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**ROUND
TABLE
38**

SCOPE FOR THE USE
OF CERTAIN OLD-ESTABLISHED
URBAN TRANSPORT TECHNIQUES
TRAMS AND TROLLEY-BUSES

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT

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ECONOMIC RESEARCH CENTRE

**REPORT OF
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on the following topic :

**SCOPE FOR THE USE
OF CERTAIN OLD-ESTABLISHED
URBAN TRANSPORT TECHNIQUES
TRAMS AND TROLLEY-BUSES**

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT

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- to take whatever measures may be necessary to achieve, at general or regional level, the maximum use and most rational development of European inland transport of international importance ;*
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SCOPE FOR THE USE
OF CERTAIN OLD-ESTABLISHED
URBAN TRANSPORT TECHNIQUES
(TRAMS AND TROLLEY-BUSES)

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1. INTRODUCTION, STATEMENT OF PROBLEM

Anyone writing about the future soon finds he has to base himself on what has happened in the past - particularly in the present case, where we are largely concerned with railborne transport, a technology that may not be as old as the Roman road - which never had rails - but which, at 150 (the first railway line was opened in England a century and a half ago), has reached a ripe old age compared with cars, motorcycles or aircraft, all of which are 20th century phenomena. Can anything that old really have a future?

In the following paragraphs, as a first step towards answering this question, a brief historical look is taken at the subject of this report (limited, of course, to passenger land transport).

150 years ago

The railway was the offspring of two inventions: the steam engine, providing the motive power, and the iron rail, offering low frictional resistance, and along which whole trains could be moved on iron wheels. Compared with the low-capacity, slow and bumpy horse-drawn coach or the even slower canal barge this was truly an enormous advance and it met, for that matter, some psychological opposition, but with the development of industry, trade and transport, there was no stopping the growth of the railways and the first lines were soon laid between major centres at home and abroad.

In view of its one-dimensional freedom of movement, however, it had to be a public transport mode although the wealthy could still travel in an enclosed environment, either by having their own private train or, as in most cases, through the class system in public trains.

125 years ago

By this time the railways had developed into real networks not just linking the big cities but reaching out to the smaller towns. Because of the high construction costs and the necessary use of big units, services of the latter kind were unprofitable which made railways characteristically a long-distance form of transport although the label did not become attached at the time.

100 years ago

Growth in trade, combined with improved communications, generated the need for better transport services, even in agricultural areas.

This requirement was felt even more intensely, on the small scale, in developing towns where the distances became too long to be covered on foot. The railway was discovered a second time, not using its own track for the high speeds and long trains this permitted, but on rails simply laid on or alongside the road on which ran slow, short trains, which also became known as trams. Out in the country they were drawn by small steam locomotives but in the towns horses or other draught animals pulled them. Local and urban transport was born. From the very start, incidentally, its function was to carry passengers to and from main railway stations.

75 years ago

Apart from further development in railways (here including the use of more modest "urban railways", which were really regional railways) the big event was the application of electric traction to trams. Faster and more reliable tramways were built which led to vigorous urban growth. Where local traffic was particularly intensive, particularly in the so-called metropolis towns, electric urban and "Metropolitan" railways were laid. The public highway could not be used for these systems and they were therefore built underground or overhead. To a small extent electric trams also flourished in the outskirts of towns, when justified by the volume of traffic, but the era of mass commuter and recreational traffic was generally still to come.

50 years ago

The internal combustion engine, pneumatic tyre and improved road surfaces saw the arrival of:

- aircraft, originally as a competitor to sea travel;
- the bicycle, an incomparable mode of individual local transport;
- the private car, for anyone who could afford it at the time;
- motorbuses and trolleybuses which became public transport's growth sector.

The bus, somewhat uncontrolled at the start but later "tamed" and "put on the right road", showed that it was far better suited (because of its manoeuvrability, small capacity and the fact that it used the public highway) for low to medium-volume traffic than the train or tram, a fact which sealed the fate of the railway as a link between the small towns, the local railway, the steam tram, and the electric tram where routes were badly chosen or in medium-size towns.

Motor traction, however, was also applied to railborne vehicles, though with qualified success at the start. Here too, it made cheaper, small units possible.

More important was the introduction of electric traction on railways, firstly for suburban traffic, linked to varying extents with the growth in commuter traffic.

25 years ago

Disregarding the stormy developments that then erupted on the transport stage, one could hardly speak of new inventions. Development was particularly spectacular in the case of the car. A "motorising for the masses" movement set in with an increasingly large number of citizens able to acquire their own universal means of transport.

The bicycle turned into a moped, extending the range of two-wheelers.

The bus had reached maturity.

Aircraft had become the favourite means of transport for distances of over 500 km. In the meantime railborne transport technology was further improved:

- electrification of all main lines, modernisation of superstructures and safety systems and operation with modern electric and diesel-electric power units permitting far higher frequencies than with steam traction.
- the introduction of modern trams, though restricted to the heavily-trafficked routes in big towns.

Today

The effects of the general use of cars have become apparent. It is not so much a matter of replacing public transport - which, as far as volume is concerned, has, by and large, managed to hold its own - instead, the car has generated new traffic and this has meant a roughly tenfold increase in mobility: having your own means of transport at your beck and call and ready at your front door to take you where you like when you like, makes you want to use it. At high average speeds, far greater distances can be covered than by public transport in the same time. A further point is that nowadays there is far more leisure. Deciding where to live and where to work is no longer a problem because, if there are no buses or trains in the vicinity or if public transport is too slow, the journey can be done by car. Hence the spread of our towns, suburban development, the separation of living and working functions, the end of the concentration of activities in town centres, the beginning of out-of-town shopping centres, intensive recreational traffic, two-house families, camping, holidays in faraway places, and so on.

Prospects for the future

Will railborne transport still exist 25 years from now? Will there still be a need for public transport? The answer is that,

although it is already in a subsidiary position, it will continue to exist because one-third of the population will just be unable to have its own personal vehicle (being too young, too old, unfit to drive, etc.). If this third is not to be completely dependent on the other two-thirds some basic public transport will have to be provided.

This is not easy, because land-use has developed in such a way that public transport can cater only for the main links by means of an interconnected series of star-shaped networks. However, since it is merely a case of providing transport for those who have no alternative, this restricted service could practically always be provided by buses. No special infrastructure would be necessary - a situation found practically everywhere in the United States even in a conurbation with a population of several million like Los Angeles.

The universal motorcar

Anyone who looks at this problem with a critical eye will surely perceive its unpleasant side-effects such as:

- over-decentralisation;
- the undermining of the functions of the town;
- hence the continuous increase in the distances to be covered;
- adverse environmental effects, both in towns (where our centuries-old culture has its real roots) and in the countryside;
- a lowering of the quality of life because of the car's spatial demands, and the smoke and noise it produces;
- the unacceptable threat to safety;
- high energy consumption (four times that of public transport);
- the need for space from every standpoint.

As regards this latter point the point to note is that, for every person or family, a car requires a parking place not only at home but also at the place of work, bank, post office, shop, store, theatre and sports stadium. Carparks also have to be provided near the beach and woods, on camping sites or purely and simply for tourists in old city centres. Linking roads are necessary along which cars move this way and that in great swarms.

The question of whether this has to continue is rhetorical. Practically everybody is aware of the need, in the densely populated countries of West Europe, for an alternative form of transport even for motorists and that alternative form is high-quality public transport. The car cannot be wished out of existence but its selective use is desirable in cases where - used in large numbers - it causes too many obstacles.

Of what is a good transport system composed?

As already said, the difference between a car and public transport is that the former can provide a service from any starting point to any destination at any time. Public transport would be able to provide the same, to a large extent, if it had very small units (mini-buses or taxis) plying a very large number of routes. We know that taxis are very expensive because of high personnel costs and in any case their use has not eliminated the obstacle of the car.

The mini-bus has similar disadvantages and, with ordinary buses, a far lower level of supply has to be excepted: not whenever required but every 5 to 60 minutes. The lower the housing density, the lower the frequency; increasing the number of destinations also lowers the frequency. A certain degree of organisation becomes necessary i.e. fixed stopping places, selected direct routes, etc. This means channelling traffic to some extent. The net result is a transport system suffering serious qualitative disadvantages compared with the car whilst general factors such as lack of space and safety unfortunately carry no weight with the travelling public as regards modal choice. Improvements are possible only by taking organisation a step further:

- concentration and directional control for the main traffic flows;
- specificity of public transport systems as follows:
 - . long-distance systems with few stopping places (in big towns only);
 - . regional transport systems, both for traffic in the region itself and to feed the long-distance system;
 - . local systems, etc.

Still a future for rail transport

With organisation and concentration, railborne transport - outstanding as a mode of mass transport because it has its own infrastructure and can use large capacity vehicles and sets of vehicles - comes back into its own. Apart from this advantage (a rail track has 5-20 times the capacity of a road-way) there are those of the maintenance of high speeds in conurbations, regularity and reliability, travelling comfort and low operating staff requirements.

The car owes its efficacy to the use of the public highway and public transport develops its potential only if it has its own track.

Looked at in this way, we have rediscovered the rail and that is a good thing because otherwise this report would close at this point on an unreassuring note. On the other hand railborne transport does not emerge as an all-sufficing public transport system, its primary use is for the main traffic flows. The bus is necessary and will remain so in a finely ramified system supplementing and closely interlinked with railborne modes, as history has clearly shown.

Urban transport: Underground trains, express trams and trolley-buses

Urban transport problems are familiar enough. Unwanted crises in the disintegration of functional concentration and the erosion of culture and quality of life will be avoided only if preference is given to the economical users of the little space available, in other words public transport, bicycles and mopeds. This means not only own track for trams and buses, good cycle lanes, priority rules for public transport, limited access for cars in town centres, etc. but also strict enforcement of parking and traffic rules.

If something is taken away on one side then it must be used to benefit the other sufficiently for it to become a real alternative for motorists. Average tram and bus speeds could be increased from 10 to 20 or 25 km/h and this would bring them up to what is presently held to be the average speed for a car. At least as important is to increase the reliability of service. Other needs are high frequency, improved comfort, easier changing, clear information and simple fare structures. This could all be achieved in a few years if the authorities would (or could) take the necessary measures far more quickly than at the moment and if transport operators would co-operate wholeheartedly. Route 10 in Zürich and Route 1 in Amsterdam are examples that need urgently to be followed.

There are examples of express trams as well but what can be said about the underground railway? It is an ideal mode of transport if it can be built quickly at predictable cost and without involving too many obstacles, and if it produces a close-mesh network for very dense traffic. In West European conditions (generally only in towns with a population of well over one million) each one of these criteria has to become a secondary consideration. A modern tramway however, in its most recent form, is more of an adapted railway or Underground that can be used on a road by being scaled down and by using overhead power lines and powerful brakes. As the "own track" proportion steadily grows, it becomes possible to have tram sets meeting the applicable capacity, regularity and cost criteria. Where high capacity is unnecessary (on lightly trafficked lines in big towns and in the smaller towns) the trolley bus will remain the right mode of transport although similar measures (often at a more modest level) will be needed here as well.

New technologies

Even on the assumption that these are a vast improvement, can they oust existing transport systems which already have so much infrastructure and know-how?

With practically none of the many hundred newly-invented transport techniques yet operational, optimism is waning in many countries

as manufacturers and governments are pulling their money out of development projects. Why? The reason is that existing public transport technologies fail not so much on technical counts but because they are public and therefore not specifically focussed on the transport requirements of each individual. In the new technologies attempts are made to solve this problem using small automatic (and therefore unaccompanied) units going to any desired destination at any desired time. This calls for a complicated and extensive network that proves to be out of the question pricewise and often materially impossible as well. There would have to be very heavy traffic to justify it but, in that case, very small units could not be used if the necessary capacity was to be offered and this brings us back to normal rolling stock on fixed routes. This puts the train/tram/bus combination back into first place provided it meets comparable criteria as regards infrastructure, comfort, etc. Things are different when it comes to opening up markets where public transport in its present form can play no part, e.g. finely webbed systems in extensive pedestrian areas in town centres or radiating from a focal point (e.g. railway stations and the service areas connected with them), and in the outer areas of suburbs. Here, then, there are opportunities for linking systems (within the general transport system) supplementing present technologies.

Conclusion

Thus, this introduction and statement of the problem, leads to the conclusion that, from every standpoint, it is worth considering the applicability of certain conventional urban transport technologies - and the trams in particular - lying somewhere between the bus and the rapid transit urban railway. Trolley-buses should also be considered because in their turn they hold an intermediate position between buses and trams. Since trolley-buses have far more points in common with ordinary buses than with trams, the accent in this report is on trams. If it is agreed that:

- transport problems primarily arise in big towns;
- public transport can perform a significant role only in towns with a population of over 100,000;
- modern trams can only serve a (main) function in conurbations with a population of more than 300,000;
- Underground railways generally come into consideration only in conurbations with a population of over 1 million, where trams can also serve an important purpose,

then it is important to note that, in all the countries of West Europe put together:

- there are 75 conurbations with populations of between 300,000 and 1 million, 38 of which still have a tramway system (France, Great Britain, Italy and Spain, in particular, have disposed of most of their trams);
- there are 25 conurbations with a population of over 1 million, 22 of which have a tramway system and/or rapid transit urban railway or are installing one (only Great Britain has towns with a population of over 1 million without any rail track).

Once again, therefore, there is plenty of fallow land for trams.

2. STRUCTURE OF THE REPORT

After this introduction (1.) - intended as an appetizer - the reader is invited to consider the rest of the bill of fare (2.) in the hope that he will find something to his liking in the following courses.

In logical order, therefore, the criteria for public transport (3.) are enumerated and the characteristics of conventional transport techniques (4.) described, so as to have the main constituents for the meal to hand. There are, however, some other basic constituents that are required: network structure and traffic flows (5.), and the technologies to be used (6.) - including route layout, safety and control. With all this under our belt it should be possible to move on to operation (7.) in a custom-built organisation. Then - on the basis of costs and benefits - it will be necessary to determine (8.) what kind of attractive, and at the same time useful, public transport meal can be prepared from all these facts and how this can be done.

