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CONTENTS

Why doesn't investment *in public transport* reduce urban *traffic congestion?*

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There is urban traffic congestion in most parts of the world, including Latin America. Among the measures aimed at solving this problem, many cities have built suburban railways or metros. However, these have had little or no effect, as is shown by studies which indicate that investments in the public transport system are incapable of solving this problem on their own. This article takes the view that when a new metro line or similar system is opened, many travellers who previously used the buses transfer to it, as do a few who previously used their cars. This frees some road space at peak hours, which is promptly used by other travellers who change their travel times or routes to take advantage of it. Furthermore, the parking spaces freed by the few persons who change from their private cars to the new trains are immediately occupied by the vehicles of people who previously used public transport because they had nowhere to park. Very soon, even though the new trains may be crowded with passengers, peak-hour traffic congestion is about as bad as ever. This sequence shows that metros and similar systems actually generate only a fraction of their potential benefits. In order for them to serve the community better, they should be coordinated with other measures, one of which would be to impose further restrictions on parking in areas around city-centre stations and other commercial areas.

I

Expectations and reality

What we see every day in the streets makes us doubt very much whether improvements in public transport systems will really reduce traffic congestion. The cities with the most extensive public transport systems, such as London or Paris, do not stand out by the freedom from congestion on their streets, and in Latin America the metros and similar systems which have been constructed do not seem to have done much to reduce congestion.

Yet one of the reasons most frequently put forward in support of investments in metros or similar systems is precisely that they will help to reduce congestion. Expectations of reduced congestion are held out in the relevant preliminary projects, in the declarations of technical experts and politicians, and even in the project appraisals made by teams of consultants. In Santiago, Chile, for example, it was forecast that in 1980 the metro would transport 202,330 passengers in the maximum peak hour, and that 95,800 of them would be people who had stopped using their private cars (i.e., more than the number of people who would stop using the buses).1 In other words, it was expected that 47.4% of metro users would change to it from private means of transport.

It may have been that the consultants (mostly foreigners) hired to evaluate the proposal to build a metro in Santiago at that time were more optimistic than their opposite numbers in other cities about the possibility of interesting private car users in the new system, but there was a good deal of optimism in other sectors too. Some experts who examined the objectives of the various metro projects noted that the main objectives of the project, in the light of the situation of urban transport and of the city itself at that time and in the future, included improving the fluidity and speed of travel, solving the problem of traffic congestion, meeting social demands, revitalizing city centres, and correcting the tendency towards agglomeration (Figueroa, 1986), and it was widely believed that a metro would relieve congestion by reducing the number of buses on the streets and would possibly attract some private car users (Allport and Thomson, 1990).

Laymen in matters of urban transport considered that it was only logical that the construction of a metro would reduce congestion in nearby streets, and many specialists shared this belief. However, as we shall show below, what really happened is something that seems to defy all logic.

II

Our basic thesis, and a methodology for the economic and social evaluation of metros

The basic thesis of this article may be summed up in only a few words:

i) An improvement in a public transport system brings about only a very small increase in the total number of users of that system, its main impact being a redistribution of demand whereby users transfer to the improved components from the competing unimproved components.

ii) The relatively few private car users who move to the improved component of the public transport system free road and parking space, but this is immediately occupied by other persons, including some who previously used public transport, so that congestion returns to the levels registered before improvements were made in the public transport system.

iii) The reduction in the number of bus passengers may also free some road space (but not parking spaces), and this will lead to some redistribution of car trips in terms of time: thus, the space freed at peak periods is occupied once again, leaving the

[1] Estimated on the basis of the tables on pages 98 and 100 of SOFRETU/BCEOM/CADE, 1968.

streets somewhat less congested at the times of day close to those periods.

A number of studies[2] make it abundantly clear that metros or similar systems do not reduce traffic congestion. This conclusion runs counter to those of other studies which assert that they do reduce congestion and therefore bring environmental and other benefits. It seems quite wrong, for example, to assert that "all countries in the world openly acknowledge the negative effects of traffic congestion on the environment, and there is therefore clear awareness of the benefits of light railways, whose advantages include clean operation, safety ..." (Jorge, 1994). If light railways, or more conventional ones, do not reduce traffic congestion, then their environmental benefits are non-existent.

