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# THE DETERMINANTS OF URBAN PUBLIC TRANSPORT DEMAND: AN INTERNATIONAL COMPARISON AND ECONOMETRIC ANALYSIS

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## Abstract

The analysis presented in this paper is based on the database created by the UITP (International Association of Public Transport), "*The Millennium Cities Database*", which covers the public transport systems in 100 of the world's cities. It contains data on demography, urban structure, transport networks, daily mobility, environmental impacts, etc. Our analysis demonstrates the contrasts between European and American travel practices. It explores possible links between public transport market share and geographical and economic conditions on the one hand and the characteristics and performances of public transport systems on the other. Our research has generated an explanatory econometric model for public transport market share. To end with, a consideration of the levers that can be used to influence the public transport system leads into a discussion about the future of cities with "European urban mobility" and the danger of a slide towards "American urban mobility" taking place.

## Keywords

Transport systems, Urban mobility, Transport policy, Public transport

J.E.L.: R40

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## **1. Introduction**

### **1.1. *The aims of the study***

The transport system is an essential element in the physical, economic and social structure of an urban area. It consists of transport infrastructure and services that permit economic agents to access the activities that are available in the city. It thus determines the space within which urban trips are made (Bonnafois, 1996).

Worldwide, most urban trips are made by private car, public transport (PT), and walking. The car provides great travel freedom but is reserved to those fortunate groups that own vehicles. Public transport is a “social” mode of transport, it nevertheless provides more limited space-time opportunities than the car. Lastly, although citizens are free to walk and walking costs nothing, it severely reduces the zone of accessibility. Classically, it is considered that modal choice basically involves a trade-off between the generalized cost of the transport mode and the zone of accessibility in terms of time and space.

The transport system differs from one city to another. Its structure depends on a variety of factors, for example the city’s history, geographical configuration or transport policy, etc. The authorities responsible for urban transport aim to make the system efficient while taking into account not only individual travel needs but also all the costs generated by the system.

The Millennium Cities Database which has been created by the UITP (International Association of Public Transport) provides a wealth of information on the urban transport systems and travel practices in 100 cities located all over the world (Vivier, 2001). The studied cities present heterogeneous levels of development and varied transport systems. Each continent is represented (35 cities in Western Europe, 6 in Eastern Europe, 15 in North America, 10 in South America, 8 in Africa, 3 in the Middle-East, 18 in Asia and 5 in Australasia). The database contains cities of all sizes, from Graz (240,000 inhabitants), to the metropolitan area of Tokyo (32.3 million inhabitants). The observations have been conducted at an aggregate level as the indicators related to the entire conurbation. The collected data relate to demography, urban structure, economic level, the characteristics of road and PT networks, parking supply, travel level, travel time and cost, energy consumption, pollutant emissions, number of accidents, etc. The database contains a total of 175 basic raw indicators, most of which are quantitative. The collected data are for 1995.

The aim of this paper<sup>1</sup> is to provide an overview of the world’s transport systems which, in particular, reveals the determinants of urban PT use. This concern has led us to start by producing homogeneous profiles of cities, based on widely differing organizations of urban transport systems (2). On the basis of this preliminary work, the econometric results from an explanatory model of the determinants of PT market share provide input for a discussion on the political levers that can encourage PT (3).

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<sup>1</sup> This paper is a continuation of a study conducted in the framework of the French National Plan on Urban Transportation (Commissariat Général du Plan, 2003).

## **1.2. A few reservations about use of the UITP database**

In spite of a considerable amount of work performed by those responsible for creating the UITP database, it is open to a number of criticisms (Godard, 2001). First, aggregated analysis at world level conceals a number of local features by applying standardized indicators. Furthermore, the sequence of hypotheses and the processing of raw information raise a set of difficult questions concerning homogeneity with regard to the geographical delimitations of cities, the reference year, how the indicators are specified and broken down and survey methods.

First of all, transport studies make use of a geographical parameter which is not systematically identical with the administrative entities that produce the data. Within the database, the available data which did not match administrative zones had to be adjusted. It was therefore necessary to organize new groupings of communes in order to create consistent metropolitan zones. Likewise, the dates of the available surveys in different cities were not the same, so extrapolation was necessary to bring all the data into line with the reference year of 1995. Next, the failure to break down certain indicators into subcategories means that they remain at an excessively aggregate level and this can lead to weaknesses in a database. For example, for some cities it is impossible to make the distinction between suburban and interurban services. Last, we have to mention the divergent results produced by different survey methods: the data collected by field surveys, telephone surveys or travel diaries does not have the same informational value or the same representativity.

Nevertheless, although the persons who created the UITP database describe it as “imperfect”, it is nevertheless the most sophisticated, complete and reliable collection of international data at the present time. Information on all the indicators has been obtained for 84 of the 100 cities. In the other cases, the collection rate varies between 30% and 95%. The large range of fields covered by the indicators in the database is an obvious quality in view of the fact that its global dimension means it is of great interest for international comparisons and gaining an understanding of travel practices at world level.

## **2. Identifying city profiles**

The UITP database contains a large variety of cities which differ as regards their transport system, their urban structure, their level of wealth and their residents’ travel practices. On the basis of these characteristics it is possible to identify a number of distinct city profiles. Table 1 sets out the average values of the indicators for each group of cities.

### **2.1. Urban structure and economic context**

Travel takes place within an urban structure and this, therefore, affects two aspects of individuals’ choice sets. First, the location of activities with respect to residential locations generates general travel requirements (this is traditionally known as “intermediate demand”). In addition, as travel demand takes place within an urban structure, the structure determines travel conditions to a considerable degree.

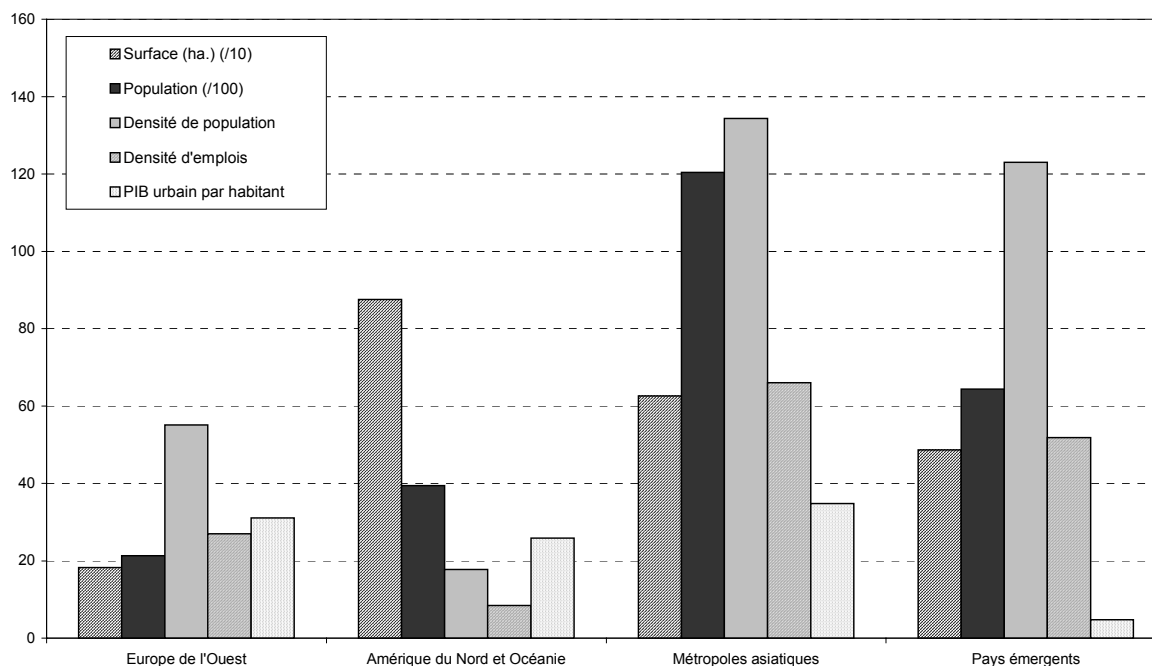
Table 1. Average indicator values for each group of cities

	Europe de l'Ouest	Amérique du Nord Océanie	Métropoles asiatiques	Amérique du Sud	Europe de l'Est	Afrique	Autres villes d'Asie
<b>Structure urbaine et contexte économique</b>							
Surface (ha.)	182 710	875 680	626 190	759 860	140 606	129 715	294 730
Population	2 130 561	3 941 434	12 045 192	8 293 098	3 878 300	3 702 787	8 763 195
Proportion d'emplois dans le centre (%)	18.29	12.27	20.08	20.69	17.03	14.03	25.53
Densité de population (pop./ha.)	55.10	17.76	134.36	78.26	71.36	101.67	191.79
Densité d'emplois (emplois/ha.)	29.97	8.45	66	32.99	38.80	27.08	86.68
PIB par tête (milliers de dollars US/hab.)	31.12	25.84	34.80	63.44	51.73	23.56	41.80
<b>Système de transport</b>							
Longueur de voirie (m./1000 pers.)	2997.88	6575.03	2424.76	1425.53	1639.33	1425.53	591.06
Longueur de lignes de TC (m./1000 pers.)	3634.16	1994.21	1127.85	3940.63	1684.41	3940.63	1327.23
Coût d'usage d'un déplacement en VP (10-4 % du PIB par pers./déplacement)	146.43	113.01	132.48	619.93	570.82	979.86	584.49
Coût d'usage d'un déplacement en TC (10-4 % du PIB par pers./déplacement)	30.31	37.25	45.73	94.21	23.93	168.77	86.26
Prix du carburant (10-5 % PIB par pers./km.)	33.98	21.07	31.55	446.30	206.20	230.79	135.56
Offre de stationnement (places/1000 emplois)	270.00	501.43	120.59	17.38	74.04	195.57	91.25
Part du PIB investi urbain en TC (%)	0.45	0.21	0.47	0.40	0.50	0.54	0.76
<b>Pratiques de mobilité</b>							
Part modale des TC (%)	25.43	5.90	42.28	50.86	60.80	42.27	39.15
Part modale de la VP (%)	67.92	92.88	48.14	41.64	36.90	56.16	41.95
Distance quotidienne moyenne de déplacement (km.)	21.39	40.17	22.49	14.80	17.88	11.70	11.37
Distance moyenne par déplacement (km.)	7.98	11.09	8.98	10.32	6.63	7.50	7.02
Distance totale moyenne par déplacement domicile-travail (km.)	9.22	16.03	11.52	10.10	7.43	11.48	7.85
Nombre moyen de déplacements quotidiens (nb./hab.)	1.45	3.04	1.02	1.71	2.81	1.6	2.13
Vitesse moyenne de déplacement sur route (km/h.)	32.94	44.20	31.34	29.33	30.92	33.57	20.83
Motorisation (véh./1000 pers.)	412	575	217	189	279	102	88

