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The Driving Factors of Passenger Transport

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Over the past few decades passenger transport has grown rapidly resulting in a multitude of problems including severe traffic congestion and pollution. It is expected that passenger transport will continue to grow rapidly in the future, which will worsen the situation even further. The traditional approach to deal with the problems is to expand the infrastructure. However, transport policy is a broad and versatile field. Many different types of policy measures can be observed in literature and practice. Sound transport policy-making requires knowledge on the drivers of transport demand This article is aimed at (re)structuring the many different insights in a single conceptual model, which reviews the key drivers, and how each affects the various choices that travellers make (activity type, destination, mode, time-of-day and route) and the resulting impact on overall passenger transport demand. The model was derived on the basis of a review of literature, which was supplemented by a review of thirteen exemplary urban area cases. In addition, a quantitative data analysis was carried out to assess the transport demand elasticities for various drivers. Current study has been carried out in response to the search for effective transport policy, which is discussed in the concluding section. The outcomes are of particular relevance of policy analysts and policy makers developing passenger transport policy, but are also useful for scholars and students in the field of transport.

Keywords: passenger transport; driving factors; transport policy

1. Introduction

Over the past few 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 rapid growth has resulted in a multitude of problems including severe traffic congestion and pollution, and the situation is expected to worsen even further in the future.

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The traditional approach to deal with the problems is to expand the infrastructure. However, transport policy is a broad and versatile field. Many different types of policy measures can be observed in literature and practice. Sound transport policy-making requires knowledge on the drivers of transport demand. Considerable resources are spent on transport studies. This includes modelling the factors that affect the (future) demand for transport as well as studies in which policy options are designed and analysed, which may include the assessment of the effectiveness and efficiency of policy options (see, for example Pendyala et al., 1997; Daly, 2000; SCENES Consortium, 2001; DfT, 2003; De Jong et al., 2004a; WBCSD, 2004). This has resulted in a wide variety of models and study outcomes.

This article is aimed at (re)structuring the many different insights in a single conceptual model, which reviews the key drivers, and how each affects the various choices that travellers make (activity type, destination, mode, time-of-day and route) and the resulting impact on overall passenger transport demand. According to the authors' knowledge there is not yet such an overarching overview.

The current study was carried out in response to the search for effective transport policy, which is discussed in the concluding section. The outcomes are of particular relevance for policy analysts and policy makers developing passenger transport policy, but are also useful for scholars and students studying the determinants of transport.

In the next section, we describe the approach taken. In section 3, we identify each of the drivers of passenger transport demand. For each driver we provide a short description, and we describe how this driver affects the various choices that travellers make (activity type, destination, mode, time-of-day and route) and the resulting impact on overall passenger transport demand. In section 4, we describe the quantitative analysis that was carried out to assess elasticities of transport demand for changes in various drivers, and compare our outcomes to those of others. In section 5, the concluding section of this article, we provide a synthesis of the findings and discuss the policy implications of the driver analysis.

2. Approach

This article is based on a study we carried out to gain insights into what drives the demand for passenger transport around the world (what are the key drivers and how do they affect passenger transport demand?) and how these drivers can be influenced.

In order to answer the research questions, a three-fold approach was taken that consisted of a literature study, case studies of urban areas, and quantitative data analysis. The three parts of the approach complement each other. The outcomes of the literature study formed the foundation for the rest. The input to the literature study included research reports from all over the world.

Exemplary cases were studied to supplement the literature review and provide concrete examples of patterns found in literature. There were thirteen case studies: five cases from the developed world, and eight cases from the developing World.[3] There were more cases from the developing world because the developing world is poorly covered in literature.

[3] The following areas in the developed world were studied: the Randstad region in the Netherlands, the San Francisco Bay area and the Chicago region in the US, the Greater Sydney Metropolitan Region in Australia, and the Aichi prefecture (including City of Nagoya) in Japan. In each of these five cases, the area considered was the metropolitan region and not just the area circumscribed by the city limits. The five regions were selected so as to cover different regions of the developed world (to capture differences in preferences, development paths, economy and culture), data availability and to include some interesting phenomena. Phenomena of particular interest for this study were the functioning of large urban areas with multiple city centres and urban areas that

The quantitative data analysis consisted of statistical models estimated on data for 133 countries and 90 cities gathered from past research projects. Univariate and multivariate regressions were estimated on this cross-sectional database. The approach taken is detailed in Section 4.

