DRIVERS OF DEMAND FOR PASSENGER TRANSPORT WORLDWIDE

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1. INTRODUCTION

Over the past decades passenger transport has grown rapidly and it is expected that it will continue to grow rapidly in the future. For example, Schafer and Victor (2000) estimate that between 1990 and 2050, passenger transport in industrialized regions will grow by a factor of three, and that there will be a nine-fold increase in developing regions.

The purpose of the investigation reported in the paper is to gain an understanding of what drives the demand for passenger transport around the world (what are the key drivers of passenger transport demand and how do they affect passenger transport demand?) and how these drivers can be influenced. The research has been carried out by a RAND *Europe* team led by the authors of this paper.

In order to answer the research questions, a three-fold approach was taken that consisted of a literature study, data analysis, and case studies of urban areas. The three parts of the approach complement each other. The outcomes of the literature study formed the foundation for the rest. The data analysis and the case studies were used to fill in missing pieces. The input to the literature study included research reports from all over the world. The data analysis consisted of statistical models estimated on data for 130 countries and 90 cities gathered from past research projects. There were thirteen case studies: five cases from the developed world, and eight cases from the developing world[1]. There were more cases from the developing world because the developing world is poorly covered in literature.

In this paper the key driving forces behind passenger transport demand and their effects are identified. In Chapter 2, for each driver we provide a short description, the range of effects of the driver on transport in various settings (for urban and interregional transport and developing and developed countries), explanations of differences in these effects across countries and cities, and a short discussion of whether or not these differences are likely to increase or decrease over time. A synthesis of these effects can be found in Chapter 3. A discussion of the possibilities and limitations of policy measures,

[1] The case studies for the developing world were carried out by Ralph Gakenheimer and Christopher Zegras, from the Massachusetts Institute of Technology.

based on the outcomes of the driver analysis, is provided in Chapter 4 of this paper.

2. DESCRIPTION OF THE DRIVERS

2.1 The general framework

Passenger transport demand was studied at the level of actual decision-making by the passengers. Several dimensions of passenger transport can be distinguished (see right hand side of Figure 1). Each dimension is the result of one or more choices made by travellers (see middle part of Figure 1), and these choices in turn are affected by drivers (see left had side of Figure 1). For instance the number of kilometers travelled (for the moment without distinguishing by mode of transport) is the result of decisions on the number of tours[2] (activity choices) as well as on the destinations of those tours. The split of this total over modes is determined by another choice of the travellers: mode choice, conditional on car ownership. The traveller also has to decide on the time-of-day period for each trip and the route through the network, choices that have a substantial effect on the level of congestion. A driver of transport demand that has a major impact on one of these five travel choices, may have a limited impact on other travel choices. Household car ownership is treated as an additional demand choice, but is at the same time a driver (included in availability of private modes) of the other demand choices.

In this chapter we discuss what the drivers of transport demand are, what the future outlook is for the development of the drivers and how each driver affects the choices mentioned. The drivers can be clustered into four groups (also see Figure 1):

- Population characteristics.
- Spatial structure.
- Economic structure.
- Mode characteristics.

The numbers in the yellow ovals in Figure 1 refer to the sections in which they are discussed.

2.2 Household disposable income

Household disposable income is the most important driver of demand for personal travel, but there is considerable variation in transport demand volumes between countries and regions with similar incomes. Household disposable income is determined by gross personal income, which is closely related to GDP, income distribution, taxes and the price level of consumer goods and services in a country, city, or region.

[2] A trip is a movement between an origin and a destination for a certain travel purpose; a tour is a series of two or more trips that starts and ends at home. The simplest tour only has an outward trip and a homebound trip, but one can also combine several activities in a single tour (trip chaining, e.g. trip from home to work, trip from home to the shop, trip from the shop back home).

