

Changing Daily Urban Mobility : Less or Differently ? France

Charles Raux

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FRANCE

Charles RAUX
Laboratoire d'Économie des Transports
Lyons
France

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1. INTRODUCTION

How can travel behaviour be reorganised in order to reduce the consumption of environmental resources arising from daily mobility? The term "environmental resources" is used here to refer to the nuisances daily mobility creates with regard to the quality of life, the local and global environment and the land and energy consumed by transport activities. Several options would seem to be open:

- -- Demand for transport could be shifted away from individual road vehicles towards modes that are less wasteful of resources per passenger-kilometre;
- -- The volume of emissions generated by the road transport sector could be reduced through technological and organisational innovations within this sector;
- -- Growth in the number of kilometres travelled by motor vehicles could be reduced or at least slowed.

Our discussion will focus on daily mobility in urban areas and the catchment area, i.e. the areas in which the bulk of the population lives. It should, nonetheless, be borne in mind that urban trips, in the strict sense of the term, and regional trips, which take account of the emergence of city regions, only account for a portion of the total number of passenger kilometres travelled (in France, such trips accounted for approximately half of the total in 1990, for all surface modes and air). The scale of this daily mobility in urban areas and the scope for achieving a modal shift from the car to public transport and non-motorised modes (walking and cycling), make daily mobility the ideal target for action. This report therefore does not prejudge the complementary, but probably different, measures that will need to be taken with regard to business or long-distance recreational mobility; the latter often requires use of the same infrastructure as that used for daily mobility, infrastructure that is also used for the transport of road freight.

1.1. Underlying trends

A number of underlying trends are together responsible for the decline in the share of urban transport accounted for by public transport and non-motorised modes (walking and cycling) and for the growth in car traffic in urban regions. These trends have been described elsewhere in the literature, notably in ECMT reports (Banister and Bayliss, 1992; Orfeuil, 1992; Banister, 1993; Bonnafous, 1993). The principal trends may be summarised as follows:

- -- A continuous and steady increase in household car ownership, which as yet shows no real signs of abating;
- -- The expansion of urban areas through the gradual incorporation of sparsely populated peripheral areas, an expansion aided by the car and accompanied by an increase in the length of distances travelled; the difficulty in concentrating flows means that conventional forms of public transport are uncompetitive in such areas;
- -- Changes in life-style with the increased levels of unemployment in certain regions, on the one hand, and the emergence of activities that are less constrained in both space and time, on the other (part-time or flexitime work, recreational and related activities); this has led to an increase in the volume of trips, which are less constrained in terms of both time and location and which are thus far more difficult for public transport to attract;
- -- Structural changes in the composition of the population: a decline in the relative share of young people too young to drive; increasing participation by women in the labour force resulting in greater financial independence and higher levels of car ownership; the emergence of cohorts of pensioners who have been car-users -- thus reducing still further the traditional client base for public transport.

1.2. Severe constraints

In addition, a number of major constraints, in terms of the adverse environmental impact of transport activities (Button and Rothengatter, 1995) and concern over funding and economic development, complicate the search for solutions:

- The threat of damage to the global environment, and notably concern over changes in the Earth's climate that might be triggered by Man's activities; such concerns call for an attempt to be made, simply as a precautionary measure, to reduce carbon-dioxide emissions and the use of fossil fuels in the transport sector;
- The threat of damage to the local environment from local emissions of air-borne pollutants and the noise generated by car traffic;
- The need to maintain the quality of life in the various districts in urban areas, which is associated with the preceding constraint, also requires efforts to be made to combat the decline in road safety as a result of increased car traffic, notably with regard to pedestrians and cyclists; it also requires an effort to be made to minimise the severance effects of transport infrastructure; this adds even further to the cost of underground or covered highway infrastructure developments which meet these conditions;
- The limited financial resources available to urban authorities precludes any massive development of public transport facilities or urban highways whose construction has been made more expensive by the above constraint;
- Last, but by no means least, the constraint of economic development, which during the current period of social upheaval requires access to be maintained to jobs and services at the lowest possible cost to the community; in countries with a car industry, this constraint is compounded by the development policies pursued with regard to the automobile sector, which conflicts with measures aimed at reducing household consumption of capital goods in this sector.

The combined effect of these constraints makes the search for a solution even more difficult in that, owing to the current configuration of the transport sector, any initial measures would have both a positive and a negative impact. This is because the tremendous increase in the accessibility of urban activities that has taken place over the past hundred years, initially brought about by the development of the railways, is primarily attributable to the rise of the car; maintaining this wider accessibility based on car use will, in the short term, fall foul of the environmental and financial constraints referred to above.

The various solutions available in terms of urban transport and land-use planning policy have been widely discussed in the literature, which has addressed both the efficiency of those already in use and more radical or futuristic solutions such as the use of urban road pricing to raise funding or alleviate congestion. Despite periodic enthusiasms for a given type of measure,

a consensus is now emerging that only a coherent strategy incorporating a series of co-ordinated measures is likely to prove effective (May, 1986; Jones, 1989; ECMT/OECD, 1995).

1.3. Questions

Co-ordinating the implementation of such measures, however, is far more complex than simply increasing the transport supply -- the approach adopted in the past -- since the aim is to manage forms of mobility and life styles which have conflicting priorities: conflicts between the users of different modes competing for increasingly scarce land resources; and also conflicts between the rationales of independent actors each operating in different territories (city/suburb/periphery) or in different supply systems (public transport/private transport/highways).

Yet daily mobility is primarily the result of individual members of social groups superimposing their programmes of activities in both time and space. The criteria used by these individuals to determine the location of their activities or the time at which they travel largely ignores the above institutional demarcations. This shows how great a need there is for a coherent approach and, by the same token, the extent to which institutional fragmentation can completely obviate the effectiveness of a given transport or urban planning policy measure.

The degree to which the car has revolutionised life in the developed countries since the turn of the century puts the problems that a reduction in daily mobility would pose even more starkly into perspective. The car has profoundly changed the way in which the inhabitants of these countries relate to each other in both time and space. The scale and apparently irreversible nature of this change should encourage us to be more modest about our ability to steer it into a more environmentally-friendly direction.

This report is based on the conviction that it nonetheless remains possible to change daily mobility behaviour within the framework of the constraints outlined above. This change will need to be brought about by measures aimed at both supply and demand. We would like to make our own modest contribution to the debate over the factors determining the effectiveness of measures currently being implemented or proposed in response to the challenges outlined above. This analysis will be conducted in the light of recent work and will draw on the insights provided by comparisons of differing historical, political and cultural contexts. In our opinion, there are five major questions

which need to be answered with regard to the different constraints described above. The first two questions have been approached from the standpoint of supply, the last three from that of demand:

1) Would increasing supply in the road sector, by charging tolls on motorists who benefit directly from the road infrastructure, reduce emissions of pollutants by improving traffic fluidity, while at the same time satisfy the funding constraint?
2) Is there a way to improve the provision of public transport, at a relatively low cost, which would encourage a growing share of car-users to change their mode of travel?
3) Are incentives to encourage car-sharing an appropriate response?
4) Under what conditions are instruments for charging for car use, and notably tolls to control traffic flows or relieve congestion, effective?
5) What can be expected from the urban planning policies?

2. NEW ROADS FUNDED BY TOLLS: IS IT POSSIBLE TO SELL SUSTAINABLE FLUIDITY?

It might seem irrelevant to approach the issue of increasing the road supply by charging tolls on its direct beneficiaries as part of a discussion on how to reduce the number of trips made by car. Many countries are studying or have recently introduced private concession arrangements for urban road infrastructure projects, whose construction and maintenance costs are covered by the tolls levied on the users of that infrastructure. There is widespread support for arrangements of this type in that they allow the limits placed on public funding to be circumvented through the use of private capital and because the use of tolls is more readily acceptable to the public since the service is new. This issue should certainly be examined, therefore, because it is not entirely unrelated to the regulation of future mobility, on the one hand and to congestion and the increased pollutant emissions and energy consumption it generates compared with fluid traffic conditions, on the other.

According to some estimates (Morcheoine *et al.*, 1994), driving under very slow, as opposed to fluid, conditions increases the volume of CO_2, CO and particulate emissions by a factor of 3 or 4 and, while NO_x emissions are slightly lower, also results in higher fuel consumption.

The conclusion we could draw from this is that, all things being equal, any measure aimed at reducing road congestion is likely to improve the local environmental efficiency of car trips. This latter argument is therefore partly used to justify the construction of new expressways in urban areas.

2.1. Induced traffic in the road network

The problem, in fact, lies in the "all things being equal" assumption, which treats the impact of construction of a new road link as an isolated and static phenomenon. Any new road link, however, is bound to have an impact both on the trend change in travel patterns over time and on the network of which it is a part.