3. Drivers of passenger transport demand

3.1 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 hand side of Figure 1). For instance the number of kilometres travelled (for the moment without distinguishing by mode of transport) is the result of decisions on the number of tours (activity choices) as well as on the destinations of those tours.[4] 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. Car ownership is treated as an additional demand choice, but at the same time it is a driver of the other demand choices and also included as such in our classification of drivers (in 'availability of private modes', see Figure 1).

In this section 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 following choices (if relevant):

- Car ownership
- Activity and destination choice
- Mode choice
- Time-of-day and route choice

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

It needs to be noted that the figure is an abstraction of the insights we found by carrying out the study. In reality, there exists a myriad of interrelationships. For reasons of clarification, the figure visualises only the main relationships. The same holds for the factors. In reality, additional

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are through important sea ports the primary hub for global freight transport. The transport system of multi-centred urban areas is still less well understood and documented in literature than the transport system of traditional mono-centred urban areas.
The case studies for the developing world were carried out by Ralph Gakenheimer and Christopher Zegras, from the Massachusetts Institute of Technology. The developing world cases were selected on the basis of data availability, contacts, and the research team's local knowledge and experience, so as to present cases that span main continental regions of the world and incorporate widely different cultures, economies, and forms of governance. Some megacities were included, where magnitudes of phenomena and problems have already attracted world attention, as well as some "non-celebrity" cities. The cases selected -Belo Horizonte, Chennai, Dakar, Kuala Lumpur, Mexico City, Mumbai, Shanghai and Wuhan- show that, overall, the cities of the developing world are more different from one another than those of the North.

[4] 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).

factors might play a role as well. This article focuses on the main factors and leaves out the factors that play a more secundary role.