The thesis proposed here has some implications for the methodology to be used in the economic and social evaluation of metros. The fact that a metro or similar system does not reduce congestion does not mean that its construction may not be appropriate from an economic and social standpoint, but it does mean that the possible benefits of constructing the new system would lie in the differences of cost between transporting users by the metro and by the previous means of public transport. Sometimes it may also be necessary to take into account the possibility that the metro permits an increase in the total number of journeys made.

In typical cases, the corresponding calculations will be quite easy: if it is assumed that metros do not have much effect on traffic congestion this would make their economic and social evaluation much simpler than if the degree of congestion had to be taken into account.

III

More detailed aspects of the proposed thesis

1. Consequences of changes in land use caused by the metro

Metros make some parts of urban areas more easily accessible, especially around metro stations. This raises property values and may give rise to tendencies towards densification in the areas around stations through, for example, the construction of tall apartment buildings and, especially, office blocks.

There are mathematical models which include both the simulation of transport patterns and land use. They have been applied in a number of Latin American cities, such as São Paulo. Although they are intellectually interesting and sometimes mathematically elegant, however, they are of very limited usefulness because they are almost impossible to calibrate. Nevertheless, although in practice it may not be possible to quantify it in advance, it cannot be denied in principle that there is a two-way relation between the transport system and land use.

This relation does not always manifest itself, for various reasons which include the existence of prior regulatory plans which constrain the natural actions of the property market. Consequently, densification of land use does not always take place, at least to a significant extent (as for example in the cases of Rio de Janeiro and San Francisco), but it has occurred in such cases as the suburbs of London in the early decades of this century and, more recently, in Santiago (Chile), Hong Kong and Toronto, sometimes through the natural action of the market and in other cases through a planning process carried out by the private or public sector.[3]

When the metro encourages the development of commercial activities around its stations, the majority of the people who work there and the clients and other users of such activities will naturally use the metro to go there and back. Nevertheless, a significant number of people will use their private cars for this purpose, thus aggravating congestion. In Santia-

[2] Foster and Beesley, 1963; Younes, 1995; Allport and Thomson, 1990; Bamford and Allport, 1990.

[3] See for example Allport and Thomson (1990) and Knight (1980).

go, the concentration of journeys by vehicles other than the metro is higher in the area of influence of the metro than in the city as a whole, and of course it is much higher than in areas where there is no metro (table 1).

Thus, although this may not seem logical, the metro would appear to give rise to an increase in the number of car trips in its own area of influence. If the metro had not been built, these trips would probably have been made in other parts of the city. It is also likely, however, that the density of commercial activities would have been less than in the area of the metro, and these trips would therefore have caused less congestion.

This indirect result of the metro –stimulation of private car use in the areas it serves– could be made a more expensive proposition for car users by imposing strict controls on parking both on the street and off it, even in new buildings, but little has been done in Latin America in this respect. Very frequently, for example, the authorities fix a minimum number of parking spaces per square metre or per employee, whereas what they ought to do is fix a maximum number (see *El Mercurio*, 1996).

TABLE 1

Journeys by means other than the Metro generated in the area of influence of the Santiago Metro and in Greater Santiago, 1991

(Number of journeys per km2 in morning peak period)

Means of transport	Area of influence of the Santiago Metro[a]	Greater Santiago as a whole
Private car journeys	816	492
Bus journeys (in car-equivalents)	206	122
Taxi journeys	21	12
Collective taxi journeys	33	14
Total	*1 076*	*640*

Source: Estimates by the author, on the basis of data from Comisión de Planificación de Inversiones en Infraestructura de Transporte (no date); Catholic University, Instituto de Economía (1993); Empresa de Transporte de Pasajeros Metro S.A. (several years), and telephone consultations with the latter company.

[a] The area of influence of the Metro is defined as a strip five blocks wide (equivalent to 500 metres) along the Metro lines.