The concept of "induced traffic" in the public transport sector, providing a major share of the new clientele attracted by an improved transport facility, is by now widely recognised. Induced traffic includes not only the additional trips made by those who already travelled by public transport, but also trips by new users -- trips that would not have been made previously by any mode. The similar effect created by any increase in road capacity appears to be less well accepted. The construction of new highways has traditionally been regarded as a response to trend growth in traffic levels, on the one hand and the desire to redirect road traffic flows in densely travelled urban areas towards peripheral urban locations, on the other. It is difficult to prove the existence of induced traffic in view of the large number of factors which, in addition to the increase in capacity (by which it is also driven), may be involved in the growth in such road-based mobility, i.e. changes in life-style, spatial dispersion of activities, etc.

It is only very slowly that certain governmental institutions in Europe are starting to realise that the commissioning of new roads would generate even more traffic, over and above the trend increase. Forecasting models have taken even longer to take account of this fact, in that it is no longer enough to forecast the allocation of traffic to networks on the basis of fixed origin-destination matrices: allowance must now be made for the fact that matrices may vary over time as a result of changes in the provision of facilities.

The construction of new motorway links might therefore be viewed as simply staving off the inevitable in an attempt to buy a little more time before the road network is eventually saturated, with the lead constantly diminishing as the level of induced traffic in the network rises. In this case, congestion might be seen as the natural state of balance in an urban road network [see also the

discussion of Wardrop's third principle by Holden (1989)]. It might thus constitute a means of regulating demand for urban travel, but one that is probably inefficient in terms of both the economics of urban activities and the environmental performance of the transport system.

There do not appear to be any firm grounds for this assertion, however, since it rests on a fairly loose definition of what constitutes congestion. While congestion is not germane to our discussion here, and is so difficult to measure that it cannot be properly defined anyway, it is worth recalling two points that might help inform our debate.

2.2. The paradoxical stability of average trip times

The first point concerns the relative stability of the average number of trips and the average time spent on daily travel per person (for all purposes and by all modes, including walking). This stability has been noted in a series of household surveys carried out in France and co-ordinated at national level by the CETUR over a period of time (between 1976 and the early 1990s) in the main urban areas (cf. the work carried out by INRETS-DEST, notably that of Bieber and Orfeuil in 1993). The stability in the Paris area is quite remarkable during the three years in which it was measured (1976, 1983 and 1991), amounting to an average daily travel time of approximately 1 hour 25 minutes. While, admittedly, the average daily travel time fluctuated either upwards or downwards in other major urban areas, the times generally averaged out to around 50 minutes.

The second point, quite remarkably, mirrors the first and concerns the "commuter paradox" revealed by the analysis of survey data from the twenty largest urban areas in the United States (Gordon *et al.,* 1991). The average journey-to-work time for American commuters declined significantly or remained unchanged between 1980 and 1985. The paradox lies in the fact that over the same period congestion appears to have increased substantially in the same urban areas. The objective, as the authors state, is therefore not to disregard the level of congestion per unit of highway, but rather to explain why average individual commuting times have remained stable or fallen. The authors put forward several explanations: the share of trips from one suburb to another is rising, i.e. in areas to which jobs are being decentralised, and these are the fastest trips; households and firms are themselves making the necessary adjustment by relocating their activities to areas where the effects of congestion

can be minimised; the time saved by commuters working in the suburbs who have moved out to the suburbs cancels out the rising travel times of those who commute from the suburbs to the central areas of cities.

These two observations relating to very different types of urban context both tend to lend support to the notion that there is a regulating mechanism at play in large urban areas, created by the multiple adjustments made by households and firms. The latter apparently take into account, in addition to the various constraints imposed by their environment and living conditions, the characteristics of the transport system which they take advantage of when these characteristics are improved: higher driving speeds and longer distances travelled as a result of improved motorway networks and lower levels of congestion in the suburbs. This regulating mechanism would seem to reach a kind of equilibrium at a level close to that of saturation, in that any improvement in traffic fluidity would immediately attract new motorists (see also the analysis by Mogridge, 1986).

In this case, the environmental justification for new road infrastructure in urban areas, based on the contention that new infrastructure would reduce congestion, will be cancelled out by the ensuing increase in traffic levels.

2.3. Scope for regulation?

The distinctive characteristics of the way in which this new road infrastructure is both funded and priced call for some additional analysis. A policy aimed at increasing road supply in response to growth in demand, primarily in the form of new toll roads, may be the first step towards a policy aimed at regulating the mobility of private cars.

F. Papon (1992) has demonstrated, for example, that a projected network of new underground urban toll roads, or "first class roads", could, by means of tariff differentiation, divide demand from motorists into segments and thus maximise the socio-economic surplus of the community. Not only would the franchise operator and, above all, the users of the toll network benefit from this, but also the users of the surface highway network, which would remain toll-free and the community, which would benefit from budget savings; at the same time, the fluidity afforded by the toll network would help to reduce pollution by relieving congestion.

2.4. Financial risks and risks of inconsistency

Such a network, were it to be put in place, would still have to meet several conditions to ensure that it was viable and in particular would need to be able to meet the objectives of relieving congestion in surface traffic flows. The project would have to be financially viable for the franchise holder so that no public funding would be required, which might mean that it would only be used for trips to the central areas of sufficiently large and built-up metropolitan areas. This is the case in the Paris area where the above-mentioned project has been tested; such a project would appear to be less viable in urban areas with a population of around a million: while the Prado-Carénage tunnel (2.5 km long, conversion of a disused railway tunnel), opened in Marseilles in 1993, did not require public funding, the *Boulevard Périphérique Nord* project in Lyons (8.5 km, three tunnels and a viaduct), due to be completed in 1997, required public funding on quite a significant scale for the construction of interchanges and other works.

In addition, reactions from North America show that, despite some enthusiasm for European experiments with toll motorways, the possibilities there appear to be limited; this is even the case in the wealthy State of California, even though the ISTEA Act passed in 1991 now allows federal funding to be used to cover up to 50 per cent of the cost of new private toll roads (Gomez-Ibanez and Meyer, 1995). The roads needed to relieve congestion in the network would be expensive to build in that roads in urban areas would face competition from the toll-free infrastructure outside peak hours and would only have customers during rush hours. According to the authors, all potentially profitable roads have probably already been built by the public authorities, which would explain why, after ten years of debate, only one private bridge and two private roads are currently under construction.

The second condition governing the construction of privately managed road infrastructure is the way in which it will be inserted into the existing road network and, more generally, the multimodal urban transport system. The creation of such toll links constitutes a potential source of inconsistency in the management of the road network, as for example in the case of the toll expressways used to by-pass Lyons where motorists are made to pay for by-passing the built-up area while access to the city centre remains free. The synergy present in the road network, which can be exploited when there is a single operator, may be lost if two operators with differing interests are involved: a public operator whose objective would be to limit the total number of trips made by car, and a private operator whose aim would be to achieve the optimal volume of traffic on his infrastructure so that he could at least balance

his books. Furthermore, the overall management of the multimodal urban transport system will not be improved if additional road capacity, even toll roads, is created without properly addressing the imbalance between car use and public transport.

2.5. Options for controlling traffic growth

These contradictions may be overcome if part of the network of toll-free roads is made unavailable to cars and reserved for other types of traffic such as public transport, bicycles or pedestrians. This partial recovery of the free road network that had previously been assigned to car traffic would represent an initial tariff regulation of trips by car and should make it possible to achieve the twin goals of reducing traffic levels and environmental improvement. This is what is often put forward as a supporting measure for underground toll-motorway networks in order to make them acceptable to the opponents of new road-building schemes, but would require strong political resolve during the project planning stage. This is why, given the time it takes to finalise such projects and the many pressures that may be brought to bear from all sides, it is doubtful whether any such resolve to reduce the supply of free roads could be maintained. It is highly likely to end, as is the case at present, with the creation of new road capacity without any concessions to other objectives.

This discussion nonetheless shows how the construction of new toll expressways could be used to ensure that major urban areas remain competitive, and could also be accompanied by coherent measures that would allow the number of trips made by car to be reduced. These measures would therefore have to be associated with stringent procedures to ensure that there is no subsequent slippage. In this respect, the ISTEA procedure in the United States is an example of how control is exercised over the use of federal funds. For example, planners cannot increase road capacity if in doing so they increase the number of single-occupant cars in an area that fails to meet air quality requirements (Paaswell, 1995; see also the detailed description of the introduction of the Clean Air Act Amendments in Shrouds, 1995).

3. CONDITIONS UNDER WHICH THE PUBLIC TRANSPORT FACILITIES SHOULD BE DEVELOPED

The cost of developing and operating public transport systems rose sharply during the 1980s, placing increasing strain on already stretched public funding budgets. Despite these difficulties, public transport, which when it can compete with the private car under conditions that are economically and socially acceptable to the community is the most economical way to use environmental resources, remains the best option for continuing to meet future mobility needs. Indeed, investment in public transport would seem to offer the only means of reversing the seemingly unstoppable rise of the car. In France, for example, only those urban areas which have heavily invested in dedicated infrastructure for public transport have managed to maintain or, in some cases, increase the share of this mode in the total number of motorised trips.

3.1. Worrying trends

The development of public transport facilities must not be pursued at any cost, however, as may be seen in the adverse impact it can have on already deepening public deficits. Two examples of this are given below.