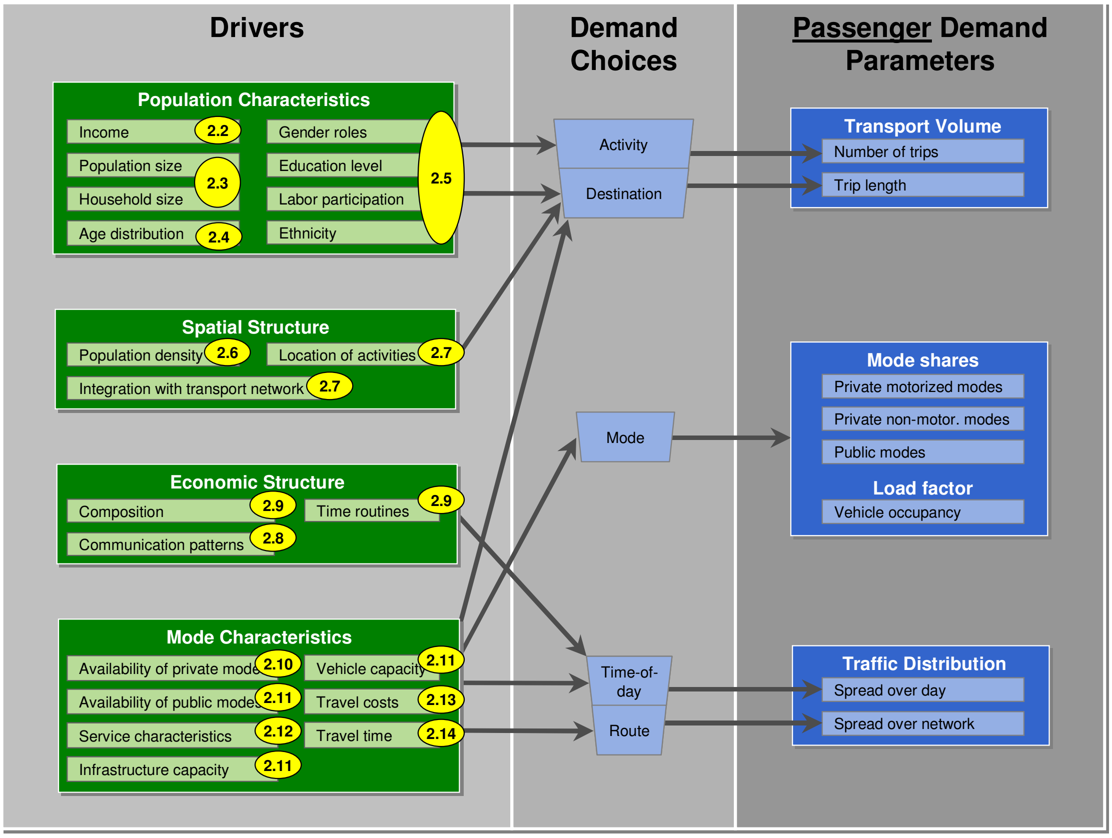

Figure 1: Relation between drivers and passenger transport demand

Income also influences a number of other drivers of transport demand, such as education levels, household size, suburbanization and motorization.

In order to be a major determinant of future transport demand two conditions need to be fulfilled:

- The driver itself must show considerable development in the future.
- A percentage change in the driver must lead to a substantial percentage change in transport demand (large demand sensitivity).

For the period 2000-2030, major growth in income is expected in most regions of the world. In the developed world, GDP per capita is predicted to grow by 2-3% per year on average. For many developing countries annual growth rates of 4-5% have been predicted for this period (for example China has had an annual GDP growth rate of 8% in recent years).

Impact on car ownership

Household disposable income is the most important determinant of household car ownership, but the income elasticity depends on the GDP per capita of a country. Based on a literature study, the National Academy of Engineering (2003) reported that more than 90% of the variation in motorization levels between countries is due to differences in per capita incomes. In the statistical analysis as part of this investigation, RAND *Europe*, using recent data on more than 130 countries around the world (developed and developing), obtained an income elasticity of motorization (the number of cars per capita) of 0.6. Ingram and Liu (1998) obtained values close to 1 on the basis of a dataset of 50 countries around the world. The National Academy of Engineering (2003) reviewed several studies on the size of the vehicle fleet across countries and cities in the developing and industrialized world, and reported an elasticity of 1 for the relation between income and national fleet size. These findings ,ay look inconsistent, but they are not; they reflect the effects of the inclusion or exclusion of developing country markets in the analysis.

Dargay and Gately (1999) report an S-shaped motorization curve; income elasticity of the car ownership rate increases from below 1 at the lowest income levels to above 2, for the middle-income-countries. As saturation is reached at the highest income levels, income elasticity falls gradually to 0. For developing countries, this pattern reflects the high purchase costs of motor vehicles.

In countries where average per capita GDP is no more than a few thousands US dollars, only the richest segment of the population can afford cars. In such countries average income is a poor predictor. Gakenheimer (1999) suggests that for low-income developing countries, the average income of the top income quintile will be a better predictor of car ownership than overall average income. However, above a GDP per capita level of a few thousand US dollars, car sales and motorization levels climb rapidly as income elasticities of demand for passenger cars run close to 2.

But apart from GDP, there are also other factors that play a role in determining motorization. For example, car ownership levels in countries with similar levels of GDP per capita can differ by as much as 50%, as a result of differences in population densities. Income elasticities for urban areas are lower than at the national level. For urban areas, per capita income explains about 80% of the variation in motorization (quoted in National Academy of Engineering (2003), on the basis of a literature review), as opposed to more than 90% in the case of data on countries (see above). However, Kenworthy and Laube (1999) report that if developing cities in Asia are excluded from the analysis, the relationship between income and motorization becomes weak.

Based on data on 90 cities around the world (from the 'UITP Millennium Cities Database for Sustainable Transport', Kenworthy and Laube, 2001), RAND *Europe* found that the income (GDP per capita) elasticity of motorization in urban areas is 0.4. Income elasticities are lower in urban areas due to other factors that influence car ownership, such as the higher population density of cities and better public transport facilities. These factors reduce the need to own a car. For example, the Ile-de-France region (Paris and surroundings) has one of the lowest motorization rates in France, despite having the highest GDP per capita within France. The same is true for Manhattan and wealthy inner boroughs of London.

In summary, car ownership is not only influenced by GDP level, but also by other factors, such as:

- Population densities.

- Levels of public transport availability and service.
- Congestion levels.
- Car ownership and traffic restraint policies (for example the very strict policies in Hong Kong and Singapore).

Impact on activity and destination choice
The number of tours for business and recreational travel purposes increases as incomes rise. Income growth also leads to longer travel distances for all types of tours. The combined effects of income (income elasticity) on the number of tours and distance (total passenger kilometers) ranges from 0.2 for cities to 1.2 for countries (source: analyses of RAND *Europe* on country and city data). In the case of both developed and developing countries, the correlation between passenger kilometers and income is primarily driven by increased tour length; the increase in the number of tours is of much less importance.

Impact on mode choice
Mode choice is partly determined by transport time and the relative costs of the various modes available for a specific tour. The importance of travel time relative to cost, i.e. the value-of-time, increases with income. In developed countries, an average income elasticity of the value-of-time of about 0.5 (Gunn, 2000) has been found. Therefore, as incomes rise, people have a stronger preference for faster modes of transport (car, high-speed trains, air). Increases in income also lead to an increased desire for comfort during the tour, as well as the ability to afford more comfortable modes. As a result, increases in income tend to lead to further shifts toward automobiles and, to a lesser extent, to train and away from non-motorized modes. For long-distance interregional transport (above ca. 150 km), higher incomes shift travel from car and coach transport to high-speed train and air transport, especially in the developed world.

