car annually than present.	80%	80%
Level 2	Each individual car drives the same km annually compare to 2011.	100%	100%
Level 3	Each car achieves much more use per year, there are more car-sharing options.	200%	150%
Level 4	Car-sharing/self-driving cars are widespread. Ownership is low and mileage high.	360%	200%

Appendix: Background of Freight Levels 1-4

Freight ton-miles or tonne-kilometres are based on total freight tonnage and the distance the freight travels. To improve the accuracy of estimates for the Global Calculator, this analysis looks at sources of freight as well as the implications of Levels 1-4 on materials needed in the future.

Figure 1 shows a break-down of freight ton-miles from the International Maritime Organization (2009 based on UNCTAD data 2006). From UNCTAD data (2013), the same data shows roughly the same proportions and about 3.5% annual growth from 2006 to 2013. Crude oil, coal, and iron ore make up 55% of the ton-miles.

Figure 1: World Seaborne trade in 2006 (billion ton-miles) IMO 2009



Product	%
Crude oil	31
Oil products	8.6
Coal	11
Iron ore	13
Grain	4.7
other	32

The goal is to estimate the impact that changing consumption of some key materials would have on changing the total tonnage of freight shipped. Two approaches to estimation are applied below to give a low and high estimate.

Using the data in Figure 1, three materials were chosen which make up a large proportion of ton-miles and correspond to categories in the Global Calculator: oil, coal, and iron. Figure 2 reflects the energy consumption associated with these different materials based on Global Calculator scenarios. These show how much energy demand there would be for each of the products under Levels 1 – 4 (Starting from the IEA 6DS pathway, Transport, Building, and Materials Levers were matched to each level – except for the freight demand lever).

Figure 2 Energy Consumption associated with materials for Levels 1 to 4

(EJ)	**2011 (IEA 6DS)**	**Level 1**	**Level 2**	**Level 3**	**Level 4**
Oil	175	487	283	146	77
Coal	150	294	214	151	75
Iron	25	53	34	23	13

Method 1:

1. The energy demand values shown in Figure 3 were converted proportionally to ton-miles based on the ratio of 2011 energy demand to 2011 tonne-km (results shown in Figure 3). The resulting ton-miles, for three major products (oil, coal, and iron) were summed.
2. The 2011 ton-mile total, 30682 billion, was decreased by 17008 billion (the sum of oil, coal, and iron ton-miles in 2011), resulting in 13674 billion ton-miles that was held constant.
3. The new sums of oil, coal, and iron tonne-miles, based on each level, were then added to 13674 billion ton-miles, to develop new totals for each level.

This estimate is assuming that only ton-miles related to these three large contributors would change in the future in each level, which is likely giving a low estimate.

Figure 3, Method 1 tonne-km totals

t-miles equivalent	**2011**	**Level 1**	**Level 2**	**Level 3**	**Level 4**
Crude oil	9516	26481	15388	7939	4187
coal	3372	6609	4810	3394	1686
iron	4120	8734	5603	3790	2142
Total of 3	**17008**	**41824**	**25801**	**15123**	**8015**
New t-mi	**30682**	**55498**	**39475**	**28797**	**21689**

Method 2: The next estimate assumes that *total* freight ton-miles would change by the same proportion as the EJ of oil, coal, and iron vs. ton-miles of these three. For example, Level 1 this would be 41,824 billion divided by 17,008 billion (from Figure 3). This creates a wider range of estimates.

Figure 4, Percentage of 2011 tonne-km

Results	**Level 1**	**Level 2**	**Level 3**	**Level 4**
Increase based on addition to 3 categories (method 1)	180%	129%	93%	70%
Proportional increase (method 2)	245%	151%	88%	47%

These two sets of estimates shown in Figure 4 are used as a high level approach to check the likelihood of the Global Calculator 2050 freight tonne-km.