The first concerns a context that is highly favourable to the car. In the Los Angeles region (Wachs, 1993), as part of a regional programme to develop the rail network, several new lines were constructed (Blue Line, Red Line, Metrolink). These lines are all making huge losses. In the case of the Blue Line, for example, the price of a ticket covers merely an eleventh of the cost of the service. The public subsidy for an average trip on the Metrolink is equivalent to a taxi ride over the same distance. This may be explained by the fact that population density of the region is too small and that the central part of Los Angeles contains only 6 per cent of the jobs in the region, whereas 90 per cent of all employees have free parking at their work place. In the San Francisco region, the example of the BART (Bay Area Rapid Transit) system, 140 miles long and opened in 1972, shows that even those residents who live near to a station (within a radius of 400 metres) make little use of the BART, either because it does not service their destination or because there is free parking available where they want to go (Cervero and Landis, 1995).

The second example is that of the Lyons conurbation where the share of motorised trips made by public transport initially rose in the early 1980s following the opening of the first metro lines (14 km), but subsequently

declined despite the completion of a further metro line in 1992 (+12 km). So what we can see here is an increase in the number of trips made by public transport, trips that are made under better conditions thanks to the metro, which has not prevented steady growth in car traffic throughout the conurbation.

3.2. An example of a future subject to severe constraints

All these examples clearly demonstrate, if further proof were needed, the falsity of the notion that all that needs to be done to increase the modal share of public transport in urban areas, at the expense of the car, is to increase the provision of public transport. In fact, it is possible to go one step further by translating the theoretical explanations that have been put forward for the mechanism governing competition between public transport and the private car into formal expressions. This is what has been done in the series of strategic models simulating the funding requirements of public transport known as QuinQuin, developed by Bonnafous (1985), Bouf (1985, 1989) and Tabourin (1988, 1989).

Using an initial version of the model developed for Lyons in 1985, it was possible to validate the performance of the model empirically by comparing it with observations made up to 1993. This validation demonstrated that the model was non-falsified, thus corroborating its relevance in the simulation of future situations based on a variety of trend assumptions (Bonnafous and Tabourin, 1995).

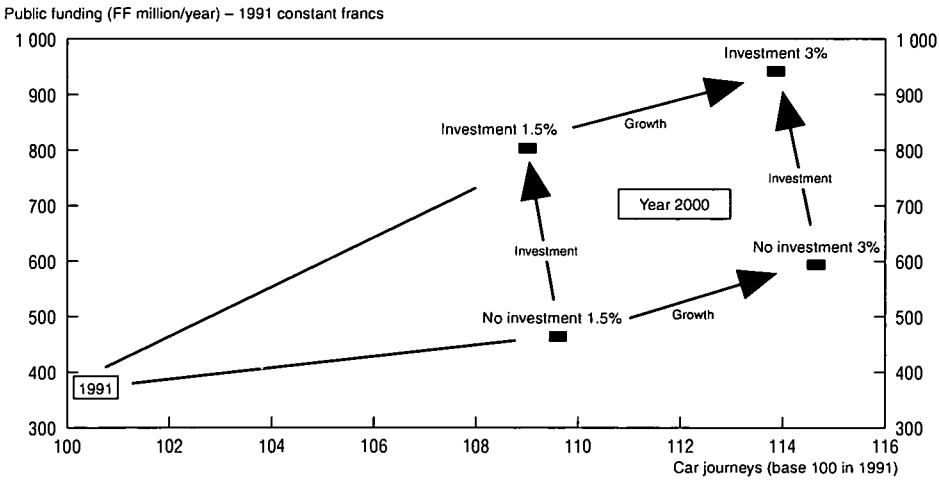
Applied to Lyons, the QuinQuin model can be used to test various transport and highway network management policies as well as future demand (Raux and Tabourin, 1992). The effects of even modest economic growth and the limits to a policy of massive investment in public transport are summarised in Figure 1.

The abscissa of this figure shows the level of trips made by car (base 100 in 1991), which is itself the combined result of: (a) growth in income and the impact of such growth on car ownership and car use; (b) the degree to which users are attracted to either cars or public transport in a context in which both modes are competing for use of a road network where congestion adversely affects surface public transport. The ordinate shows the public funding requirements of public transport systems in FF millions up to the target year of the model. This figure compares the combination of two sets of assumptions: one set of assumptions regarding economic growth (modest growth of 3 per cent or strong growth of 5 per cent per year); the second set of assumptions

consisting in either no investment or investment of the order of FF 6 billion in public transport facilities (i.e. zero investment or investment), primarily in the form of extensions to existing metro lines.

The results show that, with zero investment, strong economic growth would have an impact on both the use made of the road network (+15 per cent instead of +10 per cent compared with 1991) and the public funding requirement. The impact of congestion would make itself felt in the public transport network through a higher public spending requirement (FF 600 million instead of FF 461 million). Lastly, investment in public transport would have little impact on the number of trips made by car (a decrease of approximately one percentage point compared with the zero investment assumption). The public funding requirement would rise sharply (FF 806 million or FF 951 million, depending upon whether growth was modest or strong) and the per capita tax burden would be practically double that in 1991.

Graph 1. **Public funding requirement for public transport in the Lyons conurbation to the year 2000 based on various scenarios regarding economic growth and investment**



Source: Raux and Tabourin, 1992.

3.3. Which way out?

Is it possible to avoid this scenario of a severely constrained future? An initial response to this question may be obtained by testing some of the transport policies the model accommodates.

One possible test is that of the consequences of a partial displacement of car trips made in the city centre (the communes of Lyons and Villeurbanne communes, covering approximately 80 square kilometres). This transfer of trips to peripheral areas could be brought about by the introduction of regulatory measures or charges for access by car to the city centre. In such a scenario, the displacement to peripheral areas of 10 per cent of the car trips made in the central area would increase traffic levels in the suburbs and would thus have the adverse effect of penalising the surface public transport network in the suburbs. The effect of reduced traffic levels in the centre would have little impact on the operation of the public transport network, given the size of the initial metro component of the facilities provided in the central area. Thus the overall situation of the public transport network would be worse in terms of operating speeds, competitiveness and therefore their funding requirement. Congestion in the suburban road network could only be relieved by investing in new infrastructure, which would thus avoid further reductions in the operating speeds of public transport but which, of course, would not have any real impact on the level of car traffic.

However, the displacement of car trips from the central area would not be solely towards the peripheral areas, given the constraints that might apply to the location of activities. It would have to be accompanied by a partial transfer of such trips to the public transport mode. Even a modest shift (20 per cent of the 10 per cent fewer car trips made in the centre) would be fairly effective since it would both reduce congestion in the suburbs and, at the same time, decrease the volume of car trips made in the conurbation by one percentage point and slightly lower the funding requirement. This type of solution, for a similar public transport funding requirement, is therefore more effective than simply transferring trips to peripheral areas and providing additional road infrastructure there, given that the cost of the latter has not been incorporated in the model.

The various measures that were tested all share the same attribute of not varying significantly from the original framework for future development that was initially projected. Only a reappraisal of the type of investment planned would challenge the validity of this framework. The investment taken into account in the model consisted in a series of extensions to metro lines (amounting to approximately 11 km in all, + 12 per cent of the number of seats

per kilometre offered). The substitution of a dedicated tramway or busway for most of the metro extensions planned, which would provide the capacity to meet approximately 80 per cent of forecast demand on the metro extensions, would practically cancel out the "investment" effect on the public funding requirement.

However, the main difference lies in the fact that, unlike an underground metro line, the construction of a dedicated tramway or busway would require part of the highway network to be reassigned to public transport at the expense of private car traffic. Furthermore, the estimate of the substituted length of metro line is a minimum one. It is becoming increasingly evident that urban sprawl and the resultant dispersion of activities require a response in terms of the transport network that will entail a different type of managerial and organisational approach to the supply of transport in the entire conurbation. Indeed, the concentration of flows needed to ensure that the metro is profitable no longer appear to be feasible in the short term once the network extends beyond the central areas of conurbations with a million inhabitants, such as the Lyons conurbation. It is for this reason that the concept of an "intermediate network" has recently been developed (Clement *et al.*, 1994), combining a new type of tramway rolling stock mounted on tyres with a grid-network infrastructure covering the entire conurbation and thus increasing the number of interconnection points and a level of service in terms of frequency and punctuality that minimises the time lost at interconnections. The spatial coverage and flexibility of this type of service make it the form of public transport that is most likely to compete with the car, with a higher rate of return than more costly types of solution. However, the spatial coverage required in the conurbation as well as the capacity needed to meet future mobility demand will ultimately require heavy investment by the community, essential if overall accessibility is to be maintained by means other than by car. This investment might ultimately be almost as high as that which would be needed to pursue a strategy of extending metro lines, although the advantage to such a strategy is that the extensions could be staggered over time. The concept of an "intermediate network" has been studied with regard to the Lyons conurbation, but until now has met with opposition over the redeployment of highways.

