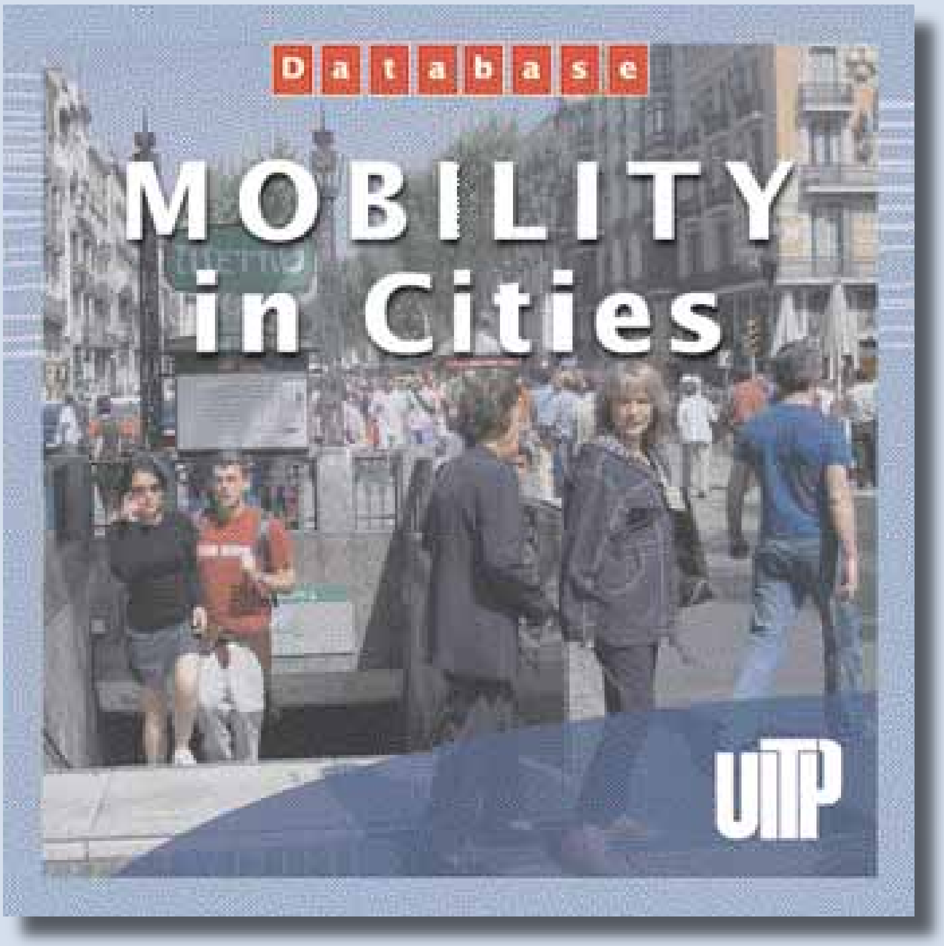
Mobility in Cities Database



Better Mobility for People Worldwide

Analysis and Recommendations

Jean Vivier
Scientific Advisor – UITP

Editorial Team:
Jean Vivier
Jérôme Pourbaix

International Association of Public Transport (UITP)
Rue Sainte-Marie 6
B-1080 Brussels
Belgium

Tel.: +32 2 673 61 00
Fax: +32 2 660 10 72
info@uitp.com
www.uitp.com

Dépôt légal: D/2005/0105/12

Summary

1. Overview of the database

Encouraged by the success of its ″Millennium Cities Database for Sustainable Transport″, UITP decided to embark on a new project for the collection and analysis of urban mobility data ″Mobility in Cities Database″ (MCD) for 2001. Like the previous version, the new database covers demographics, economics, urban structure, private vehicle stock and usage, taxis, the road network, parking, public transport networks (infrastructure and fleet of rolling stock, service, traffic, expenditure and revenue), individual mobility and modal choice, the cost of transport to the community, energy consumption, air pollution, and accidents. In total, 120 raw indicators were collected from the sample's 52 cities. Of these 52 cities, 43 formed part of the sample for the ″Millennium Cities Database for Sustainable Transport″. MCD therefore enables a more in-depth study of previous analyses, and makes it possible to measure the evolution of the key indicators of mobility economics between 1995 and 2001.

The MCD project was led by UITP in partnership with the *Régie Autonome des Transports Parisiens* (France) and with support from the *Agence de l'Environnement et de la Maîtrise de l'Energie* (France), the *Consorcio de Transportes de Madrid* (Spain), the *Communauté Urbaine de Nantes* and the *Syndicat Mixte des Transports en Commun de l'Agglomération Clermontoise* (France), *Région de Bruxelles-Capitale* (Belgium) and the *Verkehrsverbund Ost-Region* (Austria). All work relating to data collection and quality control, statistical analysis, realisation of the searchable database and drafting of reports was carried out by UITP, principally Jérôme Pourbaix, Manager in UITP's Knowledge and Membership Services Department, and Jean Vivier, UITP Scientific Advisor, who steered the scientific thrust of the project. Data collection work was facilitated by the help received from obliging and efficient correspondents, many of them UITP members. Our sincere thanks go to them.

Table 1: List of cities in the sample

Cities	Cities	Cities
Germany	Marseilles*	Glasgow*
Berlin*	Nantes*	London*
Hamburg*	Paris*	Manchester*
Munich*	***Greece***	Newcastle*
Stuttgart*	Athens*	***Russia***
Austria	***Hungary***	Moscow*
Graz*	Budapest*	***Sweden***
Vienna*	***Ireland***	Stockholm*
Belgium	Dublin	***Switzerland***
Brussels*	***Italy***	Bern*
Ghent	Bologna*	Geneva*
Denmark	Milan*	Zurich*
Copenhagen*	Rome*	
Spain	Turin*	***Australia***
Barcelona*	***Norway***	Melbourne*
Bilbao	Oslo*	***Brazil***
Madrid*	***Netherlands***	Sao Paulo*
Seville	Amsterdam*	***China***
Valencia	Rotterdam	Hong Kong*
Estonia	***Poland***	***United Arab Emirates***
Tallinn	Krakow*	Dubai
Finland	Warsaw*	***State of Singapore***
Helsinki*	***Portugal***	Singapore*
France	Lisbon*	***United States***
Clermont-Ferrand	***Czech Republic***	Chicago*
Lille*	Prague*	***Tunisia***
Lyons*	***United Kingdom***	Tunis*

* Cities also belonging to the ″Millennium Cities Database for Sustainable Transport″ sample.

The cities in the 2001 sample are mainly European (45 out of 52) and nearly all of them belong to developed countries. All sizes of conurbation are represented, from Graz, Ghent and Clermont-Ferrand (250,000 inhabitants) to Sao Paulo (17 million inhabitants). The majority of the sample comprises conurbations with a population of between 1 and 5 million inhabitants. It also includes seven very large metropolitan areas (over 5 million inhabitants) and 14 medium-sized cities (under 1 million inhabitants). The focus on European countries and cities in developed countries reflects the centres of interest expressed by UITP's partners and subscribers of the database. It also allowed the project to be completed in just two and a half years, compared to the four years needed to complete the previous project.

Raw indicators, standardised indicators and qualitative information

The data sought was essentially quantitative in nature, and constitutes the project's raw indicators, the full list of which can be found in Annex 1. Based on this raw data, 130 standardised indicators were calculated to enable relevant comparisons to be made between the cities. Comparisons of quantitative data between conurbations, such as network length, traffic volume and annual transport expenditure, only have meaning if the data is expressed in relation to population and/or the GDP of the conurbation. This UITP database therefore provides a precise definition of each of the standardised indicators.

For some cities, it was also possible to gather information on policies and measures implemented during the period 1990-2001 and of the prospects for coordination between the three pillars of urban planning and transport, traffic and parking, and public transport through until 2010. These qualitative data are invaluable for understanding the evolution of the mobility economy between 1995 and 2001, as emerges from a comparison of these indicators.

The same indicators and collection methods had to be used to accurately measure this evolution, as well as the same definitions for the metropolitan areas in the sample. As a rule, this was the method used, but adjustments were made to ensure consistency between the sources used. This was to provide the best possible conditions for making comparisons between data from the ″Millennium Cities Database for Sustainable Transport″ of 1995 and those in MCD.

Data collection and estimates

A handbook setting out the data to be collected was produced for the researchers and their correspondents for the cities in the sample. It is annexed to the database available from UITP. The handbook builds on experience gained compiling the ″Millennium Cities Database for Sustainable Transport″, and provides information on the data research and verification methods used.

Any expert involved in data collection for transport systems, urban mobility and transport expenditure knows the many difficulties that this kind of exercise poses. Whilst certain information is regularly recorded in the annual statistics of transport organising authorities and public transport operators, it should not be assumed that collecting this data is an easy task. Finding data collated within a single body is the exception: it is usually scattered amongst a large number of actors, who do not always use the same definitions for a given indicator. Even for the most straightforward indicators, a check for consistency and uniformity is nearly always required. It is also necessary to check for consistency between indicators that are clearly linked, but collected by different bodies at different times (for example, between 2001 statistics on public transport traffic and the average number of daily journeys on public transport, according to a mobility study of households conducted as close as possible to 2001). Finally, certain data is not available quite simply because it has not been collected in any statistics or studies. In this event, it is sometimes possible to evaluate a reasonable order of magnitude for a given indicator (on the basis of other, generally reliable, indicators) and submit this to our correspondents for approval. Below is a brief outline of the main difficulties encountered and the solutions found.

The first difficulty involves determining the boundaries of conurbations. The data available is sometimes collected by administrative bodies, that do not use the metropolitan area boundaries most relevant to a mobility study. The delineated area is almost always large enough to embrace the conurbation in its entirety. The area generally corresponds to a clearly defined administrative body comprising statistical departments and constitutes the zone served by urban public transport operators. However, when the data required are available for an area different from the study area, adjustments need to be made. Such adjustments relate in particular to information on regional rail transport services, serving an area that often extends beyond the limits of the metropolitan area in question. For each city, the database specifies the list of local districts or groups of local districts covered in a given metropolitan area.

The definition of ″Central Business District″ (CBD) generally does not pose any specific problems. However, it may be that the statistics are incomplete and do not allow all the indicators required to be collected.

Dates of statistics and available studies pose a further challenge. Extrapolations were made to ensure that all indicators relate to the year 2001. These adjustments essentially involve mobility data from household surveys conducted several years apart. Panel-type surveys are sometimes available to measure the evolution in mobility since the previous detailed study. Otherwise, the adjustment is based on extrapolating the trend observed between the two latest surveys and the evolution in car and public transport traffic.

In order to avoid the peak phenomena which can affect investment, actual annual expenditure was collected year on year between 1997 and 2001 and we have used the annual average for both investment in roads as well as public transport.

A significant proportion of the cities in the sample were able to provide nearly all the data required, albeit with problems involving the delineation of the metropolitan area boundaries and the year of data collection, as mentioned above. These issues, however, are generally quite easy to resolve. The most common difficulties encountered and the solutions found were:

- For demographics and economics: the delineation of the urban area differs somewhat from ours and corrections must be made. GDP is not always available for the study area: an estimate is then made based on GDP for a wider area, and corrected where necessary in line with data on household incomes.
- Private vehicle stock and traffic: estimate of annual vehicle x km and average speed on the road network. These indicators are provided by traffic models, where they exist. Other estimation methods used included mobility studies and road speed measurements.
- Parking in the CBD: counting the number of off-street parking spaces provided for employees and customers in the CBD via information from companies and retail businesses presents is problematic when there are no specific studies available. As making an estimate would be risky, MCD therefore only provides an indicator for public parking spaces.
- Taxis: only the indicator for the taxi stock is always well-known. The other indicators are hard to obtain officially, but can be estimated using mobility surveys, specific studies of taxis, or even direct interviews with taxi drivers.
- For public transport: apart from the need to make adjustments for services (essentially rail) that extend beyond the metropolitan area in question, the main difficulty stems from the large number of operators found in some cities (as many as several dozen). This makes data collection extremely arduous when there is no organising authority, or the latter does not have sufficient operator information. Deregulation and privatisation go hand in hand with increasing numbers of actors and mounting reticence to disclose information, in particular when it is accounting-related. The emergence of complex set-ups designed to boost productivity and service quality often leads to unclear situations where the collection of financial data is not easy. All the same, we have made a special effort to study these complex situations and have minimised the risks of either overlooking elements or counting them twice.

- Mobility: the number of journeys per day and modal split relate to an average annual day (including weekends and holidays). Adjustments had to be made when the available surveys related to working days. It should be underlined that indicators of average journey length and duration are approximate given the survey methods generally used.
- Transport system costs: it was nearly always possible to obtain reliable figures for investment and operational expenditure in public transport for the year 2001. On the other hand, estimating maintenance and investment expenditure for roads proved difficult, in view of the large number of financers (from the State to the local district, and given that some metropolitan areas contain several hundred local districts). Some cities preferred not to provide information on this indicator and to use a summary estimate to calculate the cost of transport for the community (this expenditure being marginal vis-à-vis the sum of public transport expenditure and running costs of private vehicles). As regards the running costs of cars, the fact that we chose an ″average vehicle″ necessarily entails a degree of approximation. Expenditure can only be estimated precisely in the rare cities where a ″transport account″ exists.
- Energy consumption of private vehicles and air pollution: when statistical sources did not exist or were deemed unreliable, we used unitary consumption figures and pollution rates multiplied by the annual number of private vehicle x km.

These further explanations useful in that they allow the MCD user to fully comprehend the difficulty of this data collection exercise and the inevitable uncertainty surrounding certain indicators. For example, the cost of transport for the community - a fundamental indicator of mobility economics - has a margin of uncertainty of between 5 and 25%, depending on the quality of the information available. Averages calculated for groups of cities are clearly more reliable. Whilst the result may not be perfect, MCD is - along with the ″ Millennium Cities Database for Sustainable Transport″ - the most comprehensive and reliable collection of data on urban mobility in existence to date. Over 95% of the data researched have been collected for 40 out of the sample's 52 cities. The overall collection rate is over 90%.

An information source of primary importance for urban planning and mobility policy makers and the public transport industry

This report outlines the main conclusions on the relationships that exists between the type of urban development, choice of transport mode by city-dwellers, and the cost and performance of transport systems. Public transport's trump cards in the face of competition from the car are also examined. These analyses follow on from conclusions published by UITP in May 2001 drawn from the ″Millennium Cities Database for Sustainable Transport″. In order to examine the relationship between urban planning, modal choice and the cost of transport, and public transport's appeal, eight additional cities featuring in the ″Millennium Cities Database for Sustainable Transport″ (Montreal and Ottawa in Canada; Houston, San Diego and Washington in the United States; Osaka, Sapporo and Tokyo in Japan), were added to make the MCD city sample more representative. This involved incorporating low density cities where car use is dominant (North America) and dense cities with high public transport use (Japan); these two city profiles were relatively under-represented in the MCD sample. For these eight additional cities, the indicators used date from 1995.

The main new feature compared to the previous study is the possibility to measure and explain the evolution of the mobility economy between 1995 and 2001. This analysis relates to the performance and costs of transport systems and public transport's appeal compared with the car. The report also gives an overview of public transport's evolution in terms of passenger numbers and market share, investment, construction of reserved routes, commercial speed, supply volume, operating expenditure, and farebox revenue. Comparisons between 1995 and 2001 are fully possible since the same indicators are used with the same definitions. However, in order to eliminate of the risk of distortion, it was sometimes necessary to correct 1995 data and update previous estimates in the light of information available today.

Products available from UITP

An interactive CD-ROM will be on sale, containing the 120 standardised indicators for each of the 52 cities. A fact sheet on local mobility policy has been produced for certain cities. It contains an overview of measures implemented during the period 1990-2001 and realised or scheduled between 2001 and 2010, together with a table comparing the evolution of key indicators between 1995 and 2001, comments on past changes, strengths and weaknesses today, and future prospects. This analysis and set of recommendations is included on the CD-ROM. UITP‘s intention is to provide its members with the chance to benchmark the performance of their cities and transport networks and also to develop a set of arguments adapted to their own situation.

2. Cost and performance of transport systems

In the eighteenth century, the habitat and economic and social activities of a city were concentrated within a confined space. Virtually all journeys were made on foot. With the advent of the industrial revolution, cities developed along railway lines that carried workers from their home to their place of work. Density remained high, with walking the dominant transport mode. The rapid development of the car has prompted a new type of urban growth in which proximity is no longer a *sine qua non*. Cities now expand to the detriment of farmland, the countryside and villages. Population and activity densities are in decline whilst the number of cars per household is steadily on the increase. The clustering of spaces according to use (housing, offices, production sites, businesses, schools, leisure) and sprawl oblige the use of cars, walking being ill-suited to overly long distances. At the same time, public transport is by its nature inefficient in lightly populated zones. Public transport tends to be concentrated in the centres of conurbations and along arteries converging towards the centre and, apart from these links, is confined to providing minimum social services for the ″car deprived″.

This model of dispersed urban development (sprawl) not only consumes spaces and non-renewable energy, but is the reason for high external costs in terms of traffic congestion, pollution, road accidents and social segregation. This latter aspect warrants particular emphasis. Inhabitants of ″sprawl″ have to be able to drive in order to have convenient access to urban activities. The only travel choice for children, elderly persons no longer able to drive, and, more generally, people without access to a car, is to rely on someone else to drive them. Households that are sufficiently affluent own more than one car to allow freedom of movement for each family member: one per household member of driving age. Another effect of segregation is the clustering of households from the same socioeconomic background in districts where all the houses look the same and the people very similar: the poor alongside other poor, and the rich alongside the rich, protected inside their gated communities and fenced in to keep out non-residents.
Already characteristic of cities in the United States, Canada and Australia, sprawl is now becoming a widespread feature the world over. The trend is towards the uniformity of outlying urban areas, predominance of the ″single living unit, shopping centre, car park″ formula, and monotonous urban planning, with often mediocre architecture. Shopping centres, like vast hangars whose frontages are bedecked with advertising, and whose huge car parks stand more often than not empty, are not particularly pleasing to the eye. Car park capacities are calculated to cope with maximum demand (the last Saturday before Christmas, for example) and cut off vast, flat expanses that are polluted by the oil deposited by parked vehicles. This causes a drop in the ground water level, irregular water flow, and pollutes neighbouring watercourses.

Citizens and policy makers are well aware of the problems caused by urban sprawl and growing car dependency, but not of their scale nor their evolution. More often than not, they are unaware that the cost to the community of the car-based urban sprawl development model is far higher than the cost of an average/high-density city well irrigated with public transport.

A raft of indicators exist to objectively measure the cost and performance of transport systems, their links with urban structure and the use of the different transport modes

One of the aims of MCD is to highlight the links that exist on the one hand between urban planning and use of transport modes and the cost and performance of the mobility system on the other (transport expenditure, energy consumption, pollution, accidents, and travel time).

Costs and performance

The key economic indicator is the cost of transport for the community. This includes:
- spending on public transport (investment and operation),
- spending on road investment and maintenance,
- spending on the use of motorised private modes (including vehicle depreciation).

In order to estimate the cost of transport for the community, expenditure for private vehicles is calculated excluding specific taxes (e.g. additional duties on new-vehicle purchases, fuel, insurance, etc.) in order not to tilt comparisons in favour of public transport.

The cost of transport for the community is expressed as a percentage of GDP for the metropolitan area to enable comparisons to be made between cities.

It must be emphasized that this cost is strictly financial and does not include ″external costs″ generated by transport (chiefly by the car) such as the consumption of urban space, pollution, noise, and traffic accidents.

The cost of transport for the community can be split into the cost of private vehicles (cars, motorised two-wheelers, taxis) and the cost of public transport.

An attempt can also be made to divide up the cost borne by the public purse (that is to say, funded by the taxpayer) and the cost paid by users. This split was made based on the assumption that the State, regions, local districts and other local bodies bear on the one hand the cost of investment in road and public transport ,and the difference between operating costs and farebox revenue of public transport undertakings, on the other. But this calculation method overstates the public share, since investment in rolling stock is generally financed by operators. Nevertheless, - and largely in Great Britain - certain types of infrastructure investment are privately funded. However, this public-private split assigns all spending on cars to households without taking company cars into account.

Energy consumption per year and per inhabitant is expressed in megajoules so as to group together electric and thermal modes. For electric modes, two calculation methods were employed: the first using vehicle consumption figures, while the second provides consumption ″at source″, ie. the efficiency of the thermal power stations producing the electricity.

Figures for average journey duration by public transport and car were collected. The overall duration was taken as including final-section journey times on foot and, for public transport, waiting times and transfer times. The average duration of a motorised journey and the number of daily journeys per mode was then calculated using this data and an estimate made of time spent per day in motorised transport per inhabitant.