Thus, by observing urban densities we can distinguish fairly clearly between the different groups of cities (Table 1 and Figure 1). North American and Australasian cities have average population densities three times lower than Western European cities. However, Asian and African cities and, to a lesser degree, South American and Eastern European cities, have considerably higher population densities than other cities. Similar conclusions are reached if one considers job densities, with the exception of African cities for which the average job density is in relative terms lower than the population density. Furthermore, it is noteworthy that African and Eastern European cities have smaller surface areas than cities elsewhere in the world while Western European cities have considerably smaller surface areas than Asian, North and South American and Australasian cities. On this basis, we can conclude that the opportunities for travel afforded by Western European cities and Asian metropolises seem to be located in a smaller and more dense area than is the case for North American and Australasian cities.

The average level of wealth (as measured on the basis of urban per capita GDP, in thousand US Dollars) of Western European cities is roughly comparable with that of North American and Australasian cities and that of Asian cities. However, this level of wealth is considerably lower in Eastern European, African and South American cities as it is in other Asian cities (Table 1 and Figure 1).

Figure 1. Average indicators of urban structure and the economic context



## 2.2. The characteristics of the transport system

The characteristics of the transport system of the studied cities have been described by means road supply indicators (total length of the urban road system and parking capacity) and PT supply indicators (length of routes and PT investment levels). If we observe the price of fuel and the cost of using the various modes of transport, we can refine our city profiles.

The total length of roads (measured in metres per 1,000 inhabitants) is, on average, twice as high in North American cities as in Western European cities and Asian metropolises (Table 1 and Figure 2). This ranking is replicated when we look at city centre parking supply (expressed in terms of the number of parking spaces per 1,000 jobs in the CBD (Central Business District)). On the other hand, the level of investment in PT (the percentage of urban GDP that is invested in PT) is twice as high in Western European cities and Asian metropolises as in North American and Australasian cities. In fact, PT infrastructure supply, in terms of metres of PT route per 1,000 inhabitants, is twice as high in the first group of cities than in the second.

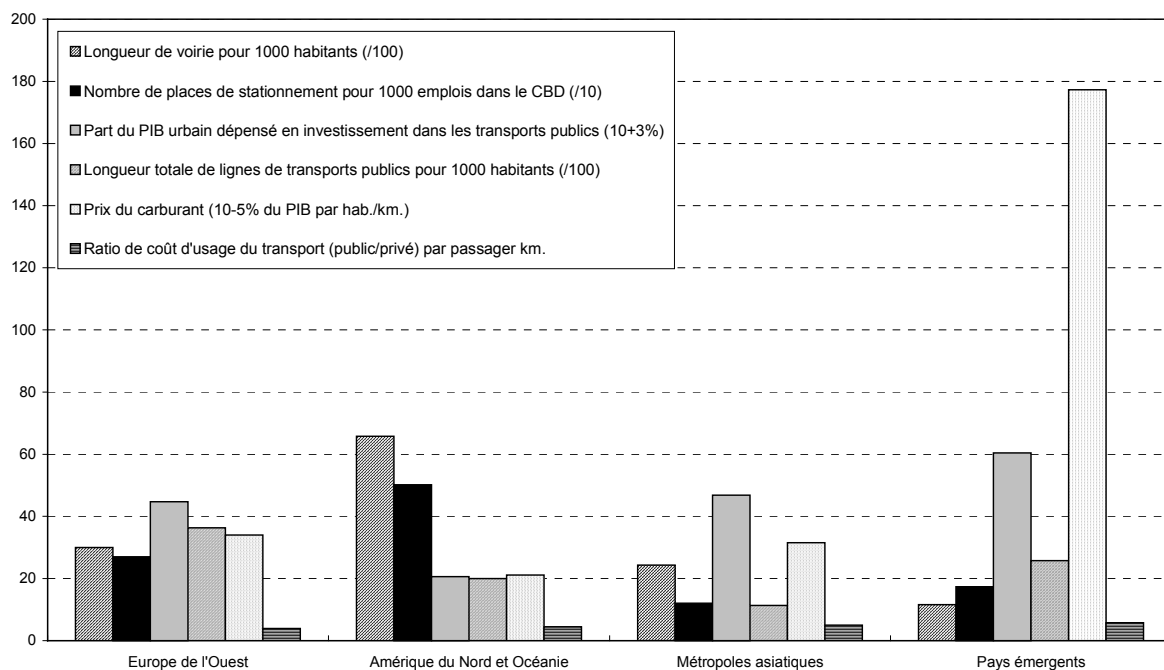
In the cities of developing countries, although PT infrastructure supply is replacing road transport supply, the levels of both are very much lower than in the cities of developed countries<sup>2</sup>.

On average, the cost of fuel is about one and a half times higher in Western European cities and Asian metropolises than in North American and Australasian cities (Table 1 and Figure 2). The difference is even more marked with respect to the cities of developing countries (a ratio of 1 to 20 for South American cities in

<sup>2</sup> In this article, the cities of North America and Australasia, Western Europe and Asian metropolises are considered as belonging to “developed countries”. Then other cities are considered to belong to “developing countries”.

comparison with North American cities). At the same time, the average cost of a car trip is by far the highest in the cities of developing countries. However, the cost of car trips is at its lowest in North American and Australasian cities. The position of West European cities and Asian metropolises is intermediate, although resembling the North American situation fairly closely. With regard to this point, a clearer distinction should be made between the situation in developed countries and that in developing countries. The disparity between North American and Australasian cities and Western European cities nevertheless seems to be significant enough to justify defining two relatively homogeneous city profiles for developed countries. However, the difference between the cities of developing countries and those of developed countries is still apparent if we observe the average cost of a PT trip. This is generally higher in developing countries than in developed countries, except for Eastern European cities where it is lower. Within developed countries, the highest average cost of PT use is observed in the Asian metropolises which, exceptionally, are marked out from the group of Western European cities where generally speaking this cost is lower than in North American cities.

Figure 2. Average value of the indicators that describe transport systems



An examination of the characteristics of the transport system confirms the conclusion we have reached with regard to urban structure. There is an obvious difference between North American and Australasian cities with low population densities and a transport system with a large amount of road infrastructure and less PT infrastructure and West European cities and Asian metropolises with high population densities, a more modest level of road infrastructure supply and a larger supply of PT infrastructure. The profile of the other cities in the sample is extremely heterogeneous.

In order to refine the homogeneous city profiles by including indicators that characterize urban transport systems, it is necessary to examine travel practices. To do this, we have observed the number of trips made per person, the distances covered, the modal shares and travel time budget.

### **2.3. Travel practices**

The modal share of PT is measured by the ratio between the number of PT trips and the total number of mechanical mode trips (Table 1 and Figure 3). Observing the relative shares of the mechanized modes allows us to distinguish between cities where travel is dominated by the car and those where PT trips play a larger role. The great majority of trips in North American and Australasian cities are made by car (93% of trips). As a consequence, the modal share of PT is very low in these cities. In West European cities, the modal share of PT is considerably higher (25%) in spite of the fact that a large proportion of mechanized trips are made by car (68%). However, the modal share of PT in Asian metropolises remains high (42%). Last, in the cities of developing countries, the market share of PT exhibits a particularly high degree of dispersion (varying from 39% in the other Asian cities to 61% in Eastern European cities).

The daily distance covered exceeds 40 km in North American and Australasian cities (Table 1 and Figure 3). It is almost half this figure in Asian metropolises and Western European cities (respectively 21.4 and 22.5 km). With regard to this measure, developing cities again exhibit a particularly high degree of dispersion. The same ranking is replicated for average journey distance (11 km in North American and Australasian cities, 9 km in Asian metropolises and 8 km in Western European cities) and the total distance covered in a home to work trip (Table 1 and Figure 3). The difference between the city profiles increases precisely when we make the comparison between the home to work distance and the average trip distance for all purposes. In fact, the average home to work trip is one and half times longer than the average trip for all purposes in North American metropolises, but only one third and one fifth higher in Asian metropolises and Western European cities respectively. Therefore, observations of travel distances shows that there is a genuine difference in the spatial consumption of travel. On the one hand, North American and Australasian travel exhibits extensive spatial consumption and on the other the spatial consumption of travel within Asian and Western European metropolises appears to be contained. We shall therefore refer to this consumption as intensive.