To help you to digest all this, a number of recipes are given at the end in the form of opinions (9.) and references to other "cookery books" (10. Bibliography).

Enjoy yourself!

3. CRITERIA TO BE MET BY LOCAL PUBLIC TRANSPORT

3.1 Compatibility with the urban-planning approach

No further confirmation is needed here of the fact that the efficient functioning of urbanised areas has been seriously undermined by the massive use of cars and the space that is needed for driving and parking them.(1) Motor traffic has presented land-use particularly egotistical requirements, in conflict with the basic

conception of the town, and yet transport should have precisely the opposite purpose - a service function stemming from society's basic goals. If public transport is to improve the way in which it performs its corrective role, it is important that it should not make any demands in conflict with the urban planning principles concerned. Here the reference is, for example, to the Manhattan effect (rapid transit urban railway stations), which would be undesirable in town centres of historic interest, and other scaling-up phenomena when a decision has to be taken on a large-coverage traffic system. Another aspect is the way conurbations with no railborne transport system tend to encourage urban sprawl.

In short, the transport technology to be selected must fit in with desired urban development.

3.2 Basic needs

The needs to be met by local (public) transport clearly need to be identified. The following table, taken from a conference on Transportation and Community Values, held by the Highway Research Board in 1969 in Warrenton, Virginia.(2)

A. Basic social needs

- personal identity and recognition,
- a sense of community or belonging,
- compatible neighbours,
- stability and security.

B. Basic environmental needs

- clean air and unpolluted water,
- low noise levels,
- conveniently situated local services,
- privacy,
- uncongested transportation systems,
- environment allowing social contact within the neighbourhood.

C. Basic access needs

- access to employment and facilities, with or without a car,
- low travel times and costs,
- safety while travelling,
- reliable means of travel,
- comfort and convenience in travel,
- choice of mode of travel,
- an easy-to-use system.

D. Basic economic needs

- avoidance of financial losses occasioned by construction of transport facilities,
- preservation of community tax base,
- maintenance of economic stability,
- low capital and operating costs,
- encouragement of economic growth.

The following paragraphs deal in greater depth with a number of the above requirements - which can never be fully met. Low travel time (a very important requirement) is considered first.

3.3 Low travel time

The findings of a number of surveys have demonstrated that public transport can compete with the car only if it enables passengers to cover the distance they have to travel in the same or less time.

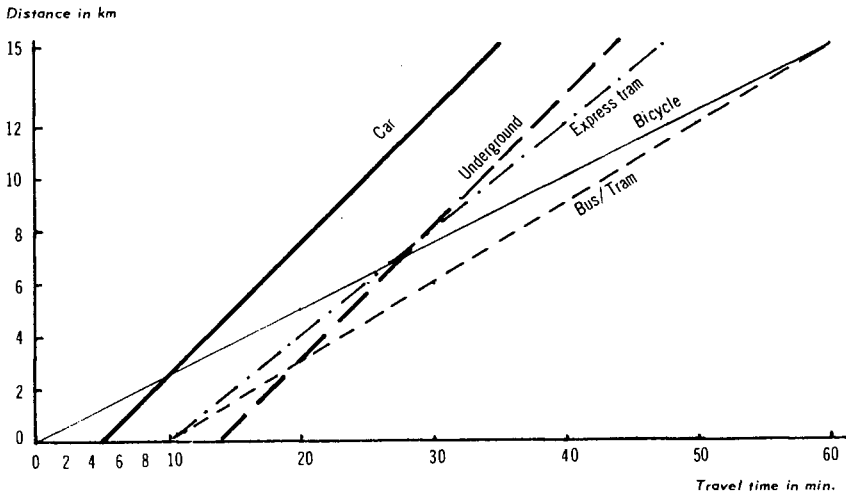
Unfortunately, and precisely in urban transport, public transport usually lags behind the car in terms of travel time, as shown by the following example (see figure 3.1).

- Car: average speed - 30 km/h;
walking time (total before and after) - 5 minutes
- Bicycle: average speed - 15 km/h (no walking time)
- Bus/tram: average speed - 18 km/h
walking time (500m) - 6 minutes;
waiting time (no changing) - 4 minutes
- Rapid transit urban railway: average speed - 24 km/h;
walking time (600m) - 7 mins.;
waiting time
(no changing) - 3 mins.;
- Underground: Average speed - 32 km/h;
walking time (1,000m) - 12 mins.;
waiting time (no changing) - 2 mins.

The figures have been greatly simplified and need a long explanation but they will serve to give a broad idea. Clearly, in urban transport, the bicycle (for short trips) and the car (for all trip lengths) has nothing to fear from public transport as regards travelling time. This limits the present market for public transport to:

- those who do not have their own personal means of transport;
- cyclists for whom travelling time and comfort both make cycling increasingly unattractive for distances of more than about 5km;
- car users encountering too many obstacles because of parking problems, driving difficulties or cost.

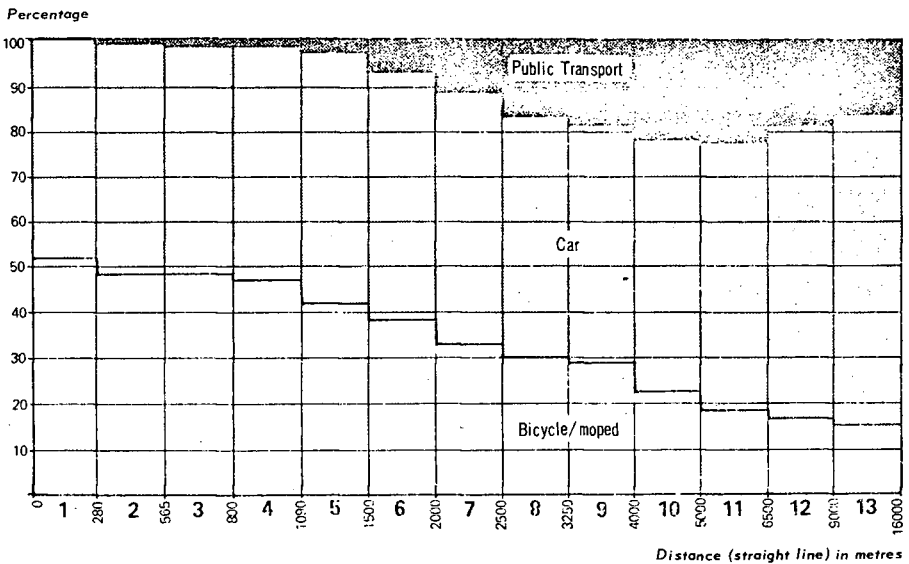
Figure 3.1



Much of this tallies with counts taken in the conurbation around the Hague (population of about 600,000) which has a rational tram and bus system and where, unlike most towns outside the Netherlands, the bicycle plays an important part (see Table 3.2).

Table 3.2

MODAL DISTRIBUTION IN PERCENTAGE VERSUS DISTANCE
(EXCLUDING DISTANCE WALKED) FOR THE HAGUE CONURBATION IN 1968



Here again the figures are averages. 32 per cent of all local trips from the centre outwards are by public transport, whilst for trips from a peripheral area (several changes often being necessary) the corresponding figure is 15 per cent. Public transport's poor competitive position is thus confirmed, even given satisfactory transport quality. It can be seen from Table 3.2 that the effect of further improvements would be slight. This agrees with the findings of a comprehensive survey carried out by the socio-cultural planning office in 1975/76 on behalf of the Netherlands Government regarding ways and means - and the acceptability - of limiting the use of cars. One of the most important findings reads as follows: "Improvements in public transport, without specific restrictions on car use, will have little effect on the volume of and attitude towards car use although the difference in opportunity for travel as between those who have cars and those who do not, would be reduced."

The acceptability of measures in these areas is high in all cases but it must be remembered that the requirements set in terms of improvements to public transport are also high. For example, it must be available close to the passenger's home and convey him or her to a point very close to his destination."

3.4 A fresh look at improvements in public transport

Measures to restrict car use are regarded as acceptable if public transport is appropriately improved.(3) The two, in fact, are interrelated: if restrictions are placed on car traffic (e.g. no left turn, bans or limitations on kerbside parking, public-transport-only roads, and reserved lanes and priority for public transport) then public transport automatically improves in terms of speed, reliability and cost.

The goal defined in the traffic movement plan for Amsterdam (population: 800,000) published in 1976(4) is in this spirit: "in-depth research and investigation have shown that, because of developments in society and environmental problems, an improvement in the traffic and transport situation is possible only if radical measures are taken."

The object of these measures is to place available space, in the first instance, at the disposal of high-capacity, space-saving and environmentally acceptable modes of transport.

Primary objective

The purpose of the traffic flow plan is to bring about a short-term redistribution of the transport space to give (provided, at least, that present communications facilities are maintained) faster

and more effective goods and passenger transport in the interests of Amsterdam's social and economic climate, the environmentally disadvantageous aspects being kept to a minimum in the process.

Seen from this angle, the rebirth of the tram in the form of an express tram is now a possibility. However this may be, the change over to buses in large towns was primarily the outcome of the obstacles that trams created for car traffic and the unwillingness to undertake even limited measures and investment on the tram's behalf. Conversely, the building of underground railways was based on the idea of avoiding reciprocal obstruction as between private and public transport, giving both modes as much room as possible and enabling public transport to compete with the private car from a position of strength, albeit at the cost of very heavy infrastructural investment.

To conclude, here is an extract from the papers issued for the 41st Congress of the International Union of Public Transport:

"Whilst transport undertakings in many of the world's big cities are preparing to attend the 41st Congress of the International Union of Public Transport (UITP) to be held in Nice from 25th to 31st May, 1975, Mr. R. Belin, President of the UITP, draws our attention to the need to find cheaper answers to the problem of congested roads and streets than the slow and expensive construction of underground railway systems. So far, research into new transport technologies has produced no significant results, leaving urban railways and reserved bus lanes still the best answers to the question of how to provide high-quality transport services in conurbations."

4. CHARACTERISTICS OF CONVENTIONAL TRANSPORT TECHNOLOGIES

4.1 General description - Trolley-buses

No general description of these systems is given because readers are assumed to be familiar with them. An exception is made for one of the less-used transport systems - trolley-buses. These seem recently to have been rediscovered because of their favourable characteristics from the environment and energy viewpoints.

Trolley-buses are rare in most West European countries - excluding Switzerland, where the use of electricity as a power source for vehicles offers big advantages because of Switzerland's hydro resources and its predominantly mountainous topography.

As a means of transport the characteristics of the trolley-bus can best be compared with those of a conventional i/c-engine bus. The main difference is in motive power which, in the case of the trolley-bus, is an electric motor receiving power direct from a two-wire overhead line. This gives trolley-buses the advantages of the electric motor's favourable traction properties: far lower noise

level, less air pollution and longer life than an internal combustion engine. These advantages are even more marked in hilly areas. On the other side of the coin, there are visual disamenity and far higher operating costs - both stemming from the overhead power supply.

Also, because of its inflexibility as regards choice of route and the fact that one trolley-bus cannot overtake another, the mode is known in transport circles as the vehicle with the combined disadvantages of trams and buses without the advantages of the tram (high capacity, good riding characteristics, etc.). In terms of technical and operational characteristics, therefore, the trolley-bus can be classed with the ordinary bus.

It is only if a bus system is decided upon that, in certain circumstances, the trolley-bus could qualify for consideration as an alternative.

4.2 Characteristics of transport

The following paragraphs briefly describe the characteristics of conventional urban transport systems on the basis of the following order: taxi, bus (stage), express bus, tram, express tram, underground railway and urban railway.

Firstly, the characteristics of interest to the passenger. Comfort and convenience in terms of quality of ride, distance from stopping place, time-table reliability, information and other aspects, increase in this order: taxi, bus, express bus, tram, express tram, underground and local railway. Accessibility, however, becomes less favourable because of the greater distances to and from boarding and alighting points which, among other things, increases the probability of having to change.

Combination with other systems (private and non-conventional) is always possible but, where high-cost installations are necessary, consideration is likely to be confined to high-capacity and high-speed systems. The growing level of safety for passengers and travelling staff is accompanied by increasing vulnerability because of the safety systems used. Put more generally, the possibilities for automation and control are increasing but this means greater vulnerability.

The following comments apply to characteristics regarded as important by transport operators:

- Flexibility - in terms of operational facility - decreases in the order given:
 - . taxi operation is governed by demand: the passenger is taken non-stop to his destination,
 - . bus and tram operation is also dependent on demand to the extent that a passenger can have the vehicle stop at the stopping place of his choice,

. other systems operate on a time-table basis, stopping at all stopping places (with the exception of non-stop trains and in some cases express buses);

- Adaptability: decreases in the above order;
- Facility of maintenance: no noteworthy differences;
- Service life: increases in the order shown;
- Consumption of energy and materials: decreases.

The characteristics of conventional systems of interest from the community's viewpoint fall into the following pattern:

Visual acceptability decreases with any increase in the number of fixed installations (more visual intrusion), but could be compensated, to some extent, by the increasing visual attraction of the vehicles.

External effects (barrier effect, difficulty of accommodating the system, short-term space and land requirement) increase in the order shown - with the exception of unfavourable environmental effects. Long-term space and land requirements could develop favourably if rail-borne transport were to help develop the structure desired by the community.

The extent to which the community's transport requirements are met - in terms of capacity - increases in the order shown in the case of concentrated traffic flows (in terms of space and time) and decreases when traffic is slight and diffuse.

To illustrate these thoughts, the main characteristics are set out in quantitative terms in Table 4.1 as averages of the figures found in practice.

4.3 Closer consideration of certain important characteristics; relationship between convenience and trip time

This question can be approached via the transport system's accessibility (distance on foot, distance between stopping places) and speed. Current views on this point are briefly summarised below.