2. The latent demand for car trips

If someone has a car, he will most likely use it to get from one place to another, even though this option may not involve any saving of time or money compared with public transport. This preference for the private car may be due to a variety of reasons, such as freedom to choose the time of the return journey, the possibility of carrying packages, protection from the weather, greater privacy, or the possibility of listening to a preferred radio station while driving.

Transport simulation models reflect this preference for car travel in different ways, for subjective reasons. One option is to determine adjustment factors quantified through calibration of the modal partition module. To put this more simply, what is done is to select essentially monetary values which, when used to modify the costs of car travel, make it possible to reproduce as accurately as possible the modal partition actually observed: these factors would represent the revealed preferences of travellers. Another method, which has been used more frequently in recent years, is to use surveys to determine the declared preferences of travellers among the various travel options, defined in terms of cost, time and other features.

Very frequently, the demand for car travel in the most highly commercial areas of cities exceeds the available parking space; this factor is incorporated into the models in different ways. If the opening of a metro or some other improvement in the public transport system initially resulted in a significant shift in demand from private cars to the improved system, this would free parking spaces. However, because of the unsatisfied demand for car travel (due to the insufficient parking space), the spaces thus freed would not remain unused for long, because other persons, who previously used public transport, would now use their cars in order to take advantage of the new situation. Thus, the number of car trips would remain the same, although the trips would probably now have different starting points.

In other words, the opening of a metro along one major thoroughfare of a city could lead to an increase in car trips on other major streets. This result can be simulated through a normal transport planning model, but there are other comparable effects which cannot be simulated through the vast majority of such models.

3. Preferences in terms of time, and road space

Initially, the metro should lead to a reduction in congestion on parallel streets, due both to a small reduction in car travel and a larger reduction in bus journeys. However, this reduction could prove to be transitory.

Many people –including the author– do not travel at peak hours because of the delays and tensions caused by the serious congestion usually prevailing at such times. In principle, it would suit them best to travel at these times, but in fact they travel a little earlier or later in order to travel at times when traffic is somewhat easier.

With the opening of a new metro or similar system, however, traffic congestion around the metro would go down, and this would encourage persons who used to travel a little before or after the peak periods to change to times when traffic is heavier.

As a result, congestion at times of heavy traffic would be almost as bad as before, while it would go down more or less permanently in the periods immediately before and after rush hours, thus making the concentration of journey frequencies at given times even more acute.

4. Political expediency

It is worth adding at this point a few words on the expediency of carrying out metro projects, as perceived by local politicians, in order to help to understand why new public transport systems are constructed that do little or nothing to reduce congestion.

With very few exceptions, mayors, regional authorities and other political figures who promote the construction of metros thereby also improve their own political prospects. Normally, the city where a metro is built pays only a small part of the investment costs involved, but almost the whole of the benefits generated by the metro are confined to that metropolitan area (see Thomson, 1985). Obviously, the citizens gain more than they lose and tend to feel grateful to their political representatives who played a part in the decision to build the metro. The losers are the other inhabitants of the country, who have to help to pay for the investment although they do not receive even the slightest part of the benefits.

Consequently, local politicians naturally tend to promote the construction of a metro in their cities, justifying their position with arguments that seem logical at first sight but do not stand up to more serious analysis.

IV

Effects of the metro on congestion: some specific cases

The following sections contain some important conclusions for our analysis, drawn from various studies carried out in order to determine the effects of a metro or other mass transport system on congestion.

Let us distinguish first of all between two types of repercussions of metros on the volume of street traffic: the direct impact, represented by the number of travellers who change to the metro, and the indirect impact, represented by changes in the behaviour of travellers as a result of that direct impact, which may have the effect of stimulating a change to private car use. We make this distinction because normally metro companies are well capable of estimating the direct impacts, through user surveys, but they, or other authorities, very rarely know much about the indirect impacts.

1. Results of analyses by simulation models

The Transport and Road Research Laboratory in the United Kingdom has used a simulation model to investigate the effects on the volume of private car traffic caused by different levels of investment in public rail transport. A model was prepared for a medium-sized city, the construction of a metro or light railway system in radial corridors was posited, and an evaluation was also made of the impact of changes in fares (see results in table 2).