In short, there would seem to be a number of constraints on further development of public transport facilities which cannot easily be avoided. The constraint of finding the funding required for major investment in public transport facilities will still apply in the future if the aim is to replace a major share of the trips made by car to public transport and to meet the needs of future mobility. In addition, analysis of demand management measures shows that:

- -- Draconian measures aimed at removing private cars from central areas can worsen traffic conditions in the suburbs and, by the same token, the operation of public transport services, thus in all probability lowering the efficiency of the entire transport system;
- -- An initial solution would seem to lie in making use of public transport technology that is adapted as fully as possible to the rising volumes of traffic flows; the development of designated intermediate networks, as a complement to rail networks, in cities with over a million inhabitants or in densely populated suburbs in cities with several million inhabitants would be one way of adjusting the competitive balance between public transport and the private car. The problem that will then have to be overcome is how such networks can be inserted into an environment in which land is scarce and used for conflicting purposes;
- -- Lastly, even an "intermediate" type of supply requires some increase in flow volumes to ensure that the traditional forms of public transport operate under conditions that are acceptable to the community. In sparsely populated areas, where higher flow volumes are hard to achieve, organisational innovations based on multimodal systems will need to be found, e.g. park-and-ride schemes.

4. IS PROMOTING CAR-SHARING AN ADEQUATE RESPONSE?

The growing dispersion of jobs and homes, coupled with the problems that conventional modes of public transport face in meeting mobility demand in sparsely populated areas, suggest that other solutions need to be found. Reducing the number of vehicles per kilometre travelled may call for greater use of an intermediate form of transport serving as a link between the private car and public transport services, for example, car-sharing. Although transferring models from one continent to another runs up against cultural barriers, the experience of the United States may nonetheless be instructive.

Two types of measure have primarily been used in the United States: (a) the reservation of certain motorway lanes, sometimes in a given direction and at certain times, to high-occupancy vehicles (HOVs); (b) programmes set up by firms to encourage car-sharing among employees for commuter trips between home and the work place. These programmes have been developed in response to concern over rising levels of congestion, the lack of funding for new

road-building projects, growing resistance by the general public to the construction of new motorways and concern over air quality, particularly in California.

4.1. Are such programmes effective?

Under Regulation XV, which has been in force in California since 1988, all public and private firms with over 100 employees are obliged to set up employee car-sharing programmes. The aim of this measure is to encourage firms to increase the average ratio of the number of employees to the number of cars used to come to work, with a regional objective of 1.50, varying from 1.30 to 1.75 depending upon area. To promote these measures, incentives have been put in place, such as priority parking for shared cars, subsidies for public transport, a programme guaranteeing lifts home, showers and changing facilities for cyclists; while parking fees are used to discourage "single-occupant" cars. According to studies cited by Wachs (1993), the estimated annual decrease in the total length of trips employees make by car is very low if not non-existent. The costs of these firm-sponsored programmes is estimated to have amounted in 1992 to an average of around US$12 per road trip saved. According to Wachs, it is probable that any reduction in the number of journey-to-work trips by car during rush hours is immediately cancelled out by other trips.

It is for this reason that it seems futile to focus efforts on journey-to-work trips if nothing is done for other types of journey. This seems all the more evident in view of the fact that the most recent trends observed show a decline in the share of journey-to-work trips in the total number of trips, even though commuter car-shares always outnumber other types of traffic during rush hours and the share of such trips is rising in terms of the distances travelled. If the aim is to reduce the relative advantage offered by cars for all types of trip, then the scope of any regulatory measures introduced would need to be similarly comprehensive.

4.2. Introducing lanes reserved solely for shared cars

The second measure aimed at encouraging car-sharing is to reserve part of the highway for high-occupancy vehicles, a practice that has been followed in the United States for several years now. Simulations (Dahlgren, 1995) would seem to show that, in practice, the proportion of HOVs and the initial level of congestion must be high for an HOV lane to be more efficient than a conventional lane, particularly with regard to curbing pollutant emissions.

Converting a conventional lane into an HOV lane is not easy, however, as shown by the legal decision taken in 1976 to return the Santa Monica Freeway to its initial status; while the experiment had been a success in promoting car-sharing and increasing the patronage of buses, the amount of time lost by car drivers who did not share their car far outweighed the time gained by shared cars and the improvements in terms of air quality were insignificant.

It is for this reason that priority should be given to the construction of new HOV lanes alongside existing lanes, although the major developments that have been planned have once again run up against the problem of funding. Furthermore, there is always a risk that HOV lanes will be under-utilised at certain times of the day, even during rush hours; this would simply add to the frustration of other car drivers who would have contributed to such funding through the taxes they pay on fuel.

One solution proposed to this problem (Fielding and Klein, 1995) is to raise the money needed for the construction of additional HOV lanes by levying tolls on single-occupant vehicles allowed to use HOV lanes; the latter would thus be transformed into high-occupancy tolled (HOT) lanes. This is an interesting concept which, through a judicious mix of tariff control and regulations (which are generally accepted more readily), would make the introduction of tolls on urban highways more acceptable to the public; it would also offer those who wished to avoid paying such tolls the possibility of using this new express infrastructure by sharing their car.

5. CAN SUSTAINABLE MOBILITY BE SOLD AS A COMMODITY?

Transport economists attribute many virtues to road pricing: it offers a means of raising funding and a way of attracting private capital to the funding and operation of networks; the shift in the pattern of demand that it is supposed to bring about allows resources to be better allocated, particularly scarce resources such as energy, air quality, the environment and land in urban areas. A third conventional aspect of road pricing, and one that is often forgotten, is its redistributive power.

Since the main problem to combat is indeed that of over-consumption of scarce resources, the first step must be to establish a link between taxes on car use and those on car ownership which is more penalising for the former than for

the latter. Taxes on car use are more or less covered by three types of instrument which are either already in use or whose introduction has been planned, namely, fuel taxes, parking fees and road pricing. Because transport is a non-stockable commodity, the tariff instruments used for regulation cannot be analysed without reference to both the time and place where that commodity is used. It is therefore with reference to both these aspects that our analysis will address each of these three types of instrument in turn.

5.1. Fuel taxes: technologically efficient ...

Fuel taxes are primarily used for their dual effect as a source of revenue and an incentive to save energy. This second aspect is, *a priori*, the more interesting of the two in terms of reducing the consumption of fossil fuels and emissions of pollutants which have both a local and global impact. The first oil shock in 1974 reversed the downwards trend in fuel prices and initiated the development of energy-saving technologies. In contrast, the second decline in oil prices observed in France since 1985, particularly in relation to average net salaries (Orfeuil, 1993) resulted in new growth in traffic levels, on the one hand and higher fuel consumption on the other as the market shifted towards heavier (i.e. safer) and more powerful cars fitted with energy-intensive accessories such as air-conditioning. Nonetheless, these increases were moderated by continuing technological improvements to fuel efficiency (Morcheoine *et al.*, 1994).

These analyses confirm that fuel taxes are a fairly effective instrument for meeting the long-term objective for technological development, namely, to reduce the impact of car traffic on the global environment. The pressure must be maintained, however, particularly in view of the fact that continuing improvements to the fuel-efficiency of cars partly offset the impact of higher fuel prices and thus weaken the impact of the latter on the behaviour of car drivers. Traffic levels are themselves increasing, thus sharply raising the risk of cancelling out the progress made in reducing unit emissions. Other, more technically effective solutions are available and consist in working directly with car manufacturers. Standards of the CAFE (Corporate Average Fuel Efficiency) type and "feebates" have been successfully used to direct customers' choice towards more environmentally-friendly cars (Kessler and Schroeer, 1995). However, the progress achieved in reducing emissions from moving cars is such that the major share of emissions will soon be generated by cold start-ups and multiple stopping and starting; indeed, to such an extent that pending the development of pre-heated catalytic converters or "zero-emission" cars (the latter have yet to appear on the market), it is the number of trips made by car, and not simply the length of trips, that will need to be reduced.

5.2. ... but not effective in spatial terms

The ability of fuel taxes to generate revenue should theoretically quicken the trend towards optimal allocation of resources, given that this optimum currently requires the development of alternative modes of transport to the private car. It is for this reason that in 1992 the mayors of the largest urban areas in France proposed to introduce a 10 *centime* surcharge on the price of a litre of petrol in order to finance the development of urban public transport services. This proposal was fiercely opposed by elected representatives in rural areas. Although there have been several price increases of the same order since then, this example illustrates the limits on the acceptability of the spatial redistribution of a tax levied nationally. It is difficult for those living in the country to see why they should pay an additional tax to be used for a purpose which they feel does not even concern them indirectly, particularly in view of the fact that the authorities are unable to provide a viable alternative means of transport in rural areas. It could even be argued that the optimal allocation of resources should mean giving priority to the car in rural areas, in view of the spatial dispersion of journeys and focusing attention on areas where substitute means of transport are available at a reasonable cost to the community. This might be countered by the argument that fuel taxes can be modulated spatially. However, the "boundary effect" of such modulation would mean that it would have to be applied solely to very isolated urban communities, as it has occasionally been possible to do in a few limited instances in Europe.