Distance on foot(5)

Various surveys carried out in Germany and elsewhere indicate that the maximum acceptable distance that has to be walked to or from the public transport stopping place or station, does not depend on the mode but on trip distance and zone of origin or destination, as follows:

Table 4.1
MAIN CHARACTERISTICS OF THE MOST IMPORTANT MODES OF PUBLIC TRANSPORT
(the figures given are averages of those found in practice)

Mode	Width of vehicle in m(c)	Length of vehicle in m(c)	Maximum "train" length in m (per unit)	Maximum capacity in seats per unit	Freedom of movement, floor area per passenger in m ²	Minimum frequency, interval in minutes	Maximum number of "trains" per hour per direction	Maximum capacity available in practice per hour per direction	Average distance between stopping places in m	Maximum speed in km/h	Average speed in km/h	Mesh size or band width in m	Range from town centre in km
Taxi	pm	pm	pm	4	pm	pm	pm	pm	-	60	30	pm	pm
Bus(a)	2.50	12	12	100	0.25	1.0	60	5,000	350	50	12	400	pm
Express bus(b)	2.50	12	12	100	0.25	1.0	60	5,000	500	50	20	800	pm
Tram(a)	2.30	10(c)	24	200	0.25	1.2	50	8,000	400	50	12	600	pm
Express tram(d)	2.65	12(c)	48	450	0.25	1.25	48	18,000	600	80	24	900	8
Underground	2.80	16	96	1,200	0.20	2.0	30	30,000	1,000	80	32	1,500	12
Rapid transit railway	3.00	20	160	1,600	0.30	2.0	30	40,000	2,000	100	45	2,000	20
Suburban railway	2.80	24	240	1,600	0.40	5.0	12	16,000	5,000	120	60	-	30
Long-distance railway (express)	2.80	26	300	800	1.00	-	-	-	30,000	140	90	-	45

(c) Given purely to illustrate the thinking.

(a) Using, almost entirely, the public highway (also applies to the trolley-bus).

(b) On reserved lanes in conurbations with priority at major same-level crossings (also applies to the express trolley-bus).

(c) Part occupied by controls.

(d) For the most part no crossings; own track, over and underpasses, with priority at level-crossings.

(e) Larger in scale than the underground: bigger rolling stock, fewer stopping places, higher speed and bigger mesh.

Trip length

Up to 5km	maximum distance on foot about 500m
Up to 10km	maximum distance on foot about 750m
Over 10km	maximum distance on foot about 1000m

Area of origin or destination (assuming average trip length in each case)

Town centre	maximum distance on foot about 400m
Outlying town area	maximum distance on foot about 600m
Suburbs	maximum distance on foot about 800m

The catchment area of stopping places and stations can be extended by providing convenient footways (including "diagonals"). In addition a longer distance on foot may be acceptable if it passes through a pleasant environment - conceivable in town and outlying centres.

As regards distance away, the catchment area can be increased by an average of about 50 per cent (and therefore about 125 per cent in surface areas), if park-and-ride facilities are provided. This brings private means of transport (two-wheelers or cars) into the picture - as well as walking - for the first or final stage of the trip. Even though the maximum length of this stage is unaffected, or almost unaffected, by the mode of public transport used, it is only at places where very heavy traffic is generated that there can be any question of a more comprehensive stopping place/railway station facility - with the general exception of large-scale systems (railway and underground, and possibly - in some cases - the rapid transit railway). Thus, mode of transport may have an indirect effort on maximum acceptable distance to a stopping place or station.

Distance between stopping places(6)

This is closely related to the distance that has to be covered on foot and urban structure. On the basis of data already established on walking distances and from practical observation, the following average distances between stopping places can be used:

	in city centres	in outlying town districts	in suburbs
Bus/tram	400m	600m	800m
Underground	600m	900m	1200m
Rapid transit railway	1000m	1500m	2000m

Mesh size, i.e. the desired distance between public transport routes, can also be found from the data on walking distance and distance

between stopping places. It is clear that this characteristic will depend very much on town layout and structure (see also Table 4.1).

Speed

Average attainable speed depends on:

- maximum speed (see Table 4.1),
- acceleration and braking power (generally averaging about 1.0 m/s^2 and 1.2 m/s^2).
- distance between stopping places,
- time spent at stopping places (averaging 15-25 seconds),
- waiting time at traffic lights and as a result of traffic jams (the former applies only to trams and buses and the latter only to modes that do not have their own track),
- the necessary tolerance (increases as quality of infrastructure decreases and as frequency increases).

Average speeds attainable in practice are listed in Table 4.1.

Trip duration:

Trip duration can be determined, with some approximation, using the figures already established for walking distance, distance between stopping places and average speed, provided the transport supply per unit of time (frequency) is also known. Frequency depends on the number of passengers per unit of time and per line, capacity and standard average occupancy ratio. An example showing how this is calculated is given in Section 3.3.

4.4 Transport capacity

The capacity of a transport system is certainly not the only factor governing choice of system. Other quality of transport factors are also involved as can be seen from a number of practical examples.

The busiest part of the Netherlands' railway system carries about 6,000 passengers per hour at peak times in the most used direction and the busiest urban transport system - the Rotterdam underground - carries about 9,000 passengers.

Altogether the six routes of the Münchener underground move 17,000 passengers per hour in peak conditions.

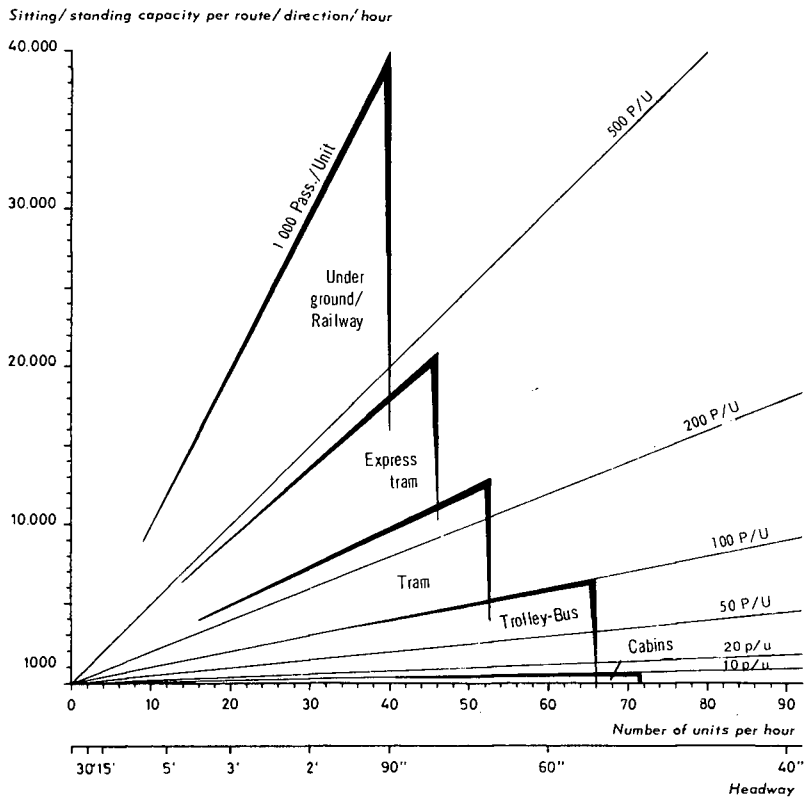
When bus route 5 in The Hague was recently converted to tram route 9 it managed to carry no more than 1,500 passengers in peak hours.⁽¹⁾ The new express tram (route No. 1) which recently came into service in Bremen carries a maximum of 3,000 passengers at peak times. The so-called route 13 in Cologne, largely laid on expensive

1) Since then traffic has increased by 20 per cent.

overhead ways has a maximum throughput of 1,000 - 1,500 passengers per hour and direction. Furthermore, the operation of a tram route in the centre - where several routes deliver a higher output than a route in an outlying district, is already viable at a figure of 2,000 - 3,000 passengers at the peak hours.

What quality aspects are involved here? For the transport operator the factor is controlability - which increases with size of transport unit and interval between services, for this means an improvement in reliability. The riding comfort of railborne transport is apparently appreciated by users; witness the larger number of trips made by this mode. An own-track transport system may also be expected to exert a favourable structural influence. All of the above is good enough reason to consider figure 4.2 below (showing sitting and standing capacity in the various modes) not purely in relation to maximum capacity but also in relation to the lower figures.

Figure 4.2
SITTING AND STANDING CAPACITY AS A CEILING FOR EACH MODE



5. NETWORK STRUCTURE AND TRAFFIC FLOWS

With the help of schematic "theoretical" towns, an attempt is made in this chapter to outline the possibilities of using express trams for public transport. The description and calculations given therefore have no practical character but are nevertheless based on and chosen from practical experience.

5.1 Public transport in towns with a population of 100,000 to 2,000,000

At the end of Chapter 1 it was stated that trams are or could be used as the main means of transport in towns with a population of 300,000 to 1,000,000.

A tramway system can also be viable in certain smaller towns and in larger ones, as well, though in that case mostly to supplement an underground system.

The following paragraphs therefore deal with a number of "prototype towns" with populations ranging from 100,000 to 2,000,000.

Table 5.1 sets out some "average" transport data.

Table 5.1

Population	Passengers travelling by urban public transport			
	per year	per weekday	in peak traffic	Morning peak, inwards** Evening peak, outwards
(i)	(j)*	(w)*	(p)*	(c)
100,000	15,000,000	45,000	7,500	5,000 = (p)x66%
300,000	50,000,000	150,000	25,000	15,000 = (p)x60%
600,000	110,000,000	330,000	55,000	30,000 = (p)x55%
1,000,000	200,000,000	600,000	100,000	50,000 = (p)x50%
2,000,000	500,000,000	1,500,000	250,000	100,000 = (p)x40%

*) Formulae used:

$$(j) = \{150 + 50 \times 10^{-6}(i)\} \quad (i)$$

$$(w) = \frac{1}{333} (j)$$

$$(p) = \frac{1}{6} (w)$$

**) Including traffic going through the town centre.

5.2 Distances in towns with a population of 100,000 to 2,000,000

In our "average" town the population density (including jobs, services and recreation) is 8,000 - 10,000 per km². On this basis it is a simple matter to determine surface area per town. If it is also assumed that the "average" town is more or less circular in shape with the town centre roughly in the middle, we obtain the following figures in relation to trip distances.

Table 5.2

Population	Town area in km ²	Town diameter in km	Maximum distance from town centre to periphery in km
100,000	12	4	3
300,000	36	7	5
600,000	72	10	7
1,000,000	120	13	9
2,000,000	240	18	12

Clearly there is a strong correlation between the use of public transport (Table 5.1) and urban structure. In a town with a population of 100,000 that is roughly circular in shape and has its town centre in the middle, the distances shown in Table 5.2 are so small that public transport can hardly have any meaning. This would be even truer if the town were flat and bicycles could be used. Conversely, in a town of the same population but of an elongated shape (e.g. 12 x 1 km²) public transport could be essential - with just one heavily trafficked main route - and economically viable for tramway operation.

A town with a population of nearly 300,000 exhibiting some of these characteristics is St. Etienne and although its system has 24 routes totalling 107 km, the only tram route, which is 6 km long, accounts for 35 per cent of the traffic (15 million passengers a year). Apart from town structure, the quality of public transport obviously plays a part.(7) This is the more important point to note, since this report is concerned with ways of improving public transport by comparison with the car.

Examples:

- Basle: good public transport system, priority rules, etc., 19 routes, including 10 tram routes;
- St. Etienne (already quoted): 24 routes, 1 being a tram route;
- Nancy: urban transport system of moderate quality, 21 bus routes.

Town	Population	Annual trips per head	Total 1974/75
Basle	360,000	365	132,000,000
St. Etienne	285,000	150	43,000,000
Nancy	300,000	75	22,000,000

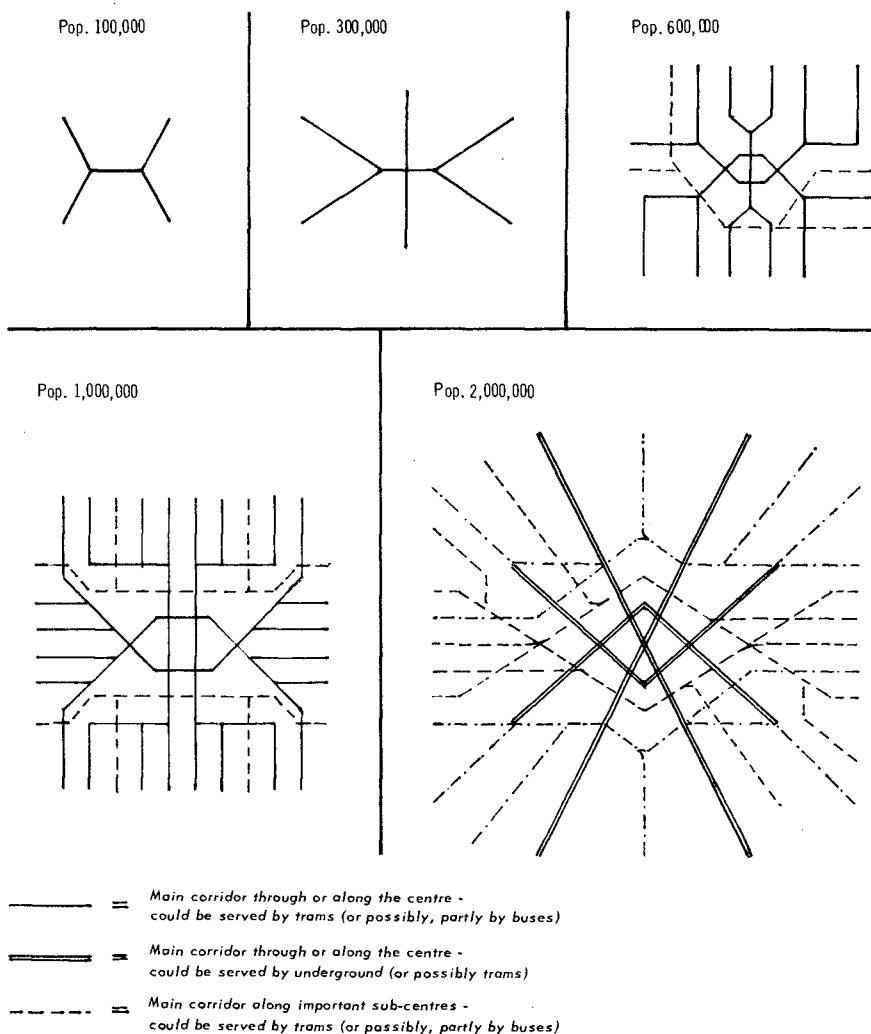
This table suggests that the figures for our "average" town (Tables 5.1 and 5.2), namely 167 trips per head per year, give a reasonable picture but it also proves the need to bear in mind, in the discussion that follows, that large variations are possible.