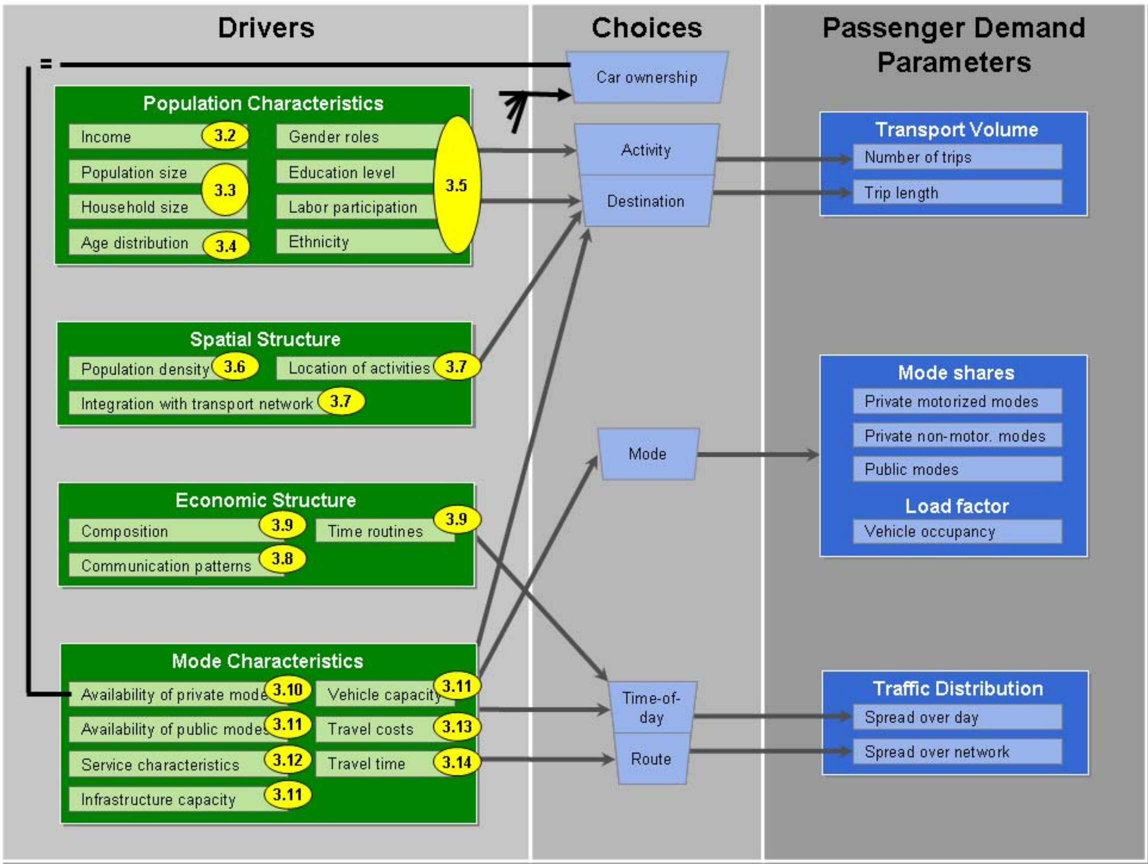

Figure 1. Drivers of passenger transport demand

In discussing the drivers, we also indicate which drivers are major determinants of future transport demand. To be a major determinant, 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).

3.2 *Household disposable income*

For the period up to 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).

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.

Income also influences a number of other drivers of transport demand, such as education levels, household size, suburbanisation and motorization, which is discussed in the appropriate section below.

3.2.1 *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. Apart from GDP, there are also other factors that play a role in determining motorization, including population densities, levels of public transport availability and service, congestion levels, and car ownership and traffic restraint policies (for example the very strict policies in Hong Kong and Singapore).

3.2.2 *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. In the case of both developed and developing countries, the correlation between passenger kilometres and income is primarily driven by increased tour length; the increase in the number of tours is of much less importance.

3.2.3 *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. [5]

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.

3.2.4 *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 (Cain et al., 2000).

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[5] Passenger transport by aircraft is more sensitive to GDP growth than the other modes. On average, the GDP elasticity of air passenger kilometrage was about 2 in the seventies and dropped to about 1.5 in recent years. For developing countries the GDP elasticity of air passenger kilometrage is expected to be closer to 2 (Airbus, 2002). Commercial forecasts of air passenger traffic arrive at global average annual growth rates for the next 20 years of over 4% (Airbus, 2002, Boeing, 2002, Rolls-Royce, 2001). This would make air transport the fastest growing of all modes in passenger transport and has great implications for surface transport around the airports. In their meta-analysis of air transport demand elasticities, Gillen et al. (2004) found a wide range: 95% of the income elasticities of air passenger kilometrage in the literature were between 0.3 and 4.6 (median value: 1.4).

3.3 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 kilometres, 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 kilometres; and on a per capita basis, total average passenger kilometres 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 (without a change in transport behaviour) 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.

3.3.1 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 (EXPEDITE consortium, 2001).[6] 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).

3.3.2 Impact on activity choice

Household size has a large impact on the number of tours made: a one-person household generates 10% more tours than a person in a larger household.[7] 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

[6] 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 (EXPEDITE consortium, 2001).

[7] Household size has been found to be a highly significant explanatory variable in many tour-frequency models (e.g. in the Dutch national model system, the Antonin model for the Paris region, the PRISM model for the West Midlands in the UK).

more social visits than larger households; people previously living together now live apart, but visit each other regularly.[8]

3.3.3 *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 1.[9] Social and recreational tours are often undertaken by the family as a whole, and here smaller family sizes directly imply lower car occupancy rates.

3.4 *The age distribution*

In most developed countries, the share of the elderly in the total population is increasing dramatically.[10]

3.4.1 *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.

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[8] This number is based on a cross sectional analysis of numbers of social tours per person (Source: LMS model, the Netherlands, see: Hague Consulting Group and Dutch Ministry of Transport, 1990).

[9] For example, about 1.12 in the Netherlands according to the 2002 national travel survey; CBS, 2004), despite efforts to promote carpooling by commuters.

[10] 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).

3.4.2 *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 neighbourhood 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).

3.5 *Gender distribution, labour force participation, education level and ethnicity*

Gender distribution, labour force participation, level of education and ethnicity have an impact on transport volume and mode shares. In developed countries, female labour force participation rates have been rising, although rates in North America and Scandinavia may be near saturation. Female labour 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.