The propensity to travel is greater in North American and Australasian cities (3.6 trips per person per day) than in Western European cities and Asian metropolises (respectively 2.9 and 2.7 trips per person per day). This tendency is even more marked if we consider private mode trips (Table 1 and Figure 4). It is accentuated when motorized travel time budgets (TTB) are considered. The average TTB is less than 45 minutes in Western European cities and Asian metropolises but rises to 55 minutes in North American and Australasian cities.



Figure 3. Average values of the indicators that describe travel practices (Part 1)

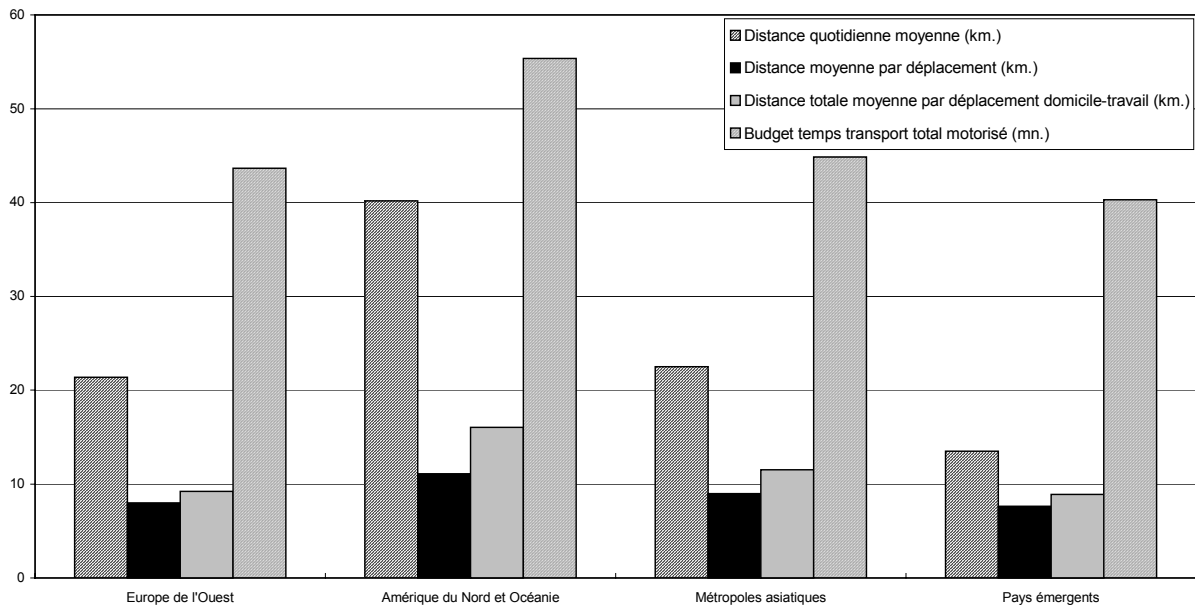
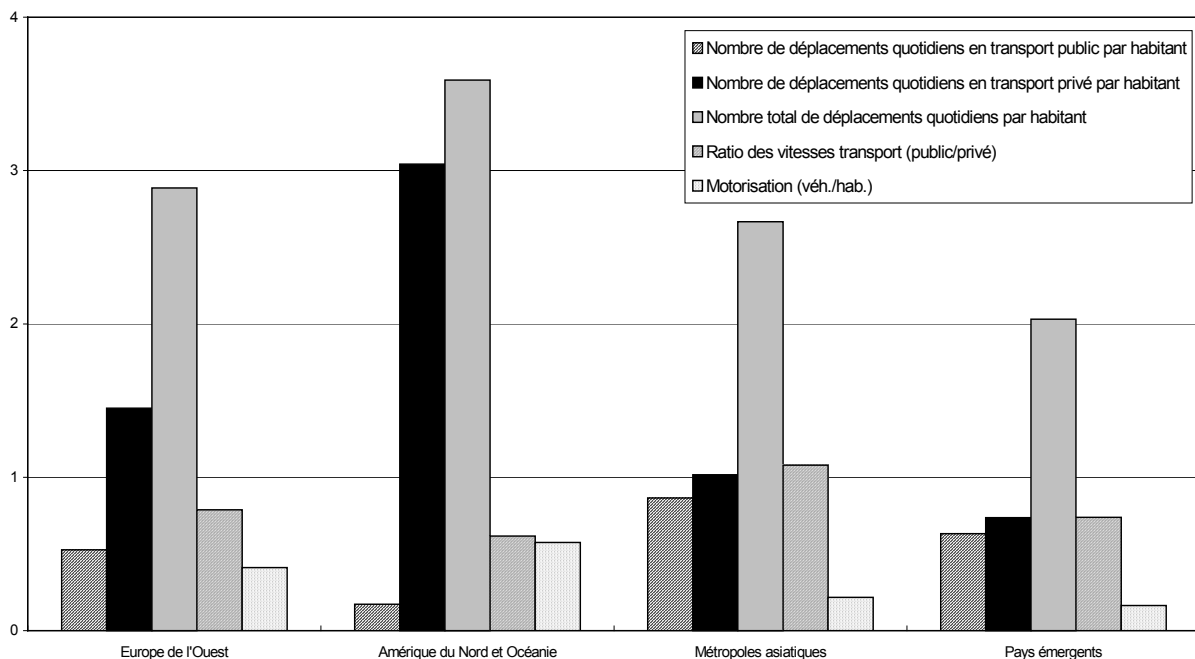


Figure 4. Average values of the indicators that describe travel practices (Part 2)



We are now able to define clearly distinct city profiles. First, North American and Australasian cities exhibit a combination of low PT market shares, low urban densities, high lengths of urban road, low fuel cost, large travel distances and high travel time budgets. On the other hand, Western European cities exhibit a combination of high PT modal shares, high urban densities, long total lengths of road, high fuel cost, and relatively low travel distances and travel time budgets. Asian

metropolises exhibit high modal shares, as well as relatively high travel distances and travel time budgets. Last, the cities of developing countries in general exhibit a combination of high PT modal shares, relatively low travel distances and travel time budgets, high trip cost<sup>3</sup> and low urban wealth.

We can thus clearly perceive two homogeneous groups of cities with regard to the studied indicators. The first group, consisting of Western European cities and Asian metropolises, is characterized by an *intensive* profile: high urban density, moderate road supply, large PT supply, modal split which provides PT with an important role. This intensive urban model applies to cities in which the consumption of space and time remains relatively stable. On the other hand, the group of North American and Australasian cities has an *extensive profile*: it exhibits low urban density, high road supply, low PT supply, and modal split which is very much in favour of the car. This extensive model applies to cities which develop by means of an extension of the consumption of space and time.

Last, the characteristics of the cities of developing countries are too heterogeneous to allow us to develop a representative profile.

### **3. An explanatory model for the determinants of PT market share**

#### **3.1. The determinants of PT market share**

Now that we have described two relatively homogeneous profiles of cities which reflect distinct organizations of urban transport systems in developed countries, it remains for us to identify the role of a number of determinants which can explain PT market share. Initially we shall examine those determinants that relate to urban structure and the economic context. Then we shall observe the links between PT market share and the characteristics of the transport system. Last, we shall examine the links between PT market share and the characteristics of travel. For each of these links, we shall merely describe the position of typical cities with the intensive and extensive profiles. The highly heterogeneous nature of the cities of developing countries means that it is impossible to identify sufficiently marked tendencies that apply to all of them.

##### *3.1.1. The determinants that relate to urban structure and the economic context.*

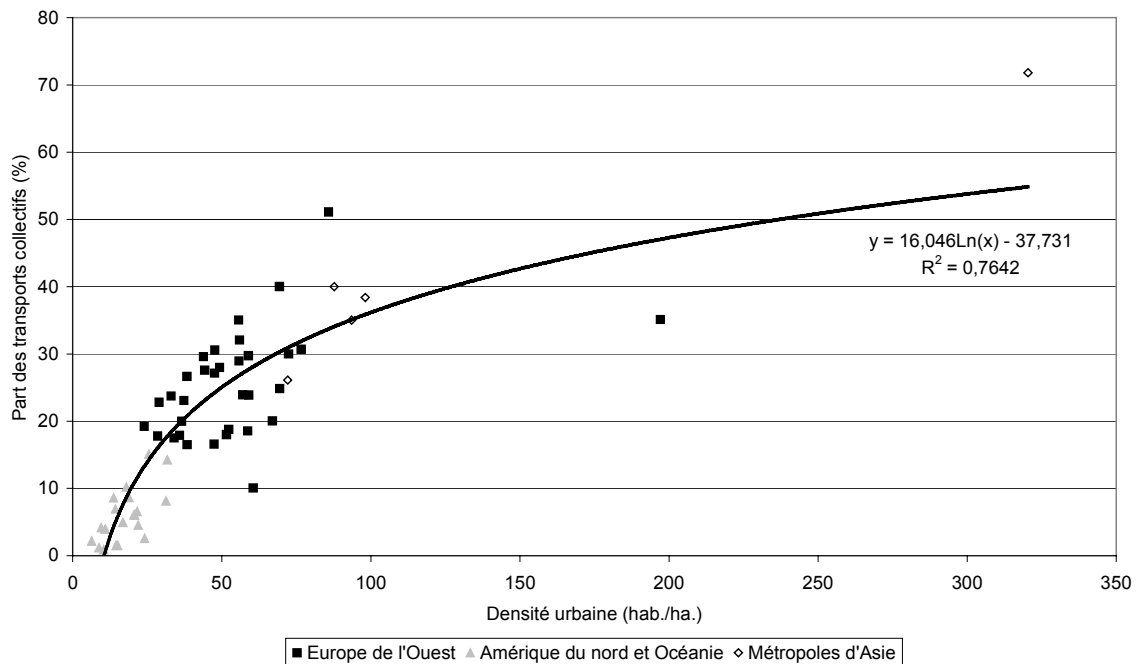
From an analysis of densities we can see that PT is only efficient in relatively dense areas which permit the massification of flows. On the other hand, when the population or jobs are dispersed within the city, the performance of PT deteriorates. With regard to the impact of population density, Figure 5 shows that cities with the intensive profile (Western European and Asian cities) occupy markedly different positions from cities with the extensive profile (North America and Australasia). The latter exhibit a combination of low population densities and low PT market share. In contrast, the cities with the intensive profile exhibit high population densities and higher PT market share. This illustrates the idea put forward by Foucher (1999), namely that there is a level of density which enables the PT system to be

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<sup>3</sup> In these cities, the high level of public transport trip making can be interpreted not as the result of a transport policy choice but rather as a constraint imposed by the level of economic development. In addition, the cost of car use is too high in these cities to become general.

competitive. However, the low presence of PT in the cities with the extensive profile is not only explained by geo-demographic constraints but also by an urban transport policy which very much favours the car. Overall, the observed link between urban density and PT market share is close to that described by Kenworthy and Laube (1999).