Kenworthy and Laube (1999), using data on 46 cities, including some developing cities in Asia, found that income significantly affects car use. However, when analyzing cities in the developed countries alone, they found practically no relationship between wealth and car use. They found that other factors, such as land density and car costs, were more important determinants of car use in cities. We discuss these factors in more detail in the following sections.

In developed countries, increases in per capita incomes lead to a shift of modes from non-motorized travel toward cars. In South and East Asia, increases in income first shift travel from non-motorized means to scooters and motorcycles, which form an intermediate transport mode. At a low level of income, people generally take public transit or use some form of non-motorized transport (including bicycles). Middle-income groups in South and East Asia use scooters or motorcycles as their mode of transportation. At higher income levels, a large percentage of the tours are made by car. In Latin America and Africa, this intermediate role for two- and three-wheelers is much less prominent and in many cases non-existent. The use of both two- and three-wheelers and cars increases total motorization dramatically.

Passenger transport by aircraft is more sensitive to GDP growth than the other modes. The GDP elasticity of air passenger kilometrage was about 2 in the seventies and dropped to 1.5 in recent years. For developing countries the GDP elasticity of air passenger kilometrage is expected to be closer to 2. Current commercial forecasts of air passenger traffic arrive at global average annual growth rates for the next 20 years of over 4%. This would make air transport the fastest growing of all modes in passenger transport and has great implications for surface transport around the airports

Impact on route choice
Route choice depends on the differences in travel times and costs between alternative routes. Because of the increase in the value-of-time, higher incomes result in an increased preference for faster routes, even if these are more expensive.

2.3 Population and household size

Population and household sizes drive the number of tours, but are less important for other travel choices. Population growth in and of itself will not be a major driver of future growth in personal transport demand. The world's population is projected to increase by 36% between 2000 and 2030 (International Energy Agency 2003). However, over 95% of this growth in population will be in developing countries. In terms of passenger kilometers, personal transport demand in developing countries is much lower than in developed countries both in aggregate and on a per capita basis. According to International Energy Agency (2003), developing countries currently account for just 26% of total passenger car kilometers; and on a per capita basis, total average passenger kilometers in developing countries are only 18% of per capita levels in developed countries. In other words, all other conditions equal, an additional person in a developing country would increase personal transport demand by less than a fifth of what an additional person in a developed country would add to global personal transport demand. Thus, because population growth is concentrated in developing countries, the increment to global personal transport demand from population growth will be relatively small.

Shrinking average household size is a global phenomenon, resulting in much more rapid growth in the number of households than in the total size of the population. In developed countries, average household size is shrinking due to lower fertility rates, earlier exit of children from the parental home, and an increase in the number of people who remain single. Household size varies greatly in the developing world. In middle income developing countries and those with rapidly growing economies, the factors mentioned above also contribute to smaller household sizes, but declining fertility rates is the primary driver. In the poorest developing countries, average household size is also shrinking, but exclusively because of declining fertility rates.

Impact on car ownership
The number of households is a more important determinant of the size of the total fleet of personal motor vehicles in a country than is the total population. The household-elasticity of car ownership at the national level in wealthy developed countries is more or less equal to 1. For example, in France the number of one-person households is projected to increase by 68% for the period 1995-2020, whereas the number of households with four or more people is projected to decline by 15%, contributing to higher motorization levels. Each household is expected to have at least one car. Exceptions to this include small households in densely populated urban areas, and elderly households whose members do not drive (anymore).

Impact on activity choice
Household size has been found to be a highly significant explanatory variable in many tour-frequency models. In households where children leave their parents' home earlier in life, these 'empty nesters' have substantially more leisure time than parents of children living at home. An appreciably larger share of this time is spent on recreational and social travel than in households with children at home. As the share of these households in the total population of households increases, they contribute to an increase in the average number and length of tours per household. Smaller households, in general, generate more social visits than larger households; people previously living together now live apart, but visit each other regularly.

Impact on mode choice
A decline in average household size will lead to lower car occupancy rates. The number of persons in the car depends rather heavily on the travel purpose in combination with household size. For commuting and business tours the car occupancy rates are often quite close to one, despite efforts to promote carpooling by commuters. Social and recreational tours are often undertaken by the family as a whole, and here smaller family sizes directly imply lower car occupancy rates.

2.4 The age distribution

In most developed countries, the share of the elderly in the total population is increasing dramatically (e.g. in Japan the share of the persons of 60 years and more is expected to increase from 23% in 2000 to 32% in 2020).

Impact on car ownership
The aging of populations can have both a positive and a negative effect on levels of motorization, depending on the degree to which the elderly have a driving license (the 'cohort effect'). The extent to which this population holds and uses driving licenses will have a major impact on future levels of car ownership. Current car ownership patterns by age differ sharply between countries. These differences are primarily due to the time at which large shares of the population began to obtain driving licenses; this coincided with the beginning of mass motorization. In the United States, mass motorization began in the 1920s. In Europe it only started after the Second World War. Therefore, in Europe a much higher share of the elderly, especially women,

currently does not possess a driving license than in the United States. The older generation of the future (10-20 years ahead) in Europe will have a much higher rate of license ownership than the current one, but still less than in the United States. Thus, by 2030 in Europe license ownership among the elderly will increase substantially because of this 'cohort effect'. The increase in license ownership will lead to a modest increase in car ownership, and also to increased competition between household members for the car(s) in the household.