5.3 Network design: traffic flows

The following figures present schematic patterns for the design of main route networks, radiating from the centre, based on optimum mesh size(8) (as described in 4.2 and 4.3) and on the assumption that the whole of the town area is to be served by public transport. In many cases the patterns tally with the actual number of main public transport routes in towns of similar size.(9)

Figure 5.3

MAIN ROUTES FROM THE CENTRE OUTWARDS AND/OR ALONG IMPORTANT SUB-CENTRES



In many cases routes (through the town centre or sub-centres) can be taken along the same itinerary in outlying districts, so that these areas can have several direct connections.

This is where trams have a big advantage over and underground system.

The towns already defined in terms of area in Table 5.2 may have to handle the following peak traffic flows per main corridor or route (Cf. total in Table 5.1).

5.4 Traffic per route and per corridor considered separately

Table 5.4 shows routes with peak traffic levels, in the direction carrying most traffic, of 600, 1,500, 2,000 and 12,000 passengers. Consideration will first be given to routes with traffic peaks of 1,500 and 2,000 passengers. On the assumption that a tram unit has a capacity of 200 (see Table 4.1 and Section 6.3) an adequate service can be provided with:

- 12 units (one every 5 minutes = 2,400 places). One-third is necessary as a reserve to cope with any irregularity in the pattern of demand (in Amsterdam, for instance, 40-45 per cent of all peak traffic is concentrated into a period of 20 minutes) and to allow for the fact that full occupation of the tram can never be achieved. The useful capacity is therefore 1,600.
- 8 couple units (2 trams each), one every $7\frac{1}{2}$ minutes giving a capacity of 3,200. If a third is deducted, as above, the useful capacity is 2,100.

In other words trams can very well be used for peak traffic levels of 1,500 to 2,000 passengers at a frequency that is not too high with regard to small deviations from the time-table (see 7.2) and not too low in terms of the time passengers may have to wait. Traffic along corridors used by two or three different routes can also be handled by a tram service. This would mean a maximum of 36 trams per hour. Even if allowance is made for the large measure of irregularity in real traffic conditions (we have been talking about an "average" town), e.g. by multiplying by a factor of two, tram operation is still perfectly feasible. In a town with a population of 1,000,000, for example, peak traffic on a main corridor could amount to $2 \times 6,000 = 12,000$ passengers. Four tram routes with coupled units could cope with this, the headway for each route being 5 minutes. This would give $(4 \times 12 \times 400) \times \frac{2}{3} = 12,800$ useful capacity. 48 trams per hour, per direction, can reasonably be handled on the surface as shown by current practice, for example, in Amsterdam, Brussels, Cologne, Milan, Vienna, Zurich and elsewhere.

Table 5.4(a) Peak hour traffic to/from centre
via main corridors

Popula- tion	Number of main corridors through centre	Number of branches per main corridor per direc- tion	Total bran- ches	Passen- gers per branch	Passengers per main corridor	Total passen- gers via main corridors	Total passen- gers to/from centre	Railborne pass- engers as a per- centage of peak traffic in centre
				in direction carrying heaviest traffic		(h _c)	(Table 5.1) (c)	
100,000	1	2	4	600	1,200	2,400	5,000	48 %
300,000	2	1 or 2	6	1,500	1,500 or 3,000	9,000	15,000	60 %
600,000	3	2	12	2,000	4,000	24,000	30,000	80 %
1,000,000	4	3	24	2,000	6,000	48,000	50,000	96 %
2,000,000	4	1	8	12,000	12,000	96,000	100,000	96 %

Table 5.4(b) Peak hour traffic to/from sub-centres
via main corridors

Popula- tion	Number of main corridors through centre	Number of bran- ches per main corridor per direction	Total bran- ches	Passengers	Passengers per	Total passengers
				per branch	main corridor	via main corridors
				in direction carrying heaviest traffic		
					(h _s)	(s)
600,000	1	2	4	1,500	3,000	6,000
1,000,000	2	2	8	1,500	3,000	12,000
2,000,000	4	3	24	2,000	6,000	48,000

Table 5.4(c) Peak traffic via main corridors

Popula- tion	Total traffic on main corridors					Total peak hour traf- fic (Tab. 5.1)	Rail- borne passen- gers as a per- centage of peak traffic $\frac{(h)}{(p)}$
	To/from centre		Through sub-centres		Total peak hour traffic (h)		
	Direction carrying heaviest traffic	Opposite direc- tion	Direction carrying heaviest traffic	Opposite direc- tion			
	(h_c)	$1/3(h_c)$	(h_s)	$1/3(h_s)$			
100,000	2,400	800	-	-	3,200	7,500	42 %
300,000	9,000	3,000	-	-	12,000	25,000	48 %
600,000	24,000	8,000	6,000	2,000	40,000	55,000	72 %
1,000,000	48,000	16,000	12,000	4,000	80,000	100,000	80 %
2,000,000	96,000	32,000	48,000	16,000	192,000	250,000	76 %

In theory, therefore, the volume of peak traffic per main corridor (in the direction of heaviest traffic) in a town with a population of 2 million could be handled by a tram system. We are, however, considering averages and variations in an upward direction could produce difficulties. In addition, distances are reaching the level at which the higher speed and reliability of the underground begins to tell (see Tables 3.1, 4.1 and 5.2). Trip distances of over 8 km from and through the town centre are frequent. An "average" underground route with 12,000 passengers at peak times can offer attractive frequency of service, namely every 4 minutes, i.e.,

$$15 \times 1,200 \times \frac{2}{3} = 12,000.$$

Splitting the route off into two branches would be feasible.

Let us now take the case of a smaller town with a population of 100,000. Figure 5.3 shows a minimal railborne network with short routes and an average of 600 passengers at average peak times. In this case buses or trolley-buses, with a six-minute headway ($10 \times 100 \times \frac{2}{3} = 665$) would be far better. The concentration of this volume of traffic on a single main route could only apply in the case of an elongated town as outlined in section 5.2 but it could also apply to a suburb connected to a much larger town. In the Netherlands, Zoetermeer, a satellite of The Hague expected to have a population of 100,000, is to have a ring railway to the main town.

Lastly a few words on traffic in off-peak hours. It is assumed that one-sixth of total weekday traffic will be handled during the peak period, whether in the morning or in the evening. A route carrying 1,500 passengers in the direction of heaviest traffic during

peak periods - and 2,000 passengers in both directions - would therefore carry 800 passengers in the 15 hours outside the two peak periods, i.e. an average of 270 passengers per hour in each direction. This justifies an average service of 6 trams per hour (every 10 minutes). A route averaging 2,000 passengers in the direction of heaviest traffic during peak periods could therefore allow for an average of 8 (single) trams per hour (every $7\frac{1}{2}$ minutes). These are acceptable average headways; frequencies on main corridors climb to twice or three times these figures. Obviously an average occupancy of 45 passengers per vehicle would present no problem for a bus service but it should not be forgotten that considerable variations could arise apart from the fact that, in principle, a traveller outside peak periods hopes to have a seat. Shorter headway could improve quality but the importance of this is not very great in a published timetable and, in addition, more staff would be needed.

5.5 The complete system

In the earlier sections, discussion has been confined to the main corridors in a railborne system. Table 5.4 shows that, in towns with a population of 300,000 to 2,000,000, trams could cope with 50-75 per cent of all urban transport (60-95 per cent in the town centre). In these cases, therefore, a supplementary bus network would be necessary, firstly - and in any case - to connect areas without railborne links to the centre, and secondly to provide cross routes between areas in which railborne routes cannot provide a good service because of detours and interchanges. A further point is that, in bigger conurbations, it is not always wise to connect remote areas with no railborne connection directly to the centre by bus. Particularly if there is an underground - or even a high quality tram route - an interchange may be better, for both passenger and transport operator, for distances of up to about 5 km.

Next there is the large volume of traffic coming into town from elsewhere. In some cases a tram or underground route runs as far as another town further off.(10) In most cases it is the other way round: a railway service generally brings traffic directly into the centre. Such a service, given high frequency and short distances between stations can perform the role of an urban railway. Intercity buses, too, may be operated as an express service bringing passengers right into the centre of the town or to a sub-centre.

If there is a good local underground or express tram route, changing over to it may be a better proposition for travelling into the town centre. However, to save the commuter a second change - if he happens to be in another part of the town - it is advisable to have the intercity bus route continue - after the underground or express tram interchange - in a tangential direction to a sub-centre in order to intersect as many other urban routes as possible.

In this way, the intercity bus can perform a suburban transport role. In the case of the car, it is worth considering, on transport engineering grounds, the possibility of holding as many vehicles as possible in peripheral car parks with their occupants transferring to the underground or express tram system. This sets high demands in terms of interchange facilities and the quality of the railborne services, which need to go in several directions. All this argues for the provision of a variety of modes in an urban transport system where underground, trams, buses, trains and cars coming from various directions all meet and combine into a simple and convenient complex. This also means limiting the number of routes if the interchange facilities are to be reasonable. An excessive number of urban routes complicates matters for users, reduces frequency, and makes the use of large units (and therefore trams) impossible, thereby reducing quality standards and increasing costs.(11)

Lastly a few words about the recurrent problem of urbanised areas with very low housing densities. There is not sufficient traffic for buses unless they go via unattractive and roundabout routes. In these cases the park-and-ride system already outlined should be encouraged, possibly through residents' associations. The promotion of cycling as a means of access to urban public transport can be attractive in flat areas although this means providing satisfactory cycle storage at the station or stopping place. A last possibility is the dial-a-bus system which is still at the experimental stage but is expected to be successful once used in large numbers as, for instance, in Turkey ("Dolmus").(12)

6. TECHNOLOGY

This subject is given regular and frequent attention in the specialised literature(13) and its discussion in this report can well be limited to pointing out a number of interesting aspects and recent developments in express tram services.

6.1 Infrastructure, route layout

Horse-drawn trams and the electric trams that succeeded them (see Section 1) had a fine-mesh network and had to be fitted into the often narrow and tortuous streets of towns built in the Middle Ages, but, with modern express trams, the idea is to lay the routes along broad thoroughfares and to have a somewhat wide-mesh layout - by virtue of the urban re-organisation that has since taken place and the far less concentrated nature of new residential areas.

The main feature of an express tram system (which, as regards layout, has more in common with large-scale urban railway and

underground systems than with the old small-scale horse-drawn and electric tram) is that routes generally follow the existing road layout, with the track isolated except at road intersections. Modern, lightweight rolling stock with good brakes is used so that crossings at the same level do not create problems. Priority rules are applied to suit the circumstances. It is thus possible to offer something approaching the advantages of an urban railway system without the high capital cost and lengthy construction of an underground system with no intersections (use of a live rail). Route layout - though it follows the roads and implies tighter curves than with a railway - permits maximum speeds of 80-50 km/h, even taking the fact that there are level crossings into account.

Dimensions in the case of express trams, therefore, tend more towards those of rapid transit railway systems: width 2.35 - 2.65m, length from 19m (single car; distance between bogie centres 6m; overhang or distance between end of car to bogie centre 3.50m) to 31m (coupled cars; distance between bogie centres 8m). The figures could be even higher if more units were coupled together.

This calls for a tram lane (14) whose width, for a double track, needs to be at least 5.60 or 6.20m $\sqrt{2} \times (2.35 + 0.45)$ or $2 \times (2.65 + 0.45)$. This sounds a lot but the figure is small when it is remembered that a width of 6.4m is required for a reserved bus lane (bus width 2.50m) just because a bus is not guided on rails. Combined tram/bus lanes can therefore be used by 2.65m wide trams. In the absence of buses the narrower lane necessary for trams has the advantage of being more easily fitted into narrow streets in which motor traffic also has to be allowed.

The length of a tram primarily depends on the radius of the curves in the track and the length to which stopping places have to be built. Much also depends on local circumstances. But even for rolling stock with a distance of 10m between bogie centres (as in Cologne, Bonn and Essen) a 25m radius is possible although for operational purposes (speed and comfort) it is better to set a minimum radius of at least 75m. For turnaround loops (no passengers on board), tight radii can be used. Two-directional rolling stock does not need any turning loops but is not always desired because of its higher cost, so that the tightest possible turnaround system may be of considerable importance in fitting a tramway in.

Gradients in express tram systems should not, if possible, be steeper than 4/100 but the use of 6/100 to 7/100 should not present insuperable problems. Gradients this steep may be the answer for underpasses and difficult spots.

A basic advantage of a tram system is that it can be installed in many different situations, whether on roads in the normal way, or on a completely independent track, like a train. Even joint use of the permanent way is possible (e.g. Cologne-Bonn, Karlsruhe, Cleveland). In addition, short or long under or overpasses can be built far more cheaply than for buses (size, ventilation - the latter point not applicable to trolley-buses). Trams can also be used pending the provision of underground trains: once the track, or part of it, is laid, an express tram can use it as in Brussels, Frankfurt and so on. The advantage of an unmetalled tram track alongside the highway is that drivers cannot make use of it. It is well known that drivers often encroach on visibly little-used reserved bus lanes.

The biggest problem in introducing a tramway system mainly arises in old parts of towns and particularly in the centre. The answer is often to run the tram (or bus) along one side of the road in company with one-way car traffic.

If necessary, the general carriageway can be used. There is no need for the noise to be a problem because modern trams can be operated relatively quietly, trams and trolley-buses being better than i/c buses in this respect. If traffic restrictions have to be introduced, answers have to be found to the problems of loading and off-loading and parking. An interesting fact is that, contrary to the expectations of local shopkeepers, turnover has increased in streets of this kind as a result of the easier accessibility by public transport and the pleasant atmosphere.

