LIGHT RAPID TRANSIT

Some Aspects of Medium-Capacity Urban Rail Systems

1972

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Photo 1: typical of modern light rapid transit practice is the terminus at Merkenich, Köln. Note the simple layout and equipment comprising substation, simple loop track, low-level loading and unloading platforms, stair access from a roadway above, a small shelter, name sign and lighting. (*F. van Dam*)

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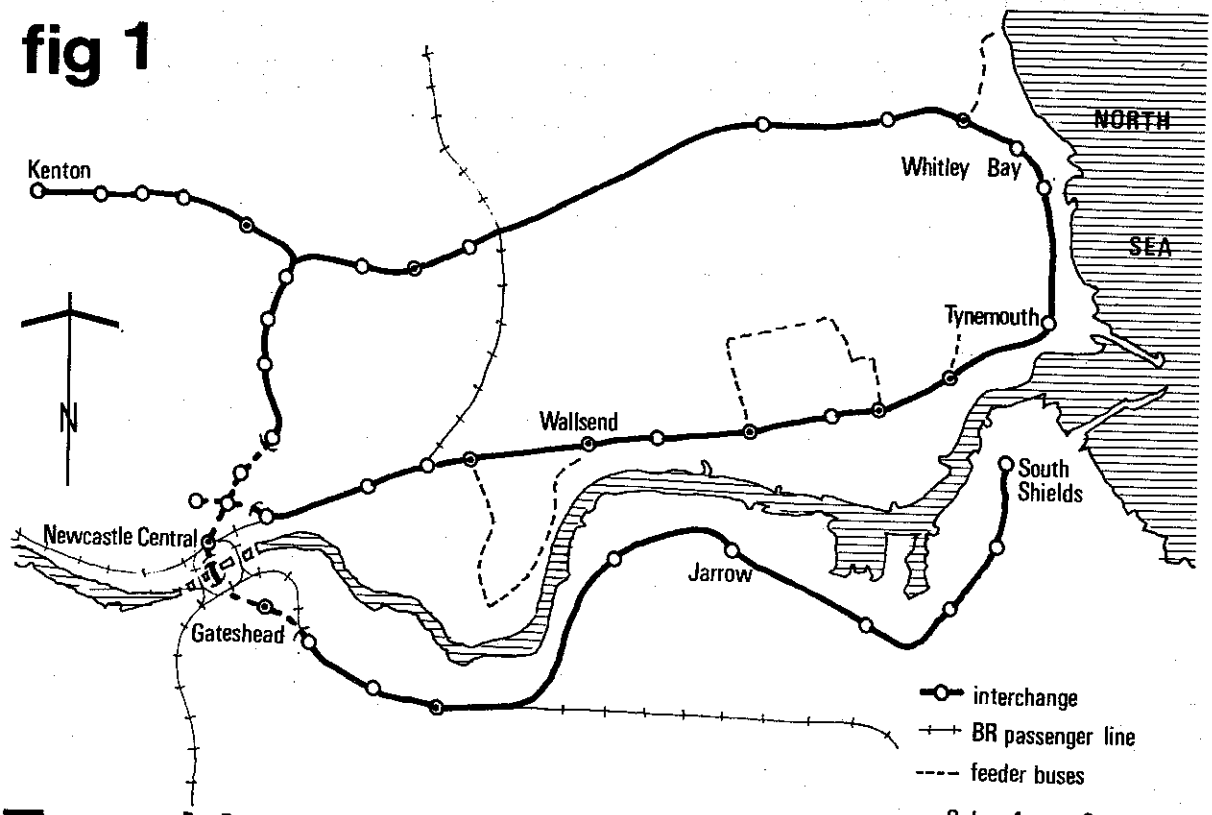
fig 1



Tyneside: semi-metro

Gent: semi-metro

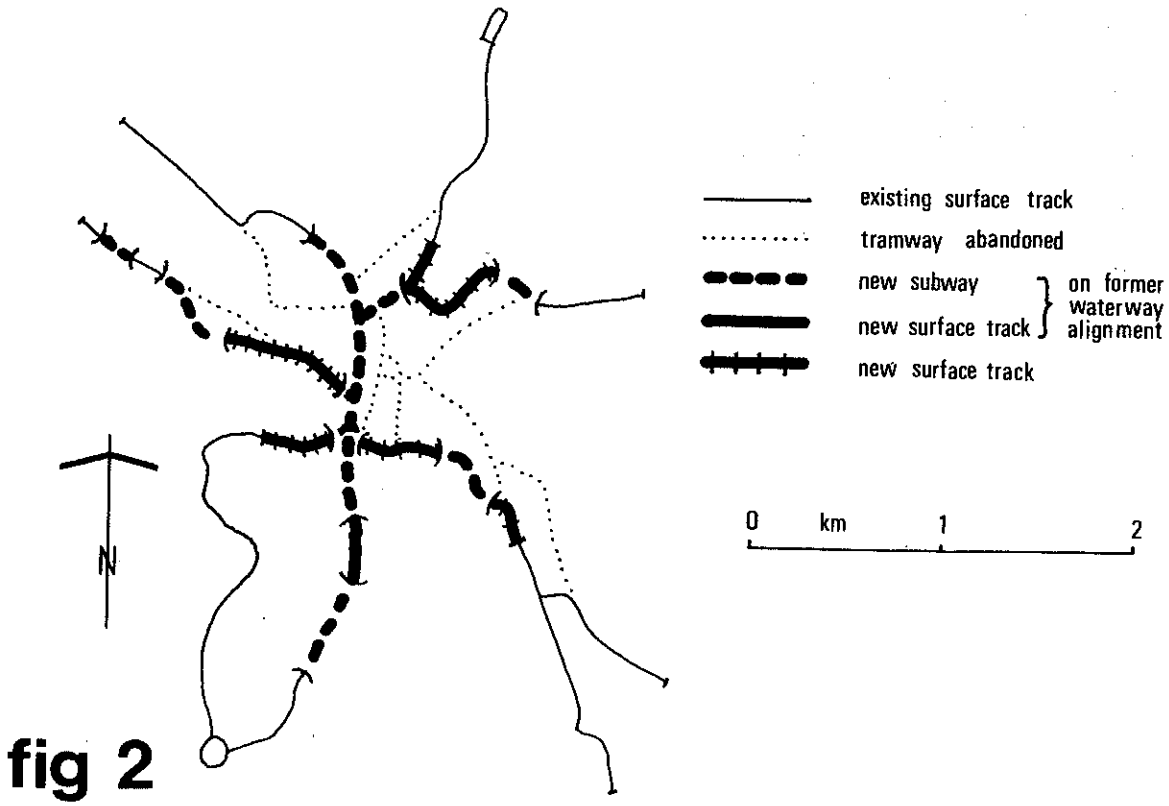


fig 2

1 GENERAL CLASSIFICATION

In many countries a variety of intermediate forms of rapid transit between classical tramway and electric railway has been developed, with the general objective of gaining the maximum benefits of segregation for minimum cost and in the minimum time. The object of this paper is to review various installations existing or proposed and to discuss the status of light rapid transit as a public transport mode.

We can classify the range of modern light rapid transit under four broad headings which may be grouped in pairs. The first pair, which we shall term *pre-metro*, comprises those systems conceived as a temporary phase in the transition to *metro* standards, and those systems designed to allow possible upgrading later. Examples of the former are found primarily in West Germany and Belgium, the most important being Antwerpen, Bruxelles, Bielefeld, Bremen, Frankfurt, Hannover, Köln, Nürnberg, the Ruhr area and Stuttgart. Examples of the latter are generally smaller towns with populations under 700 000, such as Göteborg in Sweden, and Mannheim-Ludwigshafen in West Germany. The second pair, which we shall term *semi-metro*, comprises those systems intended to complement a metro system, as in Rotterdam, Zurich, Munchen, Boston and San Francisco, or to serve as the principal public transport mode, as in Freiburg im Breisgau, Basel, Bern and Gent, for an indefinite period; and those systems closely akin to tramways which are retained for special local reasons, such as Marseille, Fort Worth in Texas, and Newark, New Jersey, and even Blackpool. To avoid confusion we shall use the terms *metro*, *semi-metro* and *pre-metro* even for German and American examples, where very different terminology is normally used.

2 PHYSICAL CHARACTERISTICS

Generally speaking, the first step in the transition from tramway to *metro* standards is the construction of high-speed segregated tracks, with a slight loss in terms of accessibility to the passenger. Most upgraded routes run close to the former tramway alignment but in subways in the central area, on viaducts or through under-passes at major road crossings or on roadside reservation or totally new right-of-way. The existence of under-used railway tracks or waterways presents an opportunity for totally new rapid transit rights-of-way in built-up areas. The proposed Tyneside *semi-metro* (Fig.1) is an example of the former (with precedents at Skokie near Chicago and at Riverside near Boston, Massachusetts), while the Gent *semi-metro* subways (Fig.2) under construction typify the latter (with a precedent in Newark, New Jersey).

While the traditional tramcar was essentially a street vehicle, although often allowed on its own right-of-way in outer areas where land was cheap, it is generally felt that public transport today should be segregated from other street users to avoid delays due to traffic congestion.

Table 1 Decline in average journey speed, Bruxelles surface tramways, 1960–66

Year	1960	1961	1962	1963	1964	1965	1966
Speed (*km/h*)	17.88	17.80	17.77	17.68	17.46	17.37	17.20

(*Source: P. G. Reynaert, UITP Congress, Barcelona, 1967*)

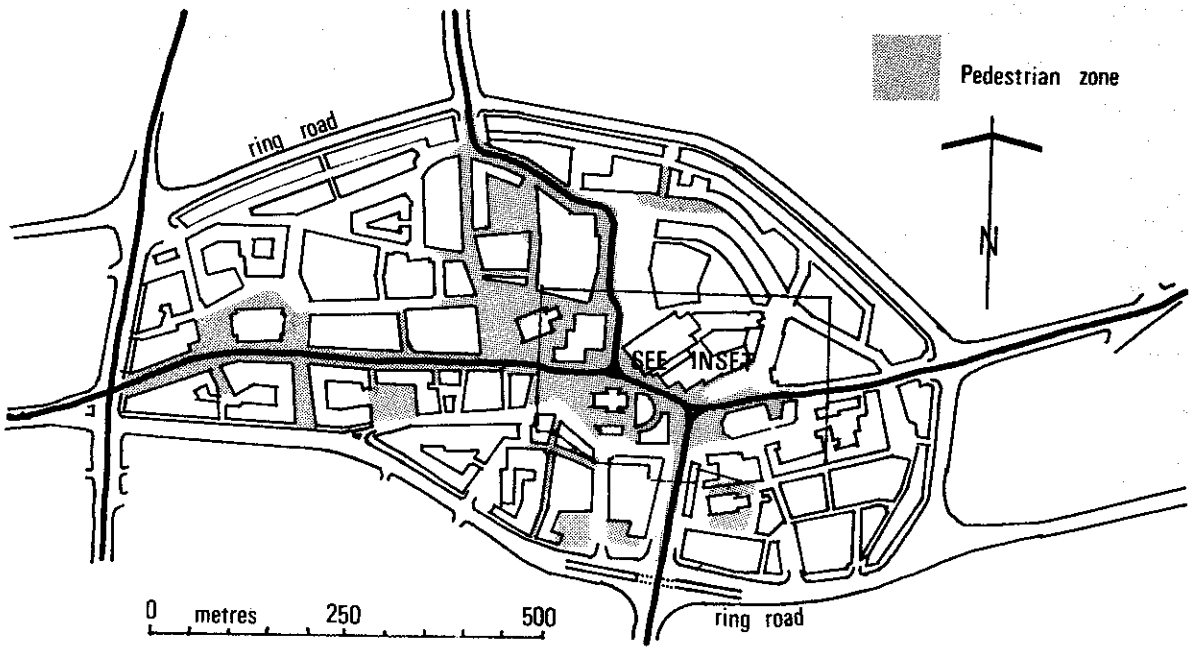
This phenomenon is universal, and it has been calculated that a 1-km/h decline in commercial speed on the Düsseldorf tramways increased operating costs by DM.1.3 million per annum. After years of development, the Köln tramways undertaking now has over 65% of its total network on reserved track.