So, the net effect of the aging of the population will be different for each country. In countries where the younger generations have high car ownership rates and the older generations do not, motorization levels are expected to rise due to the 'cohort effect'. These are primarily the European countries (West and East) and some middle-income countries. After the next two decades, the cohort effect will fade away, as is already happening in the United States. There, aging will result in a lower overall motorization level *(ceteris paribus),* since elderly people generally have fewer cars than younger people (the elderly have less need for a car since they usually do not require it for commuting or education reasons, and some elderly can no longer drive a car due to insufficient health). In many low-income countries, mass motorization is only just beginning and the cohort effect will become manifest several decades from now.

Impact on activity choice

Life cycles are the primary determinant of the number of tours made for each travel purpose. For example, the vast majority of tours for educational purposes are still made by people between the ages of 5 and 23, despite the growth in adult education. In developed countries, commutes to work are almost exclusively generated by the 18 to 65 year old cohort, although the share of the 60 to 65 year-old cohort that commutes has plummeted over the last four decades. Individuals of 55 years and older have one of the highest shares of recreational and social tours in total tours, although the average total number of tours drops sharply for cohorts 65 and older, as the infirm cease to travel.

In developing countries the number and length of tours for the purpose of education is projected to rise rapidly. This is especially true for middle-income developing countries in Latin America and East Asia where secondary and tertiary education is expanding rapidly.

In Europe and Japan, the aggregate number of tours for educational purposes is likely to stabilize or fall, and the aggregate number of commutes is likely to increase slightly and then stabilize. Europe and Japan are graying more rapidly than middle-income developing countries. Because of immigration, this is not true for the United States, which is graying more slowly than a number of developing East Asian countries, including China. The aggregate number of commutes is likely to increase slightly and then stabilize in Europe and Japan, because of the expected stability in the number of workers. It is projected to grow in the neighborhood of 1% per year in the United States through 2030.

The increasing numbers of elderly people, coupled with better health conditions and more generous pensions, have resulted in an increased number of tours made by this group. The elderly usually have more leisure time available, and are expected to spend more time on social visits, day recreation and holidays than the working-age people (more tours, to some extent also longer tours). Many of today's and tomorrow's elderly are also in good health and have substantial purchasing power (even though in many countries less extensive pension schemes and higher retirement ages are being discussed at the moment), which makes (maintaining) a mobile lifestyle possible. However, the elderly travel relatively less frequently at peak travel times, and relatively more at off-peak times. This holds true for both urban and interregional travel. An increase in the share of the elderly in the total population is therefore also likely to lead to a more even utilization of transport infrastructure, and of public transportation during the day. This will therefore also contribute to more efficient use of roads, railways, buses, etc. Most migration experts do not foresee a major shift of retired persons to areas with a warm climate, except for in the US (e.g. to Florida).

2.5 Gender distribution, labor force participation, level of education and ethnicity

Gender distribution, labor force participation, level of education and ethnicity have an impact on transport volume and mode shares. In developed countries, female labor force participation rates have been rising, although rates in North America and Scandinavia may be near saturation. Female labor participation rates vary significantly among developing countries. They are high in China, but low in most Muslim countries in the Middle East and North Africa, where women are discouraged from working outside of the home for religious and social reasons. In some of the Middle Eastern Countries women do not drive and seldom use public transport. However, there has been a general strong trend toward female employment outside the home in all regions in the developing world outside of Africa and the Middle East. Even in these regions, there have been some increases.

Impact on car ownership and activity choice
Labor participation stimulates car ownership for commuting purposes. An increase in labor participation rates (the share of the working age population that has a job) results in a significant increase in car ownership. This effect is additional to the income effect stemming from increased employment, as more vehicles are acquired specifically for commuting to work. In the western world, the large growth in female labor participation rates has increased the share of two-job households. This demographic shift is one of the main driving forces behind the trend towards two- (or more) car households. Many tours for other purposes can be made with a single car in the household, but for simultaneous commuting by household members, it is often not possible to use a single car.

There is a large potential for growth in the number of commuting tours and in car ownership in countries where female labor force participation rates are relatively low. Where participation rates are below North American and

Scandinavian levels, growth in two-car households is likely, as a result of increased female labor force participation rates.

Impact on destination choice
People with a higher education are likely to have longer commuting distances, because the jobs they tend to have are more specialized and more spatially concentrated than jobs for persons with less education. This makes it less likely that people with higher education will live close to their place of employment. As jobs become more specialized, this force is likely to contribute to longer commutes. Similarly, students enrolled in institutions of higher education travel relatively longer distances than students enrolled in other educational institutions.

Race and ethnicity can influence travel demand in a variety of ways. For example, certain ethnic groups' travel behavior may be a direct result of long-standing social discrimination, such as confinement to particular areas of metropolitan areas (i.e., blacks in South African townships). In addition, some ethnic groups may have strong cultural and extended family relationships, leading to the formation of certain ethnic neighborhoods; such neighborhoods would likely lead to shorter and more frequent social tours, but potentially longer work tours (Giuliano, 2003).

Impact on mode choice
Although in statistical models mode choice appears to be affected by demographic and socio-demographic attributes of the traveling individual, many demographic and socio-demographic attributes may work through car availability or income. For instance, women and younger persons more often choose public transport and are less often car drivers (conditional on labor participation and public transport availability). To a large extent this is due to lower car availability and the lower value-of-time, which is a result of a lower income or wage levels.

2.6 Population density

Population density is a major determinant of motorization and tour lengths, but less important for other travel choices. Population density varies dramatically among cities of the developing world. The lower end of the densities of these cities is only slightly higher than those of European cities. The upper end is more than five times those densities. The lower end tends to be the higher income developing cities where vehicle ownership is advanced (for example Kuala Lumpur and Belo Horizonte), or otherwise these are the gradually urbanizing African centers (e.g. Dakar). The higher end is characteristic of the cities of South and East Asia, where current motorization is low. In the higher density parts of Chinese and Indian cities auto ownership is very difficult because of space constraints. The important phenomenon taking place in all these cities is that of dramatic physical decentralization to lower population densities. The major trend is suburbanization, but there are cities in which government intervention has led to a renewed growth of the city center population (e.g. Sydney).