Air pollution indicators cover annual emissions of CO, NOx and volatile organic compounds by passenger transport modes. Pollution is expressed in proportion to population and urbanised area. This indicator measures the level of air pollution inhaled by city-dwellers. It should be pointed out that the quality of air pollution data, where available, varies a great deal. Caution is needed when making comparisons between cities.

The number of people killed annually in transport accidents is used to compile the indicator for safety. The number of victims is expressed as a percentage of the population. This indicator depends on the length of the period taken after accidents to count fatalities (30 days in theory). The period varies in practice from country to country and, as with pollution, the final values shown are tinged with uncertainty.

Cost and performance: explanatory factors

Urban characteristics are defined by the size of the conurbation (urban surface area) and average density of the urban area (population and jobs per hectare). The indicator of population density + jobs per hectare - the best way to measure density of activity - is used to make the analysis.

GDP per inhabitant is used to measure a city's economic level.

To describe transport modal choice we measured:

- the proportion of trips made walking, cycling, or on public transport (the remainder of journeys being provided by motorised private vehicles),
- the proportion of mechanised (bicycles) and motorised journeys provided by public transport.

The possible influence of other indicators was considered, namely: the concentration of economic activity in the centre (percentage of jobs located in the CBD); road, motorway and railway provision; levels of investment in roads and in public transport; unit costs of car use and public-transport use for the user, etc. Since the resulting correlations were unconvincing, the following next sections study the relationship between the cost and performance of mobility systems and density, urban area, choice of transport mode, and GDP per inhabitant.

2.1. Cost of transport for the community

Cities which spend the least on the mobility of their inhabitants are those whose density is average or high and where journeys are chiefly made walking, cycling, or on public transport.

The cost of transport for the community varies from 5% in dense cities with high public transport use to over 12% in sprawling cities where the car is virtually the only mode of transport.

Table 2: Density, modal choice and cost of transport for the community

Cost of transport for the community (% of GDP)			
Density: population + jobs per hectare [GRAPH 1]			
> 80	50 to 80	25 to 50	< 25
8.0	8.9	10.7	12.2
Proportion of journeys made walking, cycling, or on public transport [GRAPH 2]			
> 55%	40 to 55%	25 to 40%	< 25%
7.5	9.0	9.6	12.3

The higher the density and the proportion of journeys made walking cycling or on public transport, the more economical the transport system. This fact, already established from information collected in 1995, is shored up by an analysis of data from MCD and augmented by data from cities in the United States, Canada and Japan taken from the ″Millennium Cities Database for Sustainable Transport″ in order to make the sample as representative as possible.

The high cost of transport in low density cities stems to a large extent from the high level of motorisation they engender, given that walking and cycling are ill-suited to long distance mobility needs. Moreover, journeys are predominantly made by car, which costs the community more than public transport in average or high density cities. In low density cities, a modal shift from the car over to public transport (where it exists) would have little impact on the cost of transport for the community given that public transport is ill-suited to serving low density areas (save on routes within or to centres, where the economic efficiency of public transport always outperforms that of the car).

Journeys made in urban areas are half as expensive in Hong Kong, Singapore and Helsinki as they are in Chicago, Melbourne and Newcastle. This gulf represents a saving of around EUR 2,000 per year and per inhabitant in cities where the use of public transport and of ″green″ modes is most strongly developed. Certain cities, such as Vienna, Munich and cities in Switzerland, have chosen to offer their inhabitants very high quality public transport (notably in terms of comfort and frequency). This choice clearly has a bearing on the cost, but this is nonetheless still far lower than the cost borne by cities where the car is the dominant mode.

Whilst density and modal choice are good explanatory factors for the cost of transport for the community, there is also a very clear link with a city's level of affluence. Although cost is expressed as a percentage of GDP to facilitate making meaningful comparisons, the lower GDP per inhabitant, the higher the cost. In developing and transition countries, functions essential for economic and social life, such as transport, eat up a greater proportion of resources than they do in affluent cities. Moreover, the appeal of the car is prompting poorer households to spend a very significant proportion of their budget on car ownership and use.

Table 3: GDP per inhabitant and cost of transport for the community

Cost of transport for the community (% of GDP)			
GDP per inhabitant (euros)* [GRAPH 3]			
> 30,000	22,000 – 30,000	15,000 – 22,000	< 15,000
7.8	8.2	9.7	11.4

* cities from the MCD sample only

Tables 4 and 5 give the costs of transport for the community (2001 values) and explanatory parameters for cities located at either end of the scale.

The efficiency of major cities in the Far East is due to the combination of high density (–extremely high in Hong Kong), a significant proportion of trips made walking cycling or on public transport (over 80% in Hong Kong), and high income per inhabitant. In Europe, the most efficient cities all show average or fairly high density, a significant public transport share (particularly in Vienna), and high income levels per inhabitant.

Table 4: Cost of transport for the community and explanatory factors for the most economical cities

	Cost of transport for the community (% of GDP)	**Density: population + jobs per hectare**	**Share of trips walking cycling or on public transport (%)**	**GDP per inhabitant (euros)**
Hong Kong	4.85	424	84	27,500
Tokyo*	5.0	135	68	45,500*
Singapore	5.35	165	55	29,000
Helsinki	5.6	71	56	36,500
Munich	6.4	91	59.5	46,000
Vienna	6.55	103	64	34,500
Paris	6.65	59.5	53.5	37,000
Bologna	6.9	79	44	31,000
Turin	7.1	66	46	26,500
London*	7.5	89.5	50	36,500

1995 values GDP in USD 1995

Two categories can be discerned amongst the least economical cities: affluent cities with acute sprawl where the car is the dominant transport mode (cities in the United States, Melbourne); and cities where revenue per inhabitant is modest in relation to the car ownership rate, as in Sao Paulo, Moscow and Seville. Montreal and Newcastle occupy the middle ground (average income per inhabitant and limited walking and public transport use).

Table 5: Cost of transport for the community and explanatory factors for the least economical cities

	Cost of transport for the community (% of GDP)	Density: population + jobs per hectare	Share of journeys walking cycling or on public transport (%)	GDP per inhabitant (euros)
Moscow	17.0	231	73.5	6,100
Montreal*	14.8	45	25.5	16,000*
Houston *	14.1	13	4.5	30,500*
San Diego*	12.8	21	7.5	26,500*
Seville	12.0	67	52	10,900
Newcastle	11.9	60	43	18,400
Melbourne*	11.8	21	26	21,500*
Chicago	11.7	23.5	12.5	40,000

1995 values GDP in USD 1995

The study of the multiple explanatory correlations for the cost of transport for the community was made using several sets of explanatory parameters:

- population density, share of journeys walking, cycling, or on public transport, GDP per inhabitant,
- population density + jobs, share of journeys walking, cycling, or on public transport, GDP per inhabitant,
- population density + jobs, GDP per inhabitant,
- share of journeys walking, cycling, or on public transport, GDP per inhabitant.

The best result is obtained using the set comprising ″population density + jobs, share of trips walking, cycling, or on public transport, GDP per inhabitant″, the variation of which explains 68% of the variation in the cost of transport for the community (regression based on the logarithm of parameters).

There is a strong link between the parameters for density and the share of journeys walking, cycling, or on public transport (Table 6). It is also possible to obtain a good level of explanation for the cost of transport for the community using just two explanatory parameters. The sets comprising on the one hand density and GDP per inhabitant, and modal choice and GDP per inhabitant on the other, explain some 60% of the variation in the cost for the community (63% and 56% respectively; regression based on the logarithm of parameters).

Table 6: Density and modal choice

Share of journeys walking, cycling, or on public transport [GRAPH 10]			
Density: population + jobs per hectare			
> 80	50 to 80	25 to 50	< 25
61.0	48.4	39.4	13.2

Evolution in the cost of transport for the community between 1995 and 2001

There was no significant variation in the proportion of GDP devoted to citizens' mobility between 1995 and 2001; which remained at 8.5% on average for the MCD sample cities. Nonetheless, this overall level of stability conceals significant variations for some cities: London, Paris and Helsinki, already among the top performers in 1995, made further considerable advances; Prague and Budapest, where the role of public transport remains dominant despite a climbing motorisation rate, significantly strengthened their position (8.8% of GDP in Prague and 8.0% in Budapest in 2001, instead of 11.2% and 10.0% in 1995); Madrid, a city that has strongly backed public transport development, is indisputably seeing the fruit of this investment (drop in the cost of transport for the community from 12.0 to 10.4%), whereas transport spending increased in cities in the United Kingdom (bar London), in Brussels and in Berlin.

Split in the cost of transport for the community between public transport and individual modes

It is interesting to examine the split in total mobility expenditure for public transport and individual modes. In cities in the United States, in Melbourne and in Dubai, where transport expenditure is high, investment in roads and the car absorb virtually all of this money. On the other hand, in cities in the Far East and in the most economical European cities, the split in spending is more balanced (between 20 and 35% on public transport).

Split in financing the cost of transport for the community between the taxpayer and the user

The most economical cities are not necessarily those where the public purse (financed by the taxpayer) is the least used to cover transport spending. In Paris and in Vienna, the public authority devotes over 1.5% of GDP to financing transport (investment in roads and in public transport, contribution financing the running costs of operators not covered by farebox revenue). More generally, no correlation whatsoever can be made between the cost of transport for the community and the way it is funded. Nor are there any links between the split in spending on journeys between the public and private sectors and indicators of urban structure and modal choice.

The largest contributions from the public purse (1.5% to 3% of GDP) are from cities that have invested heavily (in roads and/or on public transport) and/or those in which public transport users only pay a small proportion of the transport cost. The first category counts in its ranks Berlin, Lille, Lisbon, Madrid, and Prague (sustained strong investment in public transport), Moscow (heavy investment in roads) and Oslo (investment in roads and in public transport). The second category includes Brussels, Lyons, Paris, Vienna and Warsaw, where the coverage rate of operating expenditure by farebox revenue is low or average and the level of investment average or sustained.

2.2. Energy consumption

The most transport energy efficient cities are those with average or high density and where trips are chiefly by walking, cycling, or on public transport.

Table 7: Density, modal choice and annual energy consumption for transport

Annual energy consumption for journeys (megajoules/inhabitant)*			
Density: population + jobs per hectare [GRAPH 4]			
> 80	50 to 80	25 to 50	< 25
13,200	14,300	20,000	53,400
Share of journeys walking, cycling, or on public transport [GRAPH 5]			
> 55%	40 to 55%	25 to 40%	< 25%
12,500	15,100	17,400	45,000
Urban area (hectares) [GRAPH 6]			
< 30,000 ha	30,000 – 70,000 ha	> 70,000 ha	
13,900	15,300	28,400	

* consumption at source

The relationship between energy consumption and density established by Peter Newman and Jeff Kenworthy is corroborated in this study, as is the link highlighted by the ″Millennium Cities Database for Sustainable Transport″ between public transport market share and green modes. The link with conurbation size is equally clear with the weight of cities in the United States, energy intensive and rampantly sprawling, tending to drive up the average for large conurbations. The gaps between ″energy efficient″ and ″energy intensive″ cities are considerable: from 10,000 to 18,000 megajoules per year and per inhabitant in most European cities and over 30,000 in the cities of North America and Australia. To give a clear picture, this gap represents 400 to 500kg of crude oil per year and per inhabitant.

Tables 8 and 9 give the values of explanatory parameters for energy consumption per inhabitant for cities at either end of the scale. Among the most economical cities, Hong Kong, Warsaw and Moscow show high or very high densities coupled with a very high usage rate for walking and public transport. Megalopolises in Japan, in spite of their huge size, only consume fairly small amounts of energy (respectively 12,300 and 13,000 megajoules per year and per inhabitant in Osaka and Tokyo in 1995). Below-average mobility per inhabitant is also a determinant economic factor, as illustrated by the examples of Spanish cities (except Madrid) and Lisbon.

Table 8: Energy consumption and explanatory factors for the most economical cities

	Annual energy consumption at source for journeys (in megajoules per inhabitant)	Density: population + jobs per hectare	Share of journeys walking, cycling, or on public transport (%)	Urban area (in hectares)
Hong Kong	5,400	424	84	23,500
Seville	7,500	67	52	22,000
Turin	9,100	66	46	32,000
Valencia	9,600	76	58.5	31,500
Lisbon	9,700	39	52	96,000
Warsaw	9,900	82	71.5	33,000
Bologna	10,100	79	43.5	8,500
Bilbao	10,300	73	65.5	21,500
Moscow	10,700	231	73.5	70,500

The most energy-intensive cities are all characterised by high mobility: over 3 journeys per day and per inhabitant, with over 2 of these being motorised journeys. This said, at equivalent mobility the highest energy consumption figures equate to the least dense cities, where car use is quasi-exclusive (cities in the United States), or widely dominant (Montreal and Melbourne). It should also be emphasised that very low fuel prices (subject to little or no tax) encourages car use, which is less economical than public transport (cf. Chapter 3). This is notably the case in the United States, Canada and Australia as well as Dubai, where consumption reaches as high as 18,000 megajoules per year and per inhabitant despite an average level of mobility and a relatively small metropolitan area. In Europe, the highest consumption figures are recorded, apart from in Stuttgart and Munich as mentioned earlier, in Hamburg, Brussels, Glasgow and in cities in Switzerland and in Scandinavia (except Helsinki).

Table 9: Energy consumption and explanatory factors for the most energy-intensive cities

	Annual energy consumption at source for journeys (in megajoules per inhabitant)	Density: population + jobs per hectare	Share of journeys walking, cycling, or on public transport (%)	Urban area (in hectares)
Houston *	86,000	13	4.5	444,500
San Diego*	54,000	21	7.5	180,500
Washington*	51,000	23.5	15.5	261,000
Chicago	44,000	23.5	12.5	530,000
Melbourne*	32,000	21	26	225,000
Montreal*	29,500	45	25.5	102,000
Stuttgart	21,500	54.5	41	67,500
Munich	21,500	91.5	59.5	24,000

*1995 values

The study of multiple explanatory correlations for journey energy consumption was based on several sets of explanatory parameters:

- population density, proportion of journeys made walking, cycling, or on public transport, urbanised area,
- population density + jobs, proportion of journeys walking, cycling, or on public transport, urbanised area,
- population density + jobs, urbanised area,
- proportion of journeys walking, cycling, or on public transport, urbanised area.

The best result using three parameters is obtained from the set comprising ″population density + jobs, proportion of journeys walking, cycling, or on public transport, urbanised area″, the variation of which explains 81.3% of the variation in energy consumption for journeys per inhabitant (regression based on the logarithm of parameters).

When only two parameters are used, the ration “proportion of journeys walking, cycling, or on public transport and the urbanised area″ gives the ebst results. It explains 80.2% of the variation in energy consumption (regression based on the logarithm of parameters).

Evolution in energy consumption between 1995 and 2001

Energy consumption for inhabitants’ urban mobility remained very constant between 1995 and 2001 at around 15,000 megajoules (at source) per year and per inhabitant on average for cities in the MCD sample. As with the cost of transport for the community, this overall stability masks varying individual situations: falls in consumption in Geneva, Vienna and Madrid linked to the rise in public transport market share during this period; increases in Brussels, Glasgow and in Eastern European cities reflecting the fall in proportion of journeys walking, cycling, or on public transport.

Nonetheless, mere stability in energy consumption stability is not sufficient at a time when the price of a barrel of oil is sky-rocketing and awareness is growing about the finite nature of oil reserves and the risk of climate change caused by the greenhouse effect (directly linked to the consumption of fossil fuel). Nearly all experts now accept that, in less than a generation, oil production will stop increasing year on year and a downward curve will begin. Pessimists believe that this trend reversal, known as ″peak oil″, will happen in 2010; optimists believe it will come between 2020 and 2030. Whatever the case, it will be necessary, between now and whenever it does occur, to devise a different pattern of economic growth and alternative means of urban development. Despite this, the model of car-based urban development is not really being called into question, especially not in the United States. The spread of urban sprawl affects the majority of cities and the decline in density is glaringly obvious: from 62.5 inhabitants per hectare in 1995 to an average of 59 in 2001 across the MCD sample. This overall trend, which is worrying for the planet's ecological balance, does not favour public transport aor green modes either. Several cities have nonetheless managed to keep urbanisation in check by maintaining sufficient population density and incorporating new public transport services into the development of new districts. Singapore, Helsinki, Munich, Vienna and the Swiss cities stand out in this regard.

The proportion of journeys walking, cycling, or on public transport has fallen in line with population density, but to a lesser degree: down from 53% to 51% in the sample cities. It is frequently the case that the decrease in the number of journeys on foot is offset by a rise in passenger numbers using public transport. Cities which have maintained density have also successfully reduced the proportion of journeys made using motorised private modes via the steady development of their public transport systems and effective traffic calming and parking policies. The cost of transport for the community and energy consumption fell between 1995 and 2001 in most of these cities.

2.3. Air pollution

The least polluted cities are those where vehicles meet tough emissions standards. At equivalent technical vehicle performance and density, pollution falls in line with the rise in the proportion of journeys walking, cycling, or on public transport.
Between 1995 and 2001, pollution was cut by half.

The pollution indicators used are expressed in kilograms per inhabitant and in kilograms per hectare of urbanised area. Freight transport vehicles are not taken into consideration. Air pollution by hydrocarbon combustion gas emissions depends on annual mileage by cars, motorised two-wheelers and buses, and on the technical characteristics of the vehicles. In virtually all MCD city countries, constructors have to comply with ever tougher standards imposed by governments or the European institutions. Nonetheless, at equivalent vehicle technical performance, the level of pollution per inhabitant increases with the intensity of car use.

Since cities where the car is virtually the sole mode of transport are also the least dense cities, the level of pollution per hectare is often lower there than that recorded in dense cities where public transport and walking are widely used. Thus, cities in the United States and Melbourne are less polluted than Hong Kong, Athens, Paris or Brussels. It should also be underlined that adverse conditions do not depend solely on the amounts of gas emitted per hectare, but also on local climatic conditions. Cities with favourable prevailing winds are less affected than those with a geographical location and climate conducive to the formation of smog.

It was not possible to find a relationship between pollution level per hectare and the parameters ‘urban structure’ and ‘modal choice’. The uncertain reliability of the data collected goes some way towards explaining this, however the main reason is that pollution depends chiefly on vehicle performance, and therefore on the on the level of stringency of the technical standards facing constructors and on the age of the car stock. The ’cleanest’ cities are those in Germany, Austria, Switzerland, Scandinavia, and Great Britain.

The most interesting result from the analysis concerns the evolution in pollution between 1995 and 2001. Progress made in limiting pollutant emissions meant that pollution levels were cut by half: from 5,000 to 2,500 kg/ha on average for cities where data on pollution was successfully collected in both 1995 and 2001. Cities across the board have cut pollution. Public transport road vehicles have also benefited from technological progress. Per passenger x km transported, it should not be forgotten that public transport pollutes between 10 and 100 times less than the car depending on the proportion of supply from electrically-powered modes (ranging from 0 to 87.5% in our sample).

2.4. Transport accidents

The cities with the fewest fatal transport accidents are those where road safety rules are adhered to the most and car use is moderate.
Between 1995 and 2001, mortality per urban transport accident fell by more than one third.

Transport accidents are mainly caused by cars. Public transport is on average 5 to 10 times safer per passenger x km transported. The main explanatory factor for the rate of fatal accidents per inhabitant is the violation of road safety rules. The extent of car use for daily journeys plays a role, but it was not possible to highlight any statistically relevant link between the number of transport accident fatalities and modal choice.

The best results (fewer than 30 fatalities per year and per million inhabitants) were recorded in Lille, Lyons, Berlin, Munich, Newcastle, Helsinki and Vienna, whereas road safety is lower in Italian cities, in Seville, in Barcelona and in Chicago (over 80 fatalities per year and per million inhabitants).

In all cities with data available for both 1995 and 2001, road safety has improved. Across all cities, the annual fatality rate per million inhabitants has fallen from 82 to 53 on average. Sure progress has been made in making urban roads a safer place. Nonetheless, there is still a long way to go, particularly when it comes to affording better protection to pedestrians and cyclists: the most frequent victims of fatal accidents in town. The huge difference between the safest cities and the rest - 1 to 4 - indicates the scale of efforts still needed in cities where road safety rules are not being followed.

2.5. Journey duration

The average motorised journey time increases with the size of the conurbation and with public transport market share…

Table 10: Urbanised area, public transport market share and average duration of a motorised journey

	Average duration of a motorised journey (minutes)*		
	Urban area (hectares) [GRAPH 7]		
	< 30,000 ha	30,000 – 90,000 ha	> 90,000 ha
Average duration of a motorised journey (in minutes)*	23.2	26.4	27.5
	Public transport market share (% of mechanised and motorised journeys) [GRAPH 9]		
	< 15%	15 to 30%	> 30%
	18.3	25.1	29.1

* only cities from the MCD sample

The larger the conurbation, the higher the average duration of a motorised journey. This fact is hardly surprising since the distances covered for home/work journeys depend on the size of the local employment area. Nonetheless, the variation is far from being proportional to the size of the conurbation, with inhabitants finding a significant proportion of their mobility opportunities close to where they live. There is quite clearly an increase in the average duration of a motorised journey in line with density: the proximity effect engendered by density is cancelled out by the traffic difficulties found in dense cities and the higher proportion of motorised journeys made by public transport.