The provision of bus lanes, now accepted in this country, has its counterpart in tramway cities such as Bremen and Den Haag, where former tramway reservations have been paved to enable both buses and trams to share a segregated right-of-way, and experience shows that the two modes are quite compatible.

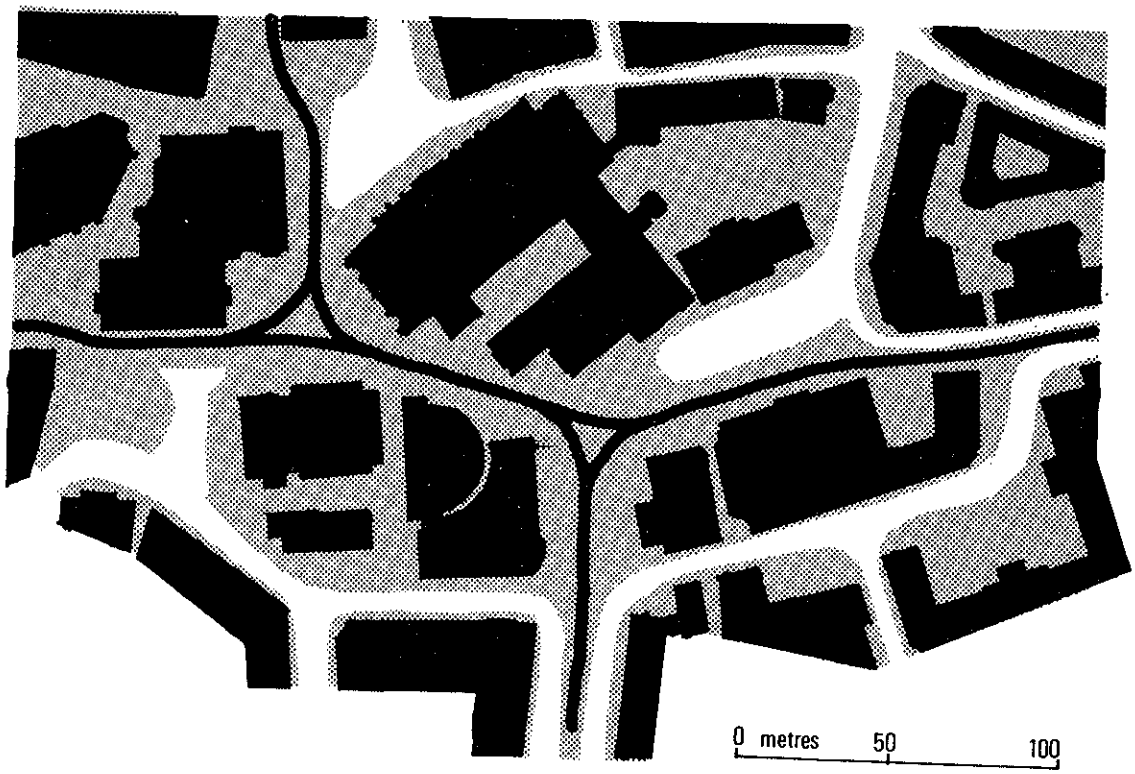
A politically difficult but cheap approach is to close central area streets to all vehicular traffic as in Bremen (Fig.3) and Göteborg. A scheme for diverting tramcars along the new Chestnut Street shopping mall in Philadelphia has been discussed for many years, but the upheaval associated with the establishment of a regional PTA has delayed any action.

Having stated the case for segregated public transport, it should be added that the need to segregate the modes diminishes if other road traffic is restrained in volume and behaviour. A growing popular concern over the inadequacies of the motor car is encouraging official measures to make private motoring more difficult in urban areas, and to give buses a priority which can be justified on grounds of overall economy and environmental improvement. The Amsterdam authorities have in recent months made radical improvements to the tramway system by traffic management methods such as reducing road widths (in some cases down to one lane only in each direction) to provide totally segregated street track. On the other hand, it can be argued that lower overall traffic volumes together with increasing lane discipline on public roads may have eliminated the problems of integrating rail public transport with other street traffic.

fig 3



Bremen city centre



3 ROUTE PATTERN

A striking contrast in route pattern between *metro* and *semi-metro* modes can be seen in the long-term plans for Rotterdam and Den Haag (Figs.4 and 5). In Rotterdam, population 723 000, where segregated tramways and bus services will complement the *metro* system, there will be only two cross-city *metro* routes plus a large number of feeders, involving a high proportion of interchange. In Den Haag, with a smaller population of 607 000, a *semi-metro* network with seven cross-city routes is proposed.

A city the size of Den Haag is probably the largest in which the *semi-metro* concept can work efficiently as the principal mode. The maximum radial route length from the central area is 8 km., and the mean journey length will probably be about 5 km. In Den Haag the stop spacing at present averages 403 metres, and journey speeds vary between 19 km/h in the off-peak and 7 km/h at peak hours. After upgrading to *semi-metro* standards and a thinning out of stations, the average stop spacing will be 428 metres and speeds are expected to reach 25 km/h using existing rolling stock. The present journey time to a terminus of 25 to 69 minutes on a tram route with only 20% private right-of-way will be reduced, after upgrading, to 19 minutes at all times.

A crude comparison of door-to-door journey speeds can be obtained by adding the mean walking time to and from stations to the vehicle journey time (Table 2).

Table 2 Comparative mean door-to-door journey speeds

A: *Metro,* 30 km/h commercial speed, 1000-metre stop spacing, plus 10 minutes' walking time.

B: *Semi-Metro,* 25 km/h commercial speed, 750-metre stop spacing, plus 7.5 minutes' walking time.

C: *Semi-Metro,* 20 km/h commercial speed, 500-metre stop spacing, plus 5 minutes' walking time.

D: Conventional tramway, 18 km/h commercial speed, 300-metre stop spacing, plus 3 minutes' walking time.

(*mean journey speeds in km/h*)

Trip length	A	B	C	D
10 km	20.0	19.0	17.1	16.5
8 km	18.5	16.6	16.2	15.0
6 km	16.3	15.3	15.7	15.3
4 km	13.3	13.3	14.4	14.8
2 km	8.6	9.2	11.5	12.6

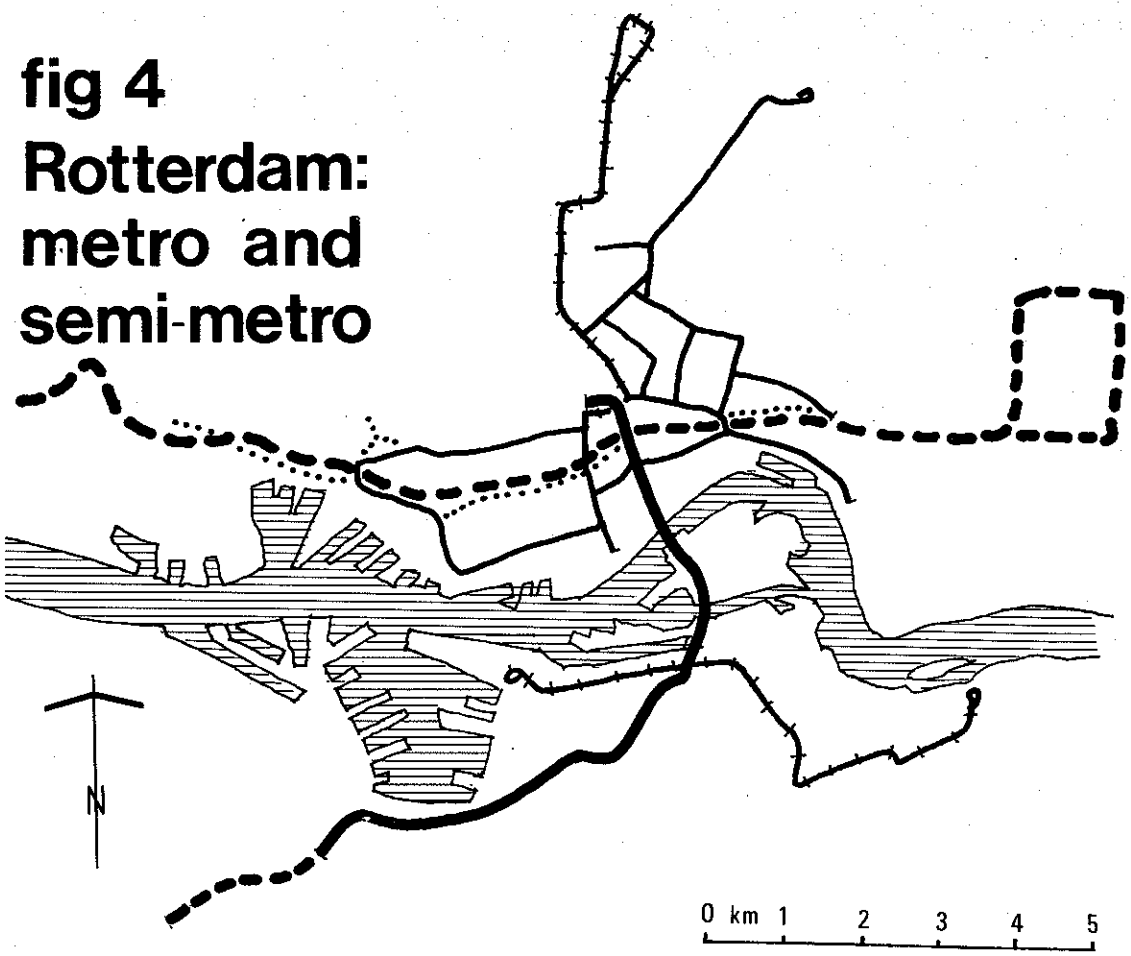
(*Source: Author*)

If we exclude waiting time on the assumption that headways by either mode would be constant, a through 8-km. trip would take 31 minutes under reasonably favourable conditions by traditional tramway, 29 minutes by *semi-metro* with stops 500 or 750 metres apart, or 26 minutes by *metro.* A 5-km. trip would take 20 minutes by any mode, while any shorter trip would be effectively faster by a mode with the most frequent stops.