Impact on car ownership

Countries with higher population densities have lower motorization rates. Higher population densities result in lower car ownership levels, *ceteris paribus,* primarily because of congestion, parking problems and costs, and the much greater availability of alternative forms of transportation. For the cost-efficient operation of public transport, large volume transport flows with similar origins and destinations are required. Large passenger volumes are even more crucial for fixed route forms of mass transit, such as metro and train. These systems are often very expensive to build, with costs running to several hundred million dollars per kilometer in some instances. Consequently, public transport operates most efficiently in areas with high population densities. Public transport on regular routes becomes very expensive to provide in low-density areas. In many instances, taxis or jitney services with flexible destinations are more cost-effective in these regions than bus service. Distances in urban areas with low population densities, like newer cities in North America or parts of Scandinavia, can be very substantial, making public transport difficult to provide in a manner that enhances sustainable mobility, especially from a cost point of view (both construction and operation). In sparsely populated non-urban areas in developed countries, day-to-day personal transport is almost exclusively provided by light duty vehicles, or for people living in towns, by foot.

In a National Academy of Engineering (2003) study, higher population density was found to be negatively correlated with both national and urban motorization levels. RAND *Europe*'s statistical analyses based on country data found that population density has a significant negative effect on the number of passenger cars per capita. The elasticity of motorization in relation to population density is –0.6 (no significant difference between developed and developing countries). We found that the impact of population density is essentially a cross-sectional phenomenon; therefore, this negative elasticity does not imply that if population density increases in a country, there will be a decline in motorization.

Kenworthy and Laube (1999) in their analysis of 46 cities around the world also found a strong negative relation between population density on the one hand and car ownership and car use on the other. This result holds for cities within developed countries. However, the results are even stronger when cities in developing countries are included in the analysis. Population density explained 84% of the variance in car ownership when all cities were included. Similar results were found from statistical analyses using data for 90 cities by RAND *Europe*.

An illustration of the impact of population density on car ownership at the urban level can be found by comparing the Randstad region (in The Netherlands) and the Sydney region (in Australia). Both areas have a similar income per capita, but the Randstad has 402 cars per 1,000 inhabitants and the Sydney region 515. The main explanation for this difference is the considerably higher population density in the Randstad (three times as high as in the Sydney region).

Impact on destination choice

When population densities are lower, people have to travel longer distances to reach their destinations. The statistical results from using the city database show that population density has a highly significant, negative impact on total passenger kilometers. The elasticity of passenger kilometers in relation to population density is around –0.4: a city with a population density 10% higher than a city of equivalent size has 4% fewer passenger kilometers. In RAND *Europe's* country database, no significant relation between the population density and the number of passenger kilometers was found.

Impact on mode choice

Areas with lower population densities have higher car use, for the same reasons that lower population densities lead to higher car ownership and use. In Northwestern Europe the modal share of car in total passenger kilometrage is more than 10% less in metropolitan areas than in rural areas (EXPEDITE Consortium, 2002).

In cities, urban population densities are more important than per capita income for car use. In models estimated by Kenworthy and Laube (1999), on data for 46 cities, urban density is highly significant. Cities with similar per capita incomes may have very different car use patterns: many European cities have per capita incomes 20-50% higher than Australian or US cities, yet they are almost four times as dense and two or three times less intensive in terms of car use (Newman and Kenworthy, 2000). Cities in the United States have 50% higher rates of car ownership, but 150% higher rates of car use than European cities. The US cities not only have more cars per capita, but average trip lengths are also longer, compared to those in European cities.

The non-linear regression lines that Kenworthy and Laube fitted to their city data indicate that at an urban density of 1,500 persons/km^2 (just above the American average) the average car use is 12,000 car kilometers per capita, whereas at 5,000 persons/km^2 (close to the European average) the average car use per capita is 4,000 car kilometers per capita. These results do not depend on whether the developing countries have been included in the analysis or not. They also fitted a regression line for the relation between the public transport share and urban density. The public transport share in all passenger kilometers traveled is 25% on average at an urban density of 5,000 persons per km^2 and 7.5% on average at 1,500 persons per km^2 (developed and developing countries).

Japanese cities have high market shares for public transport (e.g. 27% of all trips in Aichi are made by public transport; in the Chicago region with a similar GDP per capita this is only 6%). This can be explained by the high population densities, in combination with the tradition of integrated land-use and transport planning in Japan and the high quality of the public transport system.

2.7 The location of activities (and integration with transport network)

The location of activities has a large impact on average tour length, but not on other travel choices. The integration with the transport network is important for mode choice. For a number of decades, spatial separation of jobs and houses has been increasing in many parts of the world. The main force behind this phenomenon has been the move to the suburbs, satellite towns and countryside on the part of households with one or more members of working age (suburbanization).

Impact on destination choice

Destination choice is largely determined by income and spatial structure. Within the spatial structure, both the locations of the residences (discussed in Section 2.6) and of the activities at the destinations (offices, factories, schools, shops, recreation sites, etc.) drive the average tour length. The Amsterdam area can serve as an example of the urbanization process in the developed world. In the period 1970-1990 the city of Amsterdam lost more than 200,000 (25%) of its population due to net migration, mainly to the surrounding towns and villages. The dominant direction within this outward shift was to the north (north of the North Sea Canal, which divides Amsterdam region in a northern and a southern part). The growth of employment in the cities and towns north of Amsterdam was very modest; most of the employment growth took place in the city itself and to the south of Amsterdam. As a result of these developments, commuting distances in the area have increased strongly, causing congestion, especially around the tunnels crossing the North Sea Canal (Bovy et al., 1992).