3.5.1 Impact on car ownership and activity choice

Labour participation stimulates car ownership for commuting purposes. An increase in labour 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 labour 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 labour 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 labour force participation rates.

3.5.2 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 behaviour 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 neighbourhoods; such neighbourhoods would likely lead to shorter and more frequent social tours, but potentially longer work tours (Giuliano, 2003).

3.5.3 Impact on mode choice

Although in statistical models mode choice appears to be affected by demographic and socio-demographic attributes of the travelling 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 labour 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.

3.6 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 centres (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 centre population (e.g. Sydney).

3.6.1 *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 kilometre 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.

3.6.2 *Impact on destination choice*

When population densities are lower, people have to travel longer distances to reach their destinations. Population density has a highly significant, negative impact on total passenger kilometres.[11]

3.6.3 *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). Data from the US National Personal Transportation Survey (NPTS, 1995) show that residents in higher density urban areas make about 25% fewer car trips and more than twice as many pedestrian and public transport trips.

In cities, urban population densities are more important than per capita income for car use. Kenworthy and Laube (1999) found that at an urban density of 1,500 persons/km2 (just above the American average) the average car use is 12,000 car kilometres per capita, whereas at 5,000 persons/km2 (close to the European average) the average car use per capita is 4,000 car kilometres 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.

Public transport use depends on urban density as well. Kenworthy and Laube (1999) found that the public transport share in all passenger kilometres travelled is 25% on average at an urban

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[11] The San Francisco Bay Area in the US is a good example of continuing suburbanization. The Bay area can be regarded as a set of concentric rings (Metropolitan Transportation Commission, 2001), each with its own spatial and transport characteristics. In the outer rings population growth is expected to exceed employment growth, while in the urban core employment growth is expected to double the population growth. As a result, large commuting flows are expected between the outer rings and the urban core.

density of 5,000 persons per km2 and 7.5% on average at 1,500 persons per km2 (developed and developing countries).[12]

3.7 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 (suburbanisation).

3.7.1 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 3.6) and of the activities at the destinations (offices, factories, schools, shops, recreation sites, etc.) drive the average tour length.[13]

3.7.2 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.[14]

3.8 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 (De Jong et al., 2007).

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[12] For example, 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.

[13] The Amsterdam area can serve as an example of the urbanisation 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).

[14] For example, after a move of several departments within the Dutch Ministry of Transport to a single location with good public transport access, the share of solo-drivers among the employees decreased from an already low 33% to 19%. Train use (and carpooling, which was promoted heavily) increased (van Wee 1997).

3.9 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., 2003). 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 behaviour. 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.

3.10 Availability of private modes

The 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. Future growth in the level of motorization in a country or urban area depends heavily on the current level of motorization.[15]

3.10.1 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.[16] 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 behaviour, with more long distance tours.

3.10.2 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. 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 kilometres travelled (89% of all kilometres travelled in the 'car-freely-available' segment are travelled as a car driver or car

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[15] For example, in the San Francisco Bay Area (US), motorization appears to be nearing saturation levels and is no longer driving growth in transport demand. The level of motorization in the San Francisco Bay Area is one of the highest in the world (633 cars per thousand inhabitants). In the Randstad (The Netherlands), motorization (at 402 cars per thousand) is, however, moderate for an urban area in a developed country. For the period 2000-2030, traffic planners forecast a 36% increase in levels of motorization in the Randstad, but only a 3% increase in the San Francisco Bay area.

[16] 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).

passenger, EXPEDITE Consortium, 2002). The shares of train, bus/tram/metro and the non-motorized modes fall as car availability increases.

3.11 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 3.13 and 3.14 respectively.

3.12 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., 2004b).

3.13 Travel costs

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

3.13.1 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.

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 article on transport demand.

3.13.2 Impact on destination choice

Many studies have found a significant and sometimes substantial 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 kilometres are a better indicator than the number of trips or tours.

Transport costs have a significant impact on total passenger kilometres. In the overview of (European) elasticities in De Jong and Gunn (2001) the average long-term car-cost elasticity of the number of car kilometres is –0.3.