TABLE 2

Medium-sized cities: impact of construction of metro lines or light railways on car traffic

	Percentage change in car/kilometres compared with base situation	
	Peak period	Off-peak period
Metro on three radial corridors	-1.3	-0.3
Metro on six radial corridors	-2.6	-0.6
Metro on six radial corridors, fares reduced by 50%	-3.0	-0.9
Metro on six radial corridors, fares increased by 50%	-2.2	-0.5

Source: The Chartered Institute of Transport, 1996, Annex B.

No information is available on the length or cost of the metro and light railway systems modelled, but it is fairly clear that very large investments in the construction of such systems bring about only minimal reductions in private car use. Even then, the small changes calculated in such use could lead to overestimation of the accompanying changes in congestion, because it is highly improbable that the model used (of which we do not have any details) was capable of simulating the redistribution of journeys in time at peak periods, or the redistribution between those periods and the rest of the day, as a result of differential changes in the amount of road space freed by the transfer of some journeys to the metro or light railway system.

Other studies carried out in Great Britain give rather similar results. The execution in London of an extensive programme of construction of mainly underground railways –including among others the new railway along the East-West axis through the city centre, extension of the Jubilee line of the Underground, extension of the Docklands light railway, and a tramway system in the suburb of Croydon– would reduce the percentage of person/kilometres corresponding to car travel from 52.4% to 47.6%, but only if in addition the bus frequencies were increased by 20%, the traffic control system was further perfected, and rigid control over car parking on the streets of the capital was ensured.[4] Another study, also in London, estimated that the application of a strategy of improvements in bus and train frequencies, plus the extension of the system of preferential treatment for buses in traffic, would reduce the number of vehicle/kilometres by 1% in the city centre and by 2% in the rest of the city. If at the same time large sums were invested in the rail system, the figures would increase to 4% and 5%, respectively.

[4] See The Chartered Institute of Transport, 1996, Annex B.

According to the report of The Chartered Institute of Transport (1996, Annex B), all relevant studies indicate that measures designed to improve the competitiveness of public transport would probably only have minor effects on private car use. On the other hand, however, the authors of that study also consider that the models used may underestimate the effect of improvements in public transport on car traffic because they do not take due account of qualitative rather than merely quantitative aspects (*Ibid.*, p. 49).

2. The Victoria Line of the London Underground

The Victoria Line, which runs between the East-Central suburbs of London and the central area and was subsequently extended to the south, was planned in the 1960s and opened at the end of that decade. The cost-benefit analysis carried out to determine the economic feasibility of this project was considered a model of its kind at the time and is still mentioned as a classic study (Foster and Beesley, 1963, pp. 46-78). Among the stated objectives of the project was the reduction of street congestion, and it was expected that the possibility of faster travel by this means would reduce the volume of cars on the streets and make for more expeditious bus transport. According to the analysis in question, 35% of the benefits of the line would come from the reduction of that volume by 8,000 one-way car trips per day.

In reality, however, only 5,500 users of the new line were people who had changed over from private car use, and 1,400 of them still kept on using their cars to reach the subway. The researcher Bassem Younes suggests that the space freed in the streets immediately after the opening of the line may have been cancelled out by the use of this space to satisfy the latent demand for car travel (Younes, 1995, pp. 333-336), and he concludes that the impact of the Victoria Line on car traffic was very marginal and the streets continued to bear almost the same volume of traffic as before.

3. West Berlin

Younes also analysed the extension of the metro of what was then West Berlin to Spandau between 1980 and 1984; as in London, one of the objectives of this project was to reduce traffic congestion on the streets. He concluded that the case of Berlin proved once again that improvements in public transport did not automatically lead to a significant and substantial reduction in motor vehicle use (Younes, 1995, pp. 333-356).[5]

He arrived at this conclusion after studying the results of a survey carried out by the Department of Transport and Public Works of Berlin. In this particular case, however, the results may be interpreted differently. In Spandau, between 1979 and 1985 the proportion of journeys made by private car increased only modestly, from 42.6% to 43.2%, while journeys by public transport increased a little more, from 25.3% to 27.3%. In the comparable district of Lichtrenade, where there were no changes in the metro system, the proportion of journeys by car rose from 43.7% to 52.4%, while the share of public transport went down from 31.8% to 24.6%. We thus see that, using the same basic figures as Younes, it is possible to arrive at a different conclusion: that the extension of the metro to Spandau did have a significant impact on private car use and did help to reduce traffic congestion.