Although own-track transport satisfies a major condition in terms of the regularity, speed and capacity of public transport, road intersections are a serious obstacle. Traffic control is dealt with in section 6.2, but much can be achieved by keeping the number of intersections to a minimum. Good examples are Bremen and Göteborg, where the town centre is divided into cells, cars being allowed only as far as the outside of these cells, in other words direct transit from one cell to another via the town centre is not allowed. The periphery of these cells provides excellent tram routes.

In conclusion, therefore, it can be said that a tram system can be operated far more cheaply and simply than a rapid transit railway or underground but, of course, with more difficulty than the (express) bus. Even in that case, however, there are many advantages such as the lower width and easier use of reserved lanes, particularly in under and overpasses.

In addition it may even be an advantage that setting up a tramway is not as easy as for normal road vehicles like the bus, which in spite of its flexibility is generally subject to the same disadvantages as the car in conurbations. A disadvantage, however, is the long preparation and building time for tram systems (2 to 4 years)

particularly if, out of perfectionist ambition, the tram system takes the form of a rapid transit urban railway rather than an express tram network (its proper intermediate role).

6.2 Safety and control; traffic and priority rules

In the light of the extensive experience with fully protected "controlled" urban railways there is little need to add anything in this report. Suffice it to say that express trams hardly need any safety system of their own because of their modest top speed and high breaking power. Only where visibility is impeded (under and over-passes) and, of course, on one-track sections, do safety systems have to be used.

In the control of tram services, the use of the mobile telephone is gaining in importance, whilst highly advanced central control technologies are used as, for example, in Hamburg and Zurich where (in Zurich) the HÄni-Prolectron data-operated control system is in service. Philips too has developed a somewhat simpler system known as Betag ("vehicle tagging") in which vehicle and route can be identified and, with this information, their position on the route can be adjusted and traffic lights appropriately controlled.

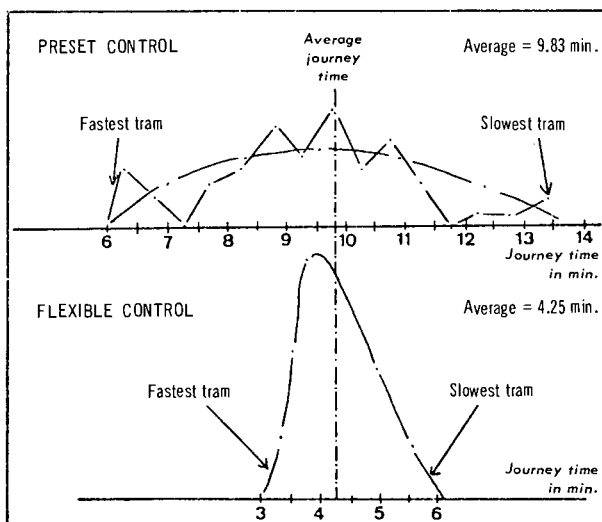
The primary feature of express trams - same-level intersections - requires that great care be exercised with regard to the relevant traffic and priority rules. An intersection can have a marked effect on speed and regularity of service and therefore on quality and cost. At local level this can be improved by conventional methods - without intervening in traffic light cycles - by having tram stops at intersections, installing advance warning signals at crossings where there are no tram stops, indicating appropriate speeds for sections controlled by synchronised traffic lights, etc., as is often done for car traffic.

More interest attaches to solutions which give trams certain priorities. In Amsterdam, for example, very good results have been obtained since 1972 with a so-called flexible traffic control, according to which trams, in principle, are able to continue without stopping across secondary intersections (no tramstop) and suffer minimum waiting time at major intersections where there is a tramstop. The system uses advanced computer techniques and takes the interests of road traffic as a whole into consideration using detectors, for example, for the rest of the traffic and conditioned circuits in the controlled programme in order to avoid unnecessary traffic jams in the transverse directions. If the volume of traffic so requires, the priority of public transport is occasionally sacrificed, on the basis - of course - of the number of persons involved, not vehicles, a principle still hotly debated in traffic police circles, for example. The measures also need to be of such a kind that transport users are able

and willing to observe them in disciplined fashion. A survey designed to evaluate the difference in time lost by trams under this system and under the conventional fixed control method gave the following findings: in comparable circumstances on various routes, the average time lost per crossing had fallen by 60 per cent, tram speed had increased by about 80 per cent (even nearly 100 per cent in the case of gross tram speed), the variation in journey times had been reduced by nearly one-third and - through the comprehensive traffic control system - disadvantageous effects on other traffic had been limited to a minimum (see figure 6.1). This flexible control system is widely used in Amsterdam and other Netherlands' towns and its use is to be extended.

Figure 6.1

VARIATION IN JOURNEY TIMES WITH PRESET AND FLEXIBLE TRAFFIC CONTROL ; RESULTS OF SURVEY IN AMSTERDAM



6.3 Rolling stock

Plentiful and regular information is published in this field even more so than for infrastructural problems. For this the reader is referred to the data that has appeared in many specialised journals and handbooks. (15) It is in rolling stock that transport engineering is at its most impressive.

Here we shall confine ourselves to average standard dimensions.

- Width: 2.35 to 2.65m [trolley-buses (16) 2.50m]
- Length: distance between bogie centres 6-8m

(exceptionally 10m)

Overhang 3.50m

Total length, no trailer (4 axles): 13-15m

with one trailer (6 axles): 19-23m

with two trailers (8 axles): 25-31m

Can be built up into trains consisting of 2, 3 or 4 units.

Length of trolley-bus (no trailer): 12m

(with trailer): 18m

- Doors: width 0.65m, mostly in pairs, making 1.30m.
Doorsill: 1.55 - 2.30m(1).
- Two-directional rolling stock: in this case two control cabs are necessary (one at the front and one at the back) and doors on both sides.
- Useful floor area (rectangular configuration - length x width). About 10 per cent has to be deducted for the driver's cab and entrances. This percentage depends on the shape of the cabs and platforms, on whether the rolling stock is one- or two-directional and on total length.
 - . Tram with no trailer: from 27 to 36m²
 - . Tram with one trailer: from 40 to 55m²
 - . Tram with two trailers: from 53 to 74m²
 - . Trolley-bus, no trailer: 27m²
 - . Trolley-bus with trailer: 40m²
- Sitting and standing room: spacing between seats: 0.80m
seat width: 0.50m
seat area: 0.40m²
area for one standing passenger: 0.25m²(2)
- Capacity: if the ratio between number of seats and number of possible standing passengers is 1:2(3) (surface area of one seat and standing room for two people = $0.4 + 2 \times 0.25 = 0.9\text{m}^2$), there is in theory room for 3.33 people for every m² of useful floor area.

-
- 1) If longer platforms (2.30m) are used, folding seats can be fitted (as in the Paris Metro), providing additional seating capacity outside peak periods and additional standing room (seats folded back) during peak periods.
 - 2) Unreal figures, starting at 0.10m², are found in technical literature - related to loading requirements.
 - 3) The number of seats there can be naturally depends very much on the width of the vehicle. There can be four seats across the width if it is 2.65m but only three if it is 2.35. Again, fewer seats are possible in two-directional rolling stock and if the number of doors is increased. A relative increase in standing room means more capacity but that should be avoided in the interests of comfort, particularly in buses (because of their proneness to lateral sway).

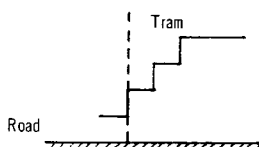
This gives the following practical capacity figures(1) (see Table 4.1):

- Tram, no trailer: room for 80-110 passengers,
- Tram with one trailer: room for 120-165,
- Tram with two trailers: room for 160 to 225,
- Trolley-bus, no trailer: room for 80,
- Trolley-bus with one trailer: room for 120.
- Weight: 0.5 tonnes per m^2 of overall surface area. One axle per $10m^2$ (maximum) of overall floor area, giving a net axle load of under 5 tonnes and a gross axle load (fully laden vehicle) of under 10 tonnes.
- Electrical equipment: power rating of motor with 4 driven axles: about 300 kW. Power rating for trolley-bus motor: about 200 kW. Maximum speed: 60-80 km/h. Acceleration: about $1 m/s^2$ (average). Braking: rheostatic braking (motor bogies) full disc brakes; (one disc per drive axle, two per dead axle); electro-magnetic slipper brakes (two per bogie) giving an average of $1.25 m/s^2$ normal braking retardation (fully occupied tram) without use of slipper brake, and $2 m/s^2$ emergency braking with slipper brake.
- Height: from top of rail to roof: 3.25m; ditto inclusive of collector shoe: 3.50m; from road surface to roof of trolley-bus: 3.50m (not including collector arm); from top of rail to floor: 0.85 to 0.95m.
- Entrances (Figure 6.2):

Figure 6.2

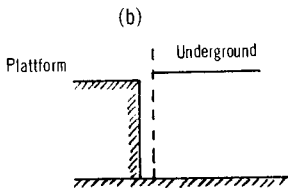
ENTRY

(a)

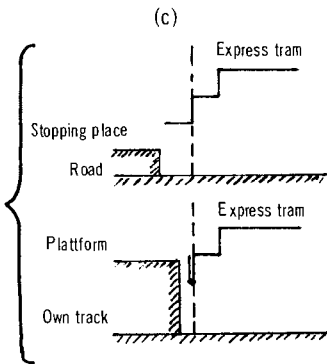


for the usual kind of tram with with a floor height of 0.90m the entrance consists of four steps, each 0.225m high, necessitating one folding step and two step-recesses 0.225m deep. This means that the width of the floor at this point is only $2.35 - 2 \times 0.225 = 1.90m$ (1.45m in the case of two-directional trams).

1) Practical capacity is theoretical capacity - 10 per cent in view of the fact that, in practice, a vehicle is rarely fully occupied throughout its length.



- Entrances to underground trains and express trams are best at platform level, platforms being at vehicle floor height less 0.05m.
- For express trams using the roads as well as running underground where there are raised platforms, an expensive, complicated and trouble-prone movable step system, is necessary in order to meet the needs of both cases (examples are Frankfurt and Cologne);



- A compromise for express trams is to build 0.30m high islands at stopping places on roads (generally this does not present any problem) and 0.70m high platforms in under and overpasses. For express trams with a floor level at 0.95m this means having three steps ($0.225 + 0.225 + 0.2m$) calling for one recess and one folding step. The folding step is dropped from platform level so that a passenger has only a height equivalent to one step to negotiate in order to board the tram. This system makes for good quality, cheap construction and saves lost floor space.

Postscript: The description of rolling stock is confined to main standards for a number of "average" trams and trolley-buses.

Unfortunately, apart from East Europe and the Soviet Union, there are no average types of tram and no standardized rolling stock at national level, certainly not at international level. This is a great pity and does not help the development or cost of trams. There is therefore an urgent need for initiatives under this heading in Western Europe.

7. OPERATION AND ORGANISATION

In Sections 5.3 and 5.4 two standard tram routes were postulated:

- one carrying - at the busiest point - 1,500 passengers at the peak hour in the direction carrying most traffic and an average of 260 passengers an hour outside peak hours in either direction. For peak traffic there would be a five-minute service of single tram units with a capacity of 200, giving a total capacity of 2,400 per hour, one-third of which is a reserve. Outside peak hours there would be trams every ten minutes on average(1) with 70-seater units (420 seats an hour), one-third again being treated as a reserve.

On the main corridor in the centre or along the sub-centres two, three and occasionally a maximum of six routes of this kind could use the same track, considerably increasing transport supply and frequency.

For urban transport a system of this kind - particularly if the time-table is published - is in practice acceptable from every viewpoint. From the operation viewpoint, however, the target must be not merely to provide the best possible system in terms of layout and planning(17) but also to ensure that operation is as reliable as possible.

Operating an express tram system is, of course, not merely a question of providing a comfortable means of transport with the necessary capacity and travelling at a good safe speed of around 20-24 km/h as a result of well-designed track layout (6.1), priority rules (6.2) and modern rolling stock (6.3). The important thing is to ensure reliability, in other words regularity of service.

7.1 Regularity

In Section 6.2 (see Figure 6.1) reference is made to the great variation in journey time. Even with priority rules, variations of several minutes are quite normal. A large share of the responsibility for this falls not only on the varying length of time trams have to wait at intersections but also on the variation in time spent at stopping places, due among other things to the varying number of passengers and the driving style and discipline of staff.

To give an example. On an average tram route with "average rolling stock" and an average distance between stopping places of 500 to 600m an average stopping time (for boarding and alighting) of

1) This means one tram every 12 to 15 minutes in the quietest periods. It is assumed that the time-table would be published and connections at the main interchanges would be pre-planned and respected.

0.3 minutes was measured in highly differing cities and situations. But variations in the time spent at stopping places were considerable, ranging from 0.1 to 0.8 minutes. That staff discipline is also highly important is clear from the observations made at the terminal of a tram route where, in situations where drivers could easily have left on time (even in peak traffic conditions), there were deviations ranging from 0.8 minutes before and 1.5 minutes after the official start time.

There are many different ways of improving regularity beginning with staff instruction and motivation, staff signals given at the right time, and indication of the correct departure time at certain points on the route, with the addition of a tolerance for average journey time. Differences in time spent at stopping places can be reduced by relieving drivers of fare collection responsibilities (see 7.3), having all doors open for boarding and alighting, using automatic door closure systems, and so on. Another point of interest here is that maximum stopping time determines minimum tram headway. A very finely adjusted system is used in the Paris Metro, although difficulties there do not arise from traffic obstacles but from other factors (very high frequencies are particularly sensitive to small troubles) such as those of an automatic, programmed departure control system ("système de commande des départs programmés automatiques"). Such a system is also being investigated for inner circle tram routes in Amsterdam and elsewhere. Central traffic control systems are used in Hamburg and Zurich as a simple way of adjusting regularity.