3.13.3 Impact on mode choice

De Jong and Gunn (2001) 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.[17] Given that in most developed countries the current car share in total passenger kilometres is many times higher than the share of public transport[18], 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 kilometres.

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 traveller segments, but in general the price sensitivity is higher than for other modes.[19]

3.13.4 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.[20]

3.14 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), with a central value for the car travel time elasticity of car kilometres of around –1 (De Jong and Gunn, 2001).

4. Quantitative data analysis

4.1 Introduction

The quantitative data analysis consisted of statistical models estimated on data for 133 countries and 90 cities gathered from past research projects. Univariate and multivariate regressions were estimated on this cross-sectional database. Both the country analysis and the city analysis were aimed at estimating the level of motorization (i.e. car ownership), and the level of mobility (i.e. the number of passenger-kilometres). For the country analysis two different datasets were used: one to estimate the level of motorization, and another one to estimate the level of mobility. The motorization calculations for countries are discussed in Section 4.2, and mobility calculations for countries are discussed in Section 4.3. Section 4.4 provides the city data calculations.

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[17] 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 kilometres by public transport, not the elasticity of the modal shares.
[18] For example, in the United States, car share is more than 20 times higher than share of public transport; in the EU it is about five times higher; Japan is an exception with only 1.5 times higher (EC-DGTREN/Eurostat, 2000).
[19] Brons et al. (2002) carried out a meta-analysis of price elasticities of air travel demand and obtained price elasticities between –0.1 and –2.2 for business travellers and between +0.2 (!) and –3.2 for leisure. Another meta-study of elasticities in air transport (Gillen et al., 2004) found that 95% of the price elasticities was between –0.1 and –1.2 for business travel and –0.7 and –2.3 for leisure.
[20] 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).

4.2 *Level of motorization in countries*

An equation explaining the number of passenger cars per capita was estimated on a dataset of 133 countries. This is a pure cross-section: there is only one observation per country. The estimation was done with the OLS regression facilities in SPSS. The best results, in terms of degree of variation explained by the regression, were obtained for a quadratic specification, as suggested in Gakenheimer (1999). However, the quadratic specification would be problematic in long-term forecasting, since at a gross domestic product (GDP) per capita of twice the present top level it would give a negative motorisation rate. This problem does not occur in the second-best specification, which is the double-logarithmic specification ('constant elasticity of substitution'), as used in Ingram and Liu (1998).

The results are presented in Table 1. The coefficients in the table are elasticities. For example, the income elasticity of motorisation is 0.635: if income increases by 10%, motorisation will increase by 6.35%.

Table 1. Country estimation results for motorisation -

Variable	Estimated coefficient	t-ratio
Constant	-4.524	-4.609
Ln (GDP per capita)	0.635	8.614
Ln (paved road density)	0.552	6.827
Ln (population density)	-0.562	-6.015
Number of observations		133
R^2		0.76

Dependent variable: natural logarithm of (passenger cars/capita)

Below a number of remarks to the model calculations are given:

- The estimated equation explains 76% of the variation in the dependent variable. All estimated coefficients are significant (at the 95% confidence level) and have the expected sign.
- The variable used for area in the calculation of road and population density is land area, not total area (land and water).
- The density of paved roads worked better than that of all roads (paved and unpaved).
- We also tested including fuel prices as regressor in the motorisation equation. The estimated coefficient of this variable was clearly not significant. Another test involved the inclusion of different coefficients for different country groups (distinguishing developed, developing and former communist countries), but this did not give significant coefficients either. 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 kilometres range between –0.05 and –0.22, depending on the distance travelled. 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.
- The above car ownership models use a measure of GDP that was not corrected for differences in purchasing power. Similar models were estimated with a GDP per capita at purchasing power parity (PPP), in 1990 US dollars (based on the data base of the University of Groningen assembled by A. Maddison).

Below, the elasticities found (and presented in Table 1) are discussed.