4. Stuttgart

This other case studied by Younes concerns the extension of line 1 of the suburban railway system, between Schwabstrasse and Vaihingen/Böblingen. This project was completed in September 1985. Here, too, one of the aims of the project was to check the growing level of private car use. Younes's task was easier because the metropolitan authorities had carried traffic studies along the line of influence of the extension both before and after its entry into service.

In spite of the extension of the line, traffic on the city streets grew more within the area of influence of the extension than in the rest of the city (table 3). The growth was generally less in areas closer to the city centre, because of the saturation of the streets and the restrictions imposed by the shortage of parking places.

Younes concluded that the impact of the extension of the suburban railway was felt within the public transport system, especially in the form of transfers from the buses to the trains, while any road capacity freed was quickly used up by the latent demand.

It is also clear that the extension of the railway made possible more journeys to the city centre and implicitly helped to make the central area of the city more viable, especially as an area of concentration of jobs.

6. Cities in developing countries

A study carried out by the United Kingdom Transport and Road Research Laboratory states that little evidence has been found of a relation between building a metro and reducing traffic volumes, and the majority of users of rail transport systems in developing countries come from other forms of public transport.

Another British study which analysed the effect of mass transport systems on congestion in developing countries (Allport and Thomson, 1990) concludes in general that in almost all the transport corridors there was congestion ranging from moderate to severe before the construction of the metro, and in the great majority of cases the improvement seems to have been slight or non-existent, while in many cases the congestion even got worse. In some cases there was a clear improvement immediately after the opening of the metro, but the benefit was only fleeting. This is consistent with the thesis put forward in this article.

Of the 12 cases shown in Box 1, only three credit the metro or light railway with bringing about a significant reduction in traffic congestion. Another study concludes that in general the proportion of private car occupants who would transfer to a metro opened in the same corridor would be between 0% and 4% (Bamford and Allport, 1990).

[5] Younes uses the term "motor vehicle", but it is clear that he is referring specifically to automobiles rather than other types of motor vehicles, which could in principle even include the motorized cars of the metro.

TABLE 3

Changes in volumes of private car traffic, before and after extension of Line 1 of the Stuttgart suburban railway

	Ring	Increase in traffic between May 1984 and April 1986 (%)	Increase in traffic between October 1984 and October 1986 (%)
Within area of influence of the extension	Inner	3.6	...
	Outer	13.3	11.5
In the city as a whole	Outer	...	6.3

Source: Younes, 1995, p. 350 (some minor errors in the original table have been corrected).

BOX 1

SELECTED CITIES IN DEVELOPING COUNTRIES: SUMMARY OF IMPACT OF METROS ON TRAFFIC CONGESTION

Cairo:	No discernible impact.
Calcutta:	No impact.
Hong Kong:	Car ownership went down around the time that the metro was opened, but the reason was an increase in taxes, rather than the metro. Some 16% of bus passengers transferred to the metro, but later bus traffic increased and congestion was the same as before.
Manila:	Some reduction in congestion was registered, probably due to the new light railway system and an economic recession.
Mexico City:	Congestion caused by private cars continued to be very severe, even though car ownership went down as a result of an economic recession. Bus speeds are relatively high, but presumably because of the establishment of exclusive bus lanes rather than the impact of the metro.
Porto Alegre:	Congestion was not very severe either before or after the construction of the metro.
Pusan:	The metro probably helped to relieve traffic congestion.
Rio de Janeiro:	Bus flows only went down a little, so there cannot have been much impact on congestion.
Santiago:	Congestion along the main East-West axis continued to be severe, and bus traffic continues to be close to the maximum possible levels.
São Paulo:	Bus flows went down by 500 per hour in each direction along each corridor; to begin with there was less congestion, but this later became severe once more and spread to many areas.
Seoul:	Congestion was serious, generalized and rapidly growing. The mass transport system did not have any observable impact on traffic volume or bus flows.
Tunis:	No impact was expected on congestion, and this was confirmed by practical experience.