4 SPEEDS

It is technically feasible to build *semi-metro* vehicles identical in performance with *metro* stock, but it can be more difficult because of the limited space to accommodate the necessary sophisticated equipment. Since *semi-metro* stations are more closely spaced, high acceleration and braking rates are more critical than a high maximum speed. The widespread transition to *pre-metro* standards in West Germany has led the German Association of Transport Undertakings (VöV) to recommend certain levels of performance and overall design specifications. Standards for three distinct types of vehicle are to become mandatory by the end of 1973: a *U-Bahnwagen* vehicle suitable for new conventional *metro* systems, a transitional *Schnellverkehr-Stadtbahnwagen* two-car unit for very high-speed *pre-metro* operation, and a *Stadtbahnwagen* (less ambitiously described as a modern tramcar) for *semi-metro* installations (Fig.6 and Table 3).

fig 4
Rotterdam: metro and semi-metro



Den Haag: semi-metro

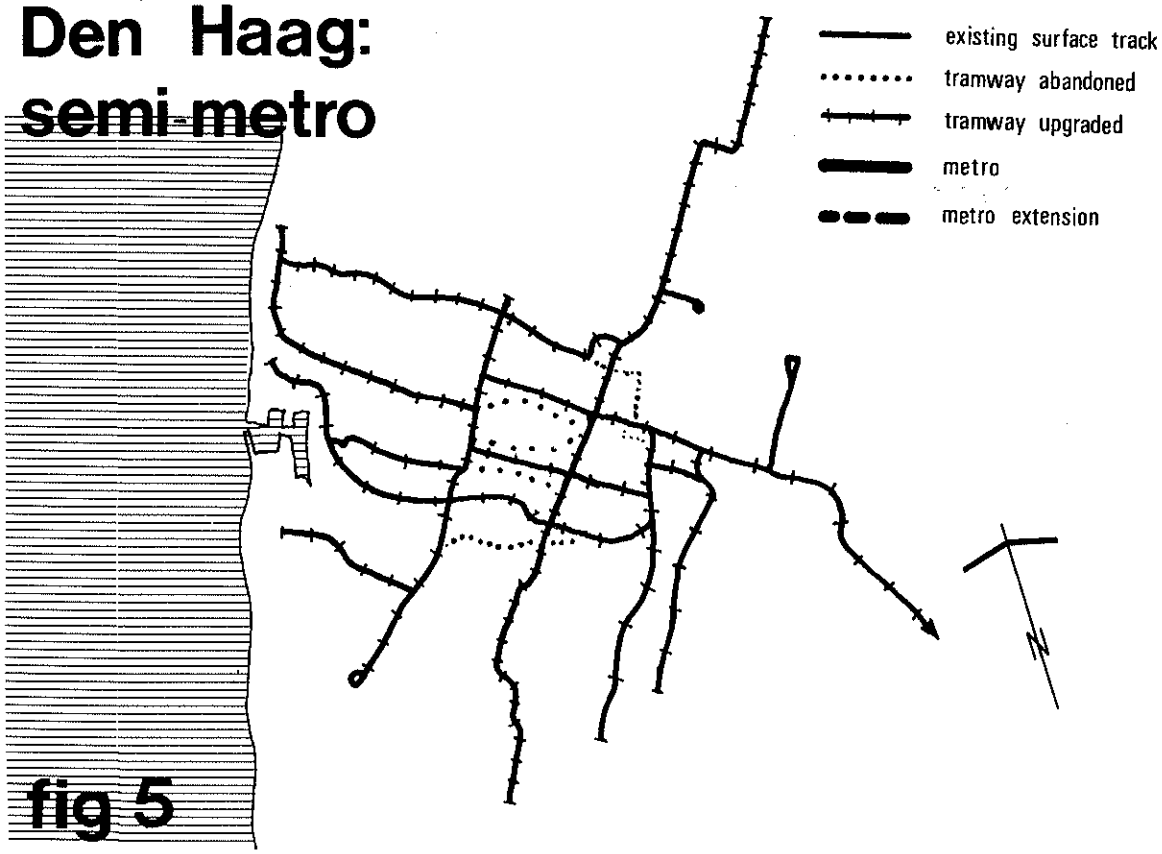


fig 5

Table 3 Verband öffentlicher Verkehrsbetriebe (German Association of Transport Undertakings) recommended standards for rapid transit rolling stock, 1970

Parameter (*unit*)	U-Bahnwagen (*metro*)	Schnellverkehr-Stadtbahnwagen (*pre-metro*)	Stadtbahnwagen (*semi-metro*)
Length of car/s (*mm*)	36 550	36 400	20 100
No. of body sections	2	2	2
No. of bogies	4	4	3
Width of car (*mm*)	2900*	2650	2400
Height of car (*mm*)	3550	3300	3280
Unladen weight (*tonnes*)	48	42	20
Max. axle load (*tonnes*)	10	10	6.5
No. of seats	98	90	51
Standing room	192	158	64
Total passenger capacity	292	248	115
Motors (*kW hourly*)	4 x 180	4 x 185	2 x 150
Voltage (*V, dc*)	750	750	600
Acceleration to 45 km/h (m/s^2)	1.2	1.2	1.28
Acceleration over 45 km/h (m/s^2)	0.5	0.5	0.46
Service braking (m/s^2)	1.3	1.3	1.69
Emergency braking (m/s^2)	2.1	2.3	3.05
Maximum speed (*km/h*)	80	100	70

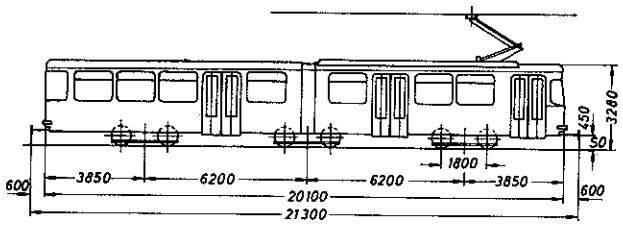
*3100 where a high comfort standard is required.
(*Source: VöV publication No. 6.030.1*)

From these recommended parameters we can draw some useful conclusions of theoretical journey speeds, first assuming constant stop duration and variable stop separation. With stops at 500-metre or 700-metre intervals, the *semi-metro* is marginally faster, while there is little difference in journey speed at 1000-metre intervals. There is, however, a considerable saving in energy consumption. *Semi-metro* cars have been built in the USA, Belgium, Italy and Czechoslovakia with acceleration rates up to 1.8 m/s^2, for operation in congested streets where any means were considered desirable to minimise delay, but such rates are generally regarded as extravagant. New cars designed in 1970 for the San Francisco *semi-metro* were to have an acceleration rate of 1.6 m/s^2 and a top speed of 105 km/h, because two stations are 2.7 km. apart, while the average station spacing is 1150 metres. On this system, a journey speed of 39 km/h was planned. These figures compare with timetable speeds of 28 km/h on the fastest part of a route in Hannover and 30.9 km/h on a long route in Kosice, Czechoslovakia on segregated tracks with a minimum number of intermediate stops. For the record, it should be added that rebuilt tramcars operate a 4.4-km. non-stop shuttle service near Chicago between Dempster and Skokie at a journey speed of 75 km/h, with a maximum speed of 120 km/h.

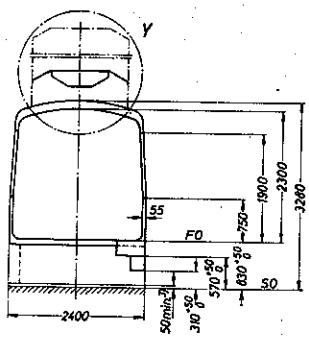
Standing time at stations is an important component of journey speeds, for a 5-second saving at each stop on a *semi-metro* system can increase overall speeds by 5%, with a corresponding saving in vehicle and staff costs (Table 4).

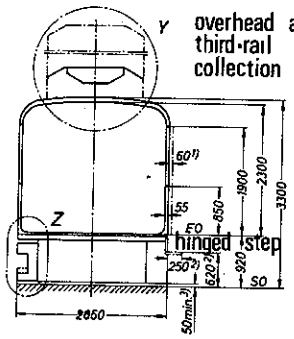
fig 6 Rolling stock

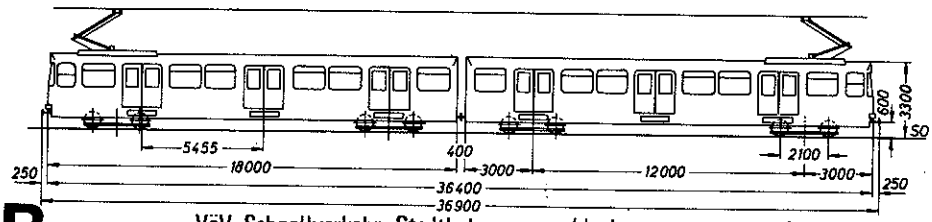
A



VöV Stadtbahnwagen (semi-metro)

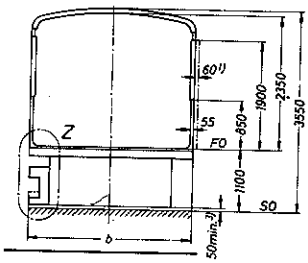


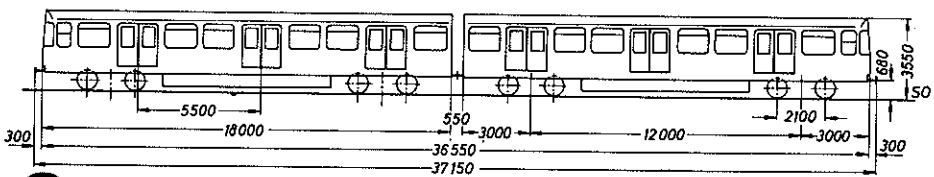




B

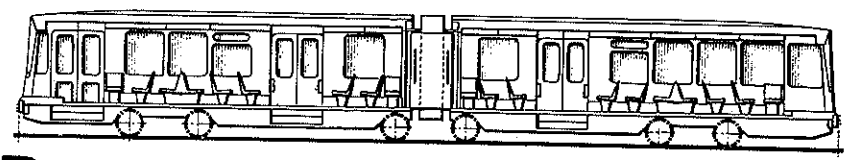
VöV Schnellverkehr-Stadtbahnwagen (dual purpose pre-metro)





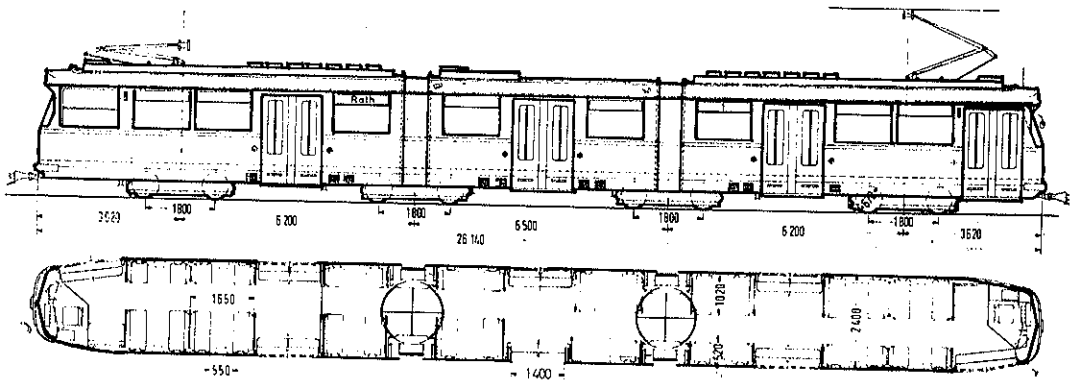
C

VöV U-Bahnwagen (metro)



D

US standard light rail vehicle, 1972



E

8-axle articulated car for Düsseldorf, 1972

Table 4 Effect of stop separation and duration on commercial speed

Based upon VöV recommended parameters for *semi-metro* stock.