5.3. Parking fees: A limited scope of application

It is for this reason that parking fees are seen as the best instrument for reducing the number of trips made by car in urban areas, although this was not the original purpose of parking fees. In France, for example, the rationale behind the use of parking fees is to increase the turnover of cars using existing parking spaces, whereas bans on on-street parking are usually aimed at improving traffic fluidity. Using parking fees or even managing the stock of available parking spaces can have a very positive impact when such measures are part of a coherent policy, as is the case in Switzerland (Bonnel, 1995).

The use of parking fees has two drawbacks, however, in that, firstly, it taxes stationary vehicles and thus has only an indirect link with the consumption of environmental resources and, secondly, vehicles which are simply passing through areas in which parking fees apply are unaffected by the fees. The latter point is worth bearing in mind in large urban areas since any reduction in traffic volumes that parking controls might bring about would be immediately

cancelled out by the increased number of motorists who find it quicker to drive through the area rather than by-pass it or who make use of the less congested peripheral network. This would therefore mean that the environmental effectiveness of parking controls would only come into play in the most central areas in which available road capacity should also be used solely for access and not for through-traffic. Nonetheless, parking controls, in whatever form they are used, remain one of the traditional instruments of transport policy in major urban areas. The principle of charging for parking spaces is widely accepted by, if not acceptable to, motorists, which is by no means the case for other types of urban road pricing, which we shall now discuss.

5.4. Urban road pricing: Some highly attractive possibilities ...

The advantage that tolls levied directly on vehicles using the road network have over parking fees is that they more accurately reflect the consumption of environmental resources -- it is mobility rather than immobility that is being taxed. In addition, unlike fuel taxes, they can be used to tax, at given times and in given locations, certain types of movement rather than others. While the concept of charging tolls for road use is by no means a recent innovation, recent advances in electronics have now made it possible to target vehicle movements in both space and time. The failed experiment with road tolls in Hong Kong in the early 1980s raised legitimate fears over the invasion of privacy, but the development of anonymous automatic debiting systems now means that this is less of a problem.

In western countries, where standards of living have been continuously rising since the last World War, resulting in increasing numbers of cars making free use of the road network put in place by the public authorities, the introduction of tolls to control traffic levels in urban areas would lead to radical changes in the socioeconomic environment. It is for this reason that the introduction of such systems, which would be likely to deny access to certain areas to the less wealthy members of society by making transport too expensive, are perceived as inequitable. It is nonetheless worth looking more closely at the nature of this inequity, i.e. the level at which tolls would have to be set in order to meet the objective of reducing the number of trips made by car.

5.5. ... but resistance to changes in behaviour

Two examples of estimates, made as part of a search for ways in which to reduce the number of trips made by car during rush hours (congestion pricing), may prove instructive.

As part of a series of studies made of the possibility of introducing electronic road pricing in London (Banister, 1994), it was estimated that the tolls needed to secure a 9 per cent reduction in traffic volumes during rush hours would need to be set at between £3 and £5; this would be equivalent to a minimum increase of 40 per cent in the average household budget for car use. According to the author, half of all car owners would have to change their mode of transport or reorganise their activities and journeys in order to minimise the impact of tolls on their overall budget.

In response to the spread of congestion in terms of both area and duration in the motorway network in the Los Angeles area, several studies were carried out to determine the level at which tolls would have to be set to relieve congestion (Giuliano, 1992). According to the author's calculations, the tolls of US$0.15 per vehicle-mile that would be needed to reduce the vehicle-miles of congestion by 8 to 12 per cent, on an average length trip combining toll-motorway and conventional road, would price the time saved at US$13 an hour. However, the average hourly salary in the region stood at US$12 an hour in 1992 and behaviour studies price time spent travelling at around half the hourly salary. There is therefore a worrying discrepancy between the behavioural preferences usually expressed with regard to time savings and the levels at which it was proposed to set tolls. The high tolls needed in Los Angeles in order to bring about significant changes in behaviour are partly explained by the extension of congestion to other parts of the day, which means that it is very difficult to find slack periods. In addition, since there are limited public transport facilities in the region, car-sharing would seem to be the most likely way of minimising the impact of tolls.

These studies illustrate or confirm the weakness that has widely been observed in the price-elasticity of demand for car use, an elasticity which increases in the long run (Goodwin, 1992) in that individuals require a certain period of time, given the constraints arising from their life-style, to adapt their behaviour to take account of price changes.

5.6. An investigation of responses to various urban road pricing scenarios

The radical changes that the introduction of urban road pricing can have on networks or even entire regions raises doubts over the ability of current models to correctly forecast anticipated changes in behaviour. It was for this reason that we decided to carry out a preliminary investigation of responses to various travel scenarios, several of which included urban road tolls. This survey method, which was developed and used with regard to the Lyons conurbation, is what is known as an interactive "declared response" method (Lee-Gosselin, 1995). While such a survey, involving some fifteen motorists, cannot claim to be of any statistical significance, it does provide an overview of how behaviour changes and an insight into the processes underlying such changes.

The validity of using such a simulation to predict realistic responses to a situation that has not been experienced nor accepted *a priori,* such as urban road pricing, has been described elsewhere (Raux *et al.*, 1994). Since the method tests scenarios on the basis of the actual day experienced by the survey respondent, it makes it possible to check whether the statements made by respondents are genuine. The scenarios were arranged to lead up to the final scenarios of tolls on trips by private cars; thus the first two categories of scenario (a worrying increase in levels of congestion leading to a temporary ban on car use following pollution warnings) were aimed at setting the scene; the presentation of a new "intermediate network" of public transport services throughout the conurbation at the same time as the toll scenarios was intended to make the latter more acceptable to the motorists involved in the simulation; these scenarios included the introduction of parking fees throughout the city centre and a toll area applicable either at certain times or all the time based on a variety of tariffs.

The guiding principle for the motorists canvassed was to maintain a life-style based on the car, which primarily offered them flexibility and independence. This guiding principle perfectly explains the type of adaptation encountered in response to the different scenarios. The first adaptation consisted in rearranging schedules. The motorist, depending upon how free he was to do so, would change the time of his trip in order to avoid congestion or to avoid tolls if the latter were to apply solely at certain times in the day. When the constraints were too strong, when tolls were charged throughout the day, or when the daily schedule could no longer be adjusted, there still remained one solution: to reorganise his schedule by cancelling his trips, which would still allow him to keep his car. Finally, when the motorist was no longer willing to pay, the last solution was to use public transport.

What is astonishing -- although to what extent is it typical? -- is the relatively large degree to which our respondents were able to rearrange their timetable. If motorists in general are indeed able to rearrange their schedules to such an extent, then this would mean that we cannot expect to see a significant reduction in mobility based on car use in scenarios where congestion is limited to certain times or where tolls are only charged during rush hours. We would be more likely to see optimisation of the use of the highway network than reduced levels of mobility.

It is above all the organisation of time schedules that would seem to be the richest potential source of adaptation in response to the pressures exerted under the various scenarios. In contrast, random changes in the duration of trips has a highly disruptive impact on the organisation of activities, as it became clear in the scenarios covering congestion. It is this feature which makes the scenarios based on random congestion unacceptable to motorists and which thus precipitates major changes in behaviour, whereas congestion that is expected can be more readily incorporated into the schedule of activities by changing the timetable.

It is also time organisation that allows motorists to avoid tolls when the latter are only applied at certain times during the day, or at least to minimise their impact by reducing the number of trips affected by such measures. In contrast, the flexibility of time organisation is completely cancelled out when the constraint applies throughout the day, as in the case of parking fees or permanent road pricing.

Irrespective of the type of toll, the first changes that survey respondents made to their daily schedule appeared fairly swiftly: some respondents reacted as soon as there was an additional cost of FF 5 a day, and from FF 20 a day upwards all respondents made an initial adaptation. However, in terms of "extraordinary" adaptations, such as a shift to public transport by those who were not already using it or changes to the location of activities, there was fairly strong resistance to price pressure. While some motorists made "extraordinary" changes as soon as the additional cost amounted to FF 10 a day, most respondents only reacted in this way once the FF 20 a day threshold had been reached or exceeded (a litre of petrol costs between FF 5 and FF 6).

This resistance to price may be explained by the cost calculations carried out by respondents during the simulation. Half of the motorists surveyed perceive tolls as a punishment which they attempt to avoid, without querying

their use of a car; only the other half reviewed their use of a car by integrating the other costs and benefits of car use (petrol, time savings, depreciation) and occasionally by comparing cars with the cost of travel time of public transport.

Furthermore, this price relationship becomes even more complex when account is taken of the fact that survey respondents reacted differently to price according to the type of activity concerned and its context. Some respondents stated that they were willing to pay more for free or special activities, or activities taking place at locations or times where public transport was unavailable. Others, managers or those who needed a car for business purposes, looked to their employer to pay for their travel costs.

This virtual lack of comparison of the cost of car use with that of public transport is due, in our opinion, to an implicit refusal to make the calculation. This refusal might stem from very negative perceptions of public transport, or conversely from highly positive attitudes towards cars. When choices are based on the positive image of cars, they primarily draw on the benefits that car use can offer. These benefits are qualitatively far too significant for respondents to consider comparing the costs of car use with those of public transport.