Source: Allport and Thomson, 1990, table 8.1. The comment about exclusive bus lanes, in the case of Mexico City, is the responsibility of the author of the present article.

V

A form of public transport capable of attracting motorists

1. Motorists' rejection of common-or-garden buses

Experience all over the world indicates that improving the common-or-garden bus systems does not succeed in attracting private car drivers. Routine rail systems (metros, tramways, etc.) interest them a little more, but not too much. Only varieties of public transport which offer private car drivers a higher level of comfort have managed to lure significant numbers of motorists out of their private cars and into the ranks of public transport users.

In wealthier countries, such higher-class public transport services could run on rails. The Metros of some United States cities such as San Francisco or Washington, for example, offer quite agreeable travelling conditions, and their suburban stations have spacious parking lots, planned for bimodal journeys combining private and collective transport. This is an interesting option for private car users. However, there are no Latin American countries where it would be socially or politically acceptable to finance (necessarily with public funds) the construction of a metro to satisfy the tastes of the elite.

2. Luxury buses

Another option is to authorize the operation of higher-class bus services, which already exist in cities such as Buenos Aires, Córdoba, Guatemala City, Rio de Janeiro, São Paulo, Santafé de Bogotá, etc. These buses usually have comfortable reclining seats, air conditioning and background music, and moreover they do not carry standing passengers. In Buenos Aires and some Brazilian cities, their fares are four or five times higher than on a regular bus, but even so these higher-class services attract enough users to make them a profitable proposition. It should be noted, however, that the financial situation of their operators is highly susceptible to changes in the economic environment. Thus, the economic problems of Brazil in the 1980s seriously affected the popularity of the *frescões* of Rio de Janeiro, and it is quite likely that the stagnation of the Argentine economy in the mid-1990s is affecting the profits of the firms operating "differential" services in Buenos Aires.

The establishment and operation of higher-class bus services usually costs the public sector little or nothing, and they have shown themselves to be successful in attracting private car users. In Buenos Aires, for example, 14% of the users of "differential" buses would otherwise have used their private cars (Vicente and Brennan, 1989). In Bogotá, 48% of the users of executive buses came from families owning one or more cars, while 19% had cars for their own personal use (Acevedo, 1989). In Amsterdam, 39% of the users of a luxury express bus service chose it instead of travelling by private car (OECD, 1994).

Higher-class buses are clearly capable of attracting persons who would otherwise have travelled by car. This would be their direct impact (see section IV.1 of this article). No information is at hand about their indirect impact, but it seems obvious that unless measures are taken to control the problem, it is very likely that the parking and road space freed through a reduction in direct car use will be occupied by people who changed in the opposite direction: i.e., from public to private transport.[6]

3. The Curitiba system

In Curitiba, Brazil, there is no higher-class collective transport system, compared with the average quality of such transport in that city, but in general terms the collective transport system is of higher quality than in almost any other Latin American city. In Curitiba, the express buses run on a system of exclusive bus lanes some 60 kilometres long. The various lines are integrated with each other, and citizens of all social classes have an excellent opinion of the system. In

[6] For fuller details on the influence of higher-class buses on congestion, see Thomson (1996).

spite of the existence of exclusive bus lanes, a journey by private car tends to take less time than the same journey by public transport (see Buleze and others, 1985, table 12), but even so a considerable percentage of collective transport users leave their cars at home and prefer to use the bus.

Some of these users assuredly choose the bus for reasons of convenience, reliability or cost, while others do so because they have nowhere to park, but it cannot be denied that the intrinsic qualities of an integrated public transport system which has been well planned for many years can make it attractive enough to be preferred by people who would otherwise have travelled by private car. What we do not know is whether the direct reduction in congestion that may have taken place will be maintained, or if it will be offset by the indirect generation of other private car journeys.