(*commercial speeds in km/h*)

Stop separation (*metres*)	Stop duration (*seconds*)		
	10	20	30
1000	41	37	34
800	36	32.5	28
600	32	27.5	23
400	25	21	17
200	17	12.5	9

(*Source: VöV and Author*)

Conventional tramcars are at a great disadvantage compared with high-platform *metro* stock because passengers have to negotiate a difference in height of up to one metre while the car is standing. This disadvantage can be worsened if the driver is required to collect fares. A crude tabulation on this basis demonstrates the effect of different platform heights upon stop duration, and it also indicates the severe dislocation caused by one-man operation under which the driver is required to collect fares (Table 5).

Table 5 Effect of number of boarding passengers upon stop duration

(*stop duration in seconds*)

No. of passengers entering through one double-width doorway	Loading from high platform	Loading from street level	Loading from street level, driver taking fares
4	10	12	32
8	12	17	56
12	14	22	80
16	16	27	104
20	18	32	128

(*Source: Author*)

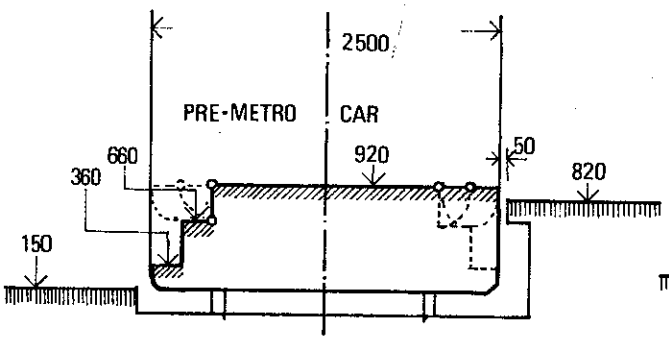
Other factors should also be taken into account, such as the internal layout of the vehicle and the fares system.

In practice, the West Berlin *U-Bahn* or *metro* operates routes with a 16–18 second station stop, while an average of 20 seconds is required in the *pre-metro* subways of Köln and Stuttgart. The Moscow *metro*, with an average stop separation of 1200 metres and a stop duration of 20 seconds, is claimed to be the fastest rapid-transit installation with a journey speed of 40 km/h.

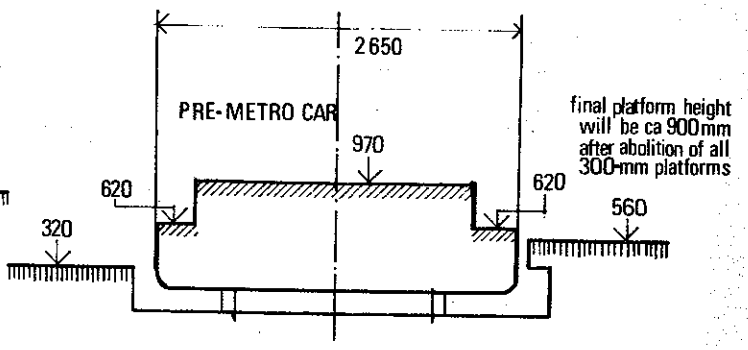
5 HEADWAYS

There are important advantages of the *semi-metro* and *pre-metro* modes in line capacity, because it is possible to admit two train units into a station simultaneously, with or without block signalling. The minimum headway for *semi-metro* operation with trains up to 30 metres in length, a stop duration of 20 seconds and a stop separation of under 500 metres is 44 seconds. If, however, two trains may enter a station together, the effective headway is reduced to 29 seconds (Table 6).

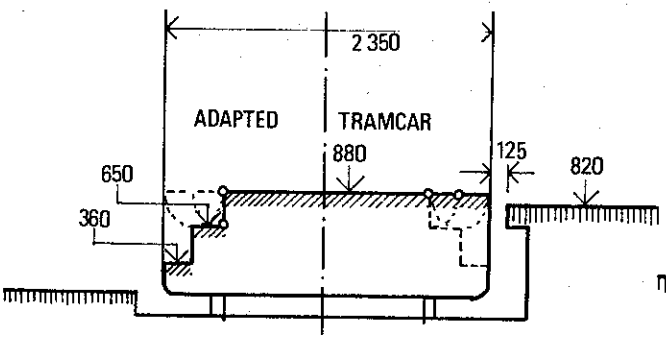
fig 7 Dual-height loading arrangements

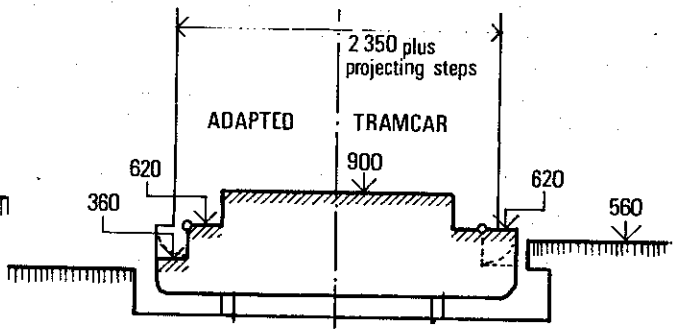


HANNOVER



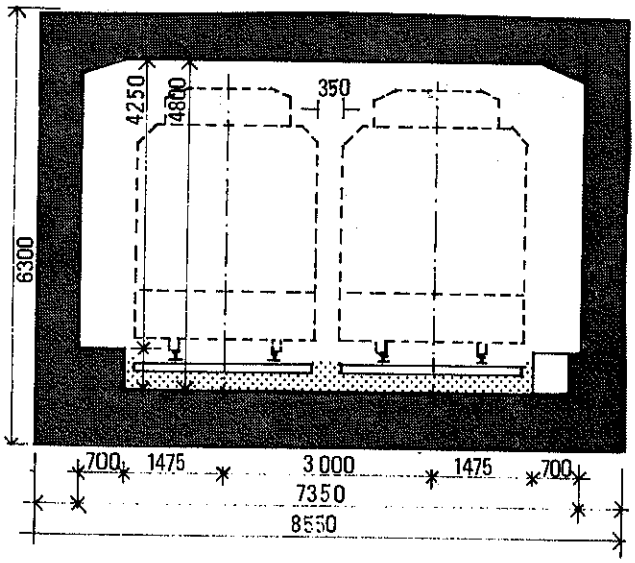
FRANKFURT





Typical tunnel cross-sections

FRANKFURT PRE-METRO



NÜRNBERG METRO

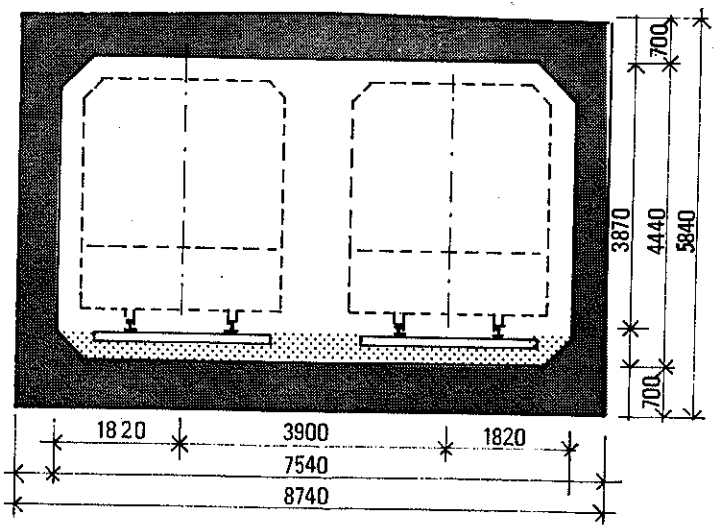


Table 6 Effect of stop separation upon headway

(*headway in seconds*)

Stop duration (*seconds*)	with signalling		without signalling	
	one train in station	two trains in station	one train in station	two trains in station
10	40	26	34	23
20	50	32	44	29
30	60	38	54	35
40	70	44	64	41
50	80	50	74	47
60	90	56	84	53

(*Source: Author*)

In practice, of course, the longest stopping times occur on the busiest sections of route, and the actual headway is largely determined by the maximum rather than the average stop duration.

A variety of signalling systems is used on *pre-metro* installations. In Stuttgart, the extensive tram subways are divided into 100-metre block sections; if two advance sections are clear, drivers may proceed at full speed, indicated by a green aspect. If one section is clear, a green and yellow aspect imposes a 30 km/h restriction, while a yellow aspect indicates an occupied section, into which a driver may proceed on sight at 15 km/h. The tunnels are illuminated throughout their length, and this simple signalling system has a capacity of at least 60 trains per hour per direction, that is, an average headway of 60 seconds.

In the Köln subways, block sections are 120–190 metres long; a green aspect indicates two advance sections clear and a speed restriction of 50 km/h. A yellow aspect indicates one section clear and imposes a restriction of 30 km/h, while a red aspect is an instruction to stop, there being a special *pre-metro* facility to allow a second train on sight into the stations. The peak capacity of this system is 80 trains per hour, with alternate headways of 60 and 30 seconds.

In Bruxelles, a complicated signalling system is used with much shorter sections, an auto-stop tripcock and a series of aspects for speed limits of 40, 33, 27, 18 and 10 km/h. On the San Francisco *semi-metro* system, a continuous cab-signalling system is proposed with commands for speed limits of 80, 56, 32 and 16 km/h, coupled with an automatic train protection device for applying brakes if a driver fails to observe the limits.

6 CAPACITIES

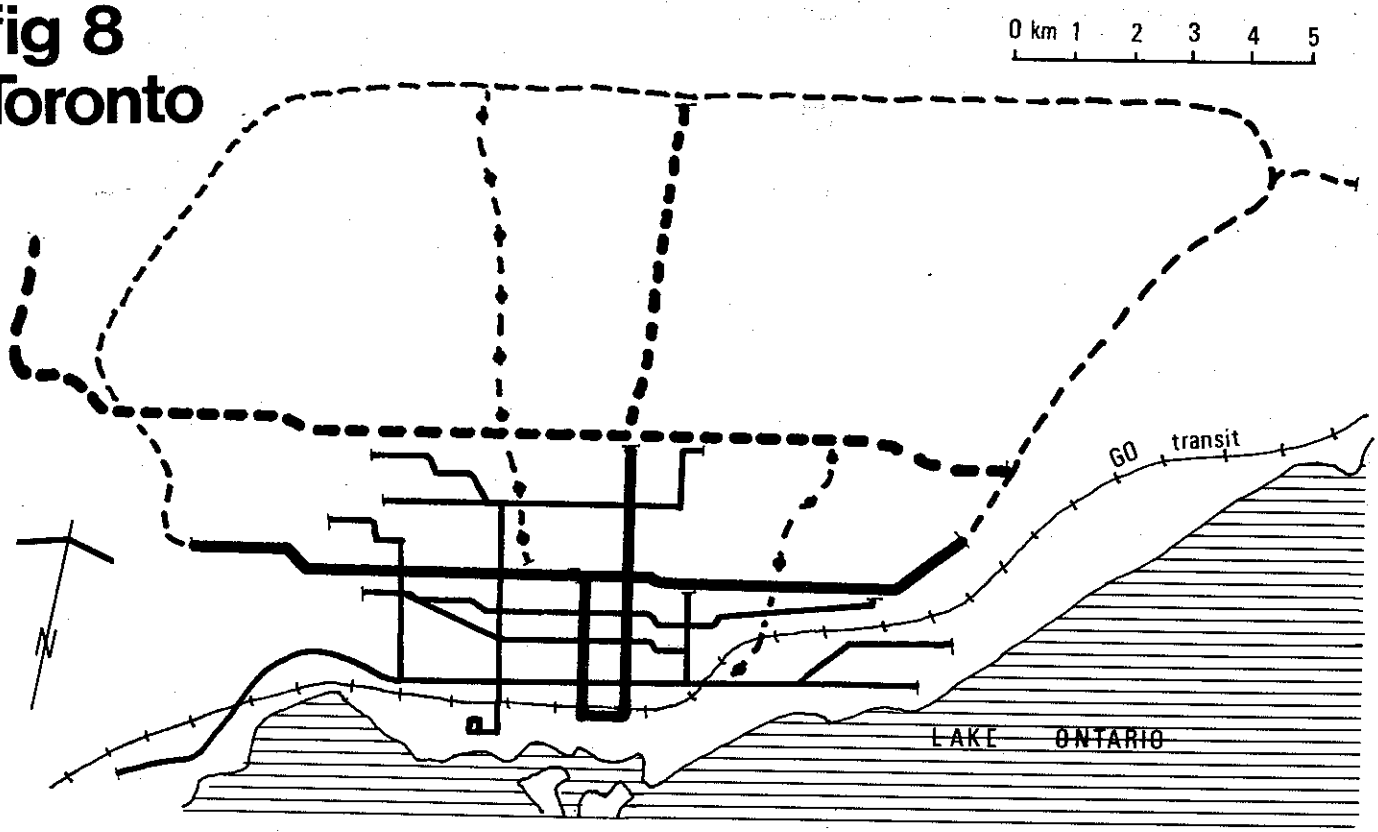
If we accept contemporary West German comfort standards with a low seating capacity, a 30-metre eight-axle car in Köln has a crush capacity of 300. In theory, therefore, the peak capacity of the Köln subway is 80 x 300 = 24 000 passengers per hour per direction but, as almost all passengers will board or alight in the subway sections, stopping times are increased and the realistic peak capacity is about 20 000 passengers per hour per direction. Happily, such extraordinary loadings do not occur; normal peak hour traffic is of the order of 15 000 passengers per hour per direction.