Impact on mode choice

People living in areas with good public transport connections and employees of firms with good public transport access have considerably higher public transport shares.

2.8 Communication patterns

The net impact of new communication technologies on travel is still unclear. The new communication technologies that will probably have the largest effect on travel demand relate to e-shopping and telecommuting. The final impact on transport depends both on the penetration rates of electronic shopping and teleworking in total shopping and commuting, and on the sensitivity of the various travel choices to being a teleshopper or teleworker. To date, the so-called information revolution has not been accompanied by a noticeable decrease in travel (Mokhtarian, 2001). The impact of e-shopping on the numbers of shopping tours can be substantial, but the size of the net impact on transport is hard to estimate because home deliveries replace some shopping tours. Most telecommuters still periodically commute to their primary place of employment. Although telecommuters make more non-work related tours than regular commuters, the net effect of telecommuting is probably a reduction in the number of tours.

2.9 Time routines of society and composition of the economy

Time routines of society are a key driver of the time-of-day choice and, hence, they have a strong impact on the departure and arrival times and the amount of congestion. Persons with flexible working hours can change their departure time to work to before or after the peak in order to avoid the peak period congestion (De Jong et al., 2003b). Extended opening hours of shops can also lead to a more balanced spreading of trips over the day.

A society's evolving economic structure and people's changing economic activities have broad implications for travel behavior. De-industrialization and the continuing growth of the service-oriented economy has changed working hours, flexibility, and habits, producing new patterns of work trips, more frequently changing job locations and, often, less predictable travel patterns.

2.10 Availability of private modes

Car ownership is the most important determinant for mode choice. The effect of car ownership on personal travel decisions (e.g. destination choice, mode choice) takes place through personal car availability: does the person have a car available for this tour? This depends on the number of cars in the household to which the person belongs, and whether the person and other household members have a driving license. In developing countries car ownership levels will sharply increase mainly as a result of income growth. In developed countries, car ownership levels will increase moderately as a result of income growth and the cohort effect, but levels are likely to reach saturation in a few decades.

Impact on activity and destination choice
Several studies have found that persons in car-owning households make more tours than persons in non-car-owning households. Such results were for instance obtained in the Dutch National Model System (Hague Consulting Group and Dutch Ministry of Transport, 1990), SCENES consortium (2001) and EXPEDITE consortium (2002). Of course, there is a two-way ('chicken-egg') causality here: more mobile households will acquire a car sooner, and owning a car leads to more travel. The most likely chain of effects is that a threshold level of mobility (and income of course) is needed to 'trigger' car ownership, but that once a car is purchased, mobility tends to rise further. Car ownership makes it easier to travel to destinations further away. Therefore, acquiring a car often leads to the gradual adoption of different travel behavior, with more long distance tours.

Impact on mode choice
If a car is available in a household, people tend to use it heavily; otherwise they make more often use of public transport and non-motorized transport modes. Figure 2 was taken from the EXPEDITE project for the European Union. It gives mode shares in total 1995 passenger kilometers (excluding distances above 160 km), by type of household according to car ownership.

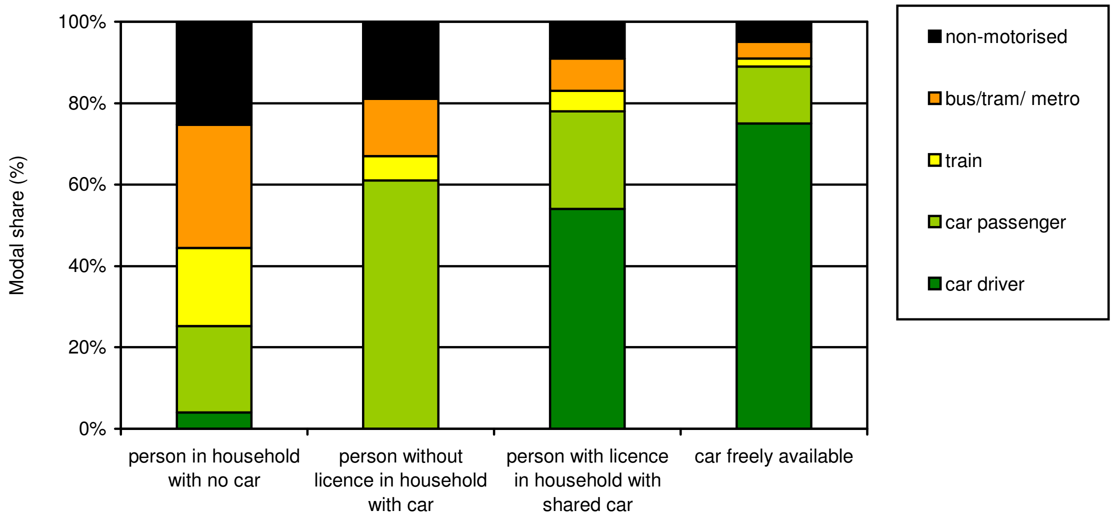

Figure 2: Mode shares (in percentages of total passenger kilometers) by type of car ownership in the EU –25
Source: Expedite consortium (2002)

If a household does not own a car, car use (rented car, borrowing somebody else's car) is minimal. If a person does not have a driving license and the household has a car, there is no individual car use, but the individual makes heavy use of cars as a car passenger. In the shared car segment and especially in the 'car-freely-available' segments, the car mode is very important in total kilometers traveled (89% of all kilometers traveled in the 'car-freely-available' segment are traveled as a car driver or car passenger). The shares of train, bus/tram/metro and the non-motorized modes fall as car availability increases.