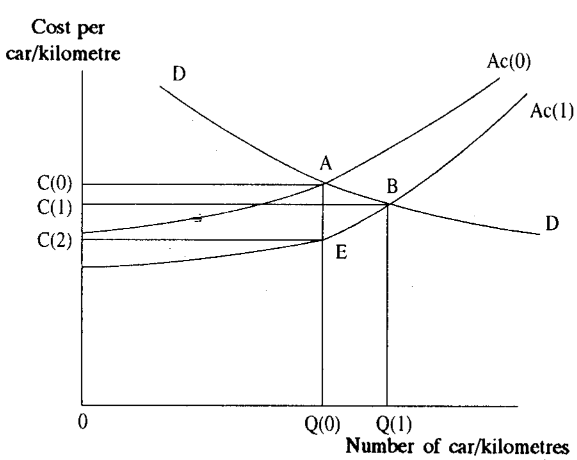
VI

The importance of measures to control private car use

1. Basic principles

If we look at the traffic situation in a corridor before and after the construction of a metro, we see that the direct impact of the latter is that it attracts a number of journeys previously made by bus and a few journeys previously made by private car, thus increasing the road space available for other road users (figure 1). The relation defining the supply of road space available to the latter is shown by curve *Ac(0)*before the construction of the metro and *Ac(1)* after it enters into operation. The relation governing the demand for road space is shown by curve *DD*, whose form reflects the elastic nature of such demand.

FIGURE 1
Theoretical representation of road use by non-Metro-users



The case shown in the figure does not provide for the application of a system of tolls whereby road users would pay charges reflecting the difference between the mean cost and the marginal social cost of their occupation of road space. Such tolls or charges could generate economic and social benefits in the situations both before and after the construction of the metro, by reducing traffic volume and congestion.

In the first situation, the volume of traffic is *0Q(0)*, at a mean cost of *0C(0)*. After construction of the metro, this volume rises significantly, to *0Q(1)*, and the mean cost goes down by a relatively smaller amount to *0C(1)*. The benefits received by users are identified by the area *C(0)-A-B-C(1)*.

If, however, it were possible in the second situation to keep the volume of traffic down to the pre-metro level, the benefits obtained would increase to the considerably larger amount of *C(0)-A-E-C(2)*. Consequently, if it were feasible to limit the increase in road use, this would be clearly desirable in terms of overall welfare.

2. Practical measures

The need to restrict the indirect impact is clear, but the ways of doing so are not so obvious. The optimum amount of restriction varies in each case, and depends in principle not only on the number of journeys transferred to the metro or the road space thus freed, but also on other factors, such as the seriousness of congestion along the metro axis.

In practical terms, however, it would be reasonable to try to reduce parking space in the area of influence of each metro station by the same amount as the number of cars and drivers who travelled to such areas each day but have now transferred to the metro as a result of its direct impact. The corresponding reductions could be quantified by analysing the results of a transport simulation model, so as to be able to reduce the parking space simultaneously with the opening of the metro.

Another option would be to carry out a survey among metro users, once it is in operation, to find out how many passengers previously travelled by private car. This method has the advantage of being more precise, but it would be more complicated from the political point of view because it would mean depriving motorists of parking spaces to which they were already becoming accustomed.

There are not many practical measures that can be taken to minimize the impact of changes in travel times by drivers who reschedule their journeys by changing from periods just before or after the rush hour to the peak period itself, in order to take advantage of the road space newly freed by the direct impact of the metro. One option could be to impose controls on the time of entry into parking areas, but this would be difficult to carry out in practice because, *inter alia*, the drivers who thus changed their journey times would not be going to a single area but to a considerable number of different areas, where they would be competing for parking spaces with other drivers who it was not intended to restrict.

In theory, the distribution of car journeys in time could be controlled by a sophisticated version of a road toll system which linked the amount of the toll to the degree of congestion at each particular time of day. Generally speaking, this arrangement would make it possible to adapt traffic volumes to the available road capacity and demand characteristics at each time, but options like this are very much in the future, and could remain there for ever. In the meantime, the available range of practical measures is much more limited.

(Original: Spanish)

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