The income elasticity of motorisation is 0.6. Income has a positive influence on motorisation. We obtained an income elasticity of motorization (the number of cars per capita) of 0.6. Other studies have resulted in different findings. For example, Ingram and Liu (1998) obtained values close to 1 on the basis of a dataset of 50 countries around the world; and the National Academy of Engineering (2003) reported an elasticity of 1 for the relation between income and national fleet size based on the review of several studies on the size of the vehicle fleet across countries and cities in the developing and industrialized world, and. These findings may look inconsistent, but they are not; they reflect the effects of the inclusion or exclusion of developing country markets in the analysis.

This point is elaborated by Dargay and Gately (1999). They 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.

The paved road density elasticity of motorisation is 0.6. Paved road density has a positive influence on motorisation in countries, just like income. The elasticity we found is 0.6.

The population density elasticity of motorisation is -0.6. We found that population density has a significant negative effect on the number of passenger cars per capita. This means that countries with higher population densities tend to have a lower motorisation rate. The elasticity of motorization in relation to population density we found is –0.6 (no significant difference between developed and developing countries). This result is consistent to a National Academy of Engineering (2003) study, in which higher population density was found to be negatively correlated with national and motorization levels.

We think that the impact of population density is essentially a cross-sectional phenomenon (less densely populated countries have higher car ownership); therefore, this negative elasticity does not imply that if population density increases in a country, there will be a decline in motorization.

4.3 Level of mobility in countries

Our dataset for estimation of the mobility equation has 49 observations for 22 countries, including mainly developed countries, but also some transition and developing countries. For a number of countries (not including developing countries) we have multiple observations (two or three different years, at intervals of about five years): the dataset is an unbalanced panel. The mobility equation is

$$PKM/CAP = g(GDP/CAP, CARS/CAP, GC) \quad (1)$$

PKM: passenger kilometres
CAP: capita (persons)
CARS: passenger cars
GC: generalised cost

PKM, passenger kilometrage (summed over modes, all purposes, all distance bands) is chosen here as the explanatory variable. Several functional forms (e.g. linear, logarithmic, constant elasticity of substitution, polynomial) were tried for (A1). In general for this relationship the linear equation worked best in terms of significant (at 95% confidence) t-ratios, and the double logarithmic (constant elasticity) specification worked best in terms of R2. Both specifications give plausible signs for the estimated coefficients and both are presented below. These equations combine the effects of extra trips and longer trips with increasing incomes. Different regressions were estimated (in SPSS) for different datasets, depending on the modes for which data on passenger kilometrage were available. These models were estimated with OLS on a pooled sample (not taking account of the panel nature of the data) in SPSS and with generalised least squares in LIMDEP as a random effects panel model (taking account of the panel character of the data). Results are in Table 2.

Table 2. Country estimation results for passenger-kilometres model

	OLS estimates on pooled sample		Random effects panel model	
Variable	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Constant	-2.189	-2.141	-3.293	-2.913
Ln (GDP/CAP)	1.153	12.263	1.126	12.824
Ln (CARS/CAP)	0.134	2.660	0.160	3.029
Ln (Population density)	-0.005	-1.878		
Ln (Generalised cost/km)	-0.408	-1.698	-1.069	-3.144
Number of observations		49		49
R^2		0.923		0.901

Dependent variable: natural logarithm of the sum of car, rail, bus/tram/metro, bicycle passenger and air kilometers per capita per year): double-logarithmic model

Below a number of remarks to the model calculations are given:

- The dependent variable in the regressions in Table 2 does not include passenger kilometres by other modes than car, train, bus/tram/metro, bicycle and aircraft, such as motorbike, ship and walking. For these other modes, no consistent statistics could be found.
- In the models estimated with specific panel model methods, population density was not significant, and therefore this variable was removed.
- The models in Table 2 have a proportion of explained variance of around 90%, which is quite high.
- GDP per capita is measured in purchasing power parity (PPP) in dollars of 1990 (based on the data base of the University of Groningen assembled by A. Maddison).
- Rail density as well as road density was tried in the linear model and double-logarithmic model, but the estimated coefficients were insignificant.
- Different coefficients for different country groups (e.g. developed, developing and former communist countries) were tried, but did not produce coefficients that were both significant at the 95% confidence level and significantly different from each other.

Below the elasticities found (and presented in Table 2) are discussed.