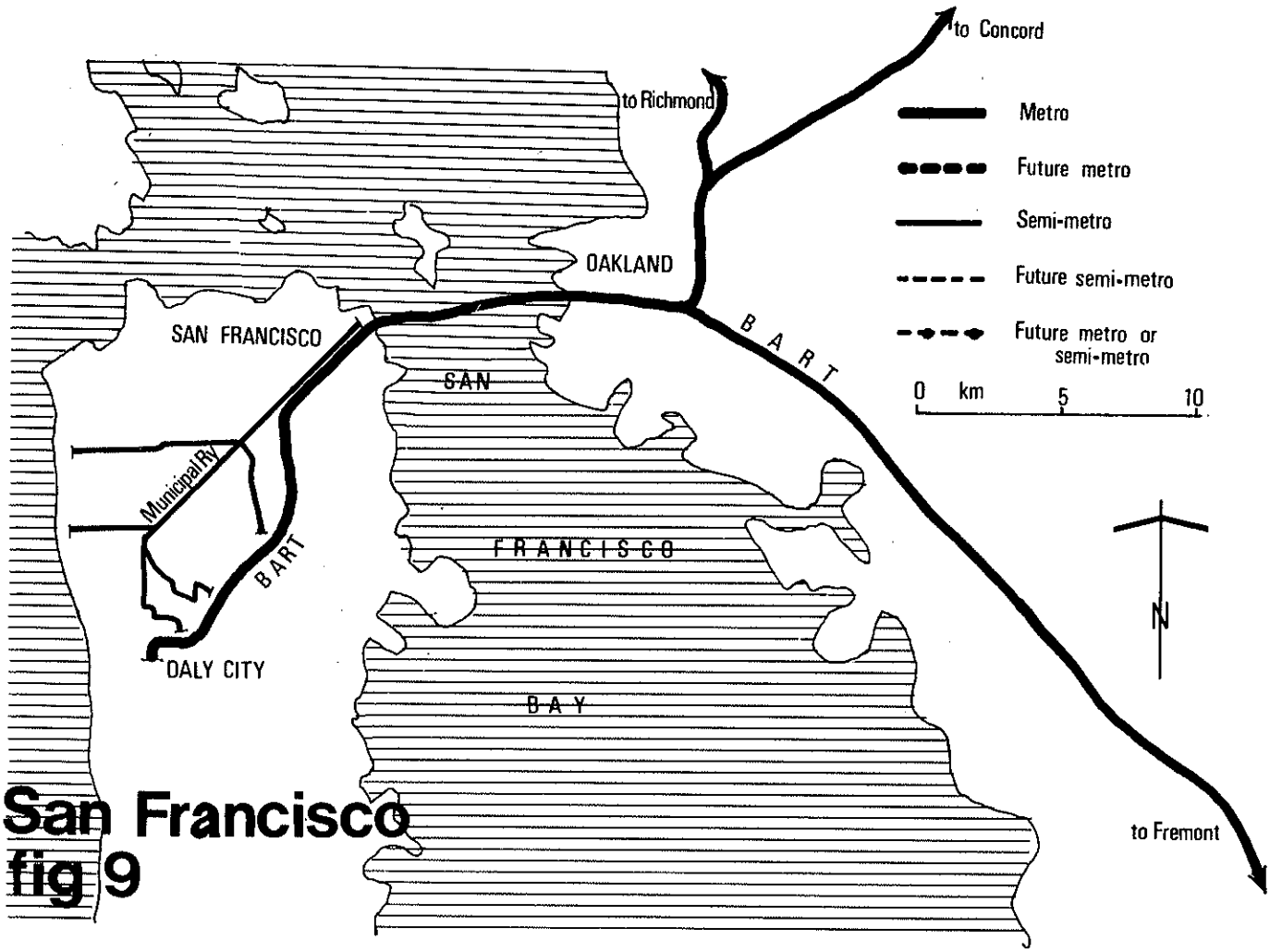
If public transport is to compete with the private motor car, there is much to be said for providing a seat for every regular commuter. The Bay Area Rapid Transit System, a *'super-metro'* installation part of which is now in operation in the San Francisco region, has been planned on this basis, and 10-car trains seating 320 passengers will operate at 90-second headways. The peak capacity of this system is therefore 40 x 320 = 12 800 seats per hour per direction, even if the last passenger may face a 220-metre walk through the length of the train to find his seat.

The highest standard of seating proposed on a *semi-metro* system to date is for the modernisation of the San Francisco Municipal Railway, where peak demands of 12 000 passengers per hour per direction are anticipated and 7000 seats will be offered. It is theoretically possible to provide 68 seats in a 20-metre *semi-metro* car, or 94 seats in a 30-metre long car, so that a total capacity of 80 x 68 = 5 440 or 80 x 94 = 7 520 seats per hour could be attained on a *semi-metro* system. If two six-axle cars were coupled together, as is envisaged in San Francisco, the peak seating capacity would be 10 880 per hour.

A conventional rapid transit train can carry 1000 passengers with 300 seats; operating at 90-second headways this gives a crush capacity of 40 x 1000 = 40 000 passengers per hour per direction. In practice this figure is exceeded on two stretches of the Tokyo metro, where overcrowding is intolerable.

fig 8
Toronto





San Francisco
fig 9

It is perhaps relevant to compare the capacity of a bus system. With current seating standards, the largest available units are 68-seat articulated single-deckers with a crush capacity of 160, and 73-seat double deckers carrying a total of 96 passengers. If we assume that no more than four buses can load simultaneously and that an average loading time is 40 seconds, we have a mean headway of 15 seconds and crush capacities of 240 x 160 = 38 400 or 240 x 96 = 22 840 passengers per hour per direction respectively. To put these figures into perspective, it should be added that 240 drivers are required to move these loads, compared with 80 for a *semi-metro* installation or about 22 for a *metro* system.

7 CLEARANCES

Upgrading from tramway to *metro* standards almost invariably involves a change in vehicle width from a minimum of 2.20 metres to a possible future maximum of 3.10 metres, but the staging of this process is varied. New *pre-metro* construction naturally allows for the maximum width vehicle proposed in the long term. Many German *pre-metro* systems, notably the Ruhr area, Köln and Frankfurt, are now permanently restricted to trains 2.65 metres wide, Bruxelles to 2.70 metres and Hannover to 2.90 metres, while most European *semi-metro* projects retain tramway widths of up to 2.40 metres. 300 mm. is generally regarded as a minimum clearance, even between passing cars in the case of Bruxelles.

Third- and fourth-rail *metro* vehicles are generally higher in construction than *semi-metro* and *pre-metro* cars, typical heights being 3.55 and 3.30 metres respectively. Modern pantograph design enables *semi-metro* and *pre-metro* cars to work with an overhead wire height between 3.785 and 6.145 metres, requiring a clear head-room above rail level of about 4.00 metres, compared with 3.87 metres on the Nürnberg *metro*.

8 CURVES AND GRADIENTS

In the past it could be said that a tramcar was as adaptable to curves and gradients as a motor bus, but this can be said of few *semi-metro* vehicles today. The minimum curve radius on the Swiss metre-gauge tramways is 12 metres, and that for West Germany is 18 metres. By contrast, the minimum radius on most new *metro* construction is 200 metres, although much sharper curves are found on the historic systems of Paris (40 metres) and Hamburg (71 metres) (See Table 7). The new standard *semi-metro* car for North America is designed for a minimum curve radius of 12.80 m., but such sharp curves are normally restricted to depots and turning loops at termini.

Table 7 Comparative curves and gradients

System	Max. gradient (%)	Min. curve radius (*metres*)
Helsinki (*metro*)	5.0	200
Oslo (*metro*)	5.0	150
Rotterdam (*metro*)	4.0	200
Bruxelles (*pre-metro*)	6.0	100
Köln (*pre-metro*)	3.3	150
Stuttgart (*pre-metro*)	7.0	
Basel (*semi-metro*)	5.5	50
Charleroi (*semi-metro*)	6.0	30

(*Source: P. G. Reynaert, UITP Congress, Barcelona, 1967*)

The German VöV recommended standards for *pre-metro* transitional rolling stock specify a minimum radius curve of 90 metres in public service or 40 metres for shunting movements, while standards laid down by the province of Nordrhein-Westfalen specify future minima for new *pre-metro* work of 300 metres generally, reduced to 250 metres on viaducts or 180 metres in tunnels beneath built-up areas. A welcome restriction is that track curvature in stations should not exceed 400 metres when the platform is on the inside of the curve, or 600 metres when the platform is on the outside.

While gradients of 8% or 1 in 12 are common on tramways, the German provincial standards for *pre-metro* construction specify a ruling gradient of 4%, increased to 6% in certain cases. A maximum grade of 0.6 to 1.0% is prescribed for tracks in stations, but approval may be given for a slope of up to 1.5% in special cases. On the San Francisco *semi-metro* system, the ruling gradient is 5%.