2.11 Availability of the public modes, infrastructure and vehicle capacity

The effects of the availability of the public modes, infrastructure capacity (for all modes) and vehicle capacity (this is especially about the size of public transport vehicles) on the travel choices made by individuals work through the travel time and costs of the different modes. The geographical layout and capacity of the networks and size of the vehicles used influence travel time and costs, including the waiting times in public transport (these are a function of the frequency and the vehicle capacity offered, and of the demand). The impacts of travel costs and time are discussed in Sections 2.13 and 2.14 respectively.

2.12 Service characteristics

Service characteristics are a driver of mode choice, but not of other choices. Other modal characteristics than time and cost, such as the level of comfort, reliability and (feelings of) public security associated with these modes, can be equally important for mode choice (see De Jong et al, 2004).

2.13 Travel costs

Travel costs have a major impact on time-of-day and route choice, and a relatively minor impact on other demand choices.

Impact on car ownership
Both fixed vehicle costs (depreciation, insurance, repairs, road tax) and variable vehicle costs (fuel costs and other distance-related costs) have a negative impact on the number of cars that a household owns. Costs affect car ownership and car use through the household budget constraint. The National Academy of Engineering (2003), reviewing studies across the world, reported a vehicle price elasticity of motorization of –0.5. This study also mentioned that the impact of fuel price on fleet size is uncertain: some studies find a significant effect of fuel price on fleet size whereas other studies find no effect. Car ownership levels in urban areas are also affected by parking policies. According to the TRACE elasticity handbook (TRACE consortium, 1998), parking cost elasticities of car kilometers range between –0.05 and –0.22, depending on the distance traveled. Long trips are less affected by parking costs than short trips, because parking costs are a smaller portion of total travel costs for longer trips.

Fuel taxes have a major impact on the composition of the vehicle fleet, as residents of countries with high fuel taxes tend to purchase more fuel-efficient vehicles (Victoria Transport Policy Institute, 2003; Johannson and Schipper, 1997; Glaister and Graham, 2000), but this choice is not studied in this paper on transport demand.

Impact on destination choice
Many studies have found a significant and considerable impact of transport cost on destination choice; if the transport costs (in real terms) fall, then in the long-run there will be a larger demand for travel to destinations that are further away (shops, recreation sites, in the long run even jobs). Therefore, for measuring the long-term effect on demand, passenger kilometers are a better indicator than the number of trips or tours.

Transport costs have a significant impact on total passenger kilometers. The generalized cost (i.e. travel time and cost) elasticity of total passenger kilometers varies between –0.6 and –1.1 depending on the modes included (this is the result obtained from the model estimated in this investigation on the country data around the world). This is the combined effect of tour frequency and destination choice, but in light of the results of other studies, the effect is largely due to shifts in destination choice. In the overview of (European) elasticities in De Jong and Gunn (2001) the average long-term car-cost elasticity of the number of car kilometers is –0.3.

Impact on mode choice
De Jong and Gunn (2001) also show that in Europe in both the short and long terms, the elasticity of the number of trips in relation to car costs is generally close to –0.2. This is the pure mode choice effect. Commuting and business

travel are less sensitive to changes in fuel prices than travel for other purposes.

Fares have a large impact on the modal share of public transport, but have usually a limited impact on car use. The effect is proportionately larger for longer distance travel. Small and Winston (1999) found that the price elasticity of demand for travel by bus or train is larger for intercity passenger transport than for urban passenger transport. Nijkamp and Pepping (1998) performed a meta-analysis of studies in Europe on public transport elasticities, and concluded that for long distance fares elasticities of demand for public transport patronage are in the range from –0.4 to –0.6. These price elasticities of public transport concern the effect on the number of trips or kilometers by public transport, not the elasticity of the modal shares. Given that in most developed countries the current car share in total passenger kilometers is many times higher than the share of public transport (in the United States, more than 20 times higher; in the EU about five times higher; Japan is an exception with only 1.5 times higher (EC-DGTREN/Eurostat, 2000), a shift from car to public transport may have a considerable impact on public transit use, and at the same time be hardly noticeable in terms of total car passenger kilometers.

Air transport is more sensitive than other modes to price changes. Air fares show a downward trend. The price elasticities in air transport vary considerably between traveler segments, but in general the price sensitivity is higher than for other modes.

Impact on time-of-day and route choice
Peak hour pricing can have a major effect on the distribution of traffic over the day and over routes. In road pricing and congestion charging, the main rationale is usually to spread traffic more evenly over the day. In practice, this implies at least that the peak charges exceed the off-peak charges. Burris and Pendyala (2002) list 19 schemes in 7 countries with variable tolls (meaning that the charge varies with time-of-day or observed congestion).

2.14 Travel time

Travel time is a major factor for time-of-day and route choice and also has an impact on mode and destination choice. The impacts are similar to those of changes in travel costs, but in general the sensitivities to time change are somewhat larger (De Jong and Gunn, 2001).

3. SYNTHESIS

Passenger transport can be decomposed into several choices that travelers make. The number of kilometers traveled (for the moment without distinguishing by mode of transport) is the result of decisions on the number of tours as well as on the destinations of those tours. The split of this total over modes is determined by another choice of the travelers: mode choice, conditional on car ownership. The traveler also has to decide on the time-of-day period for each trip and the route through the network, choices that have a substantial effect on the level of congestion. A driver of transport demand that has a major impact on one of these five travel choices, may have a limited impact on other travel choices.

In the previous sections we have found that the future **total** number of passenger kilometers in a country (developed or developing) or urban area depends largely on the following factors (an increase is denoted by +, a decrease by -):

Through its impact on the number of tours (activity choice; leading to an increase in passenger kilometrage):
Primary factors:

- Household size will decline (-), leading to an increase in the number of tours (+).
- Labor participation will increase (+), which will raise the number of tours (+).