Admittedly, public transport is nearly always less efficient than the car when it comes to journey time because of the journey to and from stops, waiting and transfer time. The only exceptions are radial links on rail modes and metro trips in congested centres where public transport is often faster than the car, particularly during peak times. Traffic conditions also play a decisive role: due to the high average duration of a motorised journey, congested cities like Rome, Bologna, Seville, Lisbon, Marseille, Athens and Budapest (30 minutes on average for these seven cities) stand out from those where traffic runs smoothly such as Chicago, Dubai, Manchester, Newcastle, Oslo, Copenhagen, Helsinki and Stuttgart (19 minutes on average for these eight cities).

The highest average travel times on public transport (over 40 minutes) were recorded in Lisbon, Rome, Paris, Athens, Hong Kong and Singapore (large cities with high transfer rates between modes), whereas the shortest journey times (25 to 27 minutes) can be seen in Clermont-Ferrand and Bologna (compact cities) and in Berlin, Vienna and Prague (relatively compact cities with a fast rail network carrying very high passenger volumes).

Across all the cities, average motorised travel time is 25 minutes; for journeys by car and on public transport, the averages are 21.5 and 34.5 minutes respectively.

The three parameters together - urbanised area, density, and public transport market share - are good explanatory factors for the average motorised travel time. More specifically, the combination of the variation between these three parameters accounts for 60% of the variation in the average length of a motorised journey (regression based on the logarithm of parameters).

…but the longest time is spent in transport in cities where the car is the dominant mode.

Daily journey time always increases in line with the size of a conurbation, but the relationship with public transport market share is inverted: the denser the city and the more significant the role of public transport, the less time inhabitants spend travelling. This paradox is no more than superficial: in low density cities, basic daily needs require trips that are too long to be compatible with walking; at the same time, fluid traffic conditions provide no incentive to reduce the number of trips made. For this reason, inhabitants of American cities spend over one hour per day in their cars (up to 90 minutes in Houston), whereas time spent travelling in European cities with a comparable number of inhabitants does not generally exceed 50 to 60 minutes. The convenience which the car supposedly provides does not prevent the steady rise in journey times, in cities where urbanisation is car-based

3. Comparison between the car and public transport: costs and performance

The analyses above clearly demonstrate that the most efficient cities in terms of money and energy spent on urban mobility are also those where the share of trips walking, cycling and by public transport is highest. It will not surprise anyone to learn that walking and cycling are less expensive than motoring. What is less obvious at first glance is public transport's advantage vis-à-vis the car. The next section therefore compares cost to the community and energy consumption per passenger x km according to transport mode (motorised public or private). Since a key factor in choice of transport mode is journey time, it also makes sense to compare the speed performance of public transport and the car.

The indicators used are ″indicator for the car / indicator for public transport″ ratios:

- ratio of costs to the community of one passenger x km, excluding investment expenditure,
- ratio of costs to the community of one passenger x km, including investment expenditure,
- ratio of energy consumption figures at source per passenger x km transported,
- average speed on the road network / commercial speed of public transport,
- average door-to-door speed by car/door-to-door speed on public transport .

The costs to the community used to calculate these ratios are described in the previous chapter. A distinction is drawn between private modes (cars, motorised two-wheelers, taxis) and public transport (road, rail, waterborne).

Speed on the road network is an annual average across the entire network for each day of the year and hour of the day. It is equal to the total annual distance travelled by vehicles divided by total annual transport time. As stated in Chapter 1, this indicator is calculated more often than not using traffic-simulation models using roadside traffic counts.

The average commercial speed of public transport was collected per mode. Passenger x km transported was then used to obtain the average weighted speed for all modes.

Door-to-door journey times are considerably longer than actual time spent in transport, in particular for public transport, which must build in waiting and transfer times. Distances on foot are also generally longer to (and from) metro and railway stations than to (and from) car parks. This is the reason why we have also estimated the ratio of door-to-door speeds, which encompasses all the stages in a journey. Speeds are calculated for each mode - private and public - using average journey lengths and durations.

3.1. Cost for the community

In cities where GDP per inhabitant is higher than EUR 10,000 public transport costs the community 1.75 times less than the car per passenger x km transported. Public transport's advantage is even greater in less affluent cities.

The superior efficiency of public transport in economic terms is also amply demonstrated: the ratio of costs to the community per passenger x km (including investment) is 1.76 in favour of public transport and 2.4 (excluding investment) for cities where GDP per inhabitant exceeds EUR 10,000. If external effects are taken into account (consumption of urban space, pollution, noise, traffic accidents), public transport's advantage is even clearer.

Nevertheless, a breakdown of performance per city shows up some strong contrasts. In Brussels, Lille, Lyon, Marseille, Manchester and Glasgow, the car is the least expensive (in Lille, Lyon and Manchester, the scale of investment in public transport over the period 1995-2001 explains the car's leading edge; when investment is excluded, public transport comes top in all three cities). Where the car matches public transport (in the United States, in Melbourne and in some European cities) across the conurbation as a whole, the same cannot be said for radial links and in the city centre, where public transport is the clear winner. On such links PT demonstrates its maximum possible efficiency, especially where urbanisation is concentrated along routes served by public transport running on reserved routes.

In most Western European cities, the ratio (including investment) is between 1.2 and 2 in favour of public transport. In Eastern Europe, and in Sao Paulo, Lisbon, Barcelona, Seville, Rome, Hong Kong and Dubai, public transport is far more efficient than the car (cost ratio of over 2.5). Excluding investment, high scores are recorded in Singapore, Madrid, Bilbao, Athens, Stockholm, Helsinki and Vienna (these cities having all invested heavily in public transport between 1995 and 2001).

A clear advantage in favour of public transport is a sign of efficient network operation but may also reflect the high cost of owning and using a car when compared to average household income. In Moscow, which has the highest ratio in favour of public transport (17.5), the two factors combine (high productivity and public transport ridership with high cost of owning and using a car compared with GDP per inhabitant), as they do (to a lesser degree) in Warsaw, Budapest and Prague (ratios between 3 and 5 inclusive). Hong Kong, Singapore and Dubai are exceptional in the remarkably high productivity of their public transport operators.

3.2. Energy consumption

Public transport consumes 2.25 times less energy than the car per passenger x km transported.

Particularly when ridership is high, public transport is far more energy efficient than the car, whose average urban occupancy rate is between 1.2 and 1.5 persons, or indeed the taxi, whose occupancy rate almost everywhere is less than 1, when empty runs are included in the calculation. Across the MCD sample, the ratio of consumption per passenger x km transported is 3.35 in favour of public transport if vehicle consumption is measured. When measuring consumption ”at source”, which takes into account the output of thermal power station on which electric vehicles run, public transport's advantage remains decisive: per passenger x km, it consumes 2.25 times less energy than the car. This average figure however conceals major disparities: in some cities in Great Britain, in Brussels, in Oslo and in Copenhagen, public transport’s lead over the car does not exceed 30%, whereas in Hong Kong, Singapore, Dubai, Sao Paulo, Lisbon, Moscow, Warsaw, Budapest, Graz, Athens and Rome, the ratio of consumption ″at source″ in favour of public transport is 3 or above.

The best energy performances from public transport, compared to the car, are seen in cities with the highest average occupancy rate for public transport vehicles (between 25 and 35%). Maximum energy efficiency is thus often obtained to the detriment of passenger comfort as networks with an average occupancy rate of around 30% are necessarily overloaded at peak times, particularly on the central sections of lines. Indeed, it is worth remembering that vehicle capacity (save on some commuter trains) is calculated on the basis of 4 standing persons per m2.

3.3. Journey duration

A car's average speed in town is 1.3 times higher than that of public transport, and its ″door-to-door″ speed 1.9 times higher.

In London, Hamburg, Munich, Moscow, Barcelona and Rome, public transport vehicles travel faster than car traffic. The major role played by rail transport (which provides over 70% of supply in these cities, save for Rome) is the main reason for its strong performance. Adverse traffic conditions help the competitiveness of public transport in Rome and in London. In all cities where the rail network is well developed (50% of supply or more), line speed for public transport is close to that of cars. This is the case in German cities as well as in French and Spanish cities with a metro system, and in Oslo, Copenhagen, Brussels, Bern, Zurich, Vienna, Budapest and Prague. Strong public transport competitiveness in Lisbon, Athens and Hong Kong, where buses are the main provider, is as much down to the difficulties facing traffic as it is to the speed of public transport. When the key public transport modes are buses or trams mixed in with car traffic and/or when traffic flows freely, the car is twice as fast (as in Newcastle, Graz and Dubai).

A comparison of ″door-to-door″ speeds corroborates the above results. The top performers are in London, Moscow and Hong Kong, where public transport is nearly on equal footing with the car for all journeys made. This means that, on the busiest routes where most tailbacks form, metro and train services are comfortable winners. Paris, Berlin, Glasgow, Vienna, Budapest and Prague have a ratio of less than or equal to 1.6. In the majority of cities, the ratio is between 1.6 and 2, whereas the highest 2001 values (above 2) correspond to situations where road traffic is fluid and/or the public transport network is largely made up of bus and tramway lines (Clermont-Ferrand, Marseille and Nantes in France; Manchester and Newcastle in Great Britain; Geneva, Graz, Seville, Turin and Dubai).

Whereas average traffic speed on the road network showed no major variation between 1995 and 2001 across the MCD cities as a whole, public transport commercial speed has increased by some 3%. In Chapter 5, we will explain how this improvement is the result of the sustained development of public transport modes running on reserved routes. Logically, cities with the developed their metro and rail network show the fastest pace of acceleration (Madrid, Oslo, Prague, Athens, Vienna, Singapore). In London, the clear improvement in commercial speed also extends to buses, as a result of the bus priority measures in place.

3.4. Total cost of transport

Although the car costs more than public transport per passenger transported, it allows for time savings since it is almost always faster door-to-door than public transport. It is always risky to try and put a value to journey time in order to aggregate it with actual expenditure. Similarly, converting external transport costs (pollution, greenhouse effect, noise and accidents) into figures is a delicate exercise. An attempt is made below to produce such overall figures for 6 cities from the sample where contrasting situations are to be found: Chicago, Singapore, Paris, London, Vienna and Budapest. The calculation involves a motorised journey of average length (average weighted for cars and for public transport, variable according the particular city). For each city in the sample, the values of indicators (cost to the community of a passenger x km by car and on public transport, ″door-to-door″ speeds by car and on public transport) were used. In order to convert travel time into figures, a time value of EUR 6 / hour was used, save in the case of Budapest (EUR 2 / hour). These values are those which emerge generally from behavioural studies of passengers during their daily travel. The cost of pollution and of accidents is evaluated (very prudently) at EUR 0.015 per passenger x km by car. The same value is negligible for public transport.

Table 11: Total cost of a journey, by transport mode

	Chicago	Singapore	Paris	London*	Vienna	Budapest
Journey length (km)	12	9.6	9.1	9.8	7.7	7.9
Cost of a journey by car (euro)	4.4	1.9	3.2	3.8	3.8	1.5
Cost of a journey on public transport (euro)	3.4	0.5	2.0	2.6	1.5	0.35
Duration of journey by car (in minutes)	26.5	23	24.5	26	19.5	23.5
Duration of journey on public transport (in minutes)	49.5	42	36	28	29.5	36
Overall cost of a journey by car (in euro)	**7.25**	**4.35**	**5.8**	**6.55**	**5.85**	**2.4**
Global cost of a journey on public transport (in euro)	**8.35**	**4.7**	**5.6**	**5.4**	**4.45**	**1.55**

In all the European cities, public transport is more efficient than the car. Its advantage, which is especially pronounced in Budapest, is also very clear-cut in London and in Vienna. Public transport in sprawling metropolitan areas like Chicago cannot compete with the car. In Singapore, extremely productive public transport in terms of production costs is still handicapped by fairly long travel times in a city where traffic flows freely (and where buses still provided the dominant public transport mode in 2001). Furthermore, the vehicle occupancy rate there is high (1.56) and the kilometre cost of the car very low due to intensive car usage.

The comparison between the five cities with similar income per inhabitant is revealing. It confirms the result outlined in Chapter 2.1: in low density cities where the car is virtually the only mode, travel is long and costly. By taking into account the value of passenger time when calculating the cost of journeys to the community, the gulf between European cities and Singapore narrows. An overall summary including the time value would probably show cities like Vienna and Helsinki to be on a par with Singapore and Hong Kong in terms of efficiency.

4. Public transport competitiveness

In this chapter, we look at mechanised and motorised journeys and the factors that guide the choice between public transport and private modes (notably the car). The indicator used to measure public transport's attractiveness is the market share of mechanised and motorised journeys (car, motorised two-wheeler, bicycle, and public transport) provided by public transport over the year as a whole. The database also contains the number of annual journeys made using public transport, a good gauge of the commercial success of operators. However, this indicator poorly reflects the level of competitiveness of a network compared with the car since it does not allow respective market shares to be judged. Moreover, this indicator depends to a large extent on the structure of a network. Indeed, the number of annual journeys per inhabitant is equal to the sum of journeys for each of the modes. A high level for this indicator, while it may reflect good public transport ridership levels, is also caused by the large volume of transfers between modes on a same journey.

When looking at public transport market share, several indicators may explain the modal choices made by passengers.

The first family of indicators concerns the car:

- motorisation rate of the population,
- lengths of the road and motorway networks per hectare of urbanised area,
- number of parking spaces in the CBD in relation to the number of jobs. Spaces taken into account are official on-road spaces, spaces in public car parks and the spaces offered by firms and retail businesses.

The second family represents public transport supply and its performance vis-à-vis the car:

- supply volume (expressed in vehicle x km or in space x km) per inhabitant and per hectare: the first indicator measures the quantity of public transport available to meet potential demand, while the second measures public transport proximity and its coverage of the urbanised area,
- ratios for the ”length of reserved routes per inhabitant and per hectare“, ”length of reserved routes / length of motorways“, ”average speed on the road network / public transport average commercial speed“, ”average speed door-to-door by car / average speed door-to-door by public transport”, and the proportion of public transport supply (expressed in place x km) provided by rail modes. These indicators are designed to assess the capacity of public transport to compete with the car in terms of speed and reliability,
- the ratio of “cost of passenger x km by car / cost of passenger x km borne by public transport users“ and the ratio of ”hourly cost of parking in the CBD / cost of travelling on public transport“. Fare box revenue (excluding subsidies) is used to calculate the cost of public transport. The hourly cost of parking is derived by weighting the costs of roadside and off-road parking. These costs include all taxes.

No mention has been made here of urban structure (density) indicators and GDP per inhabitant. As is commonly known, public transport is used most in dense cities and in poor cities. The correlations presented in the annexes confirm this. Our aim was rather to base the analysis on factors directly linked to the competitive conditions between the car and public transport.

Public transport usage tends to decrease with a rise in car ownership, but there are several cases of cities where public transport's market share is high despite a high motorisation rate.

A plentiful supply of parking in centres encourages car use. Cities with a high market share for public transport have adopted a restrictive parking policy.

Table 12: Motorisation rate, parking in the CBD and public transport market share

Public transport market share (% of mechanised and motorised journeys)			
Motorisation rate (number of cars for every 1,000 inhabitants) [GRAPH 11]			
< 350	350 - 450	450 - 550	> 550
36.4	27.1	22.2	13.2
Number of parking spaces for every 1,000 jobs in the CBD* [GRAPH 12]			
< 100	100 - 250	250 - 500	> 500
48.2	29.9	16.6	11.1

* including spaces supplied by companies and retail businesses (sample limited to cities reporting this indicator)

Competition from the car becomes ever more acute as the motorisation rate rises. Multiple car ownership within households is a strong factor in curbing reliance on public transport. Chicago and Melbourne are perfect examples in this respect. On the other hand, in Hong Kong and in Singapore, where taxes on new vehicle purchases act as a powerful deterrent, the motorisation rate is very low (when compared to the affluence of the inhabitants) and public transport use very high. All the same, the link between car distribution and public transport use is fairly loose. Italians, for example, who are among the world's biggest car owners (over 600 vehicles for every 1,000 inhabitants), are also regular users of public transport. In Prague, where the motorisation rate easily exceeds 500 vehicles for every 1,000 inhabitants, public transport is still experiencing record passenger numbers, with some 1,000 journeys per year and per inhabitant. Munich and Zurich are good examples of affluent cities with high car ownership where public transport carries very large numbers of passengers. On the contrary, in cities around the United Kingdom, excluding London, public transport use remains modest even though household motorisation is relatively low. Other modal choice factors clearly come into play. These relate to parking policy and public transport system performance.

Public transport supply is generally concentrated in city centres and along radial routes converging towards the centre. This is why parking policy in the city centre has a major bearing on public transport passenger numbers. When parking is plentiful and cheap, it is difficult to persuade motorists to leave their cars at home and take the bus, tram or metro instead. Table 12 shows how restricting the number of spaces available in the CBD has a positive impact on public transport competitiveness. Cities in the Far East, and Moscow, Prague and Budapest, where city-centre parking is tightly rationed, are all characterised by high public transport ridership levels. In contrast, in American cities and, to a lesser degree, Clermont-Ferrand and Nantes in France, public transport use is probably disadvantaged by the abundance of central parking. Nonetheless, public transport market share in Helsinki is one of the highest in Western Europe despite the lack of parking restrictions.

Charging for roadside parking and in public car parks is equally vital when there is not an overabundance of free spaces in company and retail car parks. Charging for roadside parking and in public car parks must be sufficiently dissuasive to discourage car use into (and within) city centres. In this respect, in cities like London, Copenhagen and Vienna, hourly rates in public car parks and roadside spaces can be EUR 5 or more. It should also be stressed that Eastern European capitals are not simply limiting parking in the centre, but are also charging very high hourly parking rates compared to the cost of travelling on public transport.

Indicators measuring the scale of road infrastructure provision do little to explain public transport's market share. Indeed, although a high level of road (and, above all, motorway) provision can be observed together with very low or modest market shares in cities around the United States, in Melbourne, in Dubai, and in cities around Great Britain (except London), the examples of Italian and Spanish cities and of Helsinki show that significant motorway provision is not incompatible with high public transport ridership.

The proximity of stops and stations with good transport links, speed, and regularity are positive factors that are decisive for the competitiveness of public transport

Table 13: Coverage of urban space by public transport services and public transport market share

	Public transport market share (% of mechanised and motorised journeys)			
	Number of annual vehicle x km per hectare [GRAPH 13]			
	> 5000	2500 - 5000	1500 - 2500	< 1500
	45.4	27.4	19.9	8.4
	Number of place x km per hectare (in thousands)			
	> 500	250 to 500	150 to 250	< 150
	42.1	27.9	19.9	10.5

The volume of public transport supply in relation to population is plainly linked to network traffic since operators adapt services to demand. However, this indicator does not offer a good explanation for passenger numbers (vehicle occupancy rates vary from 13 to 36% depending on the city) and even less so as regards competitiveness vis-à-vis the car. More than the supply volume per inhabitant the level of urban space coverage - measured using supply volume per hectare - is the crucial factor. This indicator provides information about stop and station proximity and about access on foot to public transport. Clearly, the greater the urban space that services cover, the higher public transport ridership. Networks providing intensive coverage of the metropolitan area on lines with sufficient transport capacity are the most attractive, as illustrated (in decreasing order of supply density) by the cases of Hong Kong, Moscow, Singapore, London, Zurich, Bern, Munich, Vienna, Berlin, Prague, Madrid, Paris, Budapest, Rome, Barcelona and Helsinki. There was no link at all between the development of Park + Ride facilities (P+R) and public transport use. In strictly statistical terms, there is even an apparent ″negative″ link: the least densely populated cities with the highest motorisation rates (in the United States, for example) are often those which have developed their P + R systems the most intensively, but without any real effect on car dominance. This fact should in no way detract from the usefulness of station car parks when they provide a more efficient alternative to feeder buses and when the parking spaces created replace parking spaces in the centre.