The income elasticity of mobility is 1.1 or 1.2. In the constant elasticity models, the GDP per capita elasticity of per capita kilometrage (following the panel models, which are to be preferred given the panel nature of the data) is around 1.2. Schafer and Victor (2000) also found a central trajectory with a slope close to 1 for this.

The cars per capita elasticity of mobility varies between 0.1 and 0.2. In the country data we found an cars per capita elasticity of 0.1-0.2.

The generalized cost elasticity of mobility varies between –0.4 (n.s.) and –1.1. The generalized cost (i.e. travel time and cost) elasticity varies between –0.4 and –1.1. In the generalised cost measure used here, the different modes are weighted according to their national share. The generalised cost are expressed as cost per passenger kilometre, and comprise both transport time and cost. In these generalised costs, the time impacts were converted to money units using average Western European values of time (TRACE, 1998) and a GDP per capita elasticity of the value of time of 0.5 for other countries (Gunn, 2000). The elasticity of transport cost alone are in the range –0.2 to –0.5 and those for time are between –0.4 and –0.7 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 kilometres is –0.3.

4.4 Level of motorization and mobility in cities

This analysis is based on data on 90 cities around the world (from the 'UITP Millennium Cities Database for Sustainable Transport', Kenworthy and Laube, 2001). This is a cross-section, not a panel. The Millennium Cities Database was compiled over three years by Kenworthy and Laube for the International Union of Public Transport (UITP) in Brussels. It covers cities on all continents and 'contains data on 69 primary variables, which depending on the city and the administrative complexity and multi-modality of its public transport system, can mean up to 175 primary data entries.' 'The methodology of data collection for all the factors was strictly controlled by agreed upon definitions contained in a technical booklet of over 100 pages and data were carefully checked and verified by three parties before being accepted into the database' (Kenworthy, 2003).

The models on this dataset were estimated using OLS.

The results for motorization and mobilisation are presented in, respectively, Table 3 and Table 4. Next they are discussed.

Table 3. City estimation results for motorisation

Variable	Estimated coefficient	t-ratio
Constant	-5.955	-11.492
Ln(GDP/CAP)	0.432	7.029
Ln(road density)	0.282	2.124
Ln(population density)	-0.499	-6.688
Number of observations		90
R^2		0.77

Dependent variable: natural logarithm of (passenger cars/capita)

Table 4. City estimation results for passenger-kilometres model

Variable	Coefficient	t-ratio
Constant	6.434	18.772
Ln (GDP/CAP)	0.234	6.201
Ln (Population density)	-0.353	-6.788
Observations		89
R^2		0.67

Dependent variable: natural logarithm of the sum of car, motorcycle, rail, bus/tram/metro, passenger per capita per year: double-logarithmic model

With respect to the model calculations it needs to be noted that variables for motorisation, road density and public transport density were also tried, but not found to be significant.

The income elasticity of motorisation is 0.4. We found an income (GDP per capita) elasticity of motorization in urban areas is 0.4. This finding is consistent with other sources. For example, National Academy of Engineering (2003) reported on the basis of a literature review, that for urban areas, per capita income explains about 80% of the variation in motorization, 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 at the urban level becomes weak.

Income elasticities for urban areas are lower than at the country level (where it was 0.6). They 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.[21]

The road density elasticity of motorisation is 0.3. The road density elasticity of motorization in urban areas we found is 0.3. This number is quite lower than for countries where it was 0.6. This means that road density has a smaller discriminatory effect than for countries.

The population density elasticity of motorisation is -0.5. The population density elasticity of motorization we found for urban areas is -0.5, which is similar to that for the country data (which was -0.6)

Similar results were found by Kenworthy and Laube (1999) in their analysis of 46 cities around the world. They also found a strong negative relation between population density on the one hand and car ownership 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.

The income elasticity of mobility is 0.2. The income elasticity is just above 0.2 here. This means that the combined effects of income (income elasticity) on the number of tours and distance (total passenger kilometres) is 0.2 for cities. This elasticity is substantially lower than the elasticity we found for countries (1.2).

The population density elasticity of mobility is -0.4. Population density has a highly significant, negative impact on total passenger kilometres. The population density elasticity of mobility we found for urban areas is around -0.4. This means that a city with a population density 10% higher than a city of equivalent size has 4% fewer passenger kilometres Similar results were found by Kenworthy and Laube (1999) in their analysis of 46 cities around the world. They also found a strong negative relation between population density on the one hand and car use on the other.