Secondary factors:

- Household income will grow (+), causing a growth in the number of tours (+).
- Population will grow (+), leading to an increase in the number of tours (+).This is not a primary factor since population is not expected to grow very fast in most regions.
- There will be a graying of the population (higher share of older persons: +). This will reduce the total number of tours (-).
- Car ownership will grow (+), leading to an increase in the number of tours (+).

Through its impact on destination choice (tour length; leading to an increase in passenger kilometrage):
Primary factors:

- Household incomes will grow (+) leading to longer tours (+).
- Car ownership will increase (+), which increases tour length (+).

Secondary factors:

- The level of education will go up (+). This leads to longer tours (+).
- The suburbanization process is likely to continue (+), leading to longer tours (+).
- The geographical specialization of areas will increase (+), which will result in longer tours (+).
- In most countries the extension of infrastructure capacity will go on (+), leading to longer tours (+).
- The real travel costs for most passenger modes have been rather stable during the past decades. Should there in the future be a notable increase (e.g. because of policy intervention: +), then this will decrease the tour lengths (-).
- The travel time for most modes in passenger transport has been decreasing. This trend can be expected to continue (-), which will lead to longer tours (+). In areas with heavy congestion however, a further decrease of transport times is unlikely.

The future number of passenger kilometers **by car** depends on the above factors (through activity and destination choice), but also on the factors that determine the share of the car in total passenger kilometrage:

Through its impact on mode choice (including vehicle occupancy):
Primary factor:

- Car ownership will increase (+), leading to a higher modal share for the car (+).

Secondary factors:

- Household income will increase (+), which will increase the mode share of car transport (+).
- The population will be graying (higher share of older persons: +), This will lead to a decrease in the car's modal share (-).
- Suburbanization will continue (+), which will lead to an increase of the mode share of the car (+).
- The availability of public modes, especially in developing countries, will increase (+), leading to a lower mode share of the car (-).
- The public transport vehicle and infrastructure capacity, especially in developing countries, will increase (+), leading to a reduction of the modal share of the car (-).
- Car travel time in most areas will decrease (-), because of market penetration of newer vehicles and investments in road capacity. This will lead to an increase in the modal share of the car (+).
- It is likely that the real running costs of the car will remain stable. Should these costs increase (e.g. because of specific policies, such as user charges: +), then the mode share of the car will decrease (-).
- The car service level is likely to increase further (+), leading to an increase in the modal share for the car (+).

Moreover, **car ownership** (the intermediate driver) is itself determined by:
Primary factors:

- Household income will increase (+), leading to car ownership growth (+).
- Suburbanization will go on (+), leading to higher car ownership (+).

Secondary factors:

- Population will grow (+), leading to an increase in car ownership (+).
- Household size will decrease (-). This will lead to an increase in car ownership (+).
- The graying of the population will continue (relatively more old-aged: +). The impact on car ownership could go both ways (+/-).
- Labor participation will increase (+), leading to higher car ownership (+).

Combining all of these changes, the most important determinant of passenger transport demand in total, and of kilometers by car in particular, is **household disposable income**. The availability of private modes (car ownership) is crucial as well, but its future development depends to a large extent on income growth. However there is no fixed trajectory between income growth and total car kilometrage, because the other drivers of demand may vary from situation to situation and in combination also have a considerable impact on car kilometrage. The most important determinants of car kilometrage after taking into account income and car ownership growth are:

- Household size.
- Size and age composition of the population.
- Labor participation and level of education.
- Population density and other elements of the spatial structure.
- Travel time and cost and other mode characteristics (these also affect the distribution of traffic over time-of-day periods and routes).

Especially the latter two categories (spatial structure and mode characteristics) provide points of leverage for policy-making. This is discussed in Chapter 4.

4. IMPLICATIONS FOR TRANSPORT POLICY

Now that we have an overview of the drivers of transport demand and their importance for transport demand, implications for the potential effectiveness of policy measures to influence transport demand can be sketched, since these policy measures affect transport demand through the drivers.

The main objectives for transport and land use policies with respect to passenger transport demand are to promote accessibility and to decrease the negative external effects of transport, such as emissions.

Of the key drivers mentioned in chapter 3, transport and land use policy can only have a tangible influence on population density (suburbanization) and on the availability and attractiveness of the transport modes. This is discussed below.

Land use policy can affect choices concerning the location of housing, commercial establishments, and places of employment to some degree. Residential choices can be influenced by making city centers more attractive by providing adequate housing, reducing crime, improving education, and developing cultural and other attractions or by regulations against greenfield developments.

Policies affecting the use of private modes of transport rather than ownership are usually more effective and more socially acceptable. For example, policies such as tolls and parking fees that affect the variable cost of using a car are more effective than ownership taxes or policies that affect the fixed cost of car ownership. However, to date policies designed to discourage car use have usually not been very effective.

Most transport policies affect transport time and cost of the modes, e.g. tolls, public transport operating or capital cost subsidies. Given that other drivers (income, suburbanization, labor force participation, household size) are more important determinants of passenger transport demand, the impact of such policies on total demand is generally small.

These policies usually have a modest effect on modal split, although there are notable exceptions (London, Singapore, some Latin-American cities, Japanese cities, some high-speed rail lines). Car usage is not very sensitive to changes in costs of use and even less sensitive to changes in the cost of ownership.

Transport policies often have a greater impact on time-of-day choices and on route choice than on modal split, and therefore the potential to reduce congestion.

To have a sizeable effect on passenger transport demand, individual measures are insufficient. Well-balanced policy packages consisting of land use policies, investments in public transport, and infrastructure user charges are needed.

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