Table 14: Proportion of public transport supply by rail, ″car average speed / public transport average speed″, ″door-to-door speed by car / door-to-door speed on public transport″ ratios, and public transport market share

Public transport market share (% of mechanised and motorised journeys)			
Share of public transport supply by rail modes (% of place x km)			
> 70%	40 to 70%	10 to 40%	< 10%
31.1	28.9	25.1	9.2
Average speed by car / average speed of public transport [GRAPH 15]			
< 1	1 to 1.25	1.25 to 1.75	> 1.75
33.2	31.5	25.7	10.5
Door-to-door speed by car/ Door-to-door speed on public transport* [GRAPH 16]			
< 1.6	1.6 to 2	2 to 2.5	> 2.5
39.0	28.5	20.6	8.3

* only cities from the MCD sample

Speed and regularity are parameters that clearly also enhance public transport's competitiveness. Speed and regularity are expressed by the ratios of car speed compared with public transport speed (in traffic and door-to-door) and the proportion of public transport provided by tramways, light rail systems, metro systems and trains, i.e. transport modes running on exclusive rights-of-way along their entire route or, in the case of tramways, along parts of it. Table 15 shows the link between the proportion of supply by rail modes and public transport speed. The indicators for length of reserved routes (per inhabitant or per hectare) and the ratio of ″length of motorways / length of reserved routes″ are also linked to public transport market share, but the correlation is not a sound one when the existence of very extensive, but little used, commuter rail networks is taken into account.

Table 15: Proportion of public transport supply by rail modes and public transport average speed

	Proportion of public transport supply by rail modes (% of place x km)			
	> 70%	40 to 70%	10 to 40%	< 10%
Public transport commercial speed (in km/h	34.7	27.5	23.7	21.7
Door-to-door speed of public transport (in km/h)*	16.9	13.8	12.6	11.7

* only cities from the MCD sample

The link between the ratio of ″average speed of road traffic / average commercial speed of public transport″ and public transport market share is unquestionable, although a public transport journey also includes a section on foot at each end that is generally longer than by car, waiting times, and often transfer times. In MCD cities (only those for which door-to-door speeds are available), the quality of the correlation is also high when these additional times are taken into account. The majority of cities where public transport market share is over 30% have a fast and regular public transport network with tramways, light rail systems, metro systems and trains accounting for more than 70% of services. Indeed, rail networks guarantee a level of speed and regularity that cars cannot compete with during peak times. The competitiveness of public transport is all the more marked in places where traffic is congested. In Vienna, Paris, Munich, Zurich, Moscow, Berlin, London, Prague, Madrid and Barcelona, where over 70% of places are provided by rail modes, public transport's market share stands at between 27 and 64%. In these cities, commercial speed for public transport generally exceeds 30 km/h and door-to-door speed 15km/h. Hong Kong and Singapore are special cases insofar as the dominant role played by public transport stems chiefly from the low motorisation rate of households, and not the relative importance of rail modes and speed.

Fare levels have little impact on public transport's competitiveness vis-à-vis the car.

In strictly statistical terms, the correlation between the indicators of cost to the passenger and choosing between the car and public transport is not a convincing one. Low, subsidised fares may be a social necessity, but are ineffective in attracting motorists. Indeed, the main factors influencing the choice of transport mode are clearly car and parking space availability and respective journey times by public transport and car. Comfort and the feeling of security also play a part, but MCD does not cover these aspects. Moreover, car costs are often underestimated by the user, who generally only takes account of petrol, parking and toll costs. All the same, Eastern European cities, Lisbon, Vienna and Singapore, where public transport market share is above 35%, present a very high ″cost of a passenger x km by car / cost of a passenger x km on public transport″ ratio (greater than 6; or greater than 10 in Eastern Europe), whereas, in Manchester and in Glasgow, where the cost ratio is merely around 2, market share is below 15%. The indicator for ”hourly cost of parking in the CBD / cost of travelling on public transport“ also varies considerably from one city to another: from around 2 in Spanish cities, in Lisbon and in Dubai, to 15 or more in Eastern European capitals. There is no relation in statistical terms between the hourly cost of parking in the centre in relation to average public transport fare and public transport market share. The modest cost of parking in the Iberian peninsula is not incompatible with achieving high passenger numbers on public transport and the high parking charges in Chicago or Manchester are not sufficient to foster public transport use throughout the conurbation as a whole (which does not mean that they are not a deterrent for motorists heading into the centre).

The study of multiple correlations to explain the competitiveness of public transport covered several sets of explanatory parameters:

- motorisation rate, number of parking spaces per jobs in the CBD, supply volume expressed in place x km per hectare, ratio of ″average speed on the road network / public transport average commercial speed″,
- motorisation rate, number of parking spaces per jobs in the CBD, supply volume expressed in place x km per hectare, ratio of ″door-to-door speed by car″ / ″door-to-door speed on public transport″,
- motorisation rate, number of parking spaces per jobs in the CBD, supply volume expressed in place x km per hectare, proportion of public transport supply provided by rail modes.

As the indicator for parking in the CBD is not available for a significant proportion of the cities, earlier families of indicators were also used to study multiple correlations, except for the indicator showing the number of parking spaces per jobs in the CBD.

The best result is obtained with the set including motorisation rates, number of parking spaces per jobs in the CBD, supply volume expressed in vehicles x km per hectare, and the ratio of ″average speed on the road network / public transport average commercial speed″, whose variation explains 89% of the variation in public transport market share (% of mechanised and motorised journeys; regression based on the logarithm of parameters).

Excluding the indicator on parking availability in the CBD, the variation in these parameters explains 84% of the variation in public transport market share.

This analysis clearly shows that the competitiveness of public transport stems from the combined action of several factors. Policy makers have several levers at their disposal to improve public transport's competitiveness vis-à-vis the car, ranging from deterring excessive car use in town to the development and promotion of high-quality public transport by:

- limiting car ownership through specifically taxing new vehicle purchases, and controlling car use with urban road tolls. These solutions are still little used outside of Singapore and Hong Kong,
- redistributing road space used for traffic and of private vehicle parking in favour of pedestrians, cyclists and public transport. The aim is to limit traffic volume and improve the speed and regularity of buses and tramways through the creation of bus lanes and reserved routes,
- discourage long-term parking linked to work, in particular in city centres, through curbs on the supply of spaces and appropriate charges,
- develop public transport services which are fast and reliable enough to compete with the car, which implies the creation of networks running on reserved routes completely separate from overall traffic (″bus rapid transit″, light rail, metro, and RER – regional express railroads),
- ensure good coverage of the entire conurbation by high-density public transport services that are easily accessible on foot.

The success of public transport depends on an integrated policy, combining urban planning, curbing of traffic and parking and fast and regular public transport services.

To illustrate this point, the two tables below relate to cities where public transport competitiveness varies between the levels of ”acceptable“ and ”excellent“. Table 16 covers cities where car use is widespread. The success of public transport therefore depends on applying measures to curb traffic and parking and a policy to develop dense and rapid public transport services. Table 17 has grouped together Hong Kong and Singapore - which vigorously limit car purchases and/or car use through fiscal measures and pricing - with Eastern European cities boasting a solid public transport infrastructure inherited from previous Communist regimes and where car use remains relatively expensive compared to household income.

Table 16: Indicators of the competitiveness of public transport for some Western European cities where public transport (PT) market share is 30% or higher

	London*	Paris	Barcelona	Stockholm	Madrid	Munich	Berlin	Helsinki	Vienna
Market share for motorised and mechanised journeys by PT (%)	26.8	27.5	28.5	28.9	30.2	30.4	33.2	34.6	46.6
Number of cars for every 1,000 inhabitants	345	440	425	400	480	540	330	360	415
Parking spaces/jobs in the CBD	85	185	405	155	185*	130*	-	385	225
PT place x km per inhabitant	15,100	12,800	6,400	17,300	11,200	15,500	13,100	10,300	11,900
PT place x km per hectare (in thousands)	830	520	475	315	620	810	715	455	795
Length of reserved routes (km/million inhabitants)	176	152	145	231	93	230	149	102	185
Proportion of PT rail services as % of place x km	75	86.5	70	67	71	85.5	81.5	43.5	87.5
PT commercial speed (km/h)	34.6	30.9	36.3	32.9	30.7	39.4	30.1	32.9	27.0
Door-to-door speed of PT (km/h)	21.2	15.2	15.4	17.4	17.2	17.1	15.5	16.0	15.6

* excluding the car parks of firms and retail businesses

These cities have all implemented an integrated urban mobility policy. According to the local context, each has strengths and areas where there is room for improvement. London and Rome are very effective at restricting car access to the centre (particularly so in London’s case* today with congestion charging). In Munich, Berlin, London, Barcelona, Madrid, Stockholm, Paris and Helsinki, commercial speed is high thanks to the development of metropolitan and commuter railways. The networks in London and Munich offer the densest service pattern. Vienna, where public transport is evenly matched with the car, has a particularly impressive sustainable mobility policy record (consistently implemented for many years now in the areas of coordination between urban planning and transport, traffic and parking controls, and a high-density and efficient public transport system).

Table 17: Indicators of public transport competitiveness for Eastern European and Far Eastern cities where public transport (PT) market share is 50% or higher

	Singapore	Prague	Budapest	Moscow	Warsaw	Hong Kong
Market share of motorised and mechanised journeys by PT (%)	45.7	54.2	55.9	63.6	64.0	73.9
Number of cars for every 1,000 inhabitants	125	535	330	190	380	50
Parking spaces/jobs in the CBD	165	45	95	30	60	25*
PT place x km per inhabitant	14,300	16,100	11,100	17,400	8,900	16,100
PT place x km per hectare (in thousands)	1.460	705	515	2,800	460	4.620
Length of reserved routes (km/million inhabitants)	29.5	235	197	40	178	22.5
Proportion of PT rail services as a% of place x km	40	72.5	64.5	84	46	31.5
PT commercial speed (km/h)	28.6	28.6	21.2	36.6	23.1	26.0
PT speed door-to-door (km/h)	13.3	16.2	13.1	21.0	-	12.0

* excluding car parks of firms and retail businesses

The network in Singapore has outstanding service density, and its usage is promoted by curbing the number of cars through applying a highly effective tax new car purchases. Hong Kong undoubtedly has the highest service density in the world in order to cope with a demand for motorised journeys which cannot rely on the car alone in such a dense city. Furthermore, the motorisation rate there is extremely low when compared to the income levels of inhabitants. Motorisation was still moderate in Moscow in 2001 and metro use intensive. Metro speed in Moscow means it can compete effectively with cars in terms of door-to-door journeys. Prague, despite a sharp rise in motorisation, has managed to keep its public transport market share significantly above 50% due to sustained supply-side efforts and a continued clampdown on parking in the centre. In all Eastern European capitals, the number of parking spaces in the centre remains very limited, as it is too in Hong Kong.

The cost of transport for the community and energy consumption are often very low in cities where the public transport market share is highest.

Table 18: Public transport competitiveness, cost of transport for the community and energy consumption

	Market share of motorised and mechanised journeys by PT (%)	Cost of transport for the community (% of GDP)	Annual energy consumption (at source) for journeys (megajoules per inhabitant)
Chicago	6.7	11.7	44,000
Melbourne*	9.0	11.8	32,000
Manchester	11.8	8.8	14,600
Copenhagen	15.0	8.3	16,600
Brussels	18.6	10.3	20,600
London*	26.8	7.5	16,100
Paris	27.5	6.65	16,000
Munich	30.4	6.4	21,500
Helsinki	34.6	5.6	13,600
Singapore	45.7	5.35	14,700
Vienna	46.6	6.55	10,900
Hong Kong	73.9	4.85	5,400

1995 values

In order to highlight clearly the effect of public transport network competitiveness on the transport system's financial and energy costs, Table 18 contains only cities that are comparable in terms of annual income per inhabitant (over EUR 20,000). The relationship between public transport market share and the cost of the transport system is less significant statistically than those highlighted in Chapter 2, but is nonetheless undeniable. Public transport use is indeed an efficiency factor, both in terms of energy consumption and transport expenditure.

5. Public transport evolution between 1995 and 2001

This chapter studies, in turn the following: passenger numbers and public transport market share, investment, the development of modes running on reserved routes, commercial speed, supply volume (expressed in vehicle x km), production costs (per vehicle x km, per trip and per passenger x km), average revenue per trip, and the coverage rate of operating expenditure through farebox revenue. For each of these indicators, the 2001 values are compared with 1995 figures for all MCD cities that provided information on these indicators in both years.

5.1. Passenger numbers and market share

Between 1995 and 2001, the majority of cities in the sample saw a marked growth in urban sprawl. At the same time, population levels fell in central and inner-urban areas. This major decline in density (-5% in only six years) is a real challenge for public transport, which is by nature ill-suited to providing services in less densely populated areas. Over this same period, car ownership rose by around 11% (from 375 to 415 cars per 1000 inhabitants).

In spite of a deterioration in competitive conditions, public transport managed to maintain its passenger numbers and its share of the mobility market.

Table 19: Evolution in the annual number of journeys per inhabitant and in public transport market share between 1995 and 2001

	1995	2001
Annual number of journeys by public transport per inhabitant*	360	360
Market share of motorised and mechanised journeys by PT (%)	31.5	30.6

* traffic including non-residents

This overall satisfactory result nonetheless conceals highly contrasting individual situations. In cities around the United Kingdom (excluding London), public transport traffic fell, and market share even more sharply. Public transport networks in Berlin and Copenhagen also saw a significant erosion in traffic and competitiveness. Cycling is used far more than public transport in Copenhagen. The drop in ridership in Moscow has been spectacular, but the level of public transport use remains very high. Passenger numbers and market share have been maintained or have increased in Madrid, Paris, London, Geneva, Vienna, Stockholm, Helsinki, Hong Kong and Singapore. The advance in the annual number of trips in Munich, Budapest and Prague has been accompanied by a sharp fall in market share. These three cities nonetheless remain exemplary in terms of public transport competitiveness and intensity of PT use. In Warsaw, Budapest and Prague, sustained growth in car numbers after the collapse of Communism prompted fears that market share would plummet. This has been averted thanks to a policy of network modernisation and restrictions on city-centre parking.

The divergences in public transport market share are considerable, ranging from 6 to 74% depending on the city: less than 15% in Chicago, Dubai, Melbourne, Ghent, Lille, Clermont-Ferrand, Manchester and Glasgow; between 15 and 25% in French cities (excluding Paris), Seville and Valencia, Bologna, Geneva, Graz, Stuttgart, Brussels, Newcastle and cities in Scandinavia (except Helsinki); 25 to 40% in Lisbon, Madrid, Barcelona and Bilbao, Rome and Turin, Athens, Paris, London, Stockholm, Helsinki, Bern and Zurich, Berlin and Munich; 40 to 50% in Vienna and Singapore; and over 50% in Eastern European capitals and in Hong Kong.

5.2. Modes running on reserved routes: investment and development

To measure the evolution in investment in public transport (infrastructure and rolling stock), the study recorded the amount of average annual expenditure for the periods 1991-1995 and 1996-2001. The scale of investment was calculated based on a given conurbation's GDP. The length of networks running on reserved routes is also expressed in proportion to the number of inhabitants.

To maintain their market share, public transport systems have developed networks running on reserved routes, in particular rail modes. The proportion of reserved routes per inhabitant increased by some 9% between 1995 and 2001.

Table 20: Investment levels and length of reserved routes

	1991-1995	1996-2001
Annual average investment (% of GDP)	0.43	0.50
Length of reserved routes (km/millions of inhabitants)	126.5	137.5

Between 1991 and 2001, the average investment level remained at between 0.45 and 0.5% of urban area GDP, but with significant variations. In some cities, such as Ghent, Seville, Marseille and Bologna, only the potential has been maintained (in the latter two cities, however, major developments are underway or planned). Higher levels of investment over this 10-year period (between 0.6 and 1.2% of GDP) could be seen in Madrid, Lisbon, London, Berlin, Vienna, Oslo, Prague, Lille, Hong Kong and Singapore. Athens, Lyons, Brussels, Bilbao, Stockholm and Copenhagen had investment levels that were lower, but still above the average.

Investments in network extensions have focused essentially on the development of rail modes: tramways, light rail systems and metro systems. The rapid expansion of the Madrid metro (50km in six years) is particularly spectacular, but we should also mention the sustained development of metro (and/or RER) networks in Hong Kong, Singapore, Munich, Vienna, Prague, Helsinki, Athens, Rome, London, Paris and Lille, and tramway in Lyon, Nantes and Geneva.

5.3. Commercial speed

The development of modes running on reserved routes has enabled a roughly 3% increase in public transport commercial speed.

Table 21: Public transport commercial speed

	1995	2001
PT commercial speed (in km/h)	27.3	28.1

The development of rail modes running on reserved routes has enabled public transport to improve its average commercial speed slightly (all modes combined) despite the degradation of bus traffic conditions in the majority of the cities in the sample. The biggest speed increases were recorded in Madrid, Athens, Vienna and Singapore, as a result of metro development, and in London, which has been effective in implementing a bus traffic priority policy.

The top speeds (35 km/h and above) were recorded in cities where rail networks provide over 70% of the transport supply (London, Barcelona, Moscow, Munich, Stuttgart and Oslo). The network in Copenhagen also ranks among the fastest, offering over 60% of network seats on rail modes and providing good conditions for bus traffic. With speeds of between 30 and 35km/h, Chicago, Paris, Madrid, Bilbao, Berlin, Hamburg, Zurich, Glasgow, Stockholm and Helsinki have a highly developed rail network and/or enjoy adequate traffic conditions for their buses and tramways. Speeds fell in cities where rail modes running on reserved routes are non-existent or play a very minor role, such as Bologna and Graz, because buses and tramways are mixed in with overall traffic and therefore increasingly hindered by traffic jams.

5.4. Supply volume

An increase of 7.5% in supply volume per inhabitant and of around 4% in supply volume per hectare have enabled passenger numbers to remain steady and public transport's market share to stabilise.

Table 22: Public transport supply volume*

	1995	2001
PT vehicle x km per inhabitant	80	86
PT vehicle x km per hectare	3950	4100

* excluding Moscow and Hong Kong (whose very high 2001 values for supply distort analysis of average changes)

Supply density per hectare, which measures a network's urban-space coverage, has increased by around 4%, which is remarkable given the expansion of urban areas. In terms of place x km available (the best indicator of supply volume), the increase is certainly higher still. The reason is that the development of rail modes has led to a rise in average vehicle capacity (an articulated tramway carries 2 to 3 times more passengers than a bus, and a metro car 1.5 to 2 times more). A comparison was however not possible since information on "place x km" indicator was not collected in 1995's ″Millennium Cities Database for Sustainable Transport″.

Madrid, Munich and Vienna recorded the largest supply increases (up by over 20% from what was already a high level in 1995). A marked increase in vehicle x km per inhabitant (between 5 and 20%) was recorded in Paris, Nantes, Brussels, Berlin, London, Stockholm, Helsinki, Prague, Athens, Bologna, Rome, Hong Kong and Singapore. In some of these cities, supply density nonetheless levelled off or fell due to urban expansion growing at a faster pace than public transport services (Paris, Athens, Bologna and Rome). Service levels decreases per inhabitant and per hectare were recorded in cities around the United Kingdom, excluding London, in Budapest and in Moscow (in the latter two cities, supply remains very dense).

In 2001, the highest levels of service were seen in Hong Kong and Moscow (respectively: 172 and 155 vehicle x km per inhabitant and 49,000 and 25,000 vehicle x km per hectare). Singapore, London, Berlin, Munich, Vienna, Bern, Zurich, Helsinki, Prague and Warsaw recorded figures above 100 vehicle x km per inhabitant and above 5,500 per hectare. Paris, Brussels, Stockholm, Madrid, Rome, Newcastle and Budapest then followed with a supply level higher than 75 vehicle x km per inhabitant and 3,000 per hectare. Chicago, Dubai, Melbourne, Seville and Clermont-Ferrand were the least well-served cities.

Table 23 Indicators of public transport competitiveness in various cities where public transport (PT) market share grew between 1995 and 2001

		London*	Madrid	Vienna	Singapore	Hong Kong	Paris
Market share of motorised and mechanised journeys by PT (%)	**1995**	23.9	27.2	43.2	44.2	71.8	27.1
	2001	26.8	30.2	46.6	45.7	73.9	27.5
Annual number of journeys on public transport per inhabitant*	**90-95**	345	250	490	480	545	260
	96-01	390	290	495	485	525	310
Average annual investment (% of GDP)	**1995**	1.13	0.88	1.07	0.44	0.37	0.45
	2001	0.64	0.81	0.62	0.84	1.00	0.32
Length of reserved routes (km/millions of inhabitants)	**1995**	172	84.5	174	22.5	17.5	149.5
	2001	176	92.5	185	29.5	22.5	151.5
PT speed (in km/h)	**1995**	31.3	28.5	24.9	27.0	26.4	31.6
	2001	34.6	30.7	27.0	28.6	26.0	30.9
PT vehicle x km/hectare per inhabitant	**1995**	145	67.5	87	110	146	71.5
	2001	157	85	106	112	172	84
PT vehicle x km per hectare	**1995**	7,850	4,500	5,850	10,300	46,700	3,400
	2001	8.650	4,750	7,100	11,500	49,200	3,400

* traffic including non-residents

In Madrid, the success of public transport is largely attributable to the development of the metro and the modernisation of the railway network. Extensions to networks running on reserved routes and service densification, together with an urban planning policy effectively incorporating public transport development, allowed the network in Vienna to consolidate its leading position in Western Europe. In Paris, where investment levels fell, public transport performed respectably thanks to a consolidation of services (new automated metro line and tramway extension) and the difficulties facing car traffic. Metro upgrading and expansion and commuter railway modernisation, following years of neglect, as well as the speeding-up of bus traffic, were the drivers of vastly improved public transport competitiveness in London, where PT use, although expensive for users, is helped by adverse car traffic conditions and an effective clampdown on parking in the centre. In Singapore and in Hong Kong, extensions to high-capacity metro networks and service densification explained the growth in public transport market share. The attractiveness of PT was also boosted by the expansion of the urban road toll scheme in Singapore and by traffic difficulties in Hong Kong.