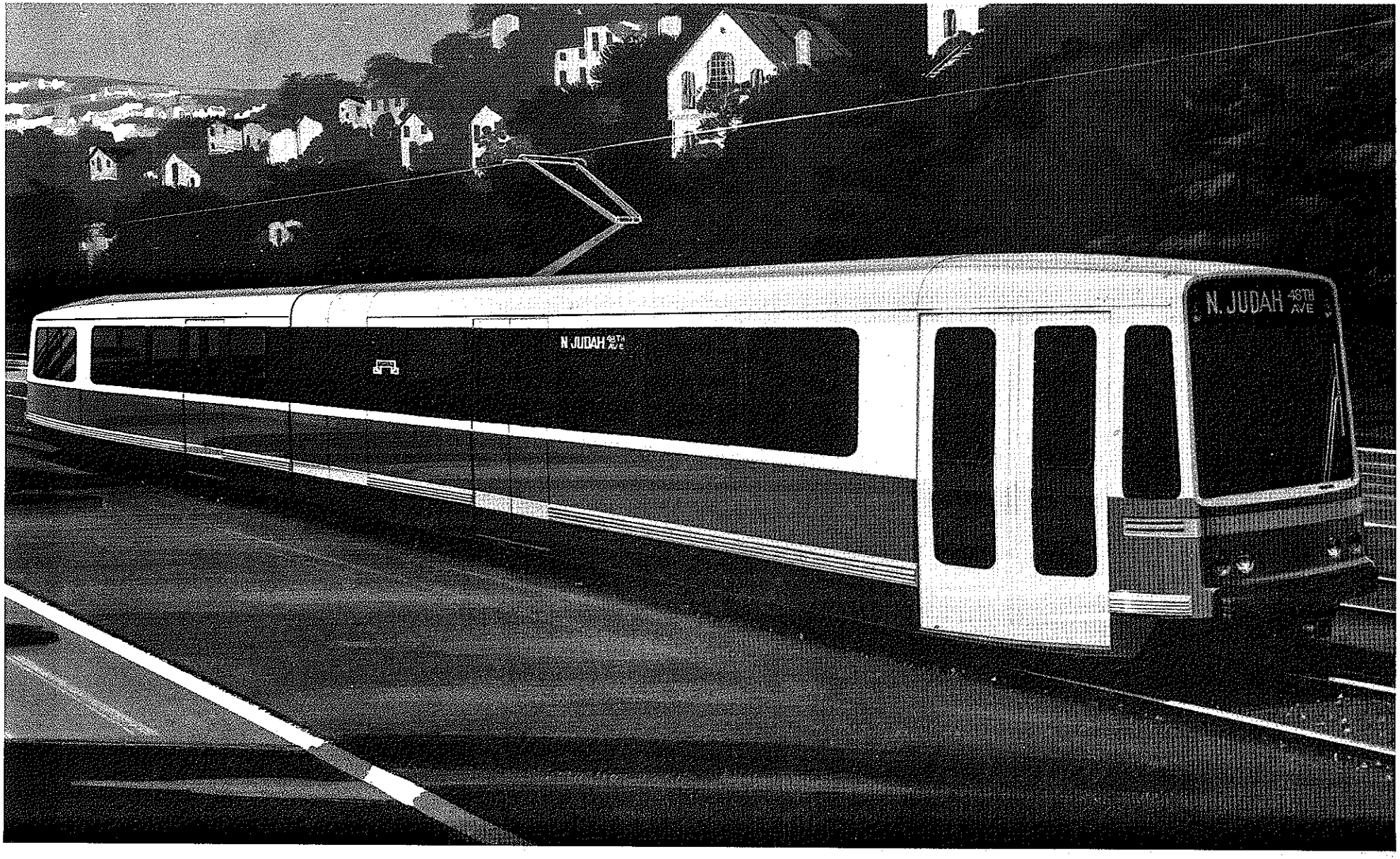


Photo 2: artist's impression of the United States standard light rail vehicle developed in 1972. 80 of these cars are now on order for San Francisco and 150 for Boston, Massachusetts, and an order for 140 will soon follow for Philadelphia. (*Boeing Vertol*)

These dimensions determine the size and configuration of rights of way and the approximate profile of tunnels. On the design of viaducts, it is worth mentioning a cost comparison published by an engineer responsible for the design of the elegant structures for new *metro* and *semi-metro* extensions, using identical main beams. Because *semi-metro* axle loadings do not exceed 8 metric *tonnes* (or 7 *tonnes* on the proposed San Francisco cars) compared with 10–12 *tonnes* on classical *metro* vehicles, a lighter construction was possible, bringing a saving of 21% in cost. It was found, incidentally, that the cost of building a tunnel would have been 70% higher (See Table 8).

Table 8 Comparative cost of metro and semi-metro structures

(Converted 1968 costs per metre length for construction in Rotterdam)

Semi-metro viaduct	£620
Metro viaduct	£780
Metro tunnel	£1325

(*Source: "Verkehr und Technik", 1968*)

There is little difference between conventional railway and *semi-metro* track because the benefit of lighter axle loadings is more or less offset by the denser traffic handled.

9 STATION PLATFORMS

One of the basic differences between *semi-metro* and *metro* concepts is that of platform height, while *pre-metro* equipment must somehow bridge the transition. In Frankfurt and Hannover, two folding step systems have been devised to permit loading from platforms of different heights. The Frankfurt system is the less satisfactory because one step is required at every station until the very low platforms have been eliminated and all cars can be modified. In Hannover, an intricate mechanism permits loading from high or low platforms. In Milano a dual system of retractable sliding steps has been developed with fair success, while the German VöV standards recommend a floor-height door threshold for high-platform loading with a single outward-folding step for lower platforms, an arrangement that may not be very satisfactory in the earlier *pre-metro* stages. A device similar to the Hannover pattern has been designed for the San Francisco *semi-metro* system, where subway platforms are at car floor height.

The tram subways of Bielefeld, Essen, Köln and Stuttgart have platforms about 300 mm. above rail level, to be raised later. The Bruxelles subway platforms have a well 60 metres long lowered to 275 mm. above rail level, while the rest of the platforms are at full height. In Antwerpen, and probably later in Gent, *pre-metro* platforms will be built at their final level and tracks ballasted up to an appropriate height for tramway operation.

10 ROLLING STOCK

There is an extraordinarily wide range of vehicles used on *semi-metro* and *pre-metro* installations, ranging from single-unit four-axle cars (often coupled in pairs or even threes) to the five-unit twelve-axle articulated cars especially developed for the cross-country line between Mannheim and Bad Dürkheim. The most popular types are the single, double and triple-unit articulated cars, with their lower weight: volume ratio.

The main reason for the development of the articulated car has been the objective of collecting all fares by one conductor. In the last few years most progressive undertakings have devised mechanical means of fare collection, but there are other advantages of articulated cars. Preliminary calculations for the San Francisco *semi-metro* modernisation demonstrated that the initial cost per seat would be $4 320 using single-unit bogie cars or $3 640 for twin-unit articulated cars. Another possibility considered was the compromise of using "married pairs" of cars permanently coupled and sharing some equipment, a practice common on conventional electric railways. It was found that the initial cost per seat would be the same as for the articulated unit, while it was considered that the greater economic headways would be too long for local demands. Generally speaking, the saving in staff and in running cost by the elimination of one bogie are regarded as decisively favouring the articulated vehicle. It is significant that articulation is used in modern *metro* practice, the most successful example being the DT3 unit in Hamburg.

While most modern *semi-metro* stock is single ended, requiring a turning loop or reversing triangle at termini, the more advanced *pre-metro* vehicles are generally double-ended. Single-ended cars are cheaper in first cost because there is no duplication of equipment, and they offer considerably more seating space since doors are on one side only. Provided adequate turning facilities are available, the drivers' duties at termini are simpler. A double-ended car, although inferior in these respects, is more adaptable for working over *pre-metro* systems, where crossovers can be inserted or removed relatively easily as construction work progresses.

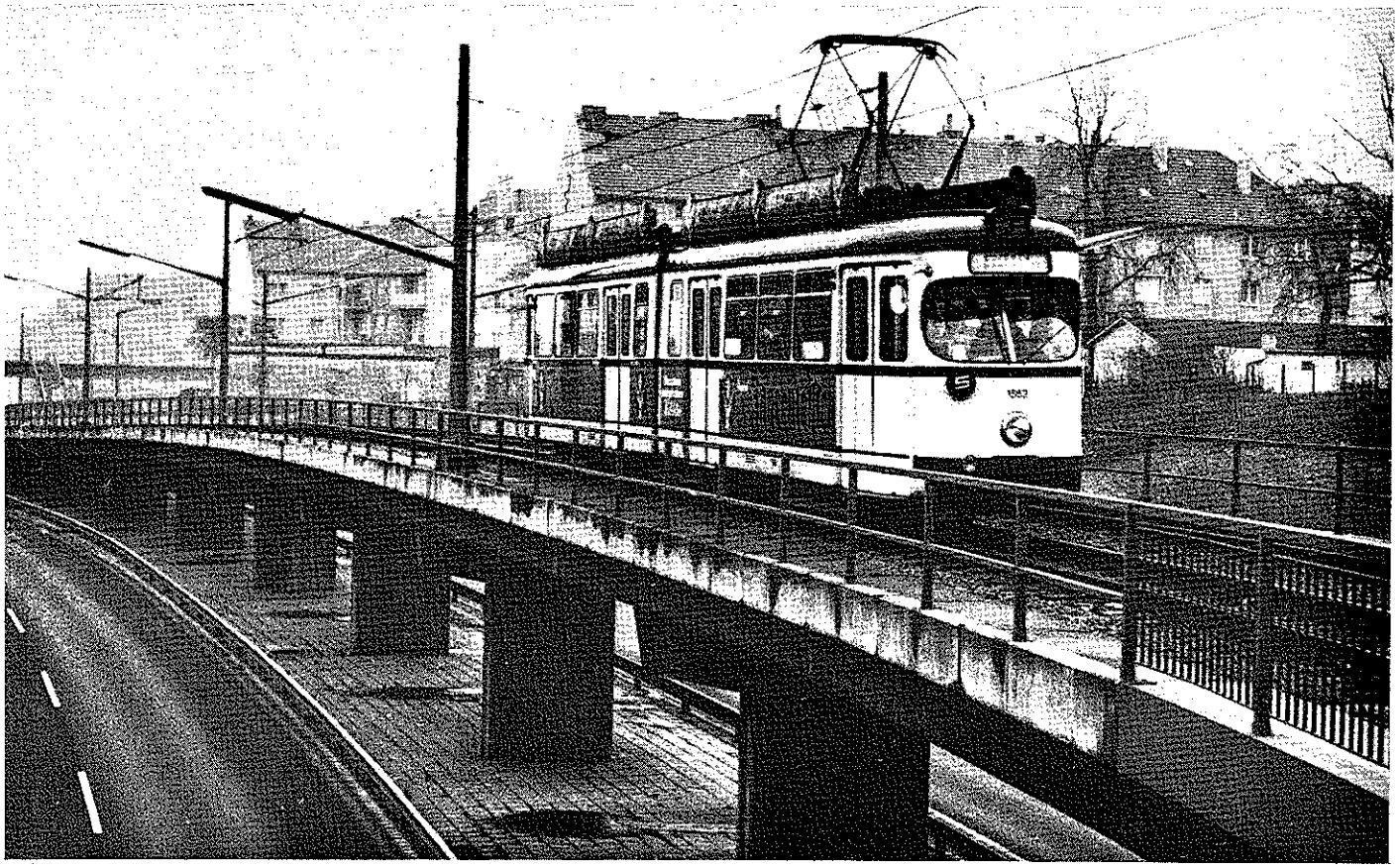


Photo 3: at Mülheim (above) light rapid transit is located on the median strip of the Ruhr Expressway. Grade separation at a junction is effected by means of a short viaduct. *(F. van Dam)*