Finally, here are a few examples showing the better situation on tramways nearer to the start of the routes (in outlying districts) where traffic obstacles are slight. Much of this data is based on measurements taken during peak traffic periods.

- Amsterdam, average distance between stopping places 490m, route length 4.9 km, speed 23-29 km/h, journey time 10-13 minutes;
- Bremen, average distance between stopping places 620m, route length 5.6 km, speeds 23-28 km/h, journey times 12-14½ minutes.
- The Hague, average distance between stopping places 510m, route length 7.7 km, speeds 23-28 km/h, journey times 16½-20 minutes.

In general, and on the basis of these figures, it can be said that the variation in time interval between trams halfway along a well-run express tram route is $\pm 1\frac{1}{2}$ minutes.

7.2 Frequency and capacity

Maximum possible peak traffic frequency per route very much depends on the level of regularity required in the service. The 5-7½-minute service suggested at the start of this chapter is perfectly compatible with an irregularity of $\pm 1\frac{1}{2}$ minutes halfway along

the route. In the "normal" case this means intervals of from $3\frac{1}{2}$ to $6\frac{1}{2}$ minutes or 6 to 9 minutes. These 30 per cent and 20 per cent deviations in relation to the planned interval could result in a proportionally larger number of waiting passengers. This can, to some extent, be offset by the one-third capacity reserve which is, incidentally, also intended to mop up the natural variation in peak hour demand. This is certainly necessary since the irregularity phenomenon is in itself an inconvenience for a passenger in terms of the additional waiting time, being confronted with a crowded vehicle and the fact that additional time has to be allowed (e.g. for changing and catching a tram). In those circumstances, having to let a tram go by because it is full up is intolerable.

On the basis of these figures, recalculation of the capacities given in Table 4.1 and section 5.4 give the following reasonable findings, namely an acceptable level of peak traffic of a maximum of 3,200 passengers per tram route (one coupled unit every 5 minutes) and a maximum of 12,800 passengers per main corridor (48 coupled units every hour).

In the case of the underground, the figures can be taken considerably higher because of the lower variation in journey time and the longer trains, e.g. a 2-minute service with trains able to carry 1,200 passengers ($30 \times 1,200 \times \frac{2}{3} = 24,000$).

The limit for trolley-buses, too, is a 5-minute service per route, in other words a maximum of $12 \times 120(1) \times \frac{2}{3} = 960$ passengers. With the help of a few "tricks of the trade" (e.g. double lines - one express, one normal), this figure can be increased, but, in the final resort, it is not possible to provide any kind of regular service along a main corridor using more than 60 vehicles an hour, the maximum in this case being $60 \times 120(1) \times \frac{2}{3} = 4,800$ passengers.

It should also be remembered that the field of application of one transport technology does not begin where the other leaves off. There is an overlap (see 4.4) which can be used for optimising the technologies to be used on the basis of other criteria apart from frequency and capacity. The conclusion from all this is that if the intention is really to provide a high-quality public transport system, the express tram is a valid proposition for towns with a population of from 300,000 to 1,000,000 and can be used in anticipation of, and to supplement, underground railway systems in large towns (see 5.4).

7.3 Fare collection

On the subject of reducing the time spent at stopping places and the level of running costs, this section refers to the fare collection

1) Trolley-buses with trailer, otherwise the figure is only 80, see 6.3.

methods used in many towns dispensing with the need to have a conductor or even to have the driver perform this function. The needs here are fare structure and provision for the following:

- maximum use of season tickets, purchasable beforehand, away from the vehicle;
- multiple trip tickets, also sold away from the vehicle and validated either at the stopping place (as in Switzerland) or after boarding the vehicle (more general practice);
- single tickets bought from ticket-issuing machines either at the stopping place (as in Switzerland) or on board the vehicle (as in Amsterdam) and in exceptional cases from the driver.

These modern fare collection methods have revived interest in trams (certainly in the form of coupled units) from the economic viewpoint: one-man crew for 450 passengers (maximum) in a 60m-long tram set compared with one driver for 120 passengers (maximum) in a (trolley) bus plus trailer.

7.4 Information

It is perhaps unnecessary to repeat that shelters at stopping places (stations), good signposting, optimum track lay-out (particularly at interchanges), clear indication of departure times (in timetables as well), general route maps and maps showing routes in relation to the surrounding area at the place concerned, etc. need not be the exclusive preserve of underground train systems. They should also be the features of a modern public transport system at road level (express tram systems, for instance).

7.5 Organisation

This section is confined to one aspect of organisation: co-ordination between different transport operators at conurbation and regional level. As a town becomes more imbricated in the surrounding area, the historical distinction between the urban transport, intercity transport and suburban trains disappears.(18) Some reference to this has already been made in Section 5.5 in connection with intercity transport. As far as the railways are concerned, the fact is that 30 to 60 per cent of passengers arriving at any of the stations in the conurbation have to change to urban transport in which case the difference in the two fare systems already acts as a barrier. We are however not concerned merely with the question of tickets and fares but primarily with the management of the whole transport and traffic sector and with operational co-operation.

A policy to have certain main urban corridors served by express tram or underground routes is adversely affected if intercity buses belonging to other transport operators or coming under other authorities continue to work parallel routes in large numbers. Money is wasted if the facilities of an existing railborne system are not fully used for urban traffic and instead an underground route is built in the neighbourhood. Continuous irritation is caused if interchange facilities between the different undertakings do not come up to expectations. And unfortunately there are many more examples.

Just as a car-user can transfer smoothly from a road in the town to a trunk road or motorway, public transport should operate as one single undertaking managed by one responsible and single-minded policy body. This is known as the integration of public transport.

Various stages are possible:

- integration of transport services: i.e. joint exploitation of the market;
- structural integration: merging of transport undertakings;
- technical integration: or technical standardization.

Integration of transport services, which came to the fore primarily because of the lead taken by German transport and fare associations(19) (Hamburg, Munich, Frankfurt) and in Stockholm and, to a certain extent, also in Great Britain (Public Transport Authorities), takes the following form:

- the "group" (independent of the member operators, its business objective is to produce the best possible transport service for the user); responsibilities:
 - . market research
 - . system development and route lay-out
 - . level of facilities/establishment of timetable
 - . fare structure and levels
 - . distribution of profits
 - . attracting custom (advertising and public relations)
- member operators (responsibilities retained by them)
 - . provision of infrastructure
 - . provision of rolling stock
 - . detailed timetables, rolling stock and staff rotas
 - . operation
 - . management
 - . fare collection
 - . technical R & D

Structural integration means, in reality, the complete merging of the various operators and this is currently meeting more and more resistance from the staff involved. Where urban and intercity railway transport is concerned, the difficulties are insoluble unless there is a completely separate infrastructure.

The main virtue of such an operation is that it leads to economies of scale. For the user, integration of this kind is of little interest because, if it is operating satisfactorily, a "group" will ensure optimum service which must, incidentally, give the impression, externally, that there is only one undertaking.

Technical integration is automatic if one of the above steps has been taken but it can also be developed on its own if passengers' interests can be served in this way, e.g. avoidance of inconvenience at interchanges, better utilisation of expensive infrastructure, etc. Because of the differences in the historical development of railways, underground systems, trams and, to a lesser extent, intercity and urban buses, this form of integration, generally implies an increase in costs initially.

From the above it should be clear that integration of transport services must be regarded as the most important step and in most cases even the only really possible one. Even a partial beginning - fare integration for instance (the "Carte Orange" in Paris) - can already produce impressive improvements.

8. THE CHOICE PROCESS - COSTS AND BENEFITS

8.1 Costs

Whereas the quantities dealt with in previous chapters (metres, kilometres, minutes, numbers, population, passengers, etc.) should not give rise to misinterpretation from country to country, difficulties may arise when costs are expressed in monetary values because of changing parities and rapid inflation. In what follows, therefore, relative figures will mainly be used, and very general ones at that because a cost study going into any depth would take us too far in this general report.

As far as rolling stock is concerned, if the cost of purchasing an i/c bus is put at 100 per potential passenger, the figure for a trolley-bus would be 160, that for an express tram 250 and that for an underground train about 250. Figures for running costs are far more consistent because electric motors are cheaper to maintain and because depreciation, particularly in the case of railborne vehicles, can be extended over a far longer period.

Infrastructure costs are difficult to compare. They are practically nil in the case of a bus service operated wholly on public roads, or at least they have no, or hardly any, effect on the

economics of running a bus service. If the express tram is compared with the completely own-track underground, the ratio in urban areas can be 1:10 or even more.

Staff costs have a decisive impact on total running costs. This is where the advantages of railborne transport come to the fore, provided there is sufficient volume of traffic to use combination trams offering several times the capacity of a bus (see Section 7) since one man per tram combination is generally sufficient. We have seen that situations of this kind arise in towns with a population of 300,000 or more.

Total running costs in such situations are, all in all, roughly similar for i/c buses and (express) trams. Trolley-buses, without the advantage of pulling a trailer, are invariably more costly than i/c buses. In Amsterdam (population 800,000), for example, annual running costs per potential passenger in the case of trams are 1.1 times what they are for buses. However, maximum tram length in this case is only twice that of a bus and, in spite of a (still limited) number of priority rules, trams mainly used in densely populated areas with narrow roads are not able to reach the same speeds as buses on routes with less dense traffic. In Zurich (population 600,000) where there are multi-unit trams and in most cases trolley and ordinary buses with trailers, trams (main routes) are cheaper than buses, whilst trolley-buses cost most to run.

Another example is Dusseldorf (population 200,000). The following extract is taken from the Rheinbahn magazine "Das Rad" dated July 1976. "A comparison between cost components immediately shows an essential difference between the two modes of transport. Unlike trams, costings for bus operation show no track costs whereas, in the case of trams, about 14 per cent of total expenditure goes on the track (maintenance, depreciation and interest).

For motor vehicles, it is generally possible to regard the vehicle or road tax as the counterpart of track costs for trams (disregarding, that is, the question of whether the tax is adequate from this viewpoint). But since motor vehicles running scheduled services pay no tax, this counterpart disappears for buses and they therefore enjoy an appreciable operating costs advantage over trams. If the two systems are compared in terms of cost breakdown, the striking thing is the staff-intensive nature of bus operation:

	Trams	Buses
Staff costs	64%	73%
Other costs	36%	27%

The high share of staff costs in the case of buses means that this mode is more effected than trams are by wage increases.

Taking the longer-term view, this aspect will gain in importance as time goes by, assuming that wages continue to increase more steeply than other costs.

An interesting light is thrown on the subject if costs are broken down into those related to output and those that are not. In the conditions applying in the Rheinische Bahngesellschaft, with output as it stands at the moment, the figures are as follows:

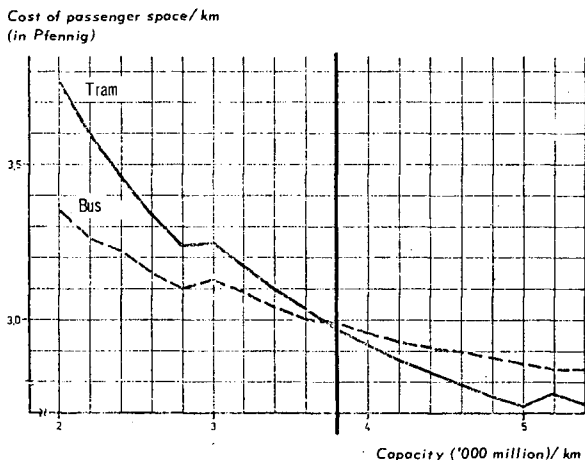
	Trams	Buses
Output-related costs	63%	73%
Non-output-related costs	73%	27%

Two conclusions can be drawn from this comparison:

- Because of the larger share of non-output-related costs, trams adjust less easily to contracting output (residual costs);
- If output increases, trams have cost advantages since the costs that are not related to output (not just fixed costs) cannot go up and therefore the average cost per unit of output falls.

To make this conclusion clearer, we can try to see what happens to average costs in both cases when output changes (by an increase or decrease in service frequency). The unit of output used is the (potential) passenger/kilometre, as generally employed for this kind of comparison in the public transport sector. For the sake of clarity the results of this calculation are represented as curves (Figure 8.1).

Figure 8.1
PRESENT OUTPUT OF DÜSSELDORF TRAM SYSTEM



The curves show that with the output achieved in Dusseldorf and in the conditions described, average costs are lower, however slightly, for trams than for buses. This means that trams are more economic than buses in this output range. In view of the relatively higher staff costs in the case of buses, and the increases that are to be expected in wage costs, the tram's cost advantage is more likely to increase than decrease in the future."

What is more, if buses have to meet high infrastructural costs then the cost calculation changes. The question, for example, arose as to whether it would be better, for new residential areas in Rotterdam-West (Schiedam, Vlaardingen-Holy) to have an express bus or express tram on segregated track or an "underground" railway. Construction costs were estimated at 100 for the express bus, 125 for the express tram and 400 for the "underground" (not a factor of 10 because in new areas track would mainly be laid on the surface). Long-term operating costs worked out in favour of the express tram, the figure for the "underground" being $2\frac{1}{2}$ times as much.

8.2 Benefits, volume of traffic

There is almost nowhere in the world - certainly not in West Europe - where proceeds from urban transport cover cost. The reasons are well enough known. If public transport still exists it is not purely to provide a minimum service for people who have no other means of transport at their disposal (as in the United States), but in order to ensure the survival of properly functioning cities. From this viewpoint, public transport must provide a quality product in order to attract as high a proportion of urban traffic as possible. The benefits can therefore be better expressed in terms of volume of passenger traffic, which determines the financial yield - from fare structures which are often based on policy considerations.

It is therefore better to compare volume of traffic with costs. Figures for volume of traffic have already been considered, as averages, in Section 5.1 (Table 5.1), where the point was also made that there is a reciprocal relationship between transport quality and volume of traffic (see Section 5.2).