5.5. Operating costs

Four indicators of operating cost were used to measure the efficiency of public transport systems:
- vehicle x km production cost,
- place x km production cost,
- travel cost,
- passenger x km cost.

Operating expenditure was calculated excluding depreciation. The first two indicators allow the efficiency of the operational process to be assessed, but do not reflect the capacity of operators to attract customers. Travel cost and passenger x km cost bring ridership levels into the equation, as they are indicators of technical productivity and commercial efficiency. All the same, a low passenger x km cost may result from a supply shortage, the repercussions of which are vehicle overcrowding, mediocre comfort levels for passengers and lack of attractiveness to car-owning city dwellers.

It should be borne in mind that the indicators cover operators as a whole, all modes combined, for each city. These 2001 average values (all modes, all operators) can conceal contrasting individual situations. For example, rail modes generally perform better than buses since they do not face the same unpredictable traffic conditions. This allows more rapid service rotation and therefore better use of capital and labour. The higher unit capacity of tramways and trains is also a productivity factor, measured in terms of place x km and passenger x km costs.

Costs for the year 2001 are expressed in euros. Conversions from local currency into euros for cities located outside the euro zone were made on the basis of the average exchange rate in 2001. In terms of cost evolution, we have used local currency adjusted for inflation. The average annual variation equals the average for annual variations calculated for all MCD cities for which data are available from both 1995 and 2001.

The public transport sector has successfully controlled production costs, even managing to maintain its share of the mobility market in a challenging climate.

Table 24: Operating costs, excluding depreciation, in 2001 and evolution between 1995 and 2001

	2001 value (euro cents)	Annual variation between 1995 and 2001* (%)		2001 value (euro cents)	Annual variation between 1995 and 2001* (%)
Vehicle x km cost	330	+ 0.55%	**Travel cost**	98.5	+ 1.2%
Place x km cost**	3.32		**Passenger x km cost**	18.0	+ 0.25%

* variation calculated in constant local currency (adjusted for inflation)
** data not available in1995

The evolution of production costs closely followed inflation in all the cities in the sample. Several networks improved their productivity (more than 1% per year in productivity gains in Chicago, Hong Kong, Singapore, Paris, Berlin, Munich, Newcastle, Stockholm, Vienna and Rome) whereas vehicle x km cost rose in Oslo, Graz, London and Brussels.

Passenger x km cost remained virtually unchanged between 1995 and 2001, whilst the cost of travel rose slightly. This difference is not surprising given that the average distance travelled by passengers has increased in line with the growth of cities. Passenger x km cost has fallen very sharply in cities where technical productivity gains have been accompanied by a ridership hike higher than the rise in supply volume (and consequently an increase in vehicle occupancy rates). This decline is 2% or more per year in Paris, Madrid, Vienna and Rome. High performance in terms of technical productivity gains can be offset by a decline in ridership levels, such as in Newcastle and Glasgow, for instance. In some cities there was a simultaneous rise in production costs and a levelling-off or fall in passenger numbers, for instance in Copenhagen, Oslo and Graz.

When comparing costs between cities, it should be borne in mind that public transport operation is a labour-intensive industry, and production costs are necessarily linked to wage levels. In this respect, there are major variations between the cities in the sample: GDP per inhabitant in Chicago, Oslo, Zurich and Munich is seven times higher than in Moscow and four times higher than in Seville or Budapest. This is why we have linked these costs to GDP per inhabitant in the following tables, which give public transport productivity performance in a range of cities from the sample. The cost indicators for a given city are adjusted using a multiplying coefficient of ”relative affluence“ equal to average GDP per inhabitant in MCD cities, divided by GDP per city inhabitant, in order to produce what we have termed ″standard″ cost indicators.

Table 25: ″Standardised″ operating costs (excluding depreciation) for 2001 for various Western European and US cities among the most efficient in terms of passenger x km cost

	″Standardised″ passenger x km cost* (euro cents)	″Standardised″ vehicle x km cost* (euro cents)
Munich	8.9 *(16.2)*	214 *(388)*
Helsinki	9.4 *(13.5)*	173 *(249)*
Stockholm	11.3 *(14.6)*	189 *(244)*
Madrid	12.3 *(9.8)*	336 *(267)*
Copenhagen	13.1 *(17.6)*	196 *(264)*
Barcelona	13.2 *(8.9)*	343 *(232)*
Vienna	14.4 *(19.5)*	317 *(430)*
Paris	15.0 *(22.0)*	386 *(568)*
Chicago	18.0 *(28.4)*	324 *(512)*
London*	18.3 *(26.3)*	293 *(421)*
Nantes	19.8 *(19.7)*	342 *(341)*

* between brackets, non ″standardised″ real cost

Table 26: ″Standardised″ operating costs (excluding depreciation) from 2001 for various Eastern European and Asian cities among the most efficient in terms of passenger x km cost

	″Standardised″ passenger x km cost* (euro cents)	″Standardised″ vehicle x km cost* (euro cents)
Singapore	4.4 *(5.0)*	126 *(144)*
Moscow	5.8 *(1.4)*	203 *(49)*
Hong Kong	7.1 *(7.8)*	154 *(168)*
Prague	9.0 *(5.4)*	298 *(178)*
Budapest	11.0 *(4.3)*	375 *(146)*

* between brackets, non ″standardised″ real cost

The most efficient networks in terms of vehicle x km and place x km production are those with the following features (or at least some of them):

- a low-cost labour force, which is the case in cities where GDP per inhabitant is below EUR 15,000, but also in some other cities, like Dubai, where operators use cheap foreign labour,
- the bulk of services is supplied by rail modes running on reserved routes and/or traffic conditions for buses are favourable,
- infrastructures are recent and organisation of work efficient.

A detailed study would be needed in order to determine the productivity conditions of the most efficient networks. However, we can equivocally state that Eastern European capitals owe their productivity as much to the existence of a fast, extensive and often modern metro network as they do to low labour costs. A comparison between Tables 25 and 26 shows that the networks in Moscow, Prague and Budapest perform very respectably in terms of ”standardised“ vehicle x km costs when compared to those in Western European cities. The exceptional efficiency of the networks in Singapore and in Hong Kong (far superior to the best European networks) is probably attributable to their powerful, modern metro network, efficient management and the modest hourly labour cost of operating staff.

In Western Europe, cities with below average income levels (Seville, Athens, Newcastle) and Scandinavian cities have the least expensive public transport networks in terms of service production. Madrid, Barcelona and Bilbao also stand out on account of their very moderate production costs. When income per inhabitant (Table 25) is included in the equation, the advantage of Scandinavian cities becomes even more apparent. The same is true for Munich. The high performance of these networks is produced by a combination of the following factors: recent infrastructures and equipment, good commercial speed, efficient management organisation, and high staff productivity when compared to the total wage and salary bill.

The ”standardised“ cost per passenger x km criterion, which brings public transport ridership into the equation, markedly alters these rankings, but without turning them on their head. Singapore and Hong Kong confirm their dominant position, some distance ahead of the Eastern European capitals; Munich, Helsinki, Stockholm, Copenhagen, Madrid, Barcelona, Vienna, Paris, Rome and Lisbon. Networks in cities around the United Kingdom (excluding London), which have a fairly low production cost, score less well for this criterion owing to their lack of attractiveness to users. A high vehicle occupancy rate (close to 30% or higher, as in Moscow, Warsaw, Budapest, Prague, Lisbon, Rome, Dubai and Singapore), whilst unfavourable to passenger comfort, is nonetheless an important productivity factor.

5.6. Fares and the financing of operating expenditure

The indicators for the revenue and financial balance of public transport are:

- average revenue collected per journey, which is equal to the quotient of annual traffic revenue, excluding compensatory subsidies for discount fares, multiplied by the number of annual trips,
- coverage rate of operating expenditure (excluding depreciation) through annual operator revenue (including compensatory subsidies for discount fares and miscellaneous revenue: eg. advertising, rental of spaces).

These indicators cover all operators, and all modes combined.

Table 27 provides the value of these indicators for 2001 and their evolution from 1995 to 2001 (average annual variation) for all MCD cities for which these data were available in 1995 and 2001.

Between 1995 and 2001, fares went up by over 2% above inflation, which allowed a considerable adjustment in the coverage rate of operator expenditure through own revenue.

Table 27: Average revenue per trip and coverage rate of operating expenditure through revenue in 2001; evolution between 1995 and 2001

	2001 value (euro cents)	Annual variation between 1995 and 2001
Average revenue per trip**	52.2	+ 2.2%*
Coverage rate of operating expenditure through revenue***	0.605	+ 0.8%

* variation calculated in constant local currency (adjusted for inflation)
** traffic revenue excluding compensatory subsidies for discount fares
*** operator revenue, including compensatory subsidies for discount fares; operating expenditure, excluding depreciation.

A rise in the passenger fares was seen virtually across the board with the exception of Helsinki and one or two French cities. Nonetheless, fare policies remained extremely variable: the coverage rate of operating expenditure, excluding depreciation, through revenue was less than 30% in Brussels, Rome and Turin, whereas the networks in Hong Kong, Singapore and Dubai recorded profits and those in Manchester and Newcastle are close to break-even point. Between 1995 and 2001, the rise in the average coverage rate remained well below the rise in average revenue per journey. The improvement in the ratio of ”revenue / cost“ per trip has been affected by a fall in compensatory subsidies for social fare reductions.

When linked to GDP per inhabitant using the method outlined in paragraph 5.5, the lowest fares are for passengers in Rome, Ghent and the Eastern European capitals, whereas the highest fares are recorded in the United Kingdom. As already mentioned in Chapter 4, there is no clear relationship between fare levels and public transport's attractiveness. Table 28 confirms this fact and also shows that there are no links either between the coverage rate of operating expenditure and operator efficiency, even though the examples of Hong Kong and Singapore show that financial profitability and economic efficiency can go hand in hand. Indeed, coverage rates of less than 50% are found in networks with satisfactory efficiency levels (in France, Nantes and Paris; Vienna; Prague; and in Italian cities).

Table 28: Average revenue per journey, coverage rate of operating expenditure through revenue, public transport market share and ″standardised″ cost of passenger x km

	″Standardised″ average revenue per trip* (euro cents)	Market share of mechanised and motorised journeys provided by public transport (%)	Coverage rate of operating expenditure through revenue**	″Standardised″ passenger x km cost (euro cents)
Prague	12.9	54.2	0.305	9.0
Budapest	20.0	55.9	0.725	11.0
Vienna	31.6	46.6	0.485	14.4
Helsinki	36.7	34.6	0.530	9.4
Singapore	36.7	45.7	1.260	4.4
Marseille	44.9	17.2	0.540	36.1
Paris	47.5	27.5	0.455	15.0
Madrid	59.9	30.2	0.615	12.3
Berlin	59.9	33.2	0.425	32.4
Copenhagen	70.2	15.0	0.680	13.1
Hong Kong	78.7	73.9	1.570	7.1
London*	89.6	26.8	0.810	18.3
Manchester	112.4	11.8	0.960	26.3

* traffic revenue, excluding compensatory subsidies for discount fares
** operator revenue, including compensatory subsidies for discount fares operating expenditure, excluding depreciation

6. Summary and recommendations

UITP is one of the most informed and convinced advocates of sustainable mobility that is based on an overarching policy of urban dynamics, traffic and parking control, and public transport development. The advantages of sufficiently dense urban development well irrigated by high performance public transport were clearly demonstrated in ″Millennium Cities Database for Sustainable Transport″. With MCD, which sheds objective light on the recent evolution of the urban mobility, UITP intends to present a more in-depth diagnosis and come up with fresh proposals concerning the three pillars of sustainable mobility: urban planning, traffic and parking, and public transport.

6.1. Towards dynamic, community-focused urban growth that is more space and energy efficient.

Between 1995 and 2001, the majority of cities expanded and lost inhabitants from their central and inner-city areas. Average population density fell by 5% and the proportion of journeys made by car rose by just over 4%. The effects of urban sprawl are nonetheless well-known: longer journeys, more time spent travelling, higher energy consumption and an intensification of the greenhouse effect, severance of neighbourhood social ties, and the marginalisation of the ″car-deprived″ in the absence of efficient public transport serving less densely populated zones. This development model is not viable and it is important that, no time is lost in implementing a new urbanisation policy. When radically overhauling the organisation of the urban economy and lifestyles, it takes at least one generation before the new approach bears fruit. The severity of climatic change, the looming prospect of ”peak oil” and the heightening of social tensions mean that we can procrastinate no longer.

Statistical analyses conducted by UITP reveal that when density is halved (from 80 to 40 inhabitants + jobs per hectare), the cost to the community (expressed as a % of GDP) increases by some 40% and energy consumption for urban journeys by over 50%.

The trend towards ever more sparse and sprawling urban development is nevertheless not inevitable. Cities like Helsinki, Vienna and Singapore show that a controlled urban development policy is possible and can be profitable for the mobility economy and boost economic dynamism. Furthermore, the desire for open space and moving to the countryside is a long way from becoming the norm when one looks at the trend for households returning to the centre, provided town centres are lively, well serviced by public transport and house prices remain affordable. By championing the cause of the compact town, well served by high-quality public transport, UITP is not only supporting the cause for public transport, but on a more general level, that of an urban civilisation that is dynamic, community-focused and concerned with the shape of things for future generations.

In order to check the advance of urban sprawl, - responsible for the increase in transport expenditure and the consumption of non-renewable energy sources - preserve the historic and cultural heritage of cities, stimulate their economic dynamism and combat segregation and exclusion, UITP recommends:

- **establishing urban planning schemes which curb building on vacant periurban sites,**
- **incorporating a public transport service scheme as an integral part of every urban development project**
- **promoting densification around metro and railway stations, through urban planning / public transport integration plans,**
- **implementing a housing policy that encourages the construction of sufficiently dense living areas and the proper upkeep of existing housing stocks in city centres and populous suburbs,**
- **strictly limiting the number of parking spaces in office buildings and retail businesses in line with public transport service provision in the area.**

6.2. For cities free from car congestion

Congestion is a scourge affecting the vast majority of our cities. Time wasted in traffic jams is money down the drain economically speaking and a source of frustration and stress. Excessive car use in towns harms the health of inhabitants through pollution and noise and contributes to greenhouse gas emissions and the depletion of non-renewable energy sources. Over and above the need to service more sparsely populated peripheral areas, the solution does not involve building more motorways, but implementing a rational policy for existing road space that gives priority to public transport, cyclists and pedestrians - transport modes that are more efficient in terms of traffic and parking space consumption.

Outside sparsely populated areas, the car is clearly less efficient than public transport. Based on the MCD city sample, it is possible to assert that, per passenger x km transported, public transport consumes 2.25 times less energy and costs the community 1.75 times less than the car.
The advantage of public transport is even greater when external mobility costs are taken into account (consumption of space, pollution, noise, traffic accidents).

A growing number of political decision makers have taken these realities on board and committed to reducing dependency vis-à-vis the car and reclaiming space for public transport, cyclists and pedestrians in their city centres. UITP is encouraging the promotion of ″civilised spaces″ as one of the best and most popular ways to end dependency on the car and improve environmental quality. Of course, when space for car traffic is reduced, it is important for public transport capacity to be increased by at least the same proportion in order to maintain the level of mobility vital for economic activity. Priority policies favouring non-motorised traffic implemented in Swiss and Scandinavian cities, Munich and Vienna, are exemplary in this respect. Strictly curbing parking in the centre, as in for example London, Geneva, Graz and Prague is also highly effective in combating car congestion. Of course, Singapore remains the most spectacular case of restricted car use, where an urban toll shores up the (already highly dissuasive) impact of taxing new car purchases.

UITP is fully aware that the car is an essential factor in economic activity and remains one of the favourite consumer goods of our fellow citizens. Nevertheless ”too many cars kill the car and kill the city“. Therefore, in order to reduce congestion and improve the quality of urban life, UITP recommends:

- **reassigning road space to pedestrians, cyclists, public transport vehicles and taxis,**
- **restricting access to city centres, either through congestion charging as in London or regulatory measures such as in Rome,**
- **developing ″quiet neighbourhoods″ where speeds are limited and road space managed to foster the security and comfort of residents,**
- **limiting the number of parking spaces in city centres and restricting the construction of new public car parks to residents’ parking,**
- **making roadside charging widespread and raising charges for non-residents,**
- **stepping up parking inspection and improving fine recovery systems,**
- **discouraging firms from providing free parking spaces for their employees.**

6.3. For efficient and enjoyable public transport

It is a remarkable feat that public transport successfully maintained its share of the mobility market between 1995 and 2001 at a time when conurbation density fell by 5% and motorisation rates rose by 11%. This performance can be attributed to political decision makers, who began to implement recommendations formulated by UITP, and to the public transport industry, which managed to offer its customers an attractive service.

The key conditions governing the appeal of public transport are well known: developing an extensive range of transport services over a network covering the whole of the metropolitan area, improving speed and regularity by creating reserved routes, and expanding rail modes.
Improvements to service have not entailed any major increase in spending: the cost per passenger x km transported remained almost unchanged between 1995 and 2001.

Obviously, these general observations need to be tailored to the city in question. The most striking successes have been recorded by Vienna, Helsinki and Singapore, where the majority of the conditions for success were indeed met: curbs on car use, sustained levels of investment in public transport, rail network expansion, high and constantly growing supply volume (per inhabitant and per hectare), and control of operating expenditure. The expansion of metro and RER networks capable of competing with the car in terms of speed and regularity has led to a stable or growing public transport market share in Madrid, Paris, London, Vienna, Oslo, Hong Kong and Singapore. Neither fare policies nor types of public transport organisation seem to be decisive factors when it comes to service quality, growth in traffic, and control over spending. The choice of an "integrated network" operated for the most part by public undertakings, has not prevented Paris and Madrid from gaining customers and reducing the cost per passenger x km. All the same, the systematic or partial introduction of competition has yielded excellent results in Helsinki, in Stockholm and in London. Only deregulation, implemented in the United Kingdom outside London, gave less positive results: low production costs, granted, but a drop in public transport market share and a rise in the cost of transport for the community.