Figure 5. PT market share and population density

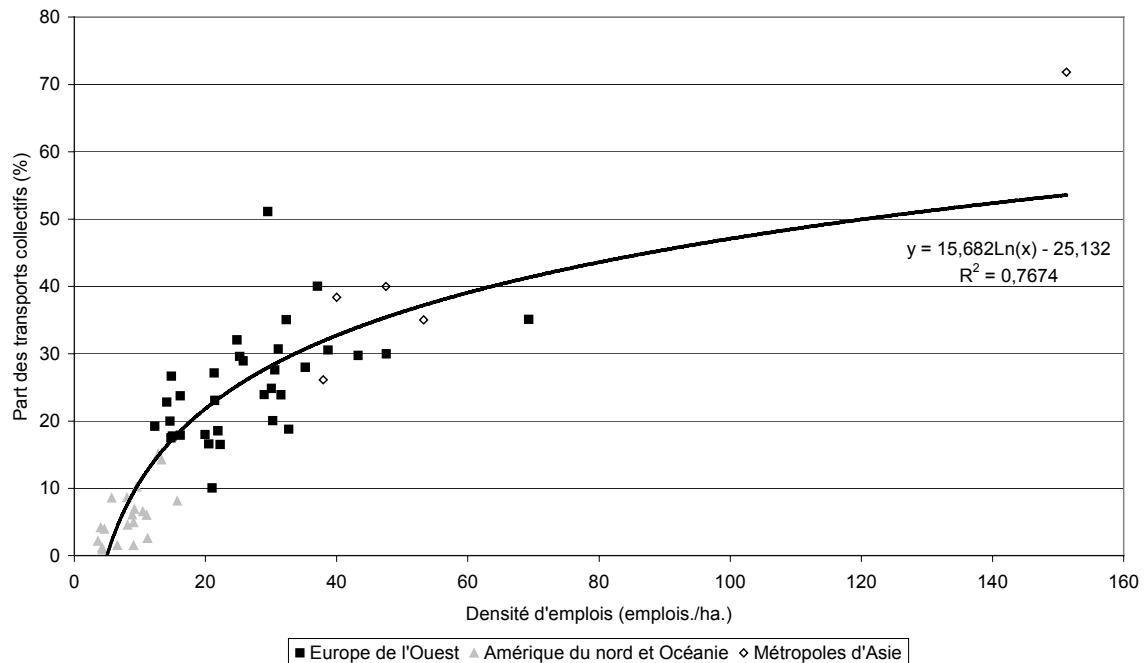


Job density within the city has the same kind of effect on PT market share as population density (Figure 6). When jobs are dispersed within the urban area it is more difficult for a PT system to be competitive. For example, cities with an extensive profile have job densities that are too low to sustain a competitive PT system. On the other hand, PT market share in cities with an intensive profile increase with job density.

While PT market share seems to be linked to urban density, there is however no significant link between PT market share and the urban population or the size of the urban area. Likewise, we have not been able to show any link between PT market share and the percentage of jobs that are centrally located. Furthermore, if we compare the cities with the intensive profile with the cities with the extensive profile, we can see that the urban GDP has practically no influence on PT market share in developed countries. It is not possible to distinguish between cities on the basis of

urban GDP. Consequently, local economic wealth is unable to explain the differences in modal split between these two groups <sup>4</sup>.

Figure 6. PT market share and job density

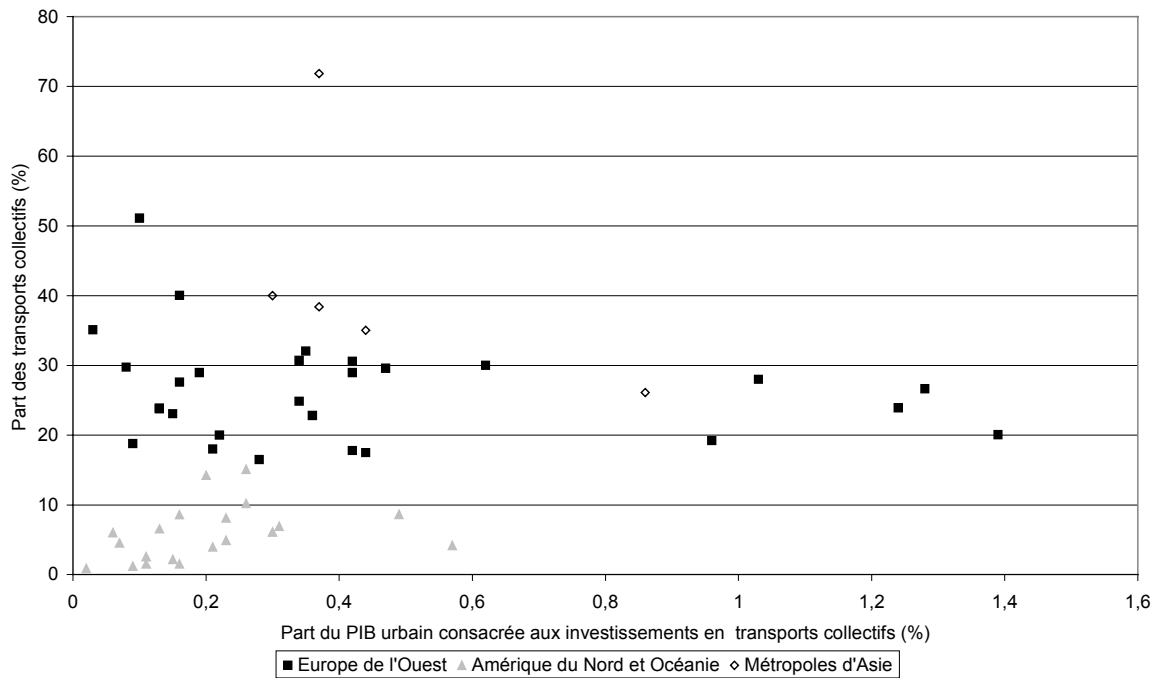


### 3.1.2. The determinants that relate to the transport system

There are a number of ways in which urban transport policy can influence the development of the transport system. One classical economic measure, the percentage of urban GDP which is invested, can be used as an indicator that reveals the direction of the city's transport policy. There is however no strong trend that applies to all the cities in developed countries. The cities with an extensive profile are nevertheless remarkable in that they exhibit both low PT market shares and very low investment levels (Figure 7). Cities with an intensive profile generally have higher investment and a PT system with a greater market share.

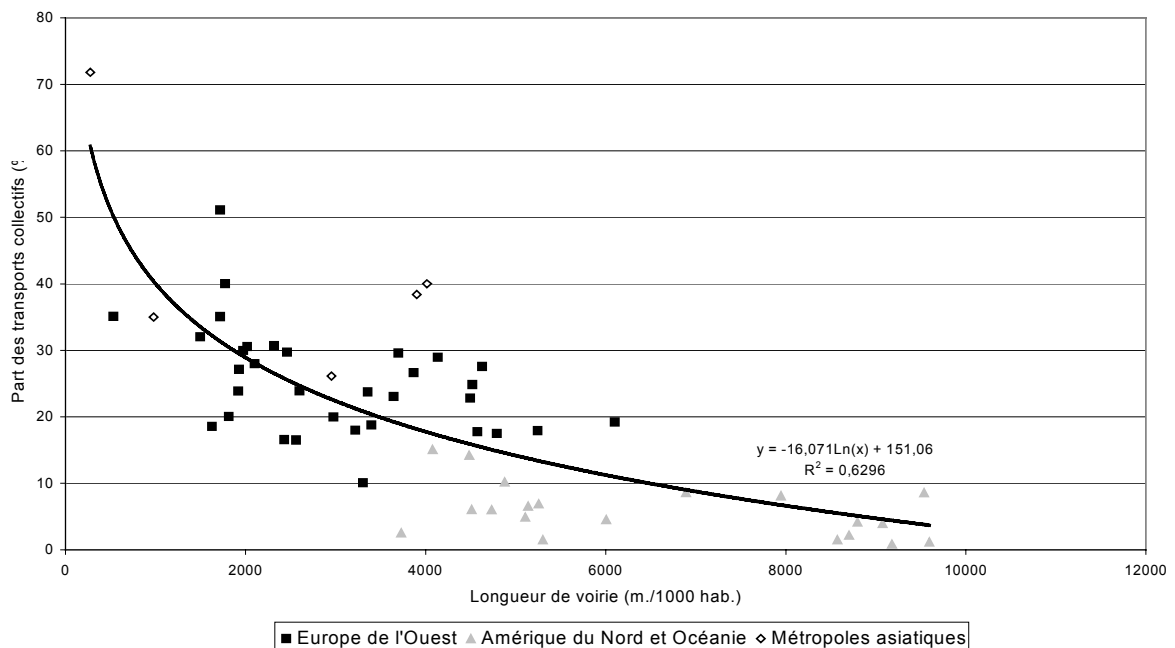
<sup>4</sup> However, if we look at all the cities in the database, there is a strong inverse link between urban GDP and public transport market share. This trend reveals a contrast between industrialized and developing countries, where public transport market share remains high because car ownership is confined to wealthier groups. The indicator of economic wealth seems to explain a major part of the relative position of developing countries with respect to developed countries. This leads us to presume that there is a level of GDP beyond which the use of public transport is no longer an obligation but a choice. This too echoes Kenworthy and Laube's findings (1999), namely that at an equivalent level of GDP there is no economic gain associated with an orientation of the transport system towards the car. Consequently, dependency on the car is not the result of the city's economic growth but the result of interaction with other variables.