A possible extension of the quantitative analysis would be to estimate the motorisation and the mobility equation simultaneously as a system of equations, since in the models on the country data car ownership is an exogenous variable in the mobility equation and the endogenous variable of the second equation. However, for more than half of the observations on car ownership we have no mobility (passenger kilometres) observations. This problem does not occur in the city data. In the mobility equation on the city data there is no car ownership variable (a question is whether it would be significant in a simultaneous model on this data).

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[21] 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.

5. Conclusions and policy implications

Passenger transport can be decomposed into several choices that travellers make. The number of kilometres travelled (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 travellers: mode choice, conditional on car ownership choice. 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. The latter two choices only have a limited impact on total mobility and emissions, but are important determinants of congestion.

The main drivers of the passenger travel demand in a country (developed or developing) or urban area are summarised in Table 5. The first column lists the driving factors. The second column gives the expected trend in this factor for the next decades (++ for strong growth, + for moderate growth, - for decline). The importance of the factor on various choices is given in the columns 3-6. Factors having a strong positive influence are denoted by ++, a more limited positive influence by +, a limited negative influence by -. If there is no + or – in column 3-6, the factor is not among the main drivers of the choice in the column.

The main drivers of the future *total* number of passenger kilometres can be seen in the columns 4 and 5 of Table 5, since traveller kilometres are determined by the number of tours and the tour length. Car ownership is one of the drivers of tour frequency and one of the key drivers of tour length, but is itself driven by a number of exogenous influencing factors. In column 3 are the main drivers of car ownership.

The future number of passenger kilometres *by car* depends on the same factors (through activity and destination choice), but also on the factors that determine the share of the car in total passenger kilometrage (column 6).

Table 5. Relative importance of drivers of the future number of passenger kilometres by car

Influencing factor	Trend in factor over time	Impact through car ownership	Impact through the number of tours made (activity choice)	Impact through destination choice (tour length)	Impact through mode choice
Household income	++	++	+	++	+
Suburbanization	Lower densities	++		+	+
Household size	-	+	++		
Labour participation	+	+	++		
Population	+	+	+		
Aging of population	Higher % elderly	+/-	-		-
Car ownership	++ (except areas with highest motorization)		+	++	++
Education level	++			+	
Geographic specialisation	+			+	
Infrastructure	Extensions			+	
Travel cost	+ (also policy-variable)			-	-
Travel times (incl. car)	- (except very congested areas)			+	+
Availability and capacity of public modes	+ (especially in developing world)				-
Comfort, reliability, security (esp. of car)	+				+

Combining all of these effects, the most important determinant of passenger transport demand in total, and of kilometres 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.
- Labour 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).

Now the 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 the previous section, transport and land use policy can only have a tangible influence on population density (suburbanisation) and on the availability and attractiveness of the transport modes. Given that transport and land use policy can only affect two of the seven main drivers to some degree, not including the two most important drivers (income and car ownership[22], the scope for transport and land use policy as a means to shape total mobility in a country is quite limited. In particular, the following policy conclusions can be drawn:

- 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 centres more attractive by providing adequate housing, reducing crime, improving education, and developing cultural and other attractions or by regulations against greenfield developments.
- The impact of transport policies affecting transport time and cost of the modes (e.g. tolls, public transport operating or capital cost subsidies) on total demand is generally small, as other drivers (income, suburbanisation, labour force participation, household size) are more important determinants of passenger transport demand. 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). This can also be seen from the generally small time and cost (though usually not zero) costs elasticities of travel demand and modal share. Car usage is not very sensitive to changes in costs of use and even less sensitive to changes in the cost of ownership. Air travel however, especially for leisure purposes, is more sensitive to costs changes.
- 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.

[22] Fiscal policies and regulation (purchase tax, road tax, car purchasing or ownership permits) are sometimes used to reduce (the growth of) car ownership. Policies affecting the use of private modes of transport rather than ownership are usually more socially acceptable.

In general, 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, and even then policy-makers should take care not to expect large impacts on total mobility.

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