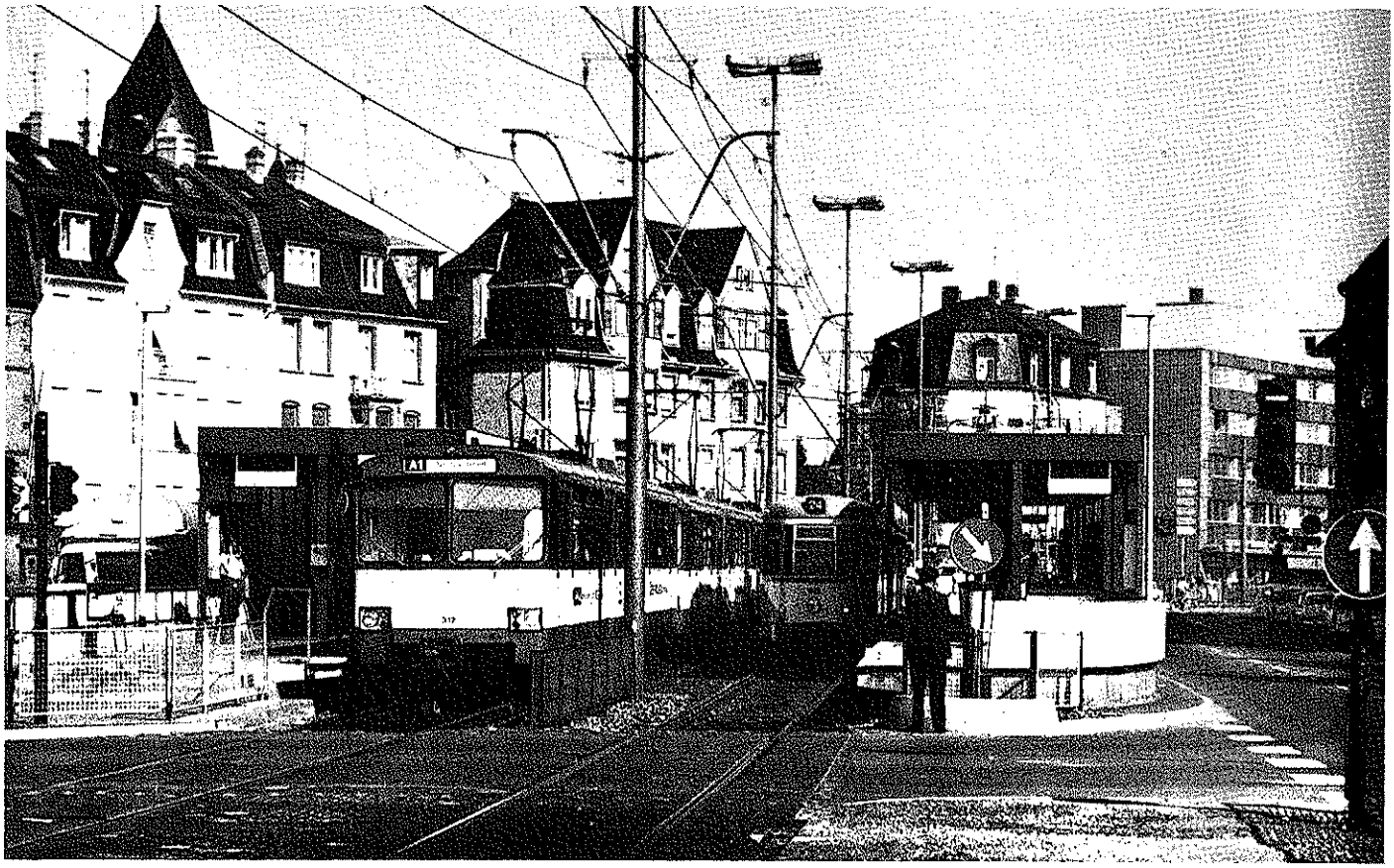


Photo 4: in Frankfurt-am-Main, advanced pre-metro stock and converted tramcars work side by side on a centre reservation. Note the simple station with medium-height platforms and signal-protected road crossing. *(F. van Dam)*

To summarise on the present state of light rapid transit rolling stock, during the last six years, single-unit cars have been delivered to Antwerpen, Bruxelles, Gent, Göteborg, Den Haag, Marseille, Norrköping and most Eastern European countries, while six-axle cars have been built for St. Etienne, Bruxelles, Rotterdam, Cairo and Eastern Europe. In West Germany, 115 new six-axle cars have been built for 9 undertakings; 218 eight-axle cars have been built for 11 undertakings; in addition to 7 five-axle articulated cars of an odd design, 169 four-axle articulated cars and 4 twelve-axle cars have been built.

In the West German *pre-metro* field, Frankfurt has made the greatest progress with 67 six-axle *Stadtbahn* cars 2.65 metres wide for working on upgraded routes (although not fully conforming to accepted *metro* standards) and 100 transitional cars for dual working on existing or upgraded routes. The latter design became necessary when it was realised that the upgrading process could not keep pace with the need to replace old tramway rolling stock. In Hannover, two prototype transitional cars were built in 1970, and 25 cars of a slightly different type are now under construction.

In the USA, where 1893 tramcars each over 20 years old are operating in nine cities, the federal Government has aided their replacement by sponsoring a standard design, completed in 1972. Contracts have now been placed for 150 cars by the Boston undertaking and 80 cars for San Francisco, while an order for 140 cars is about to be placed in Philadelphia. These vehicles will be six-axle double-ended, with chopper control, and an adjustable step for low/high platform operation will be an optional extra. In Canada, new light rapid transit routes are to be built in Toronto, for which the Hawker Siddeley company has designed a four-axle car. In Melbourne, the prototype of 100 new four-axle cars was delivered in 1973.

In this country, of course, a new car will have to be designed for the Tyneside project. A mock up of part of such a car was built by one interested manufacturer and exhibited in 1973.

11 ENVIRONMENT

There are some popular misconceptions on the environmental quality of public transport in general and of rail systems in particular, but it is a fact that there is much squalor in our public transport installations in this country. The *semi-metro* concept is at no special disadvantage in this respect. Noise levels can be controlled below those of buses and lorries by the use of welded rail joints and resilient wheels: the new US standard car is not to exceed a noise emission level of 80 dBA measured 15 metres from the track centre-line; there is no vibration and no toxic exhaust. A high standard of visual amenity can also be achieved. Segregated rights-of-way, if properly maintained, can be attractively landscaped, while tracks can be finished with anything from turf to steel chequer plate according to local conditions. In brief, a *semi-metro* track is almost always less offensive than a road surface of comparable width and much smaller capacity.

The presence of overhead wires is popularly regarded as the greatest disadvantage of the *semi-metro* concept, and this weakness is too often worsened by careless design of overhead structures. All motor traffic requires overhead lighting in addition to a multitude of traffic signs, and it can be argued that the inconspicuous presence of properly-designed overhead wiring is a small price to pay for the other environmental advantages of the *semi-metro* concept.

12 COSTS

In the absence of any recent precedents in this country, it is impossible to be definite about costs. Capital costs for land acquisition, tunnels, cuttings and embankments are the same as for conventional railway practice. A slight saving can be effected on bridges and flyovers, but it is the lower incidence of major works on a *semi-metro* that reduces total capital costs. Rolling stock is little cheaper than comparable *metro* equipment. Operating costs are inevitably higher than a modern *metro* installation when traffic is very dense, but considerably less than a bus system of comparable capacity. At lower traffic levels, *semi-metro* operation is substantially cheaper than classical *metro*, and cheaper than buses at levels above 2–5000 passengers/hour/direction.

Costs can only be calculated after performance standards have been postulated and a practicable route pattern has been established. Costs of various solutions can then be compared, taking into account the potential of each mode for attracting new traffic and the quality of service.

The recent study for the North Tyne Loop area has produced figures which clearly favour the *semi-metro* solution. Details of this study were published in the October, 1971, issue of Railway Gazette International (See Table 9).

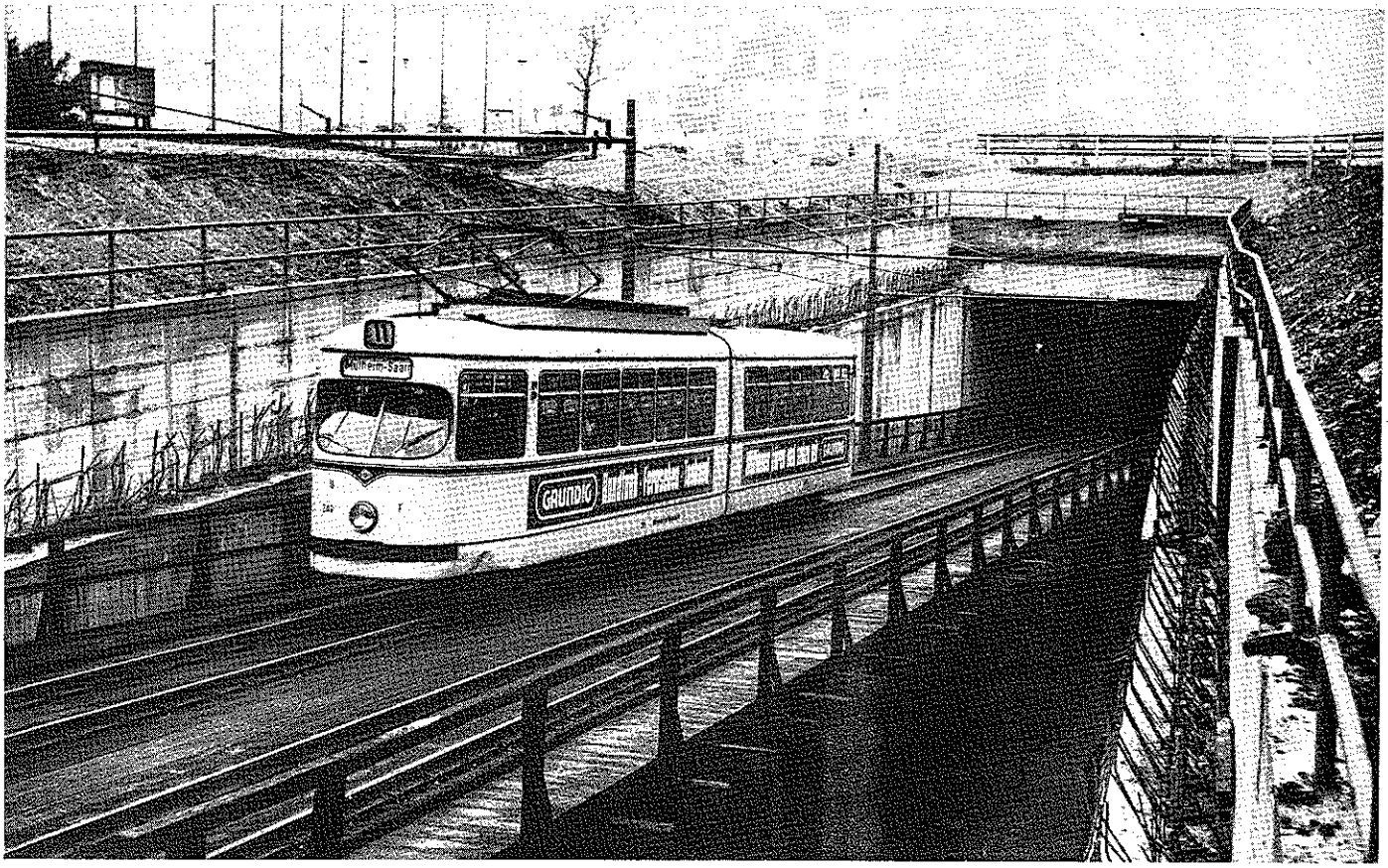


Photo 5: an advantage of *pre-metro* operation is that short lengths of subway can be built and opened at critical points long before a continuous network is complete. This view shows a temporary trestle ramp and short subway section at Huyssenallee in Essen, opened in 1968. *(F. van Dam)*

Photo 6: at Bruxelles, a short sunken well has been left in subway station platforms for *pre-metro* operation. *(F van Dam)*

Table 9 North Tyne Loop study: financial predictions for 1984

(costs in £ million)

Mode	Capital cost	Annual operating	Annual improvement		Incremental rate of return
			No grant	75% grant	
Existing	–	6.9	–	–	–
All-bus	0.9	6.4	+0.37	+0.44	27%
Upgraded Railway	5.2	7.0	–0.36	+0.05	20%
Semi-metro	6.5	6.1	+0.43	+0.94	103%
Busway	13.9	6.3	–0.35	+0.75	4%

(Source: "Railway Gazette International", October 1971)

13 CONCLUSIONS

Having discussed several aspects of *semi-metro* and *pre-metro* systems, it is relevant to review briefly the prospects.