Figure 7. PT market share and percentage of urban GDP invested in PT



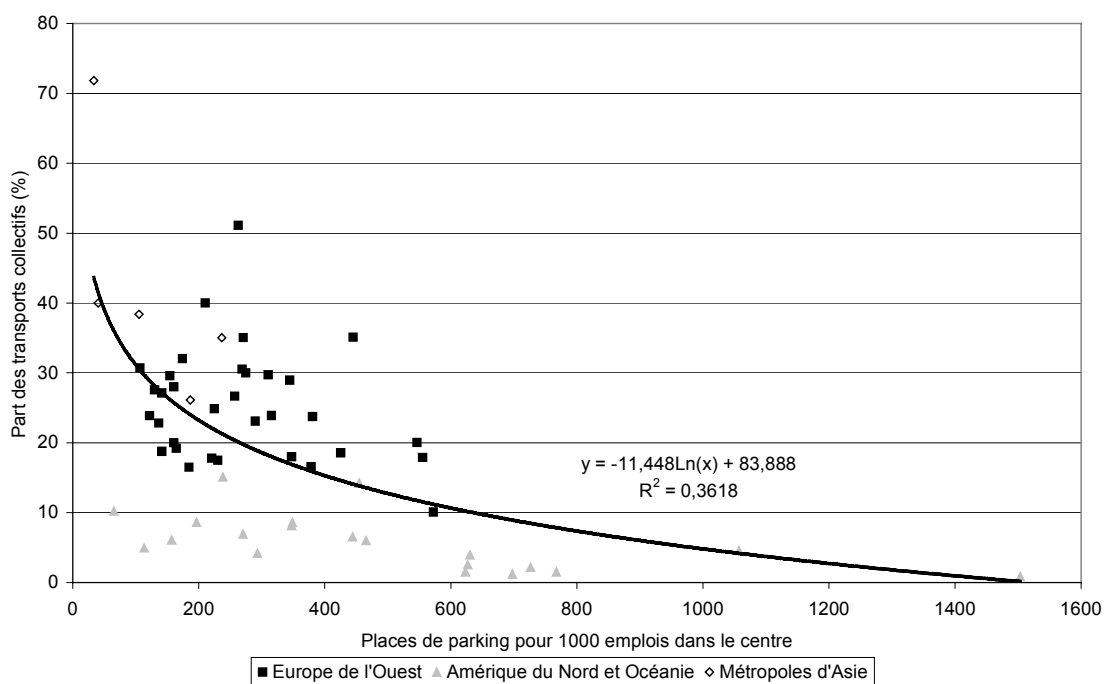
There appears to be an inverse link between PT market share and the total length of the road system (Figure 8). Here again we can distinguish between cities with the intensive profile and those with the extensive profile. On average, PT market share is higher in the first than in the second and road supply is lower. No significant link can be shown however between PT market share and the length of PT routes.

Figure 8. PT market share and total length of the road system



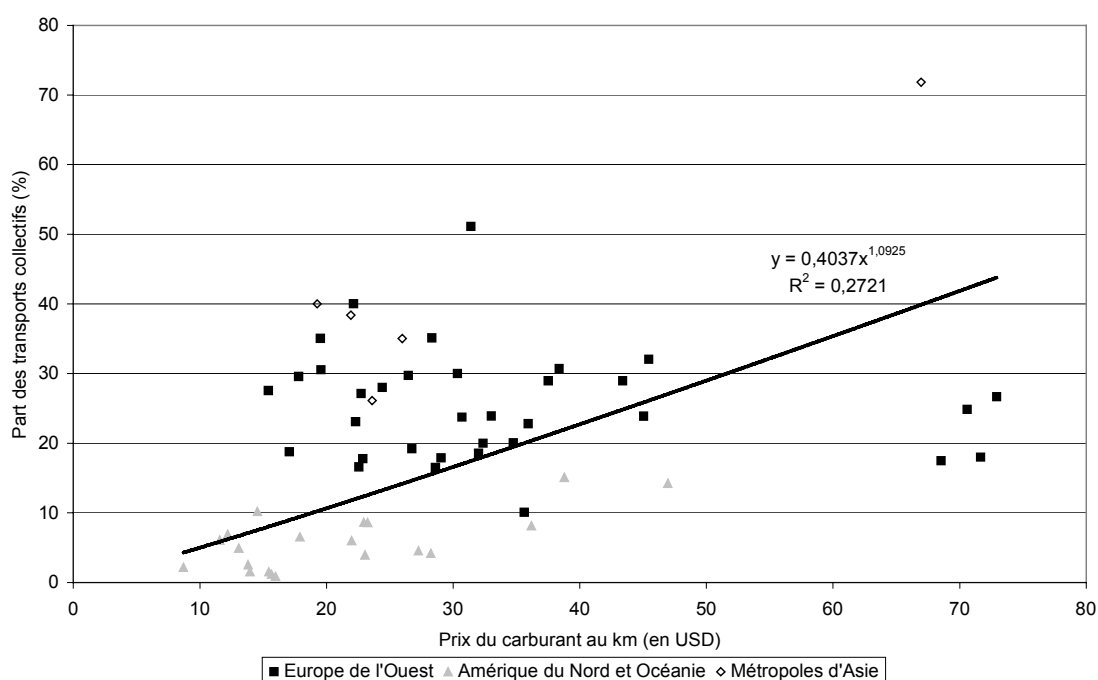
The number of centrally located parking spaces per 1,000 jobs has an adverse effect on PT market share (Figure 9). In the cities with an extensive profile, despite the low concentration of jobs in the city centre, parking policy is clearly extensive and appears to act in favour of private travel modes. However, in cities with an intensive profile, jobs are concentrated in the centre but parking supply is relatively low. This may be explained by the scarcity of urban space as a result of high density, and can also be linked with a deliberate policy to limit parking at the workplace (CETUR, 1994).

*Figure 9. PT market share and centrally located parking spaces*



There is a strong positive link between PT market share and the cost of fuel (Figure 10). The latter plays a role in modal choice as this is a direct cost of motorized private modes. The price of fuel has a direct negative effect on private transport demand. On the other hand, the higher the price of fuel the higher the market share of PT. Fuel is obviously more expensive in Western European cities than in those cities with an extensive profile. Fuel prices therefore have a very marked impact on PT market share.

Figure 10. PT market share and the price of fuel



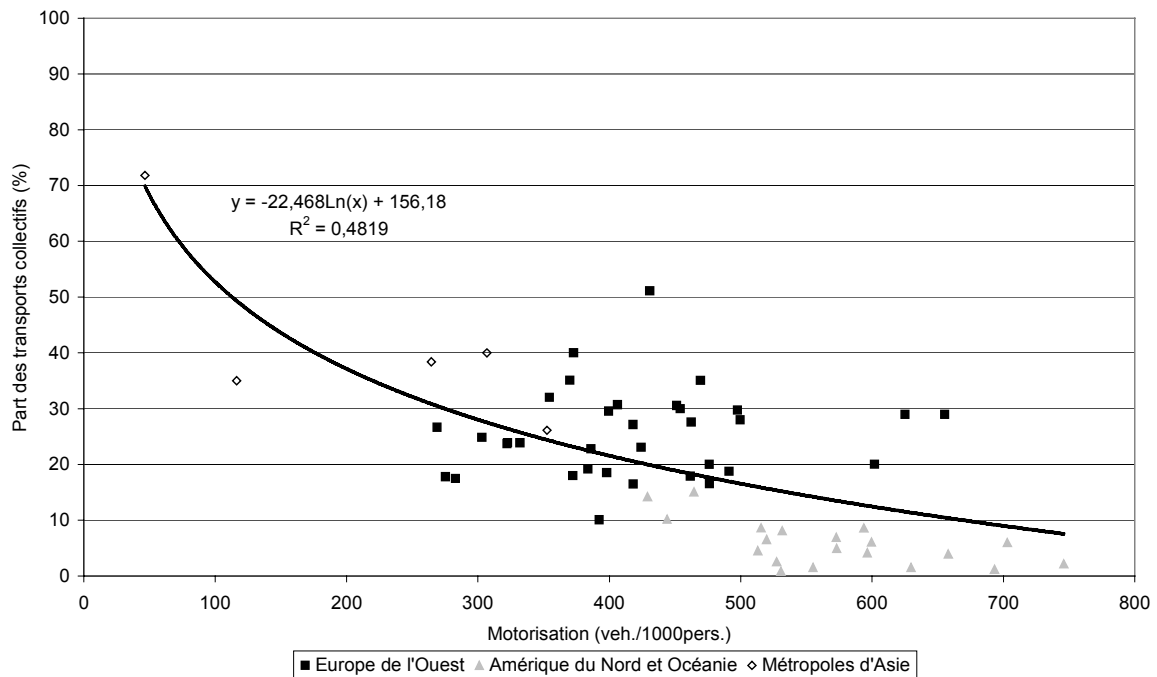
Last, we need to examine the ratio between the cost of private and public transport modes. This quotient is determined on the basis of the per km cost of using each mode. PT market share decreases rapidly when the cost of PT grows in relationship to that of private transport. The price ratios in North America and Western Europe however appear to be similar. From the point of view of per km price, the two transport modes are similar in the intensive and extensive groups. In contrast to the situation as regards fuel, the ratio of per km prices is unable to explain the relative positions of the two groups of cities.