The complexity of the relationship with travel costs, combined with the various types of reorganisation of respondents' schedules of activities, explains why the disposable income available to respondents or their households plays merely a limited role in the simulation. At any rate, this role would seem to be less important than the negotiating power of the individual, firstly, in terms of his personal or professional activities and, secondly, in the defraying of business expenses. This degree of power which the individual has acquired would seem to be itself a fundamental resource and may be interpreted as an additional source of inequity alongside the income effect on tolls.

5.7. Congestion pricing has only a limited impact on modal shifts

Tolls levied during rush hours can therefore only be expected to have a limited impact on modal change, particularly if, in addition, employers agree to pay the expenses of some of their employees. It is only if the tolls are sufficiently high, or are applied throughout the day, that users who pay the additional cost of their trips themselves will make significant changes to their mode of transport and that firms will think again about reimbursing their employees' travel expenses. All-day tolls would therefore be quite different to congestion pricing, but would go further towards meeting financial or environmental objectives.

Some additional insights may be gained from observation of motorists' responses to the Trondheim toll ring, designed not to reduce congestion but to raise funding. This toll ring was set up in 1991 and divides the town in such a way that 60 per cent of the inhabitants live outside the ring while most jobs and commercial or leisure activities are located inside the ring. The tolls on cars entering the ring between 6 a.m. and 5 p.m. from Monday to Friday are relatively modest, amounting to a maximum of FF 10 with lower charges after 10 a.m. and depending upon type of payment (reductions for electronic payment or prepayment). Before-and-after studies (1990-92) failed to produce any evidence of a decline in private car use as a result of the introduction of tolls; in any case, traffic levels had fallen substantially within the region as a whole. In contrast, there has been a change in the time at which journeys are made during the day, during both peak and off-peak toll periods, towards the evenings and week-ends, associated with changes in shop closing hours (Meland, 1994).

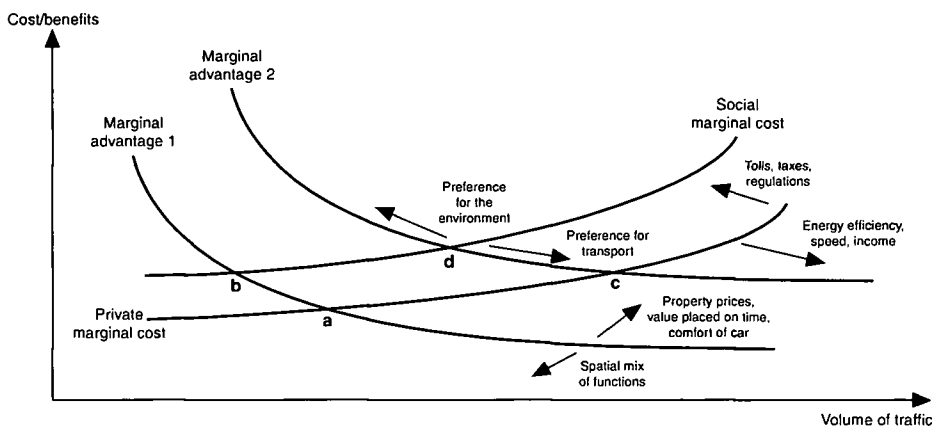
Lastly, mention must be made of the example of Singapore, which has been extensively reviewed in the literature since it is the oldest area-toll system in operation and the sole to be aimed at controlling traffic levels. In fact, the way in which the system of right of access focusses on the business centre is something of a smokescreen for Singapore's policy towards urban planning and car traffic. Apart from the concentration of power which allows the government to keep firm control over housing, transport and parking, Singapore also operates a draconian policy towards car purchase and use throughout the island (Phang, 1993). Despite the introduction of exorbitant taxes on cars and a vigorous policy in favour of public transport, the number of cars has grown steadily from a rate of 15.8 inhabitants per car in 1980 to 10 in 1989. The system whereby registration certificates are sold at auction, according to a quota set by the authorities, set up in 1990, and the creation of certificates for so-called week-end cars, set up under the same procedure, illustrates how much the weight of cultural and economic pressure in favour of the car remains high in a country experiencing strong economic growth.

All of these considerations point to the same conclusions and show that attempting to reduce car movements by means of congestion pricing does not seem feasible in the short term unless use is made of tolls which are so high that they would become socially unacceptable. Tolls at certain times of the day would at best reduce the volume of traffic during rush hours in areas where congestion does not last all day, thus achieving a kind of optimisation of use of the road network during the day. However, this internal optimum in terms of road network operation is not necessarily an optimum for the community, particularly in terms of the environment. A brief digression to discuss the theoretical basis of this statement might prove instructive.

5.8. A race in which the environment is the loser

To do this, we shall develop an idea put forward by A. Perl and J.-D. Han (1994). Figure 2 represents the volume of traffic (and volume of pollution generated by traffic) compared with the costs and benefits of car traffic expressed in monetary terms. The figure shows several conventional curves, one for the social marginal cost (to the community), one for the private marginal cost (to the motorist) and two curves representing the marginal benefit to the motorist. Perl and Han explain that tariffs set at marginal cost produce a price at which those motorists who are prepared to pay can buy the right to damage the environment. Even if environmental costs and the costs of congestion are incorporated into the marginal tariff setting, these costs will always be evaluated with regard to the benefits derived from car use. A classical Pigovian tax would ensure the progression from equilibrium point *a* where motorists take account solely of their private costs, to equilibrium point *b*, considered to be socially acceptable. However, in the case of both high-growth economies (South-East Asia) and developed economies in which there is spatial differentiation of property values, the trend is for an increasingly high value to be placed on the benefits attached to mobility. The curve for marginal benefit 1 will move closer to curve 2 and the Pigovian tax will produce a new equilibrium at point *d*, corresponding to a new optimum car use producing less pollution.

Graph 2. **The costs and benefits of mobility may change over time**
Based on a graph proposed by Perl and Han (1994)



We can pursue the line of argument advanced by A. Perl and J.-D. Han further by showing that the two marginal cost curves can also be displaced over time in accordance with changes in social preferences and in the technical transport system. Thus:

- The social marginal cost curve can move upwards as the preference expressed for the environment by society increases (rich and developed regions); it can also move downwards when preference is given to greater trade in order to promote economic development in a given region and to combat unemployment (developing regions or regions in economic crisis);
- The private marginal cost curve can move upwards as a result of road pricing or the introduction of regulations lowering the speed limits for cars; increases in general living standards, improvements to the fuel efficiency of cars by car manufacturers, as well as the efficiency gains, such as speed, afforded by the road network or by the provision of real-time information to vehicles, can move the private marginal cost curve downwards;
- Lastly, the marginal benefit curve can move both upwards in response to increasingly higher values being placed on time savings or to greater value being placed on mobility as a result of greater spatial segregation in terms of property values, and downwards in response to trends in the opposite direction and notably the relaxation of the constraints on the location of activities.

The optimum equilibrium point for demand for car travel and therefore for the consumption of environmental resources would thus appear to be the outcome of a race between three major trends: the growing preference for the environment; the improved technical efficiency of the road network; and the value placed on time saved. In this race, the second and particularly the third of these trends would appear to have been in the lead until now. This explains why such high tolls have to be used in congestion pricing before any significant change in behaviour can be brought about. This would also suggest that the equilibrium that has currently been achieved is perhaps not an optimum one in terms of the environmental goals pursued.

5.9. Using road pricing to regulate the transport system in the long term

The difficulty, if not impossibility, of introducing congestion pricing in urban areas does not necessarily mean to say that the principle of road pricing has to be abandoned. It should be possible to use this instrument in the search

for an optimum allocation of resources, an optimum that is defined for society according to economic, social and environmental criteria. The optimum allocation of resources must address the transport system as a whole and the long-term trends in that system, and not just the road system.

A. Bonnafous (1991) and P. Goodwin (1991) have shown in particular, based on statistical data for Lyons and London respectively, the extent to which car users have benefited from policies aimed at improving public transport as a result of the competition between motorists and public transport services for access to road space. These results would therefore justify allocating at least part of the revenue from tolls on cars in urban areas to the development of public transport facilities.

It is known that the allocation of revenue from urban road tolls to the financing of measures aimed at developing alternative modes of transport to the car and at improving the physical environment can bring about a significant change in public opinion with regard to the principle of urban road pricing (Jones and Harvey, 1992). The allocation of part of this revenue to the development of public transport facilities may be one way of responding to this change.

In the case of the Lyons conurbation, we simulated the implementation of an all-day toll system initially restricted to the very centre of the city which is currently well served by underground trains and buses, i.e. the area where the high quality of transport facilities would justify the introduction of tolls. This strategy then included improvements to the supply of public transport and the gradual extension of tolls to other areas in the city centre and the rest of the conurbation (Le Nir *et al.*, 1992). We have shown, using a variety of assumed elasticities taken from the literature and a daily toll of FF 10, that revenue could rise to an amount equivalent to the public transport deficit by the year 2000. The level of tolls envisaged would have a very modest impact on motorists and would therefore be socially acceptable. The intended effect of such a strategy is therefore not one of short-term traffic regulation, but to spur improvements in the supply of public transport, funded partly out of tolls aimed at sending a price signal to motorists. This would thereby initiate a change in modal behaviour. The advantage to introducing tolls gradually is that by beginning with limited application it would be possible to reverse the process and would also be possible to defuse any objections in principle.