Public transport provides all city-dwellers, whether they are motorised or not, with access to jobs, to education, to services, to shops and to leisure facilities. It is more energy-efficient, more environmentally friendly, better for the health of city-dwellers and, away from areas of sprawl, costs the community less than the car. In order to promote its development, UITP recommends:

- **extending the responsibilities of organising authorities to include the remits for traffic, parking and coordination between urban planning and transport across the entire metropolitan area (as in London and in Helsinki),**
- **maintaining or increasing investment in public transport in such a way that it at least matches investment in the road network,**
- **prioritising buses and tramways along congested routes via reserved routes and traffic-signal control systems,**
- **developing public transport running on reserved routes, which alone is capable of offering an effective alternative to the car in terms of speed and reliability; rail modes are particularly efficient in this respect.**
- **applying appropriate policies for fares and subsidies to ensure that operators have the financial resources with which to offer their customers a quality service able to compete with the car (in terms of frequency, comfort, passenger information, safety and staff qualifications),**
- **depending on the local political and social context, selecting the most effective model for the relationship between organising authorities and operators for promoting service quality and controlling operating expenditure.**

Annexes

1. List of raw indicators
2. Factors accounting for the cost and the performance of transport systems
3. Factors accounting for the competitiveness of public transport

Annex 1

List of raw indicators

A : Study year

B : Country

C : City

D : Currency

E : Exchange rate in euros

F : Definition of the metropolitan area

G : Definition of the Central Business District (CBD)

Demographic and economic data

1. Total surface area of metropolitan area

2. Total surface area of built-up (urbanised) area

3. Population of metropolitan area

4. Number of jobs in metropolitan area

5. Number of jobs in CBD

6. Gross Domestic Product of the metropolitan area

Traffic data

7. Number of private cars

8. Number of motorcycles

9. Annual vehicle x km in private cars

9a. Annual km per private car

10. Annual vehicle x km on motorcycles

10a. Annual km per motorcycle

11. Passenger x km in private cars

12. Passenger x km on motorcycle

13. Average road network speed

Road and parking data

14. Total length of road network

15. Total length of express road network

16. Number of off-street parking places in CBD

17. Number of on-street parking places in CBD

18. Maximum rate for one hour's off-street parking in the CBD

19. Maximum rate for one hour's on-street parking in the CBD

20. Park and Ride car park number

21. Park and Ride total capacity

Data on taxis

22. Total number of taxis

23. Total number of shared taxis

24. Total vehicle x km in taxis

25. Total vehicle x km in shared taxis

26. Annual passenger trips in taxis

27. Annual passenger trips in shared taxis

28. Annual passenger x km in taxis

29. Annual passenger x km in shared taxis

Data on public transport

30. Total public transport farebox revenue including reimbursement for reduced social fares

30a. Total public transport farebox revenue excluding reimbursement for reduced social fares

31. Total public transport vehicle fleet

31a Bus fleet

31b Minibus fleet

31c Tramway fleet

31d Light rail fleet

31e Metro fleet

31f Fleet of suburban/regional railways

31g Fleet of other public transport modes

32. Total length of public transport lines

(32a to 32g : total length of lines by mode)

33. Length of reserved public transport routes

(33a to 33g : length of reserved routes by mode)

34. Average public transport speed

(34a to 34g : average speed by mode)

35. Annual public transport vehicle x km

(35a to 35g : annual vehicle x km by mode)

36. Annual public transport place x km

(36a to 36g : annual place x km by mode)

37. Annual public transport boardings

(37a to 37g : annual boardings by mode)

38. Annual public transport passenger x km

(38a to 38g : annual passenger x km by mode)

Data on mobility and modal split

39. Average number of daily trips (all modes)

39a Average number of daily walking trips

39b Average number of daily mechanized non-motorised trips (bicycle)

39c Average number of daily trips by public transport

39d Average number of daily trips on motorised private modes (private car, motorcycle, taxi)

Modal split: all modes

40a % of daily trips by non-motorised modes (walking and cycling)

40b % of daily trips by public transport

40c % of daily trips by motorised private modes

Modal split: mechanized and motorised modes

41a % of daily trips by bicycle

41b % of daily trips by public transport

41c % of daily trips by motorised private modes

Average trip length

42. Average length of a public transport trip

43. Average length of a motorised private mode trip

Data on costs and performance of transport systems

44. Average annual spending on public roads (investment, maintenance, operation)

(44a to 44e: spending for years 1997 to 2001)

45. Average annual investment on public transport

(45a to 45e: investment for years 1997 to 2001)

46. Annual operating expenses of public transport including depreciation

46a Annual operating expenses of public transport excluding depreciation

47. Rate of coverage of operating costs (excluding depreciation) by farebox revenue (including reimbursement for reduced social fares)

48. Average user cost of a passenger x km by private car

48a. Average user cost of a passenger x km by private car (excluding surtax on fuel and cars)

49. Average user cost of a passenger x km by public transport

49a. Average cost of a passenger x km by public transport for the community

50. Annual cost of passenger transport for the community

50a. Annual cost of private passenger transport for the community

50b. Annual cost of public transport for the community

51. Annual cost of passenger transport for the community as a % of the GDP

51a. Annual cost of private passenger transport for the community as a % of the GDP

51b. Annual cost of public transport for the community as a % of the GDP

52. Private transport energy use

53. Public transport energy use

53a. Public transport energy use (road modes)

53b. Public rail transport energy use (rail modes)

54. Total transport energy use

55. Average duration of a car trip

56. Average duration of a public transport trip

57. Number of annual transport fatalities

58. Air pollutants emissions

58a CO

58b VHC

58c Nox

Annex 2

Factors accounting for the cost and performance of transport systems

[GRAPH 1] Cost of transport for the community vs. Density

[GRAPH 2] Cost of transport for the community vs. Modal split

[GRAPH 3] Cost of transport for the community vs. GDP/inhabitant

[GRAPH 4] Energy consumption for passenger transport vs. Density

[GRAPH 5] Energy consumption for passenger transport vs. Modal split

[GRAPH 6] Energy consumption for passenger transport vs. Urban area

[GRAPH 7] Average duration of a motorised journey vs. Urban area

[GRAPH 8] Average duration of a motorised journey vs. Density

[GRAPH 9] Average duration of a motorised journey vs. Modal split of mechanised and motorised trips

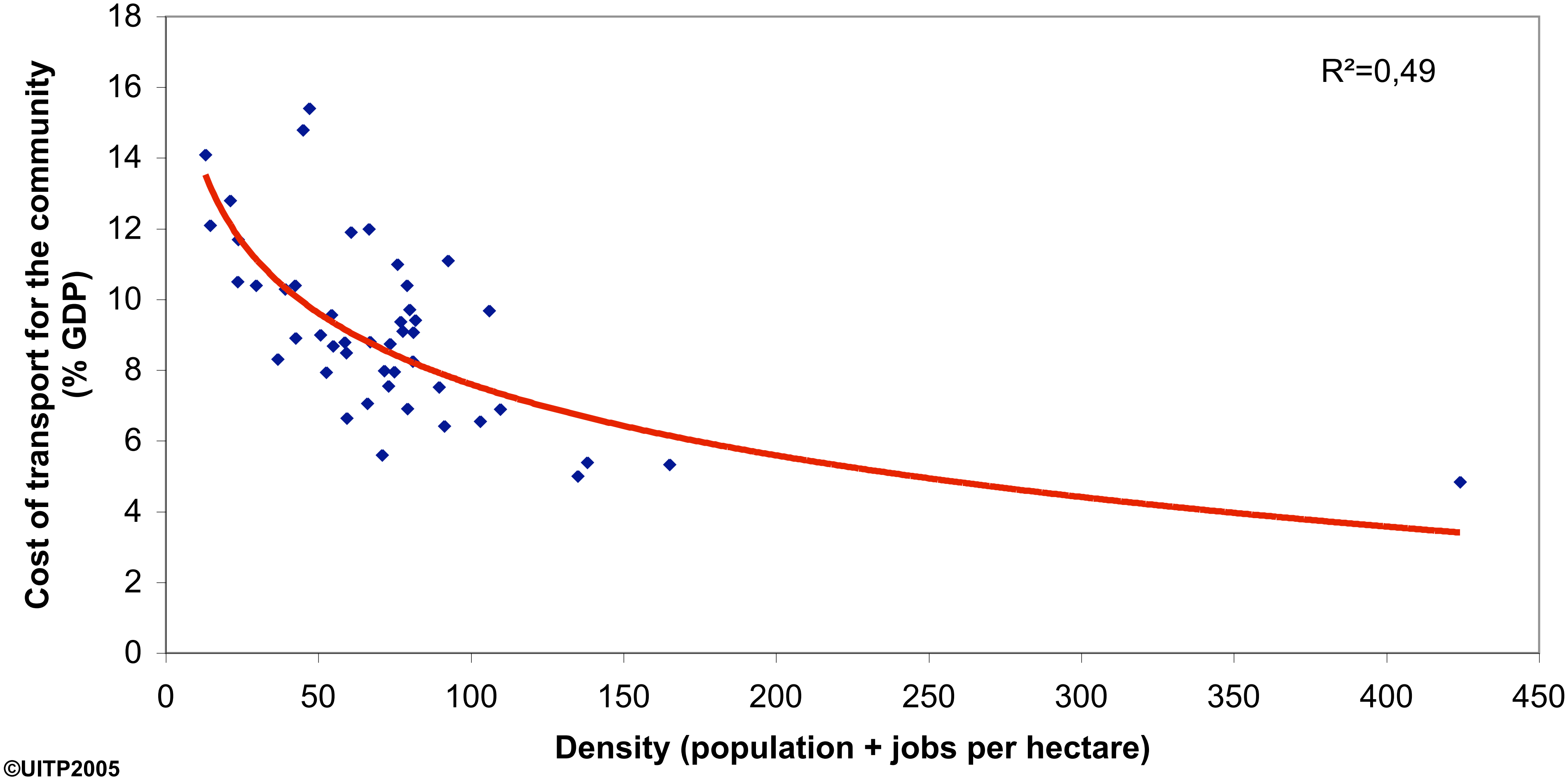
[GRAPH 10] Modal split vs. Density

Annex 3

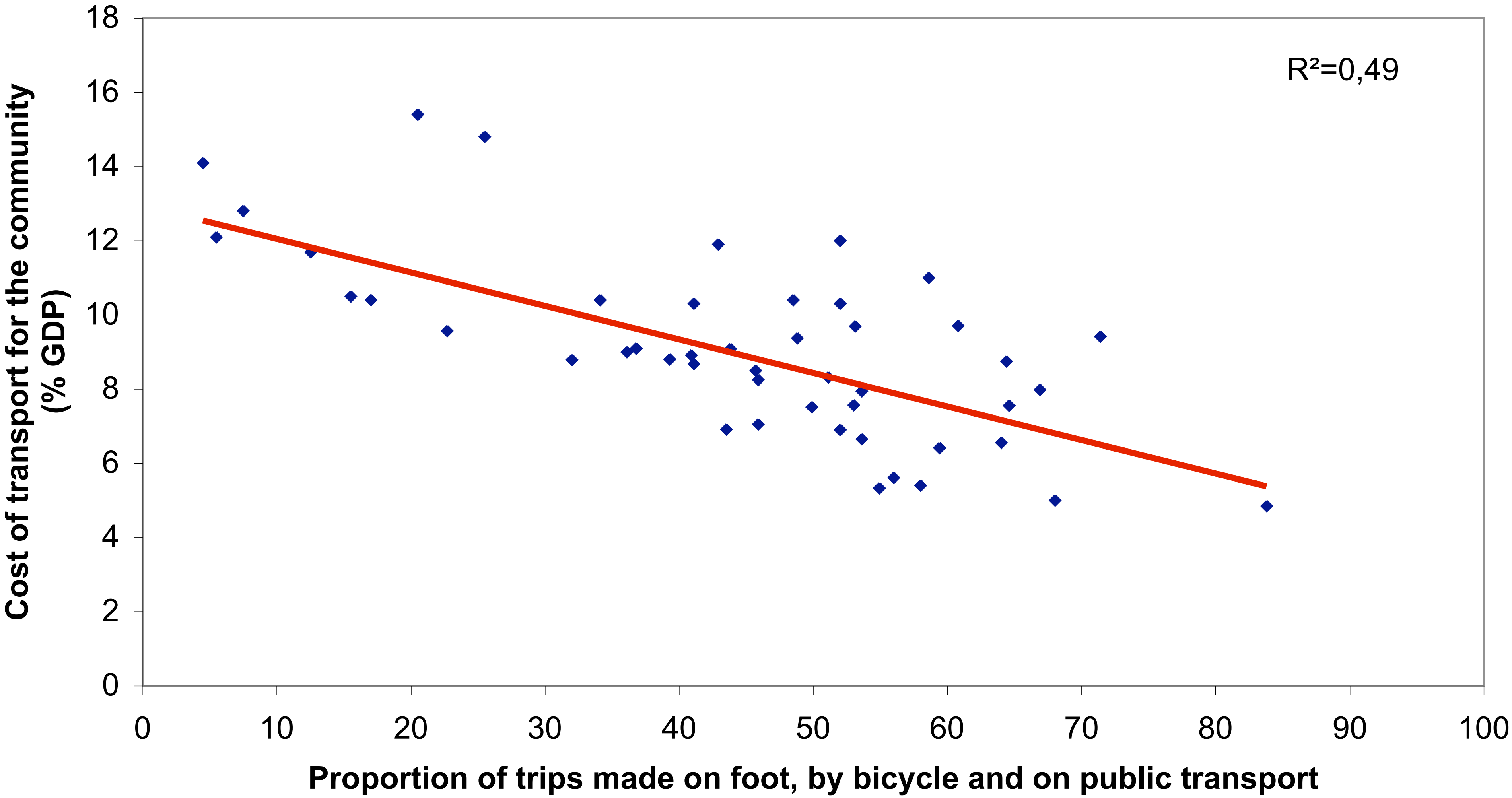
Factors accounting for the competitiveness of public transport

[GRAPH 11]	Public transport market share vs. Motorisation rate
[GRAPH 12]	Public transport market share vs. Parking supply
[GRAPH 13]	Public transport market share vs. Public transport supply
[GRAPH 14]	Public transport market share vs. Proportion of public transport supply through rail modes
[GRAPH 15]	Public transport market share vs. Relative speed of private and public modes
[GRAPH 16]	Public transport market share vs. Relative door-to-door speed of private and public modes

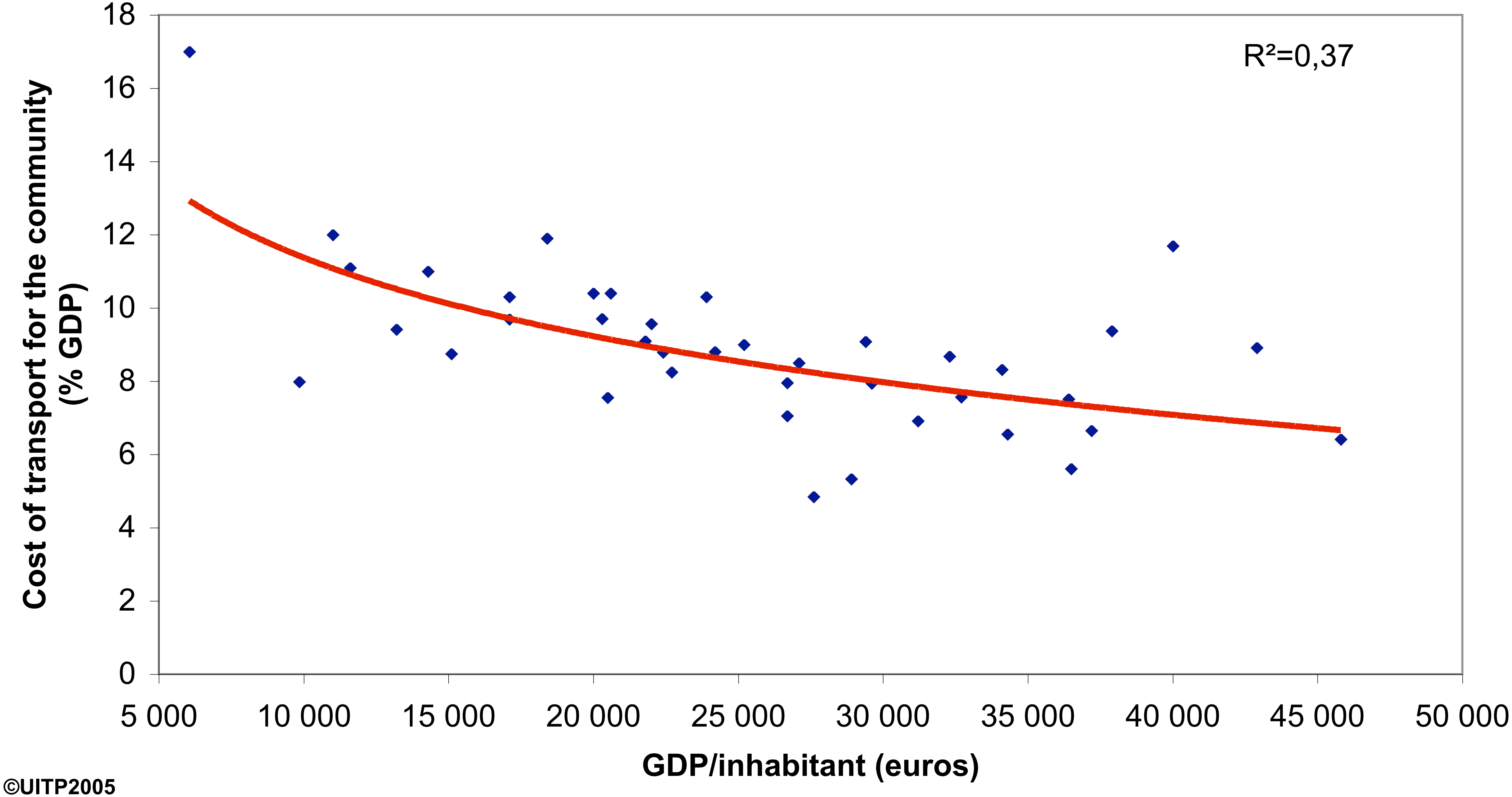
Cost of transport for the community vs. Density



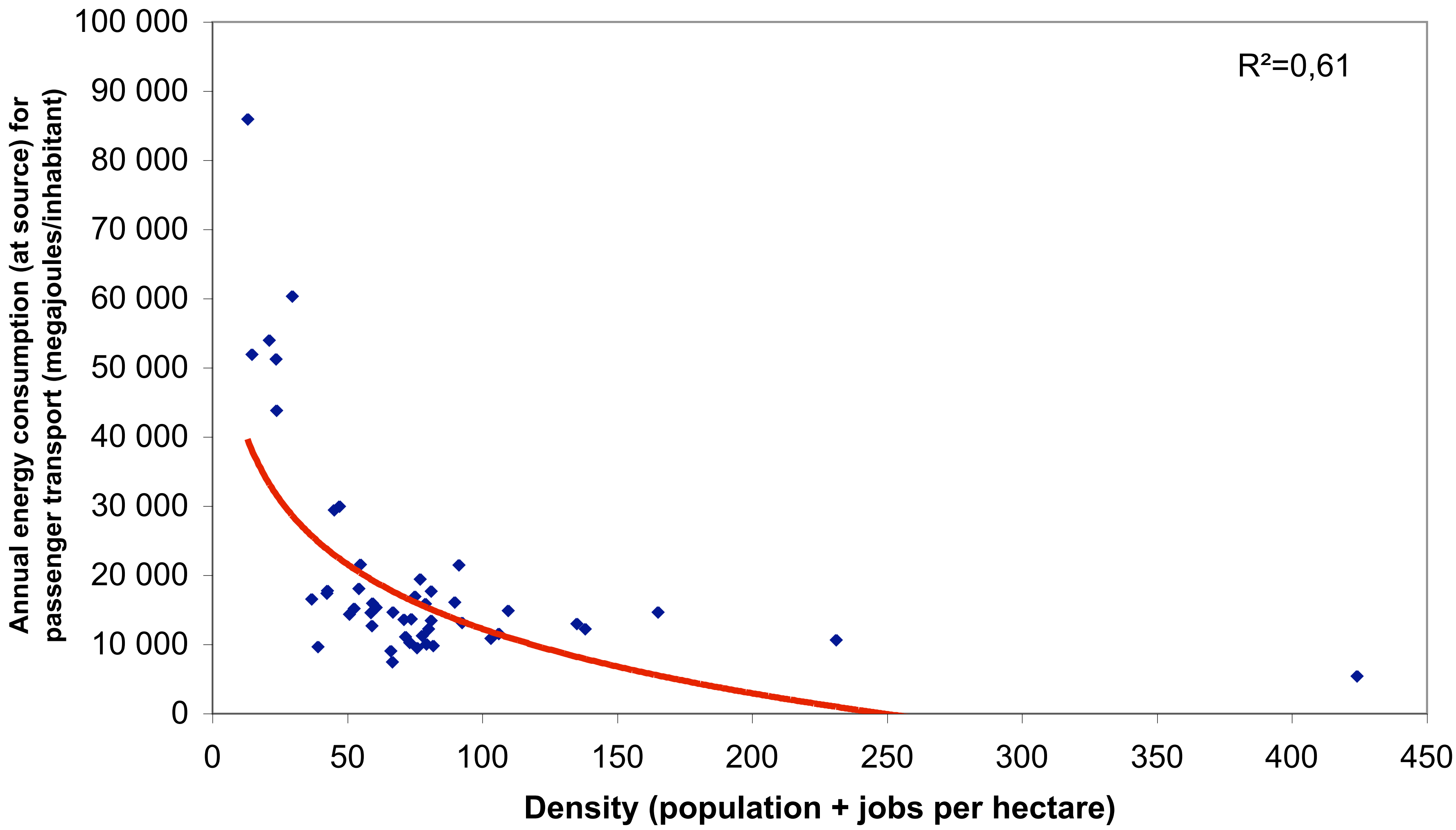
Cost of transport for the community vs. Modal split