### 3.1.3. The determinants that relate to travel practices

An inverse functional relationship links car ownership (number of vehicles per 1,000 persons) and PT market share (Figure 11). There is still a clear difference in the position of cities, on one hand the cities with the extensive profile with high car ownership combined with low PT market share and on the other the cities with the intensive profile with low rates of car ownership and higher PT market share.



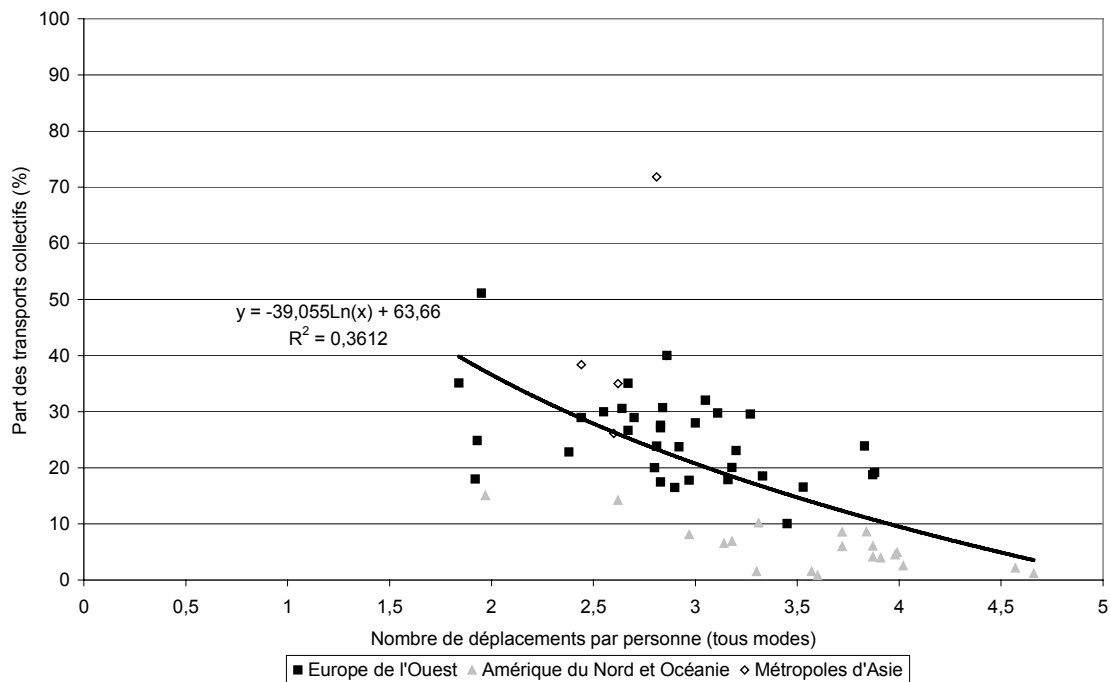
Figure 11. PT market share and car ownership



No sufficiently strong functional relationship links daily average distance travelled and PT market share. We can simply observe that average daily travel distances are higher in the cities with the extensive profile as a result of high urban sprawl and that this is combined with low PT market shares. This reflects the difficulty for urban PT to be competitive over long distances. Likewise, there is no significant link between PT market share and average trip distance.

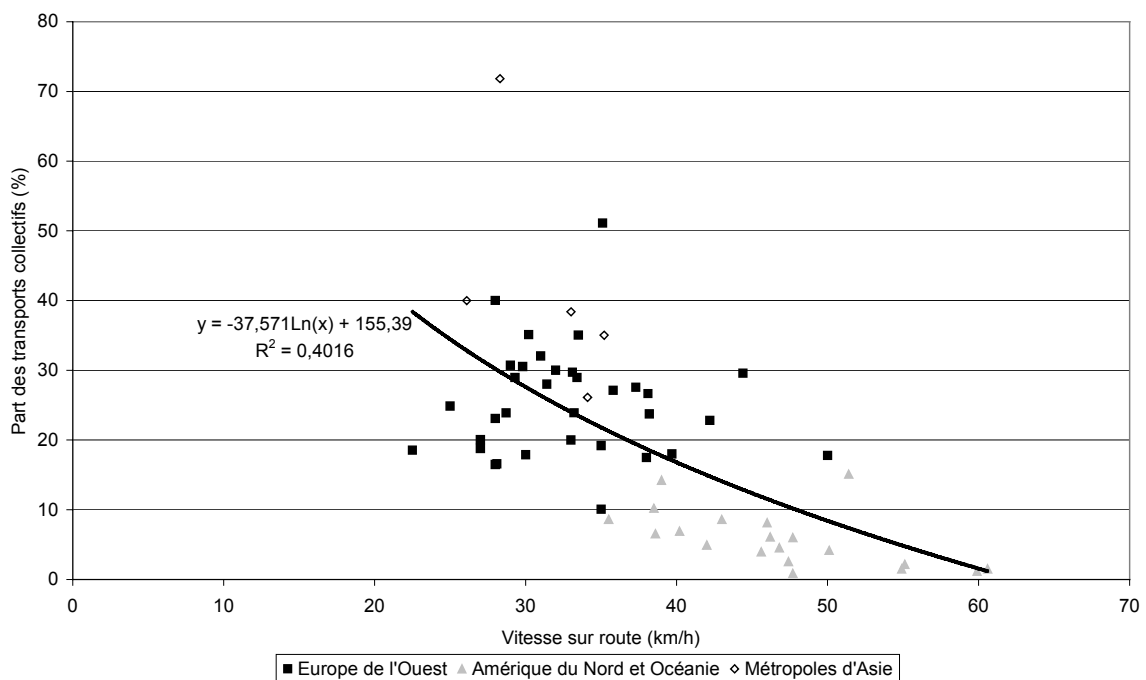
A negative functional relationship can be observed between PT modal share and the number of trips made per person (Figure 12). Total travel levels are higher in cities with the extensive profile and most of this travel is by car (low PT market share). In the case of the cities with the intensive profile, the increase in the number of trips is combined with a reduction in PT market share.

Figure 12. PT market share and the number of trips per person made by all modes



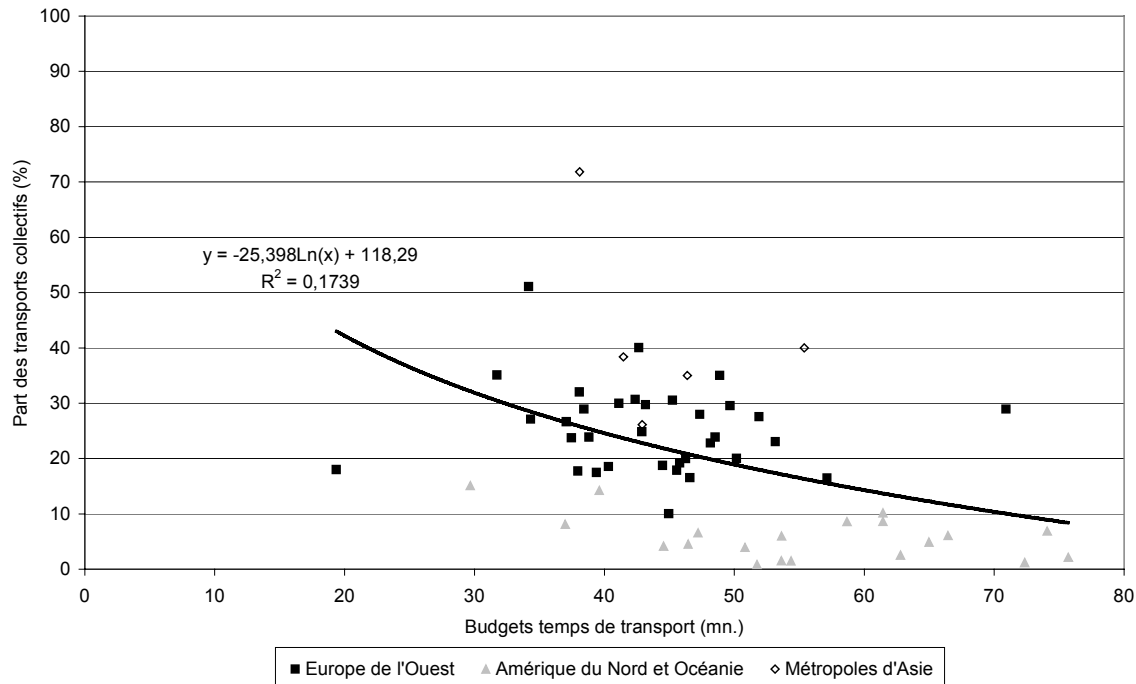
There is a negative relationship between PT market share and speed on the roads (Figure 13). The cities with the extensive profile have both the highest road travel speeds and the lowest PT market shares, in contrast with the profile of cities with the intensive profile. Likewise, private mode speeds are markedly higher than PT speeds in the cities with the extensive profile.