The successful introduction of toll rings in Norway, which was even accompanied by dynamic marketing campaigns to promote the use of electronic tags, shows that the principle of levying tolls of this kind is perfectly acceptable.

Even though the tolls were aimed at raising funding primarily for building road infrastructure, in the case of Trondheim, following changes in the legislation, the package of financial measures also included measures to safeguard the public transport network and improvements for pedestrians and cyclists. What we have here, therefore, is the emergence of a system combining price-signals and funding which will provide a basis on which to develop an optimal transport system for the community.

Despite all these potential advantages, the implementation of such policies is a complex process. The main problem lies in securing approval for the transition to a situation deemed to be better for the community from individuals who, in some cases, may feel that they will be penalised by the new rules of the game. Goodwin (1989) proposed a rule for the sharing of revenue from urban road tolls between road improvements, public transport facilities and the physical urban environment. He also outlined (1995) the principles on which the opposition between environmental improvements and economic efficiency could be reconciled. Small (1992) proposed a strategy towards distributing the impacts of programmes funded out of toll revenue which embraced all the interest groups concerned in such a way that each user affected would be given at least some form of compensation. These various proposals offer interesting avenues to explore with regard to the development and implementation of policies towards trip demand management.

Our analysis of the possible movements of the equilibrium points between the marginal cost and the marginal benefit curves briefly touched upon the interplay between property values and the constraints on the siting of activities. It is this other aspect which we shall now discuss.

6. WHAT CAN WE EXPECT FROM URBAN PLANNING POLICIES?

It is commonly advanced that a land-use planning policy aimed at lowering the distance between home and work, and thus at promoting density, would curb growth in car traffic. To inform this debate, it might be worth starting with an initial analysis of the process of residential migration towards the urban fringes and with an analysis of the gradual dispersion of activities, as a result of car use, within towns and cities in France.

6.1. Catchment areas for cars

A detailed analysis of the daily behaviour of 300 households which had moved into detached houses in five communes in the outer suburbs of Lyons (located at a distance of 10 to 20 km from the centre of the city) provides a number of insights into the residential and daily commuting habits of the residents of the outer suburbs. These communes are representative of the various waves of movements towards the outer areas that the conurbation has experienced. The results of the survey carried out in 1988-89 have been described in several reports (Andan *et al.*, 1989 and 1991) and some of the main findings are given in Andan and Faivre d'Arcier (1993):

- The car is obviously king of these peripheral urban areas; there are few obstacles to its use as congestion and parking are not perceived as major problems; in addition, as there are limited public transport facilities in such communes, objectively there is a very limited choice of mode of transport, either for journey-to-work trips or for escorting children, a major constraint on the way of life for parents living in peripheral areas;
- The city centre is usually of limited interest, attracting merely 10 per cent of shopping or escort trips, 18 per cent of recreational trips and 36 per cent of trips for work. Most of the jobs for the employed members of households are located in the suburbs, usually in the same geographical sector as the home;
- Lastly, the findings reveal two discrete poles: firstly, the home commune and its immediate surroundings (for non wage-earners, small children, but also for the recreational activities of wage-earners); secondly, the city centre (for a third of wage-earners, who work in the central area, and for young people who go to school there). The other activities are dispersed in areas outside these two poles but generally in the same geographical sector as the home commune.

The amount of time spent outside the central area of the city would seem to indicate that the inhabitants of outer urban areas add little, if at all, to congestion within the conurbation. The authors' conclusion was that the movement of residents into peripheral areas poses no immediate threat to the central areas, except in terms of the minority of such residents who work in the centre. Instead, in the long term, congestion is more likely to arise at the entry-points to urban areas. This view is borne out by the rapid growth in traffic between urban areas and their peripheral employment catchment area; while such traffic still accounts for a very small percentage of the total, it is concentrated at motorway access points (Routhier, 1993).

This broad overview of the spatial considerations of the inhabitants of peripheral urban areas makes it uncertain what role transport supply could have played in their decision to live there. Analysis of the processes of residential mobility of households (Raux and Andan, 1996) shows that the latter have no plans for daily mobility. Unlike households which move to an urban environment, those which move to peripheral areas do not appear to take any account of the constraints on transport imposed by their new environment or the transport facilities that are available there. It is as if they assume that a road network will be available, since car use is an integral part of their way of life. People move out to live in peripheral areas because they want to own a detached house, and their motive for moving is not so much the attraction of the countryside as a rejection of the city and the social climate they experienced there. Where they choose to move to is largely subject to the vagaries of the property market in terms of the cost of housing.

This lack of any clear impact of the quality of transport supply on the choice of residential location is somewhat disturbing to transport engineers accustomed to thinking in terms of structural links with the transport system. While it was the development of the railways which initiated and subsequently shaped the growth of the suburbs in many urban areas in the early twentieth century, the extensive coverage of the highway network and mass production of motor cars now makes it possible to travel rapidly to any point within a metropolitan region. In addition, the expansion of the suburban road network, which continued until only a few years ago, explains why the possibility of a major deterioration of the road network does not immediately occur to households moving to peripheral areas.

6.2. Ever further thanks to the car

These analyses need to be supplemented by a more systematic examination of trends in behaviour noted in the course of surveys of a more comprehensive nature.

A comparison was therefore made of the findings of household travel surveys carried out in the Lyons conurbation in 1976 and 1986 (Raux, 1993). The internal autonomy of the various zones within the conurbation -- as shown by the share of trips made by the inhabitants of a zone to destinations within the same zone -- remained high, reflecting a balance in terms of the proximity of homes to work places or services to households. However, there is a trend decline in this autonomy as a result of the gradual dispersion of trip destinations towards both central areas and the rest of the conurbation. Journey-to-work trips

have contributed to this dispersion as a result of the strong attraction of central areas in terms of employment to the inhabitants of peripheral areas. This centrality is declining over time as destinations become increasingly dispersed throughout the conurbation. Journey-to-work trips, however, account for less than a third of all trips and their share of the total is declining, even though their spatial concentration, particularly at certain times during the day, is the main cause of the congestion currently being experienced (cf. similar trends in the USA; Kessler and Schroeer, 1995).

The share of trips made for miscellaneous purposes (shopping, leisure and other activities) amounts to almost half of the number of trips made and is tending to rise. Even though it is this latter type of trip rather than journey-to-work trips which is currently helping individual zones to maintain their internal autonomy, the trend change is generally one of extroversion. This is true of both the inhabitants of central areas and those living in other zones. The private car is the enabling factor in the dispersion of activities and is helping to reinforce this trend over time. Public transport, on the other hand, is primarily a centralising factor and because of their conventional technology (mass transit flows, hub and spoke network) are poorly placed to respond to the growing dispersion of activities; however, they may be able to shape the organisation of trips around secondary poles of activity.

An analysis based on census data (for 1975 and 1990) provides a more comprehensive picture of the situation in France with regard to the respective trends in the location of homes and work places (Massot, 1995). While most of the cities at the centre of conurbations have lost wage-earning residents and jobs to suburban and peripheral areas, the movement of residents has outstripped that of jobs. Thus the ratio of jobs available to residents in employment has risen in central city and suburbs, but has fallen in outside peripheral areas. As the author comments, it might be thought that this dual movement towards the suburbs would fuel moderate growth in the distances between the home and the place of work; yet while the average distance between the city centre and the home has risen by 12 per cent, the average distance between home and the work place has increased by 56 per cent.

Growth in jobs has mainly taken place in the suburbs, where good and relatively uncongested transport infrastructure is available. Improved accessibility in the suburbs is matched by strong growth in the number of trips made to the city centre and the rest of the conurbation, as well as in trips made outside the commune in the suburbs, at the expense of intra-commune proximity trips. In terms of employment, firms tend to recruit locally in peripheral zones, whereas the catchment area for jobs in the central city and inner suburbs is

growing wider. These trends should be compared with the fluidity of residential movements, which are penalised both by taxes on property sales and by the near-impossibility of households with members working in different areas being able to optimise their choice of place of residence, particularly in a context of high unemployment.

6.3. Density, volume and length of trips

These trend data provide an insight into the debate over the possible use of a policy aimed at increasing development densities as a means of reducing trip lengths. This debate was opened by the work of Newman and Kenworthy, whose famous curve showing per capita fuel consumption as a function of population density has been widely disseminated. In a comparison of ten major US cities, both between themselves and with thirty or so other cities throughout the world (Newman and Kenworthy, 1989), the authors stress the extent to which the structure of the city plays a central role, alongside price, income and vehicle energy-efficiency variables, in explaining differences in consumption. They therefore argue that not only should transport policy objectives be changed accordingly but also that urban areas should be redeveloped.