There are only four areas (Bruxelles, Nürnberg, the Ruhr and Wien) where the final stage of upgrading to *metro* standards is likely to be reached by 1980, and in each case this will apply to only part of the system. A substantial part of the operation may be completed in Frankfurt and Hannover, economic and political conditions permitting. We can expect considerable progress at Bonn, Bremen and Köln, but final upgrading in these towns is probably more than a decade further away. Even more remote is the transition process in Antwerpen, Bielefeld, Den Haag, Göteborg, and Stuttgart.

There are at least 70 tramway systems (excluding a number of uncertainties in the USSR) which are being upgraded into *semi-metro* standards without any prospect of complete transition to *metro* norms. Very recently, a number of schemes has been mooted for completely new *semi-metro* installations, such as Dallas, Dayton, Niagara and Rochester in the USA, Edmonton in Canada, while interest has been shown in Britain. The Tyneside PTE now has the necessary legal powers and a promise of the necessary finance to build its *semi-metro* system; the Selnec PTE is considering either light rapid transit or personal rapid transit for medium-volume corridors not served by existing railways; the South Hampshire new town will have a series of segregated public transport routes for which light rapid transit is favoured; while at least one London borough (Lambeth) is interested in the feasibility of a surface *semi-metro* installation mainly on existing streets as a cheaper alternative to tube railway construction, now costing in the region of £4 million per kilometre.

There appear to be three identifiable roles in which light rapid transit could perform more efficiently than other public transport modes. First is as a more economical means of operating existing railway routes. Second is (with some grade separation) as a cheaper alternative to the classical *metro* but suitable for later upgrading, should traffic volumes increase sufficiently. The last role is (given a policy of traffic restraint) as a *street-metro* offering a superior and less labour-intensive alternative to buses where traffic levels are sufficiently heavy.

Photo 7: a tram-only lane in Den Haag gives public transport due priority over private vehicles. *(F. van Dam)*

Photo 8: the narrow Leidsestraat in Amsterdam was closed to all vehicular traffic except trams in 1971, making an attractive shopping precinct for pedestrians and giving public transport due priority. *(F. van der Gragt)*

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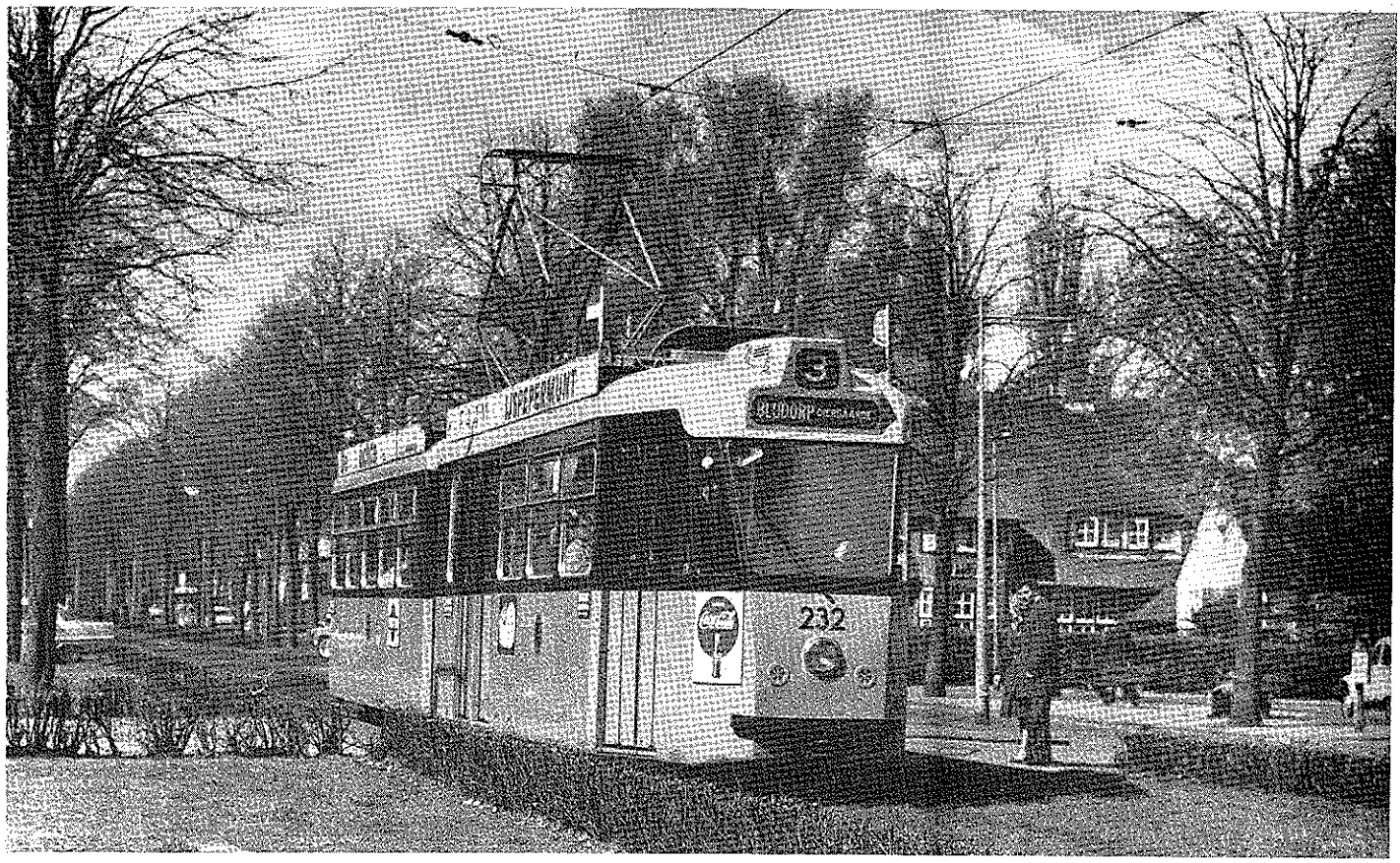

Photo 9: turfed tracks form part of the garden landscaping of an attractive residential suburb in Rotterdam.
(F. van Dam)

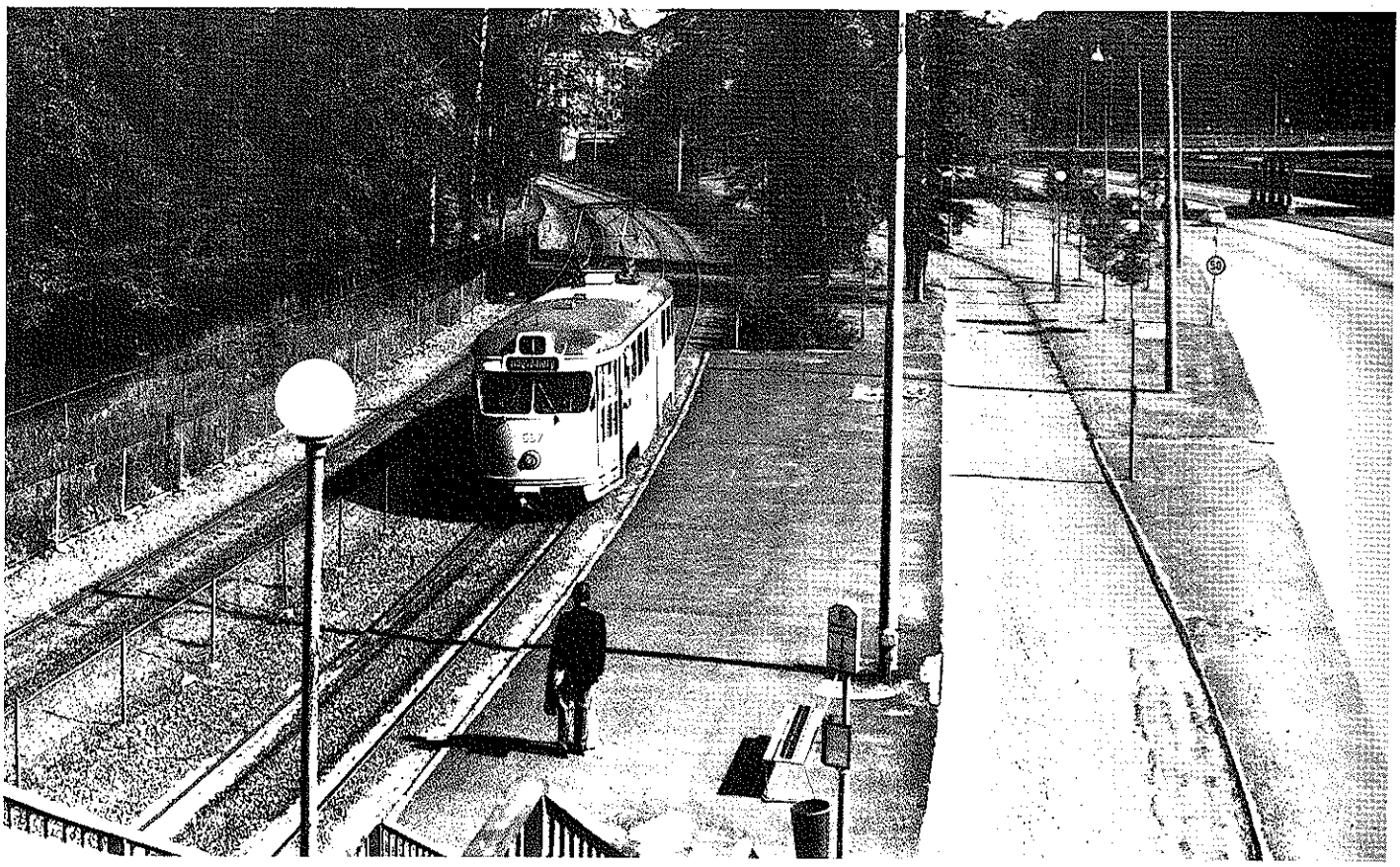

Photo 10: in Göteborg, light rapid transit is unobtrusively located parallel with a major road. The passenger-carrying capacity of the tracks, incidentally, is over five times that of the six-lane carriageway on the right of the picture.
(F. van Dam)