Figure 13. PT market share and speed on the roads



Last, the travel time budget (TTB) appears to influence PT market share. Figure 14 reveals that cities with the extensive profile have a higher temporal expenditure. This contrast between the temporal consumption of cities with the two profiles has been analyzed by Joly (2003). The profile of cities with the intensive model shows that the TTB of cities with the intensive profile is linked to the presence of relatively competitive PT. This analysis relates urban organization, transport system and travel practices and reveals the contrast between cities in terms of the management of spatial and temporal resources. It also leads us to question the validity of the hypothesis that TTBs are stable (a conjecture made by Zahavi, 1979).

Figure 14. PT market share and travel time budget



### 3.2. An econometric explanatory model

No unidimensional approach is able to explain modal split. The dependencies we have shown above suggest, however, that we can explore some relationships with multiple explanatory variables which are statistically significant. In this part of our study, we shall only consider cities in developed countries (60 in all)<sup>5</sup>.

#### 3.2.1. Econometric analysis based on 5 essential variables

The objective of an econometric approach is to verify the simultaneous statistical validity of the relationships that have been revealed above. In the first model we have applied, the five key variables identified by Vivier (2001) and which have been found previously by the single correlation study have been tested:

- The percentage of metropolitan GDP spent on PT investment;
- The price of fuel;
- The ratio of public versus private transport total cost;
- The ratio public versus private transport speeds;
- The number of parking spaces per 1,000 CBD jobs.

<sup>5</sup> The cities of developing countries have been excluded because of the high degree of dispersion which they exhibit compared to the other cities and the uncertainty associated with their data. The transport policy implications of the model could only be applied in these cities with extreme difficulty.

We have estimated a log-log relationship between market share and the indicators that describe these variables. While it is certainly true that the linear form is not the best method for estimating bounded variables, the previous results have given us the impression that a log-log model is appropriate for the data. The model, with its estimated coefficients is as follows:

$$\ln(PTshare) = 1.26 + 0.21 \times \ln(\%GDP) + 1.35 \times \ln(ratio\_speed) + 0.83 \times \ln(price\_fuel) - 0.36 \times \ln(park\_CBD) - 0.44 \times \ln(ratio\_price) \quad (1)$$

The results for the estimated model are encouraging (Table 2, column 2) while variations in the 5 variables we have used explain 73% of variations in PT market share ( $R^2 = 0.7371$  and adjusted  $R^2 = 0.7113$ ). The significance of these variables has been confirmed at the 5% confidence limit by Fisher's and Student's tests. Only the constant fails to achieve significance at this confidence level. However, this coefficient has no economic meaning in that it represents the PT market share for a city in which the value of the 5 variables in the model is equal to unity. The signs of the coefficients that measure the impact of each of the variables in the model are all compatible with the starting hypotheses. The percentage of urban GDP invested in PT, the price of fuel and the ratio between the speeds have a positive effect on PT market share. The price ratio between the different modes has a negative effect. It is nevertheless difficult to compare the order of magnitude of the coefficients obtained in order to determine the relative power of one of these levers compared with the other variables<sup>6</sup>.

In order to test the discriminating power of the profiles we have described above, we have introduced the dichotomous *profile* variable into the model. This identifies the cities with an intensive profile. The introduction of this variable significantly improves the explanatory power of the model (Table 2, Column 3). The adjusted  $R^2$  value rises from 0.71 to 0.85. The coefficient for the profile is relatively significant and means that PT market share increases by 0.35 percentage points<sup>7</sup> in the cities with the intensive profile.

However, while the impact of this profile variable is relatively small, its level of significance reveals shortcomings in the first model. The variables contained in the model are unable to explain the difference between the two city profiles. We then considered the variables in the model with the profile in order to identify the effects which are specific to the profiles. So as to retain only the most influential of the 11 variables contained in this new model<sup>8</sup> and exclude those which repeat the same information, the stepwise econometric technique has been applied. In this method, variables are included or excluded on the basis of their level of significance in the regression. This third model reveals that fuel price and parking supply have specific effects in the case of the intensive profile (Table 2, column 4). The coefficient of determination  $R^2$  is equal to 0.91 (adjusted  $R^2 = 0.89$ ). The signs of the coefficients are identical to those in the previous models. The coefficients that apply to the two groups as a whole are once again similar. The combined effects indicate a reduction

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<sup>6</sup> The values taken on by these variables are not comparable. When the ratio between the prices is between 0.01 and 0.07, the number of centrally located parking spaces is between 2.5 and 1.883. Consequently, the coefficients produced are disproportionate.

<sup>7</sup>  $e^{-1.06} = 0.346$ , because the profile is a binary variable (which cannot be expressed as a logarithm), we need to consider the exponential of the coefficient which is displayed in Table 2.

<sup>8</sup> Introducing the profile into the regression doubles the number of explanatory variables which require a constant.

in the positive effect of the price of fuel and an increase in the negative effect of parking supply with respect to PT market share.

The transport policy instruments identified above have therefore all been validated from the econometric standpoint. PT market share seems to be linked to the use of these five instruments. The regressions we have performed confirmed that investment, fuel price and the ratio between the speeds of the different transport modes have a positive effect on PT market share. In addition, they highlight the negative effect of the price ratio between different modes and the amount of parking in relation to the number of centrally located jobs.

The existence of two profiles of urban organization seems to be confirmed and these profiles influence the scale of the effects of the transport policy instruments we have considered. When we combine different variables with the profile it is apparent that some variables have a less pronounced effect in cities with the intensive profile. Thus, when the measures implemented to encourage PT use are on the same scale, PT market share gains appear to be greater in cities with the extensive profile than in cities with the intensive profile. The marginal productivity of measures to encourage PT use therefore seems to be decreasing. This decrease in the marginal effectiveness of transport policy instruments is apparent here because the model has a logarithmic functional form rather than a simple linear form.

*Tableau 2. Results of multiple regressions of the log-log model for PT market share*

Variable en log	Régression avec 5 variables MCO simples			Régression avec la distinction binaire de profils MCO simples			Régression avec les croisements : profil – variables Sélection <i>stepwise</i>		
	Coefficient	Ecart type	t	Coefficient	Ecart type	t	Coefficient	Ecart type	t
Constante	1.26	0.97	1.30	4.02	0.79	5.05	2.65	0.58	4.50
Part du PIB urbain investi dans les TC	0.21	0.09	2.15	0.15	0.07	2.17	-	-	-
Rapport des vitesses des TC et des modes privés motorisés	1.35	0.35	3.85	0.53*	0.28	1.93*	0.45	0.22	1.99
Prix du carburant	0.83	0.15	5.31	0.41	0.13	3.34	0.88	0.14	6.05
Rapport des prix des TC et des modes privés motorisés	-0.44	0.15	-2.86	-0.28	0.11	-2.52	-0.31	0.09	-3.49
Nombre de places de parking pour 1000 emplois dans le centre	-0.36	0.14	-2.59	-0.33	0.10	-3.33	-0.75	0.09	-7.99
Profil (variable binaire non en log)				-1.06	0.15	-7.04	-	-	-
Prix du carburant CROISE avec profil							-0.75	0.16	-4.66
Nombre de places de parking pour 1000 emplois dans le centre CROISE avec profil							0.60	0.09	6.75
R <sup>2</sup>		0.7371			0.8680			0.9102	
R <sup>2</sup> adj		0.7113			0.8521			0.8994	
F		28.60			54.79			84.47	

\* coefficient significatif à 10%

\*\* coefficient significatif à 15%

### 3.2.2. The variable selection process

During this process, construction of the economic model is no longer based on *a priori* selection of variables. The objective is to identify which of the variables best explain PT market share. To achieve this, we have constructed a linear model using the following variables:

- Urban density;
- Job density;
- Proportion of jobs in CBD;
- Metropolitan GDP per capita;

- Density of roads (per hectare and per person);
- Parking spaces per 1,000 CBD jobs;
- Total length of reserved PT routes per 1,000 people;
- Metro network length (per 1,000 persons and per hectare);
- Percentage of metropolitan GDP spent on PT investment;
- Percentage of metropolitan GDP spent on road investment;
- Passenger cars per 1,000 people;
- Total daily trips per capita;
- Overall average trip distance;
- Overall average distance of the journey-to-work;
- Average daily distance travelled;
- Daily travel time budget;
- Average road network speed;
- Overall average speed of PT;
- Average user cost of a car trip;
- Average user cost of a PT trip;
- Price of fuel per km;
- Ratio between the price of PT and private motorized modes;
- Ratio between the speed of PT and that of private motorized modes;
- Whether there is a metro system;
- Whether there is a train system;
- The city profile (intensive/extensive)

The fact that the model includes all the variables which appear to be linked with PT market share means that it is possible to select the most influential, thereby improving the results. Here again, we have applied a stepwise selection. In this case, three regressions have been performed: one for all 60 cities (Table 3, Column 2) and one for each city profile (Table 3, Column 3 for the intensive profile, Column 4 for the extensive profile). In the first regression, the variables have also been combined with the profile indicator. In the second, the variables have been combined with an indicator for the existence metro system and an indicator for the existence of a train system.

The differences between the three regressions are considerable. These differences suggest that city profile affects the reactivity of PT modal share. Thus, the dichotomous variables, *i.e.* city profile, presence of a metro system, presence of a train system are apparent via combined effects.