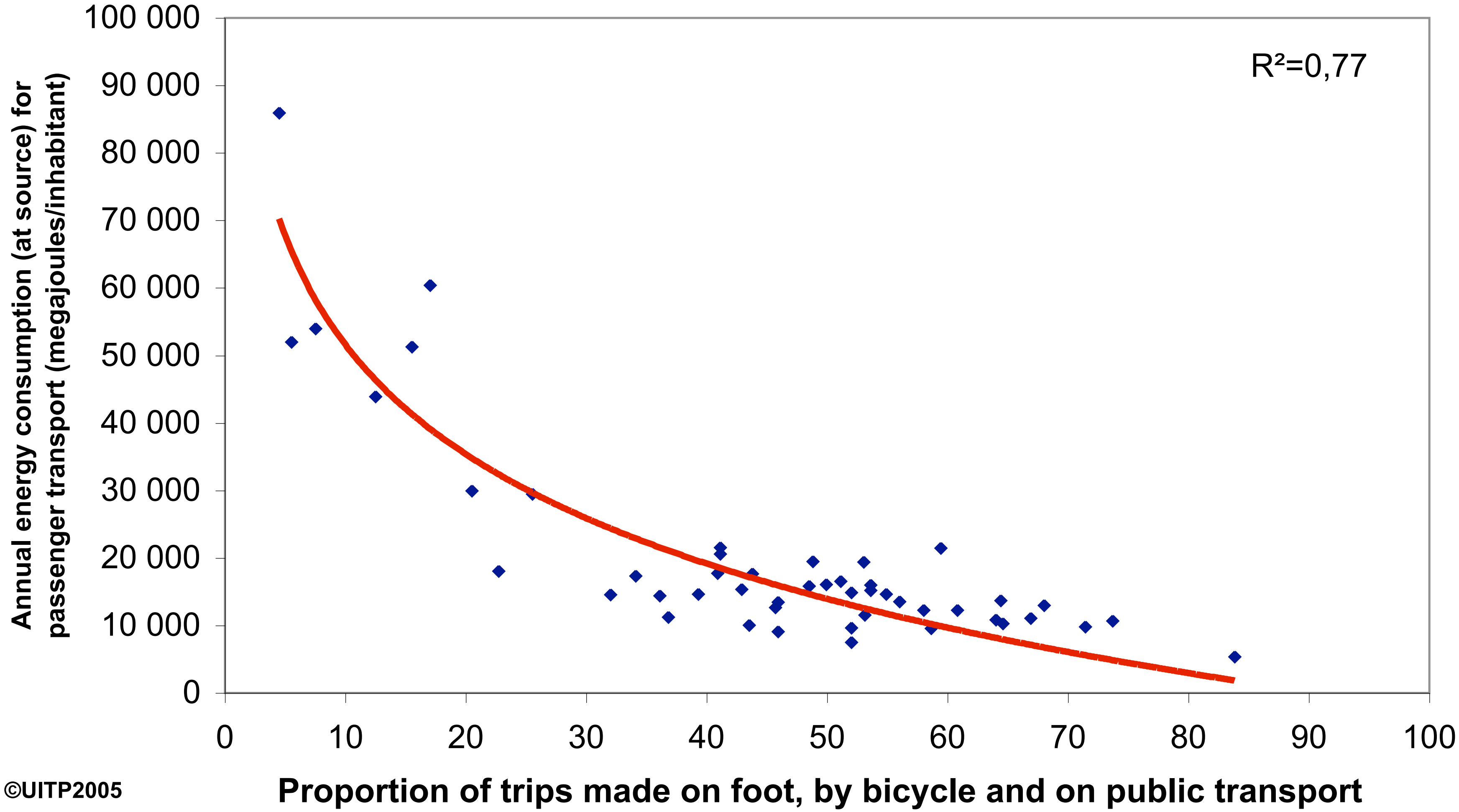
Cost of transport for the community vs. GDP/inhabitant



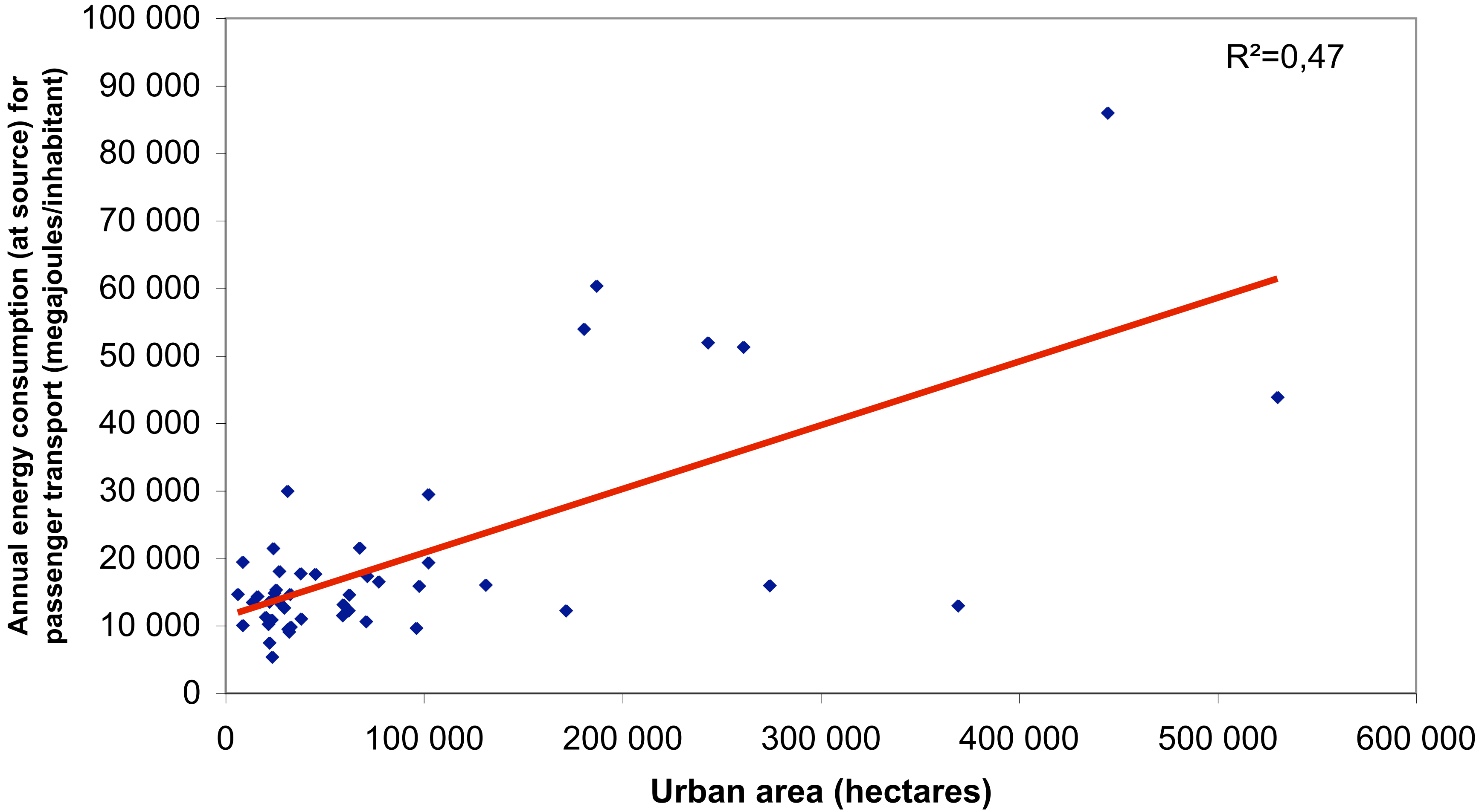
Energy consumption for passenger transport vs. Density



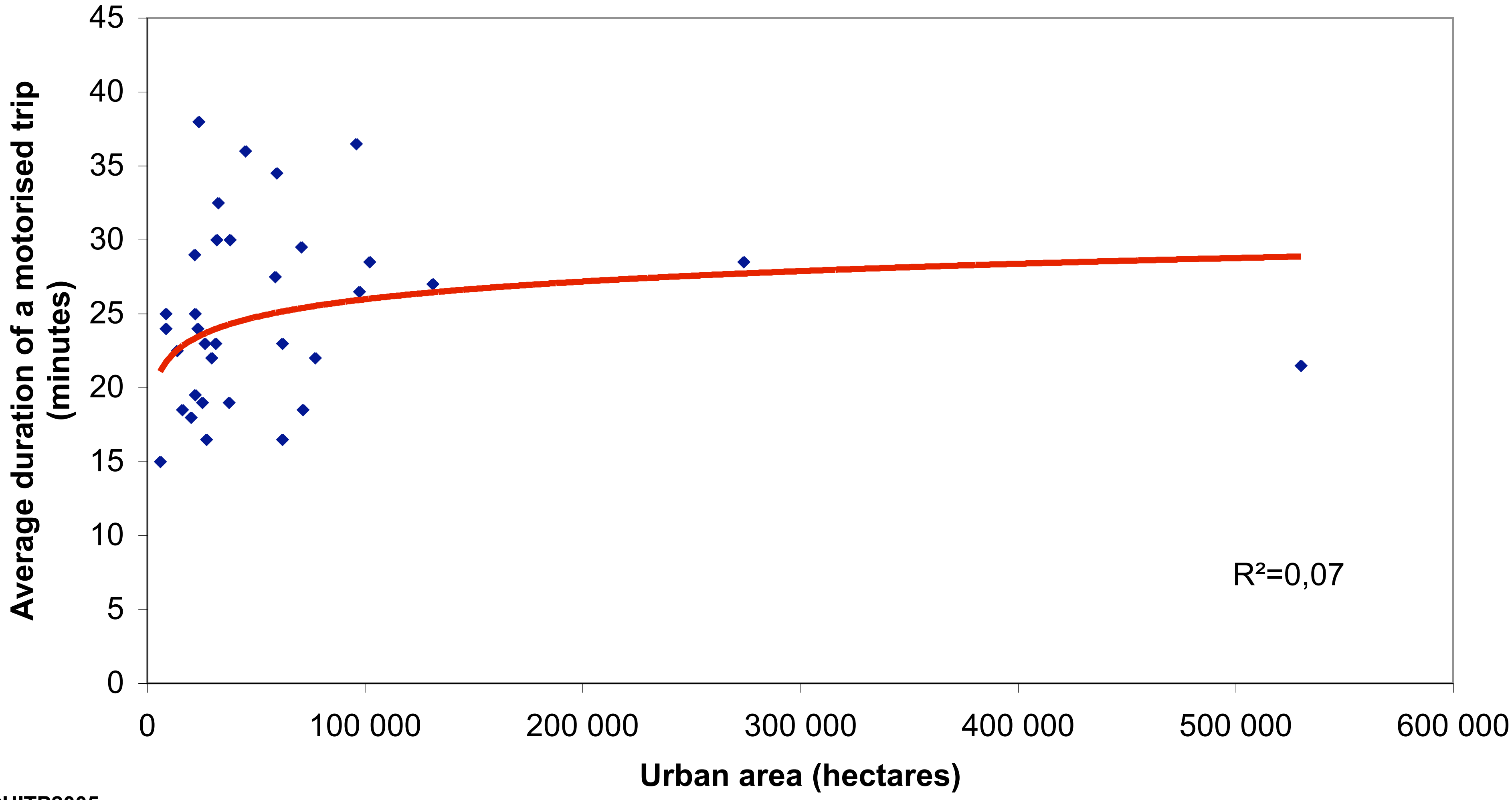
Energy consumption for passenger transport vs. Modal split



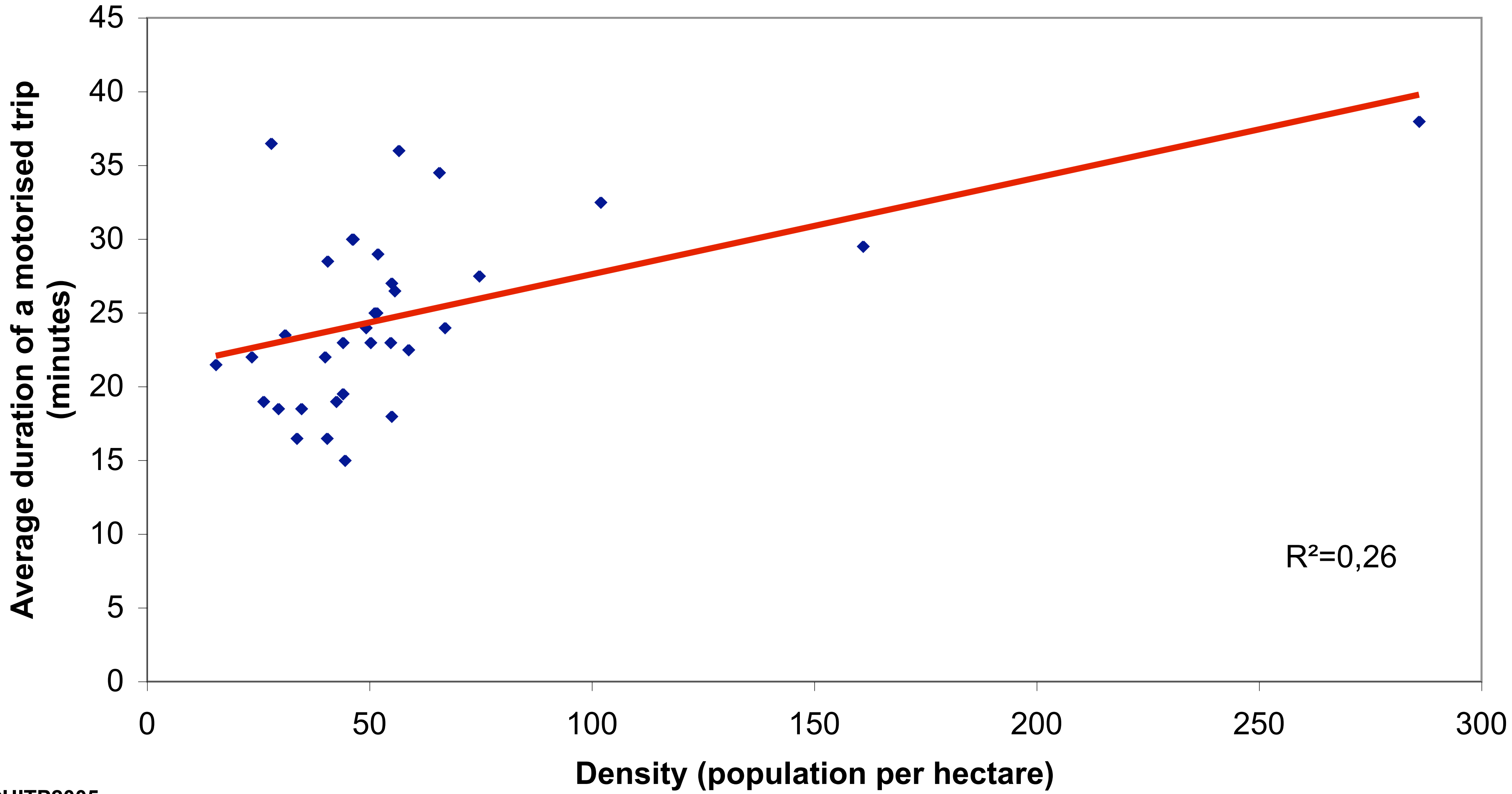
Energy consumption for passenger transport vs. Urban area



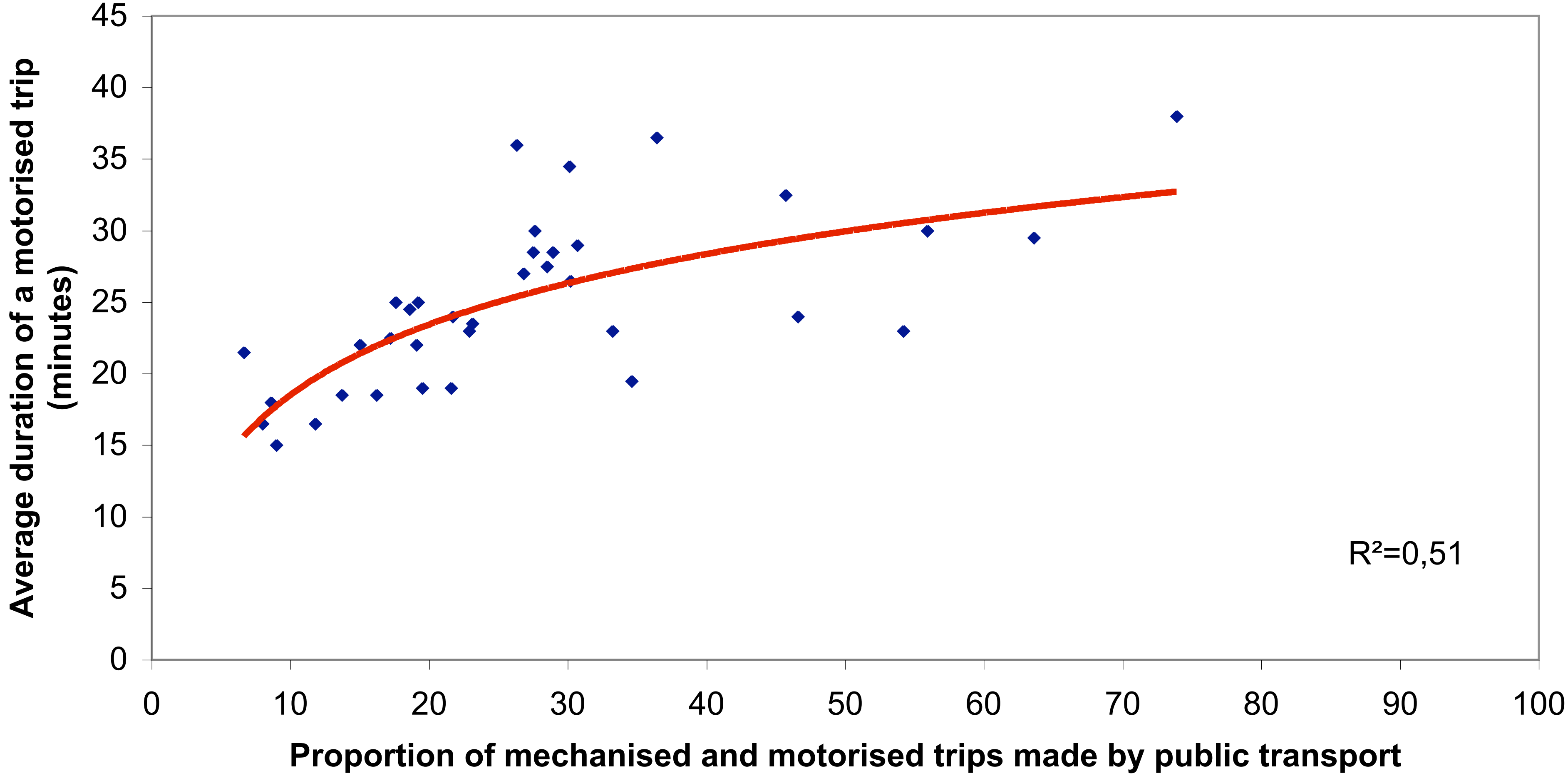
Average duration of a motorised trip vs. Urban area