However, an analysis of the potential impact of the redevelopment of urban areas shows that a shift would have to be made from a static approach with regard to the relationship between density and car fuel consumption to a dynamic one. As Wachs notes (1993), the densely developed cities taken as examples were already densely developed before the arrival of the motor car. These urban areas, particularly in fringe areas, were currently experiencing car-related urban development similar to that observed in the newest American cities.

Furthermore, density, when combined with certain urban structures, can generate congestion and long journeys. This is the case in major urban areas in France where there is both rapid suburbanisation and a relative distortion in the link between the place of residence of households and the place where the wage-earners in those households work; the policy of placing a strong emphasis on development of the central area of cities has a negative side in that it leads to spatial distortions in property values with jobs tending to be concentrated in the same area and poorer families being driven out into peripheral areas.

Zoning has already been accused of generating long and therefore mechanised journeys, usually by car. Mixing homes and jobs in urban areas is often put forward as a means of minimising the length of journeys and thus

making modes such as walking or cycling more advantageous. This mix would therefore need to be achieved not only in city centres but also in the suburbs and peripheral areas. A policy of mixed land-use would also need to address the social profile of residents in the areas concerned, if only, for example, to ensure that employees and their families can live near to the place of work even in areas where property prices are high. However, the fragmentation of local authorities in France makes it unlikely that there will be any reversal in the trend towards functional specialisation in the use made of land in urban areas. It is inevitable that the population of certain middle or upper class residential districts will be opposed to the construction of social housing or the arrival of economic or industrial activities which might disturb the local way of life. The decentralised nature of local government makes it particularly difficult to implement coherent planning policies at the level of a conurbation.

Regardless of these problems, the solution would therefore be to attempt to create areas that are both densely populated and that have a mix of functions. However, it is by no means certain that bringing homes and jobs closer together will lower the average distance between an employee's home and his place of work. The many examples that have been given above show that while such proximity still exists, the long-term trend is one of steep decline as a result of increased car use. Moreover, the increase in the distance between work and home may be attributed to the effect of two main factors. Taxes on property sales and the current depressed state of the property market in France are discouraging households from seeking to move to an area closer to their place of work. In addition, in couples with children, it is now common for both parents to have jobs, which means that attempting to move closer to two separate places of work is something of a conundrum, particularly in the present economic climate in which it is not easy for employees to change jobs. This explains why, in a society which places a high value on owning property, people decide to remain in the area where they are already living, and transport, the other half of the equation, must more or less adapt itself to the location chosen by the household. As a result, the aim must be to facilitate the modal shift to public transport by providing incentives to firms to install their premises near to the public transport terminuses, as is the case in the Netherlands.

6.4. Can proximity be maintained to activities other than work?

While it is unlikely that measures to improve the mix of homes and jobs in urban areas will bring about any significant reduction in journey-to-work distances, efforts can at least be made to slow the growth in the length of trips for other activities, to which we have drawn attention above in the case of

Lyons. Two lines of approach would seem to be required: firstly, an attempt must be made to combat the current movement of households out of the more central areas.

The example of the survey on residential migration to urban fringe areas (Raux and Andan, *op. cit.*) shows in particular that this movement is motivated not so much by the attraction of the "coun tryside" as by the rejection of a certain way of life experienced in the city. Over 80 per cent of the survey respondents did not have full control over all the factors in their move and their decision on where to move to was subject to constraints, usually that of property prices. The reasons why people moved included the desire for a pleasanter living environment, the desire to live in a house which they owned, a rejection of city life, particularly in terms of the environment for children, and a rejection of communal living. This would indicate that one possible line of action might be to restructure the built environment and social framework in certain high-density areas in order to slow this movement towards peripheral areas.

The promotion of proximity mobility in areas where people lead their daily lives calls for greater emphasis to be given to walking and cycling through the provision of dedicated tracks and paths. This would have the advantage of making it safe again for pedestrian and bicycle traffic, which would have the added benefit of reducing the number of car trips to accompany children that parents make because of fears over safety. It would also provide a means of reducing noise and local pollution caused by car traffic, another factor in the deterioration of living conditions.

In conclusion, against a background of weak economic growth and a stagnant housing market, it would appear that there are few major changes to be expected in the use of land in urban and outer-urban areas in their current configuration. The value placed by society on home ownership and the desire for pleasanter living conditions constitute a social drive which, combined with decentralisation of local government, make it difficult to reverse any trend towards a decrease in population density. In fact, such a decrease would not necessarily be bad if it were to relieve congestion in densely trafficked areas; if that were the case, it should be accompanied by measures aimed at preventing the functional segregation of land areas (lifting of zoning controls), slowing the migration by restructuring urban areas, or directing the flows to more polarised forms of suburb (emphasis placed on the village centre; schools, leisure facilities and shopping precincts) that are accessible by the proximity modes to which priority has been given.

7. CONCLUSION

The scale of the changes that need to be made to meet the desired goal of reducing the environmental consumption of daily mobility, and the apparently limited scope for action, raises issues that must be addressed. Plans for action may be drawn up and then progressively stripped of their contents through the abandonment of measures deemed to be unacceptable to public opinion (Rietveld, 1995). It is tempting simply to ignore the warning signs by saying that the situation is not as bad as it seems and that in any case doubts remain, notably with regard to the reality of the threat of global warming. Even though doubts may indeed remain over this latter threat, whose impact lies far in the future and therefore impinges less on public opinion, the reality of congestion and the rise in the local nuisances attributable to transport cannot be denied. This is why the measures discussed above could be introduced in order to guide urban transport systems onto a development path that would be more environmentally-friendly, even if the results in the short term might only be modest.

Congestion pricing does not appear to be an efficient instrument since it can only achieve a significant reduction in car traffic if tolls are set at such a high level that they would be socially unacceptable. Furthermore, in the long term, the increasing premium placed on time and accessibility to residential areas of higher quality and ever further from the city centre would lead to a rather different balance in the optimum based on public health criteria. It is for this reason that environmental goals must be set and a wide variety of measures introduced to meet these goals.

Urban road pricing, in contrast, can be used to meet environmental objectives; tolls must target urban traffic flows in areas where alternative public transport facilities are available, and may initially be set at a modest level. Road pricing would offer the dual advantage of sending a signal to motorists regarding the cost of environmental resources and of providing a boost to the funding of improvements to the quality of the urban environment, including facilities for all modes of transport. It would be reasonable to assume that under the dual influence of incentives to reduce use of the car and the provision of transport facilities aimed primarily but not exclusively at alternative modes of transport, the urban transport system would be directed onto a path which would be better both for the environment and for the quality of urban life.

The provision of new toll-expressways in urban areas would be one way in which this form of road pricing could gradually be introduced, provided that an equivalent portion of the existing highway network is reserved for alternative modes of transport and for improving the urban environment. Such a policy would, however, require strong political resolve. Ways must be found to make this policy acceptable, notably to users who do not dispose of what would be considered to be adequate means of public transport, by giving a clearly environmental thrust to tolls. For example, free access to the new toll-expressways could be given to shared cars. The toll would therefore be presented not as the right to travel fast but as a right to pollute. A mix of pricing and regulation would thereby help to smooth the transition.

The political resolve required of local government could be reinforced through the introduction of codified funding procedures. Financial aid from central government could be provided under multimodal transport plans and made conditional upon local authorities meeting environmental goals by providing incentives to reduce the number of single-occupant vehicles. Linking such funding arrangements to environmental objectives at the level of a conurbation or city region might, perhaps, be one way to strengthen the co-ordination of the actions of different institutional actors. Such a change would, however, require greater awareness of environmental concerns, the level of which still varies significantly from one European country to another.

While there are still segments on the supply side in which conventional rail services are the most appropriate response, the current pattern and growing deconcentration of activities calls for the creation of a light-rail network of public transport which would provide comprehensive coverage of the urban area, and high-speed services, in order to match as closely as possible the flexibility of the car. These facilities would nonetheless be expensive and would require the allocation of road space to be re-examined. The approach outlined above and consisting of the introduction of new toll-expressways with free access for shared cars would, at the same time, generate new funding resources and make existing highways available for other uses.

Lastly, there is little to be gained from a forced march, even if it were possible, towards raising the density of urban areas. The most that can be done is, firstly, to dampen enthusiasm for "houses in the country" by improving the residential environment in cities and, secondly, to guide deconcentration flows towards suburban areas and away from total dispersion. While attempting to control where households choose to live is both socially unacceptable and, in any case, of limited effectiveness, encouraging firms to locate to sites near to public transport terminuses may help safeguard the possible future uses of this

mode. However, it is difficult to acquire this necessary degree of control over land use in urban areas in that the requisite powers are divided between a variety of authorities which often have conflicting interests.

In short, the answer may lie in a strategy which takes account of the potential savings in environmental resources afforded by each mode and which links transport facilities to the areas served. The aim must be, depending on the nature of the area concerned, to give priority to combining neighbourhood development measures with the most efficient modes of transport for the community: proximity modes, car-sharing, private car, light or conventional rail. The overall management of daily mobility in large urban areas requires coherent co-ordination of transport planning and land development. Achieving this co-ordination is perhaps the greatest challenge.

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