The results from the model are set out in Table 3. The relevant indicators with regard to urban structure and economic context are the percentage of centrally located jobs, the job density and the percentage of urban GDP invested in PT. These results demonstrate, for all cities, the positive effects of the central location of jobs on travel practices, in particular on the modal share of PT. This effect is reinforced by investment in PT in the case of cities with the extensive profile (this is a result of the specific type of spatial concentration that applies to jobs in North American cities). In the case of cities with the intensive profile, the level of investment does not seem to be significant, but the results do highlight the impact of the broader concept of the distribution of jobs within the city. Some characteristics of the transport system also act as determinants, for example, the length of road per 1,000 jobs, the number of parking spaces per 1,000 centrally located jobs, the ratio between the prices of different modes and the presence of a train system. These variables play a role in all cities. As one would expect, parking supply and the ratio between the price of different modes have a negative effect on PT modal share. However, the presence of a train seems to have a positive effect ( $e^{-6.29}$ ). The positive effect of road supply (0.15) can only be validated statistically at the 15% confidence level. The speeds of different modes are important variables, but in a differentiated manner. As one would expect, PT speed has a strong positive effect on PT market share in cities with the intensive profile. In contrast, the speed of road travel has a strong negative effect on PT market share in cities with the extensive profile. The modal share of PT in cities with an urban rail system or in cities with the intensive profile which have a metro system seems to be sensitive to the ratios between the speeds of different modes. However, surprisingly, the ratio between the speed of different modes combined with the presence of a metro, and the ratio between the speed of different modes combined with the presence of a train system and the profile have negative coefficients<sup>9</sup>. Last, as regards the characteristics of travel, only the travel distance has an impact on PT modal share. The average distance travelled daily, has a negative coefficient for all cities. This is what one would expect and highlights the

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<sup>9</sup> The counter-intuitive sign of this coefficient may reveal a problem in the specification of the model. There may, for example, be a relationship of reverse causality. However, the negative sign may be justified in two ways. First, the construction of metro lines in some cities may be explained by the desire to make the PT system more competitive and increase demand from a very low initial level. On the other hand, as the metro is completely unconnected with the urban road system, congestion may be reduced on the surface network, which will improve traffic flow. Two conjoint effects may result: generated car demand and a modal transfer from PT to the car.



counter-productive effect of distance and hence urban sprawl on PT's market share. It is however interesting to note that this effect does not seem to be restricted to cities with the intensive profile, where in contrast, it is the average distance per trip which reduces PT market share. The urban structure of cities with the extensive profile seems to account for the particularly strong negative effect of daily distances travelled on PT market share. However, the positive effect of average distances poses serious interpretation problems.

This multiple regression is more meaningful than the other models as it has been conducted with a larger number of variables. The goodness of fit is considerably better than for the other models (adjusted  $R^2 = 0.94$ ). It highlights the effects of such classical variables as density, parking policy, relative prices, relative speeds and distance travelled.

Even if the small number of observations means that the results of the model for different city profiles need to be interpreted with caution, they indicate that different levers affect the market share of PT depending on the city profile. This finding is summarized in Table 4.

*Table 3. Results of the multiple regressions of the log-log model for PT market share*

Variable en log	Régression sur toutes les variables Toutes les agglomérations			Régression sur toutes les variables Profil intensif			Régression sur toutes les variables Profil extensif		
	Sélection stepwise			Sélection stepwise			Sélection stepwise		
	Coefficient	Ecart-type	t	Coefficient	Ecart-type	t	Coefficient	Ecart-type	t
Constante	7.85	1.59	4.92	-0.84**	0.92	-0.91**	8.75	2.06	4.23
<b>Structure urbaine et le contexte économique</b>									
Densité d'emplois				0.40	0.05	6.97			
Proportion d'emplois dans le centre	0.30	0.06	4.38	-			0.59	0.14	4.01
Part du PIB consacrée aux investissements en TC				-			0.21	0.10	2.09
Densité d'emplois CROISE avec le profil	0.24	0.03	6.75						
<b>Système de transport</b>									
Vitesse sur le réseau routier				-			-1.35	0.52	-2.59
Vitesse des transports collectifs				0.58	0.16	3.60			
Longueur de voirie pour 1000 emplois dans le centre	0.15**	0.09	1.62**						
Nb de places de parking pour 1000 emplois dans le centre	-0.34	0.06	-5.72	-0.10*	0.05	-1.94*			
Rapport des prix des TC et des modes privés motorisés	-0.31	0.07	-4.40	-0.33	0.074	-4.43			
Coût pour l'utilisateur des TC				0.18*	0.09	2.04*			
Présence de train	-6.29	2.13	-2.95						
Rapport des vitesses CROISE avec présence métro	-0.90	0.22	-3.95	-0.26*	0.14	-1.77*	-0.72	0.26	-2.69
Rapport des vitesses CROISE avec présence métro et profil	0.46**	0.29	1.55**						
Rapport des vitesses CROISE avec présence train et profil	-0.07*	0.03	-1.88*						
Vitesse des TC CROISE avec la présence de train	0.83	0.26	3.14						
<b>Pratiques de mobilité</b>									
Distance quotidienne	-0.91	0.14	-6.23				-1.64	0.39	-4.21
Distance moyenne par déplacement				-0.19**	0.12	-1.62**	1.16*	0.58	2.01*
R <sup>2</sup>	0.96			0.83			0.92		
R <sup>2</sup> adj	0.94			0.79			0.88		
F	88.27			20.72			26.53		

\* coefficient significatif à 10%  
\*\* coefficient significatif à 15%

*Table 4. The determinants for each city profile*

	Déterminants propres au profil intensif	Déterminants propres au profil extensif
<b>Structure urbaine et contexte économique</b>	Densité d'emplois	Proportions d'emplois dans le centre Part du PIB investi en TC
<b>Système de transport</b>	Vitesse des TC Offre de stationnement dans le centre Rapport des prix des modes Rapport des vitesses CROISE avec le métro	Vitesse sur le réseau routier Rapport des vitesses Rapport des vitesses CROISE avec le métro
<b>Pratiques de mobilité</b>	Distance moyenne par déplacement	Distance quotidienne Distance moyenne par déplacement

#### **4. Conclusion**

The diversity of the cities contained in the UITP database means that extremely varied urban transport systems can be easily observed and compared. By studying these systems it should be possible to identify appropriate levers for managing urban transport demand, in particular, instruments which are compatible with the urban organization in question.

An initial descriptive analysis of urban structures and economic contexts, transport systems and travel practices has allowed us to identify distinct city profiles. Three groups of cities emerge very clearly. The first two groups consist of homogeneous city profiles that belong to developed countries: first, the intensive profile which consists of cities whose PT system is organized around a stable and limited consumption of space and time (Western European cities and Asian metropolises), second, an extensive profile which contains cities whose transport system develops by an extension of the consumption of space and time (North American and Australasian cities). The third group contains cities whose profiles are too heterogeneous for us to be able to propose valid conclusions with regard to urban transport policy (cities of developing countries).

First of all, the position of PT in cities reveals a very marked tendency in developed countries for transport systems to be organized around the car. Car ownership is nevertheless at its highest level in the cities with the extensive profile. In these cities travel speeds are generally higher and the distance covered greater. These cities also generally occupy more space and are less dense. Jobs are dispersed. The urban transport system is therefore generally clearly oriented towards the car which seems to be the most suitable transport mode for this type of urban organization. It is also the case that the urban transport policy in these cities tends to perpetuate this type of organization as there is little investment in PT compared with roads. Furthermore, parking policy, the cost of car use and the price of fuel create a set of latent conditions which favour the use of private motorized modes. In contrast, cities with the intensive profile are organized in such a way that PT remains competitive in terms of market share. This situation is, on the one hand, the result of specific features of the urban structure, but on the other hand the effect of deliberate transport policies which are aimed at achieving or maintaining balanced modal split. This initial analysis therefore highlights the distinction between "American" urban mobility and "European" urban mobility.

The second level of analysis we have applied is based on the use of classical econometric techniques. First, we have identified the conditions which are favourable to the competitiveness of PT by conducting an analysis of the determinants of PT market share in the cities of developed countries. The results were then used to test a set of transport policy levers which are intended to maintain the urban PT system in an attractive state. It was found that the spatial distribution of jobs, travel distances, the relative price of different modes, and the relative speeds of different modes play a direct role in modal choice. However, we must stress that for reasons that involve urban organization and the organization of the existing transport system, the ratio between prices plays a more important role in cities with the intensive profile, while the ratio between speeds tends to have more of an impact in cities with the extensive profile. Public decisions concerning the development of the transport system, for

example parking policy in the case of cities with the intensive profile, or investment policy for all cities, have a significant impact on modal choice.

However, this analysis has its limits, which are essentially due to the structure of the UITP database. While it is true that the data contains a wealth of information, this information consists of “combined series” which are by their nature less capable of revealing the full complexity of the determinants at work in the transport system than “time series” data.

Finally, it is noteworthy that French cities occupy an atypical position among the cities with an intensive profile. They have the lowest PT market share in the group, which can first of all be explained by the fact that the urban context is slightly less favourable (the population density, job density and percentage of centrally located jobs are on average lower). This highlights the importance of controlling urban sprawl in connection with the efficiency of PT. Furthermore, in spite of the fact that the level of investment in PT is higher than the average for cities with the intensive profile, French cities have a shorter total length of PT routes. Above all, French cities have the lowest cost for private car use and a considerably larger parking supply than is average of the cities with the intensive profile. However, with regard to this, Bresson, Dargay and Pirotte (2003) have pointed out that on average the possibility of parking at the workplace is statistically equivalent to a time-saving of 24 minutes on a trip which shows how parking supply can have as large an impact on modal choice as the availability of a car. Our analysis of the position of French cities in comparison with cities with a relatively similar profile shows how the absence of a strong policy to favour PT use, in particular via parking policy has a direct influence on modal split.

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