This is clear from a number of examples:

- on a route from the centre of Rotterdam to Schiebroek (an outlying district) a changeover from buses to express trams (8 km) in 1969 resulted in a 15 per cent increase in traffic;
- in 1971 the conversion of a tram route from the centre of Amsterdam to Osdorp (another outlying district) to an own-track express tram route (10 km) with certain priority rules (see the end of Section 6.2) produced a 60 per cent increase in traffic;

- in 1974 replacing an ordinary and express bus service from the centre of The Hague to Vrederust (outlying district) by an express tram route (12 $\frac{1}{2}$ km, 8 km from the centre) resulted in a 20 per cent increase in traffic;
- further away from home, a bus service was introduced to connect the satellite town of Skokie with Chicago, after the antiquated railway service was shut down. Adequate capacity was provided but custom fell off steeply. Re-introduction of railborne transport in 1964 in the form of a kind of express tram started the traffic figures climbing steeply in spite of the moderate accessibility of the station. An interesting point is that, for a peak load of 1,300 passengers per hour, the route was meeting requirements satisfactorily within a few months after its re-opening. In 1965, a senior official of the Chicago traffic authority stated that normally, transport planners recommended only buses for a maximum load of about 5,000 passengers per hour and tended to think of figures like 15,000 to 40,000 an hour for rapid transit. But probabilities today as regards possible traffic figures lay well below 5,000 an hour and the "Skokie Swift Junior rapid transit" line, with its peak capacity of over 1,300 passengers seemed to permit a far higher service quality than buses. In reality it appeared that the question of whether buses could carry a considerable number of passengers was irrelevant if they could not attract traffic in the first place.

8.3 The process of choice

The decision on what transport technique should be used in which situation is a very difficult process of selection in which much depends on local circumstances and intentions as regards future options. It has already been said on several occasions in this report that, in towns with a population lying between 300,000 (or often less) and 2,000,000, the express tram has become a more attractive proposition on main links or to supplement the underground (from a population of 1,000,000 on), for many reasons including the following:

- moderate investment cost;
- adaptability;
- the possibility of phased and relatively rapid construction;
- acceptable operating costs (good future prospects because of low manpower requirements);
- adequate capacity;
- satisfactory regularity;
- high quality;
- environmental advantages;

- positive perceptive value (a visible infrastructure invites people to travel by rail);
- no undesired scaling-up effects.

To wind up, here are two pertinent and recent examples.

Utrecht - Nieuwegein. The problem here was to connect Utrecht (population 300,000) with the new satellite town of Nieuwegein (population 50,000), a distance of about 12 km, via two branches totaling 17 km. Alternatives considered were railway, express trams and buses.

System	Railway	Express trams	Buses
. Infrastructural investment	Fl.175 million	Fl.106 million	Fl.32 million
. Annual costs(1)	Fl.20.5 million	Fl.16.5 million	Fl.8 million
. Quality	good	good	mediocre
. Capacity	largely sufficient	sufficient	insufficient
. Journey time	18 min.(2)	18 min.	21-30 min.
. Adaptability	partial	good	partial
. Effect on urban development	negative	positive	negative

1) Including infrastructural charges.

2) Because of the roundabout route necessary in the case of a railway.

Further research of the various possibilities led the authorities with whom the final decision lay, to decide that the most acceptable solution was an express tram link, free - as far as possible - of intersections. This decision was taken in 1974 and was based on the following considerations:

- . effect on urban development;
- . environmental and safety considerations;
- . cost.

It is clear from the above that the cost of the service could not have been a positive factor in the decision. The main consideration was the quality of tram transport and therefore the avoidance of excessive pressure on the use of roads by cars and buses which might possibly have led to further road building and interference with urban development.

Tyneside. (Population about 500,000.) Here the problem was to provide transport for the so-called North Tyne Loop, at present served by diesel trains. Five possibilities were investigated by the consultants, Allen. M. Voorhees & Associates, with 1984 as the horizon year (but at 1969 prices).

System→	Train (un- changed)	Bus	Train (im- proved)	Tram	Express bus
. Investment	0	£0.9 mil.	£5.2 mil.	£6.5 mil.	£13.9 mil.
. Annual costs	£6.9 mil.	£6.4 mil.	£7.0 mil.	£6.1 mil.	£6.3 mil.
. Peak traffic	"100"	96	104	106	107
. Proportion of service on own track	20.3%	0	37.3%	44.2%	43.7%

Although the investigation was primarily confined to the North Tyne Loop, these relate to the complete Tyneside transport system.(20)

Here too costs are not the only factor in the recommendation that trams ("light rapid transit") be selected. The qualitative judgement took into account the performance of the various systems in terms of their satisfaction of the following four criteria:

- . simplicity of implementation;
- . effect on motorways, etc.;
- . long-term prospects;
- . compatibility with regional planning.

The report found that the express tram system (light rapid transit) appeared to have many of the desirable characteristics of the improved railway and bus alternatives but not the same number of disadvantages. It was the only one of the own-track systems that represented a real financial advantage in relation to the existing systems, if the level of loan capital were disregarded. The system would attract a large amount of passengers and offered a 38 per cent return on total investment. Also, it would be the only one of the alternatives researched that would be fully compatible with the public transport recommendations in the Tyne Wear Plan on the provision of a certain level of service.

In view of the time available for producing the study, benefits and disadvantages for highway users were not considered. Had these factors been taken into account, the conclusions of the study would have been reinforced in that they would have further heightened the advantages of high performance own-track public transport (such as express trams).

One general comment in conclusion. In the decision-making process, it is of extreme importance that wide scope be given for the population concerned and potential passengers to be consulted, not merely because of the co-operation necessary from them in implementing the decision but also so as to interest public opinion in the new development.

9. SUMMARY OF THE ARGUMENT

9.1 Car transport gains its advantage from the use of public roads and public transport can realise its potential only if it uses a track reserved exclusively for it.(1)

9.2 Readers wishing to form a fair judgement of the problems dealt with in this report will not confine themselves just to reading the introduction but will take the trouble to read the whole report.(2)

9.3 The transport technology chosen must fit in with the urban development that is desired. In this respect buses are neutral, an underground system will develop dense concentration along a number of main corridors and trams occupy an intermediate position, either requiring or favouring a certain degree of organisation.(3)

9.4 Improvements to public transport without any specific restrictions on car traffic will have little effect on the extent of car use and the attitudes of car users. Reviving the tram therefore fits in well with an active policy to influence car-users.(3)

9.5 Apart from the favourable properties of the electric motor, trolley-buses have no specific advantages compared with ordinary buses. None of the advantages of trams such as own track, high capacity and low manpower requirement are offered by the trolley-bus.(4)

9.6 Maximum acceptable walking distance to or from public transport stopping places is unrelated to mode but people are more prepared to use their car or bicycle to reach a stopping place in the case of high-quality railborne transport.(4)

9.7 In towns with a population of over 300,000 the express tram is highly suitable for use on main routes in terms of network mesh size, distance and quality. In towns with a population of over one million these main routes would best be served by an underground system but this could well be supplemented by trams.(4)

9.8 There is a close correlation between urban structure, and the quality and use of public transport.(4)

9.9 An urban transport network should be simple (limited number of routes and clear structure), and have a number of well-equipped points of interchange where the different urban and/or inter-city routes and/or railways would meet.(5)

9.10 Trams are a good method of transport that can be gradually improved by the provision of segregated track, the introduction of priority rules and the building of short under and/or overpasses, all of which help to reduce journey time and improve the control of traffic flow.(6)

9.11 Promoting public transport does not therefore mean plunging directly, through an escalation in requirements, into the building of an underground railway system. Measures which restrict car

traffic to some extent, such as traffic cells, priority for public transport at intersections and special tram lanes, can all help to activate the redevelopment of urban functions.(6)

9.12 In connection with the above it would be wise to remember that:

- people are more attracted towards perfect, all-out solutions and not to what is the best possible in the circumstances;
- one single, large-scale prestige project makes a greater impression on local patriotism than a series of smaller-scale but useful projects, however undemocratic this may be in its effect;
- technocratic approaches go on and on in community life but municipal councils do not. Major decisions on vast projects, "inch-by-inch" tactics and pressures to safeguard jobs in the building industry keep the bulldozers moving and concrete mixers turning.....

9.13 Standardization (express) tram technology, particularly in rolling stock, is urgently required - at least at West European level - if this mode, in the interests of future development and costs, is to be a match for the vast motor industry.(6)

9.14 Maximum possible frequency on a public transport route depends very much on regularity. This means that capacity is much lower than theoretically possible but, all in all, trams are very suitable, in terms of capacity, for towns with populations of between 300,000 and 2 million.(7)

9.15 The use of a simple fare structure, well-designed rolling stock and infrastructures and the provision of useful travel information enable quality to be improved and manpower requirements to be reduced to a minimum - this being a particularly important point when combination express trams are used.(7)

9.16 In interconnected urbanised areas the whole public transport system (urban and regional transport and the main-line railways) must operate as a single unit under the management of a single responsible and united policy body.(7)

9.17 In the process of deciding on the transport technique to be used, economic results are not the only criterion. The main factor is volume of traffic in relation to installation constraints, effects on urban structure, influence on other forms of traffic, etc. In this light, the tram often has much to recommend.(8)

9.18 Forecasts, in many cases based on a large number of hypotheses and simplifications, are indispensable as an aid to decision-making but they cannot be used as the only basis for decision, nor can they replace common sense.(8)

9.19 Before a decision is taken, it is vitally important to give adequate scope for the population concerned and potential users to be consulted.(8)

9.20 When a transport specialist is asked to produce a preliminary report on "Scope for the use of certain old-established urban transport techniques (trams and trolley-buses)" there is a danger that the report will present these techniques as "the" solution for all transport and traffic problems. It can never be the intention of the author of such a report to give this kind of unqualified impression to the reader - whence this last comment.(9)

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SUMMARY OF THE DISCUSSION

The object of the discussion at the Round Table was to integrate the tram and trolleybus question into an overall conurbation policy and therefore went beyond the technical and operational aspects which constitute transport organisation in the strict sense.

The following aspects were therefore considered in this order:

1. Urban planning,
2. The operator's viewpoint,
3. The viewpoint of the highway authority (traffic systems and priorities),
4. The local authority's viewpoint (options and financing),
5. Conclusions.

1. URBAN PLANNING

Decisions on transport are conditioned from the outset by urban layout as it is and as envisaged for the future. Harmony in the interaction between urban planning and transport is possible only in terms of the future and even then only in the light of the ways in which the existing urban layout and transport system will continue to determine future lines of approach.

The primary objective for transport is to provide a regular and reliable system.

In the case of railborne transport, a very important consideration is whether segregated track already exists or infrastructures that are not always used to the best advantage. A further point is that railway networks are often inadequately integrated in urban transport as a whole, so that shortcomings on the supply side (fares, connections or timetables) may result in under-utilisation.

Knowledge of what has already been provided (in the form of segregated track) and what has been envisaged in the way of extensions (reservation of future routes) is essential. Here, there are very appreciable differences between countries and even between towns.

The transport strategies to be considered are therefore very different according to whether a reliable infrastructure does or does not already exist. Policy cannot over-reach available resources. Moreover, the time is past when tramway companies kept well ahead

of urban development, in particular by participating in land purchase. Modern urban planning is affected by certain constraints (e.g. the price of land) which also apply to transport.

On the whole, the flexibility of the bus acts against it since it encourages an urban layout that is too dispersed having been largely tailored to the size of the vehicle. Ultimately, so many ramifications, variants and extensions are needed, all to meet a fairly low level of demand, that a sufficiently frequent service on each route can no longer be economically envisaged.

Conversely, underground railway systems are often ill-suited to the population dispersal which has already taken place in peripheral areas. The intermediate solution of the tram, being more flexible in layout possibilities, enables a more ramified network to be provided than the underground train while at the same time not encouraging urban sprawl.

The major concerns in urban planning are the revival of the centre and the functional arrangement of new peripheral extensions. Town centres must continue to be general meeting places; at the present time they are declining because of the accumulation of what are sometimes conflicting functions and which in their turn generate a traffic overload. In addition, housing resources in town centres sometimes suffer from an ageing process followed by the appearance of empty areas in or near the centres.

In some medium-sized towns, the retention or introduction of trams is impeded by the existing urban layout. The problem relates mainly to the centre but is aggravated when the structures for extensions or access roads add further complications as regards the reservation of segregated track.

Town size, however, is less important than town shape, population density, location of the various types of activity, etc., all of which affect the volume and direction of journeys.

As for journeys themselves, it should be fully realised that, in the case of the car, supply is always ahead of demand, since the roads are always available, which is not the case for public transport. This being so, the influence of public transport layouts on urban planning is not decisive; it is questionable, in some cases, whether it exists. The fact is that for the past 30 years towns have been built almost exclusively with the car in mind and public transport networks have been forced to fall in line. Public transport could have some effect on future urban planning provided that public transport layouts are reserved early enough.

Severe restrictions on the use of cars are not realistic if a satisfactory supply of public transport does not exist - otherwise the danger of the centre splitting up is even greater. Any solution to the transport problem must necessarily ensure that a high level of mobility is preserved.

Populations of satellite towns, in which large traffic flows towards the centre of the main town are often generated, will fall into the habit of using cars unless public transport services are available from the outset. This pattern of behaviour will be difficult to change thereafter in favour of public transport. Some countries have therefore made it a legal requirement to provide a public transport service immediately the satellite town is built. Because of the volume of traffic which may be expected buses are often unsuited for such a service.

As regards policy, the Round Table reached three basic conclusions:

- a) the demand to be met should first be ascertained before deciding on transport supply;
- b) it is important to take the political decision-making structures into consideration and, in particular, to know which authority will be responsible for financing the project;
- c) it is essential to have a policy covering the complete conurbation which means, in particular, there has to be a general development plan for the entire urban entity (regardless of certain administrative divisions not coinciding with the boundaries of the entity).

To sum up, the Round Table considers that public transport is confronted with an enormous "catching up" problem, since there has been very little investment in this sector since before the war, save in a few exceptional cases of very large towns or countries which have shown some foresight in the matter. The answer in many cases, therefore, must be to make better use of existing facilities and resources.