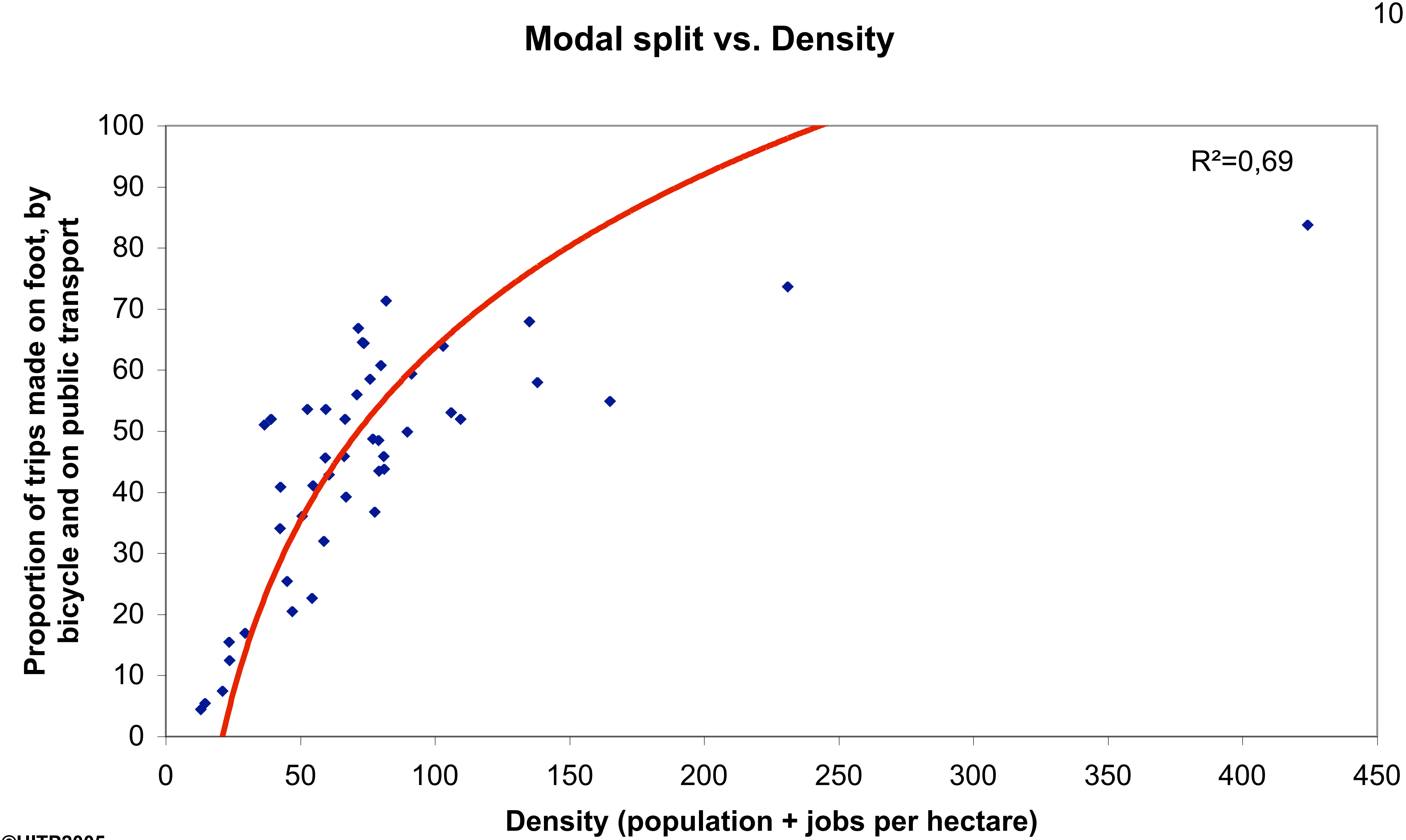


Average duration of a motorised trip vs. Density

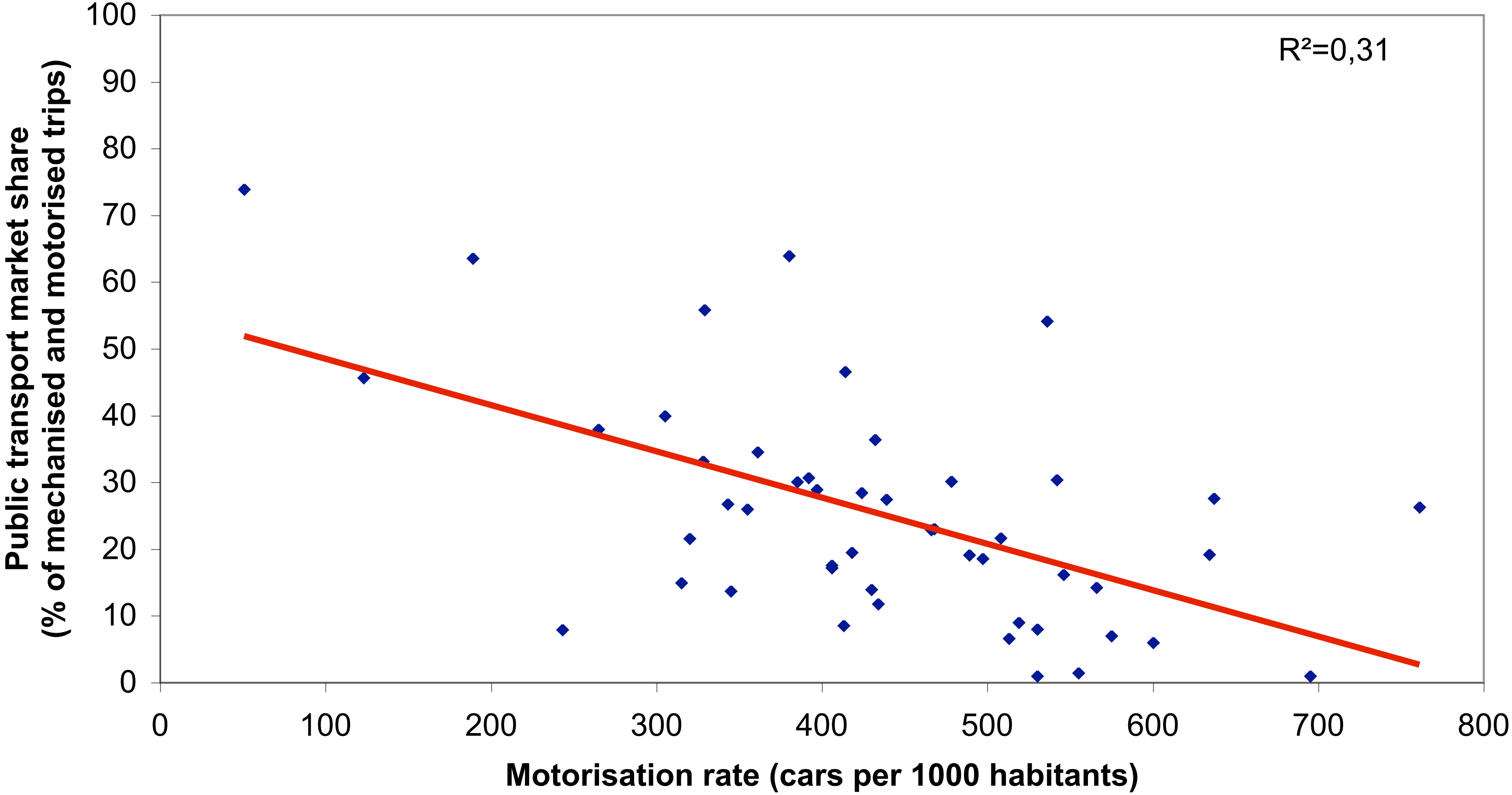


Average duration of a motorised trip vs. Modal split of mechanised and motorised trips

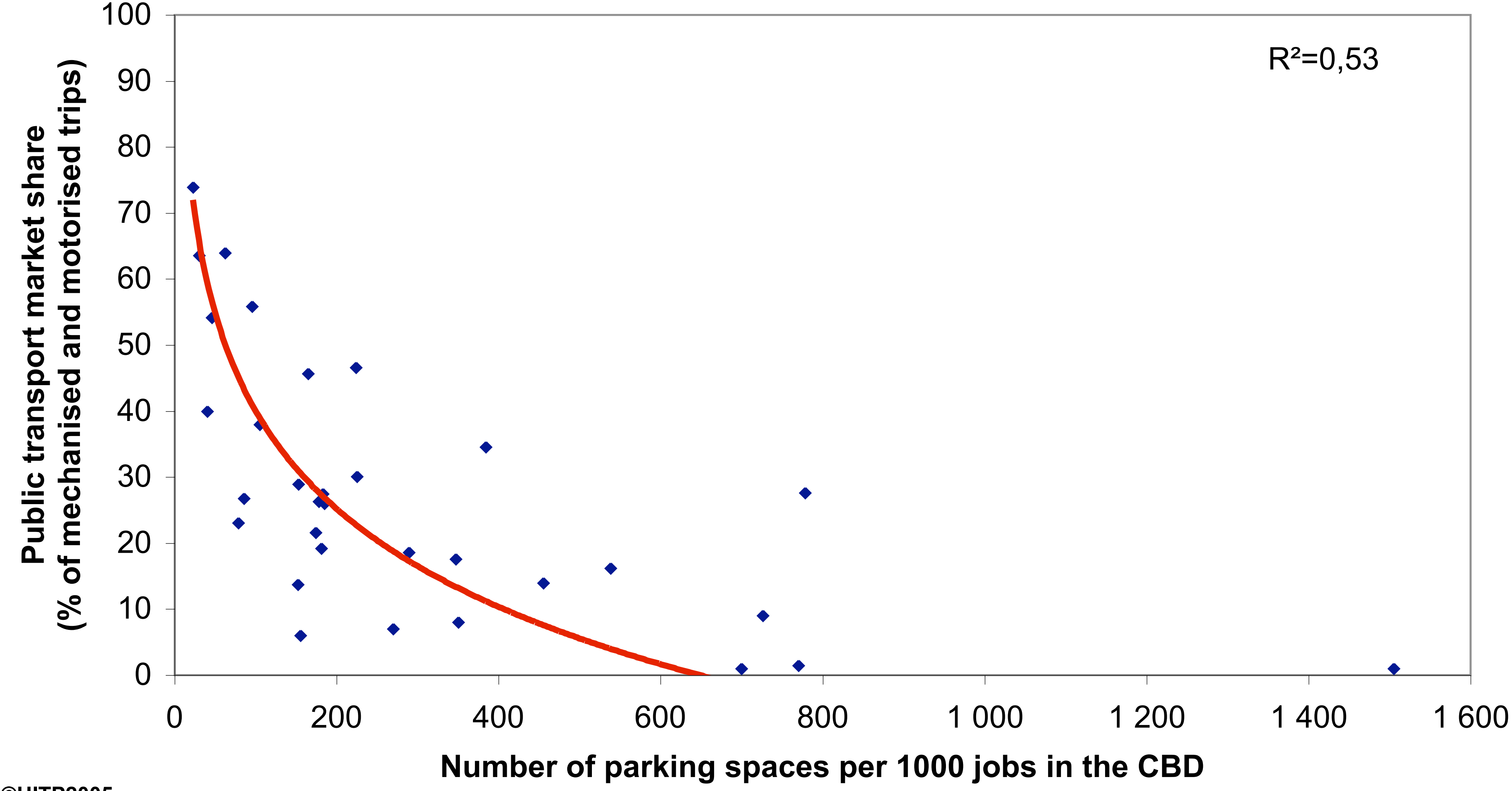



Modal split vs. Density
R²=0,69
Proportion of trips made on foot, by bicycle and on public transport
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400
450
Density (population + jobs per hectare)

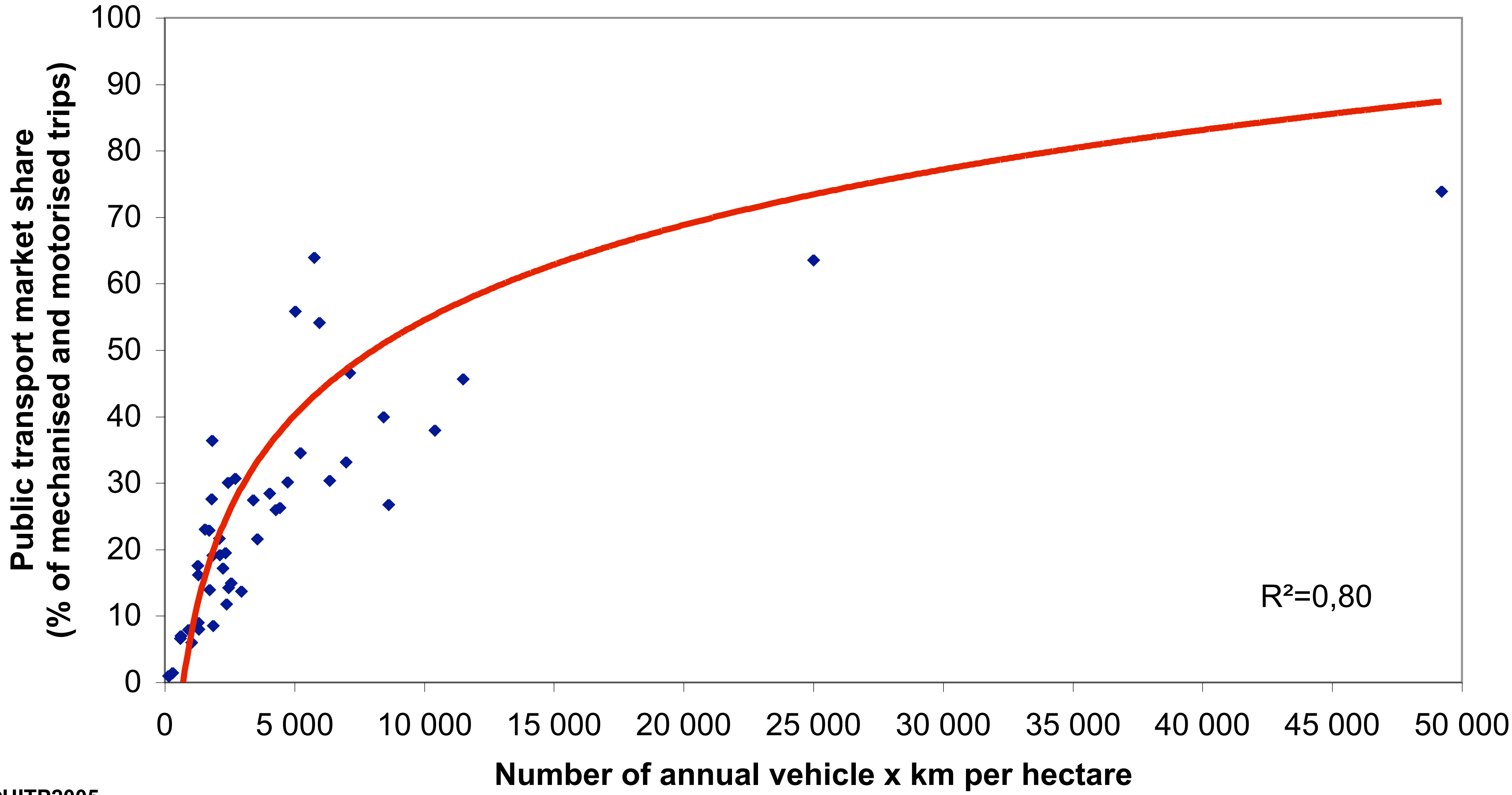
Public transport market share vs. Motorisation rate



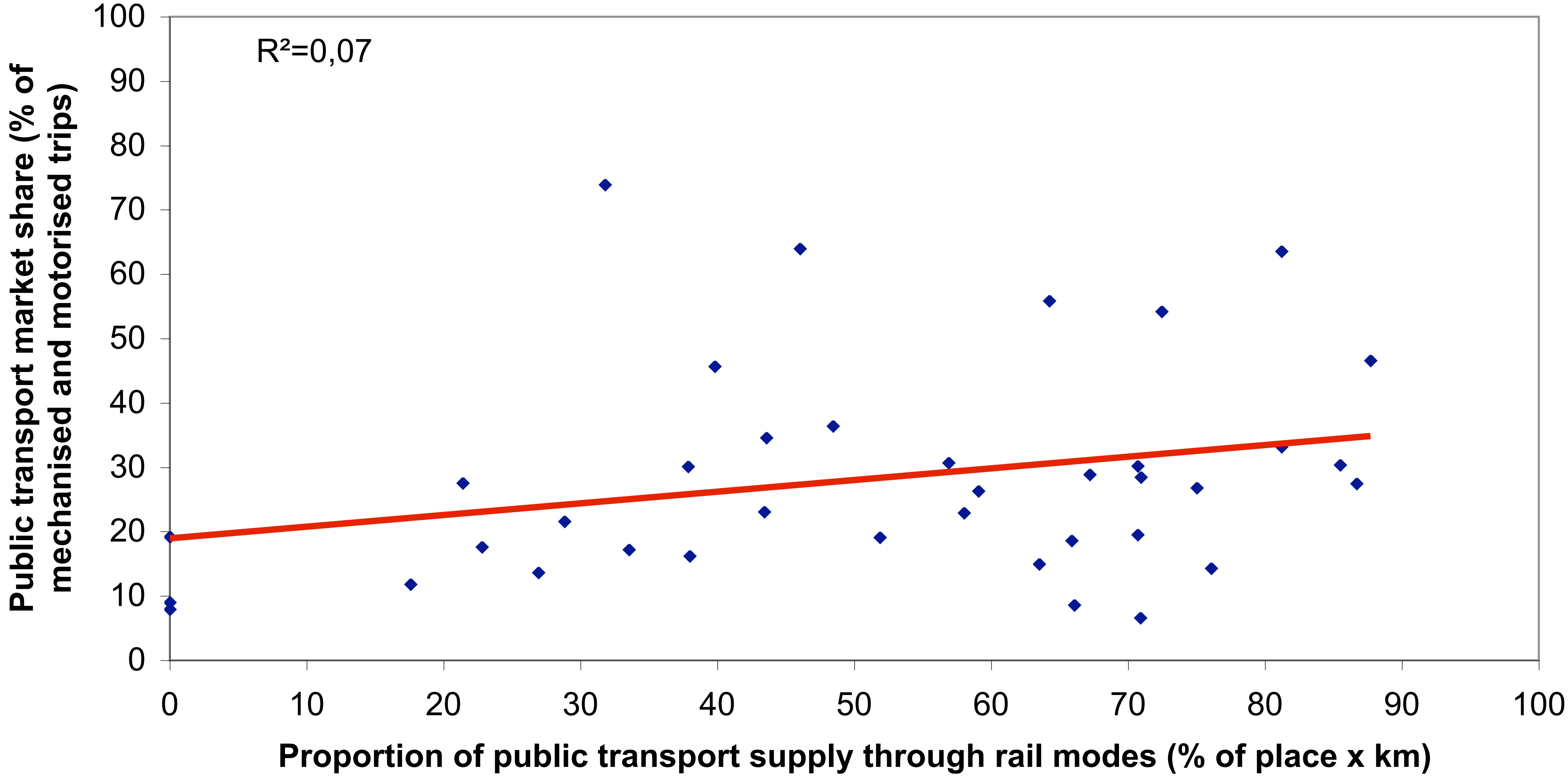
Public transport market share vs. Parking supply



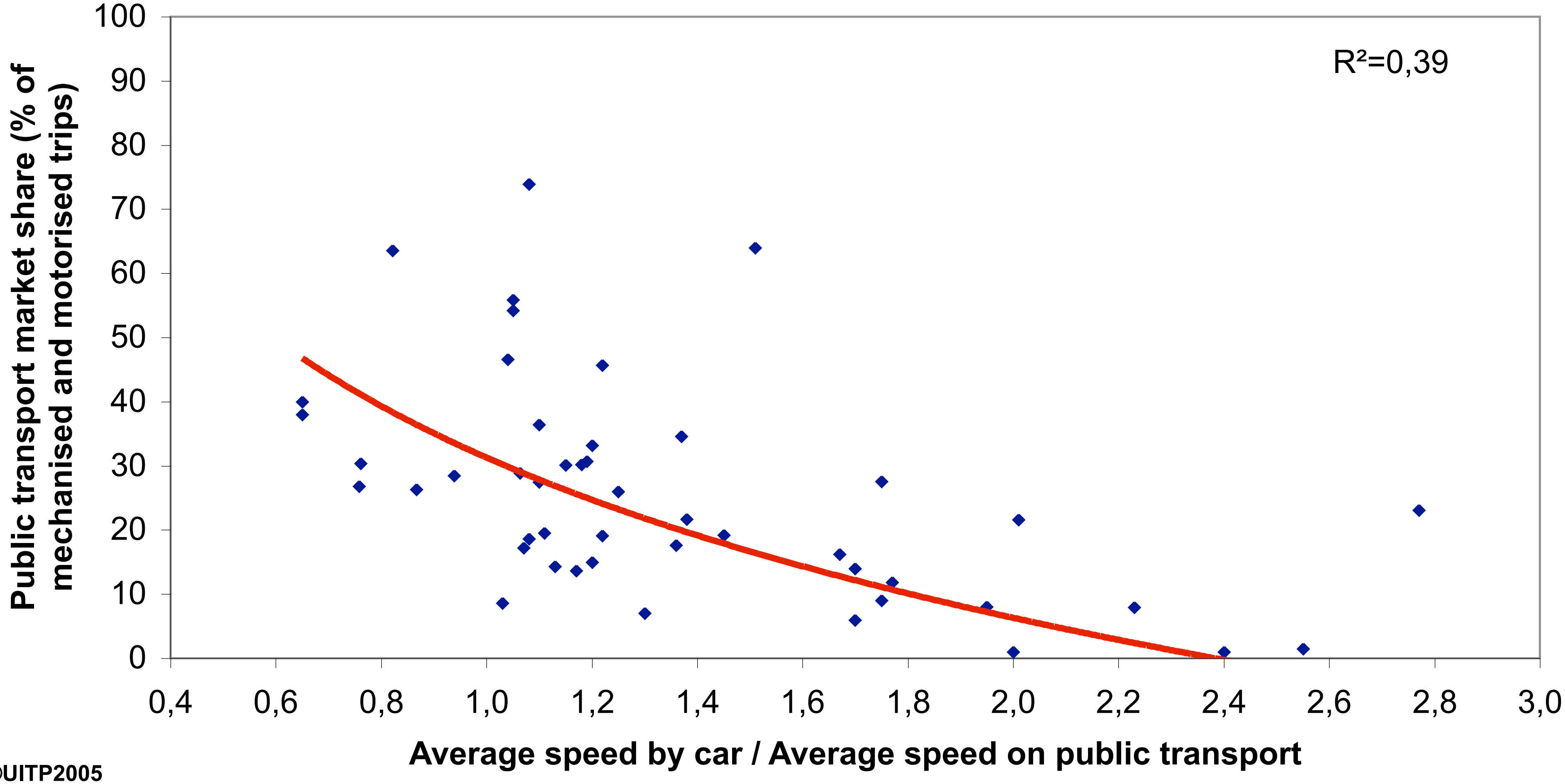
Public transport market share vs. Public transport supply



Public transport market share vs. Proportion of public transport supply through rail modes



Public transport market share vs. Relative speed of private and public modes



Public transport market share vs. Relative door-to-door speed of private and public modes