2. USE OF TRAMS

The almost invariable growth of urban units affects decisions on the provision of transport since the number of trips increases; they tend to be more concentrated at peak hours and the networks necessarily have to be developed on a geographical basis. Forecasting brackets are therefore needed in order to simplify coping with more traffic, making vehicles longer and extending routes.

The Round Table considered the arguments which carried the day in certain cases where tramway services were discontinued or would prevent their rational reintroduction in the future.

Public transport must be regarded as an integrated set of transport resources in a complete region. In certain cases it may be found that the availability of a basic urban railway network supplemented by a bus system leaves no real role for trams. This is particularly true if the suburban pattern is highly dispersed.

If there is a fairly well-developed network of urban motorways that is not yet saturated, express bus routes are relatively easy to operate.

In certain cases, there are several operators in the same town. This rules out any unified approach. In such cases, there should at the very least, be only one person responsible for policy.

By withdrawing tram services operators have often made substantial budgetary savings, mainly in three fields: infrastructure, personnel and vehicles. It is scarcely necessary to point out that a comparison of infrastructure costs can not be valid if one mode (the tram) pays directly for its infrastructure and the other (buses) pays only partly or not at all.

Finally, tramways require, in practical terms, a separate infrastructure if they are to provide a service with the desired regularity and speed; this criterion was, and still is, far from being met in many cases.

In the past trams were often withdrawn to save manpower, dispose of rolling stock that had become too heterogeneous and ease traffic conditions; it is very difficult to put the clock back. However, the mode introduced in their place has become more dependent on the highway authorities and is also under constant pressure to expand the network out of due proportion.

In short, a clear distinction should be made between two situations: that in which trams are still operated and that in which there are none. In the latter case, a global strategy is needed extending far beyond a few local adaptations.

If the urban layout appears not to lend itself to much modification the possibility of a tramway system can be discounted straight away. In the other case, two types of global propped strategy offer themselves: one based on the semi-metro and the other on the priority tram; the choice depends a great deal on the type and stage of urban development that has been reached.

Furthermore, the introduction of trams implies certain policy problems; since it will be gradual certain quarters of the conurbation will necessarily benefit more than others. Subsequently, there is a risk of the mode being allowed to penetrate too far into the centre and attract too many activities there.

Certain participants, on the other hand, consider that it is never too late to bring back trams. Everything depends on the service that it is intended to offer the population. Since the present situation falls short of what is needed to promote public transport, it is not simply a matter of transporting "captive" public transport passengers but of reducing car use for many well-known reasons (energy, environment, restoration of satisfactory traffic flow).

On top of this there are several objectives which tramways can largely help to achieve. First, it is essential to remodel the use of town centres. Second, investment should be designed to spread the benefit over a large number of citizens; this latter requirement is not served if overweight investment means projects have to be implemented on a piecemeal basis.

The flexibility argument is often used against trams. In the view of some participants, everything depends on what exactly is meant. Flexibility is negative when the need for it is a matter of making up for deficiencies in planning. In such cases, it can only be temporary since, with or without trams, the outcome is congestion all the same.

However, tramway systems are flexible in that a route can be improved step by step and capacity adjusted to meet increasing demand.

Moreover, a large number of routes is not always an advantage; geographical dispersal of the supply of transport services is one of the main reasons for the present escalation in the cost of urban transport.

In practice, priority rules are better observed in the case of trams than in that of buses, it being assumed that buses are better able to negotiate obstacles, even when in the lanes theoretically reserved for them. Bus lanes have proved to be unreliable and not very fast.

In vehicle capacity and availability of segregated infrastructures, modern tramways lie somewhere between bus and rail transport whose characteristics they may be said to combine. It is therefore not a substitute for the bus and it would therefore be an error of judgement on the part of the tram operator to try to provide a bus-type service.

Practice provides certain information that weighs in favour of trams. Public opinion polls have shown that, at present, users have least liking for buses as a means of urban transport. This certainly provides a pointer as regards meeting future needs. Another fact pointing in the same direction is that increases in traffic are mainly found on routes served by rail.

One important operating condition is that rail should carry a large share of the traffic; if the tramways were to serve only a minority it would generally be better to do away with them.

Trams' essential function is to serve the main radial access routes, unlike the old tramway systems which spread into a dense network in town centres.

Public transport calls for reliability and regularity, and good connections; reserve capacity for peak hours is also essential. A further point is that if frequency is too high there can, in

practice, be no priority at intersections, which argues in favour of large capacity vehicles on heavy-traffic routes.

Conversely, it was pointed out that in off-peak periods the interval between high capacity vehicles is necessarily considerable and economy of operation thus has its limits which cannot be exceeded without reducing the quality of service the passenger has to accept. To obviate this, operating speeds have to be increased allowing faster turnround and greater frequency. Generally speaking it is best to have a number of routes on the same track in the centre and fanning out in the periphery, thereby offering high service frequency on the busier sections and for the shorter trip distances.

Because of the scale of the problems to be solved in urban transport at national level, and the lack of real financial resources, many experts advocate a policy consisting in first making the utmost use of the possibilities of surface transport. The problem is to make optimum use of urban space, which necessarily implies certain priorities for public transport. This priority should be considered case by case. In certain relatively favourable situations, it will be possible to reserve one route for public transport and divert car traffic to other parallel routes. In less favourable situations, it will be necessary to be satisfied for the time being with bans on certain parts.

Express trams are mainly characterised by their high commercial speed which depends on line speed, frequency, access doors and connections. What matters to the user, when judging the speed of a trip, is the time the whole trip takes - door to door.

Speed is achieved by the combination of segregated track and modern vehicles; as regards the track, two quality levels may continue for a long time and have to be accepted, since it may not be possible to convert certain sections to segregated track. As regards the vehicles, standardization will be most useful not in terms of a standardized vehicle for all towns but in the standardization of as many different parts as possible.

Finally, it is very important to eradicate the old image of the tram and to present to the public a mode of transport that has been transformed in speed and comfort; changes in outward appearance can have a considerable psychological effect on the public's recognition of the metamorphosis.

2 bis. USE OF TROLLEYBUSES

The Round Table as a whole was not in favour of trolleybuses; it found that they had no telling advantage over other conventional modes of road transport.

However, the use of trolleybuses may be a necessary choice for policy reasons unconnected with trolleybuses themselves (energy,

environment). But, here, too, some countries have developed buses which make as little noise as trolleybuses.

In any event, the trolleybus is not involved in the rail versus road issue; it is a secondary choice between different types of road transport.

There is general agreement among operators that trolleybuses often cost more to operate without offering any specific advantages over buses. On heavy traffic routes, trolleybuses are less regular since, they cannot maintain too high a frequency.

Trolleybuses may perhaps be suitable for certain particular types of town provided, even so, that they are operated not as isolated routes but as a sufficiently coherent and dense network.

3. USE OF ROAD SPACE

In this connection, there is often a combination of objectives transcending the problems of the use of road space. Certain types of road use may be a way of implementing more general options (environmental decisions, for example).

In addition, measures regarding the use of road space often enable problems, for which alternative solutions imply major high-cost and lengthy projects, to be solved cheaply and quickly.

Generally, therefore, the combined objective is to improve public transport and the environment in town centres and to do so by relatively simple means. Thus restrictions on the use of cars on trunk routes are proposed primarily to improve the environment for the benefit of residents and visitors in the town centre.

In this context ensuring the public is informed is an important aspect. An attitude of communal responsibility towards the use of available space needs to be cultivated and this can best be achieved by making better known the monetary and time-saving advantages of the measures taken.

One serious handicap in achieving optimum use of essential space is the presence, in these areas, of considerable parking capacity, usually in private hands. An imbalance gradually forms as between parking capacity and the capacity of the roads to and from these parking areas.

Another handicap lies in the large number of administrations with responsibilities in this matter. However, during recent years certain countries have set up local administrations with overall responsibility for transport; the financial resources available to these authorities are generally limited and their policy is necessarily confined to the task of making best use of existing capacities.

Each town has its own characteristics and its population their own mentality: it is therefore difficult to advance solutions

applicable to Europe as a whole especially as the variety of restrictions that could be imposed on car use is considerable. There is one general rule however: measures of one kind or another are practically always necessary, since no town escapes saturation.

Pedestrian-only roads where trams or buses are also allowed should be of sufficient width if pedestrians are to retain sufficient freedom movement.

Certain experiments indicate that a large proportion, often the majority, of shoppers may come to the centre without a car and therefore need good public transport services to bring them to the pedestrian-only streets themselves or to points in their immediate vicinity.

The problem of access to the centre by public transport is often complicated on roads through the ring zone immediately surrounding it where it is sometimes very difficult to reserve lanes for public transport. In many cases, these sections are not of sufficient width and hardly any parallel routes exist on which to divert traffic. Even so, some towns have tried out relatively large-scale diversions for traffic into the centre by making some streets reversibly one-way on certain radial routes thus denying traffic the use of such streets over long stretches and reserving them for public transport and local users.

A last important point here is to ensure the co-operation of the police since they have the task of enforcing the measures and are the target at which reactions are primarily directed when problems arise. Consequently, continuous contact is necessary in order to find out the way traffic behaves and changes in practice. In cases where such co-operation is fully ensured, the police have proved to be a valuable source of help to public transport.

4. OPTIONS AND FINANCING

There has been a great shift in transport policy attitudes in recent years. Only ten years ago the underground railway seemed to be the almost universal solution.

But it was soon found that a "metro" did not always provide a sufficiently closeknit network in built-up areas with relatively scattered residential areas. In towns where they do not already exist, the cost and time involved in building them are major objections particularly since the traffic situation often demands speedy and effective solutions.

In these cases, the objective will be to improve the level of service throughout the network. The first measure will be to protect public transport routes and will involve restrictions on car traffic. This immediately produces an appreciable reduction in operating costs, and at the same time wins back custom. Next, modern

vehicles need to be acquired making the service even more attractive and further reducing operating costs. Later, the system can be further improved either by reserving streets or building underpasses in the centre and at certain intersections.

One decisive advantage in the case of the tram is the possible existence of long sections located on segregated track. Conversely, the creation of new networks generally involves large-scale and immediate infrastructure construction unless route reservation is resorted to, which may come up against political difficulties.

The first step is often the most difficult to take. Once the benefits of modernisation are seen in the effects it has, further investment will come more easily. In this connection, positive results in one town may prompt others to introduce certain measures; it is therefore important to carry out tests, financed by the national community as a whole.

The Round Table has considered several aspects bound up with the question of network size. While it is generally undesirable to operate just one tram route, since this usually involves problems of scale for the tramway operator, ambitious projects leading to overdeveloped networks are to be guarded against as well for they inevitably mean running at a heavy loss for many years.

Financing is primarily a problem of source (central or local government); the easiest way of obtaining funds is by reallocating certain transport appropriations (e.g. from roads to public transport) which implies a basic policy change.

Two key aspects are how the overall cost is to be met and the question of which authority will foot the bill. The situation in both respects differs from country to country. In certain cases the fact that the cost of heavy infrastructure projects is shouldered by the central government may obviously affect the choices made by local authorities. Furthermore, major works (tunnels) are not easily repaid out of traffic receipts and so the investment cannot be recovered. This calls for a political choice between alternatives and other claims on public money (e.g. underground, university or hospital). Above all, finance should not be earmarked for a single purpose, e.g. tunnelling. This fairly widespread practice entirely distorts decision-making as regards the various transport alternatives and sometimes even as regards the community's overall allocation of resources.

A subject of keen debate in several countries is the question of whether preference should go to building track on the surface or underground. In principle, costly tunnelling should be resorted to only when no other solution is possible. For tramways its main function is to avoid bottlenecks and tunnels should therefore not be continuous. More importantly, it is sometimes more effective to

have several short underground sections on a line since they are the best way of maintaining speed and regularity; a long tunnel in a town centre will lose much of its effectiveness if the trams are still held up and caught in traffic jams at intersections above ground in peripheral areas.

When a surface track segregation is decided upon it is important to enforce respect for it by other traffic. This is comparatively easier for trams which unlike buses, are unable to avoid an obstacle. However, it will be useful to authorise public transport staff to report drivers of vehicles obstructing the line. The procedure should include a certified statement of the delays incurred and entitle the operator to compensation.

New surface routes are increasingly the target for protests from that fraction of public opinion which is particularly sensitive to environmental damage. In this case, a detailed inventory should be made of all the environmental pros and cons of the different solutions which will show that underground travel also involves disamenities and that tunnelling causes a great deal of inconvenience for local residents, sometimes going on for several years.

If it is decided to lay track underground it must be at least compensated for by substantial environmental improvement above ground; in other words, the metro should not be used as a way of increasing the number of cars in the centre.

The greatly varying geology in the different towns means that the cost of a tunnel may vary from twice to ten times that of the same length of surface track. Legislation, public opinion (sometimes against surface transport, sometimes against underground) and source of funds, etc. also vary.

Instead of comparing things that are not fully comparable, the costs and benefits of each possibility should be systematically worked out.

5. CONCLUSIONS

Capital and running costs are not always the deciding factor in favour of tramways since the overall costs of different transport systems are often much the same.

Two essential yardsticks for assessing transport systems are the environment and uniformly easy access to the centre. In both respects, the limitations of the bus are immediately apparent:

- the tram is preferable from an environmental standpoint, and
- from the access standpoint, with trams:
 - a) own-track routes can be introduced more easily;
 - b) priorities can be established at intersections because of the lower frequency;

c) services are far more regular - a vital factor in making a public transport service attractive.

The financing procedures used largely determine which solution is chosen and here it is essential to take the total cost into consideration. No distinction should be made between operating and investment grants, particularly when they come from different sources.

A tramway system has no special value unless it is run in such a way that the system's particular advantages can be exploited. A tram should therefore never be operated in the same way as a bus. A decision in favour of trams is not just a transport decision. A tramway affects structures and the decision to build a tramway should therefore fit into the complete pattern of urban planning, town centre revival, road management, etc.

The future potential of the trolleybus seems limited since it can be justified only in the case of a complete network. It is not basically different from the other modes but just a variation on the bus, mainly for cases where no railborne system is envisaged.

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