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Succès pour les tramways et métro à plancher surbaissés

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Successful developments of low floor vehicles for trams and metropolitan railways.

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PLANCHER SURBAISSE. TRANSPORT URBAIN. TRANSPORT FERROVIAIRE. TRAMWAY. METRO. MATERIEL ROULANT. TECHNOLOGIE. PROJET. TRAIN MODULAIRE. HISTORIQUE.

(Document de langue anglaise)

Successful Developments of Low-floor Vehicles for Trams and Metropolitan Railways

1 Passenger Benefits

Today, short-distance public-transport operators are increasingly seeing themselves as providers of services who want to win the competitive struggle with other public-transport undertakings and the private car. Their marketing concepts are targeted on what their customers — the travelling public — expect, with the objective of maintaining the passengers they already have as loyal customers and of winning over new ones. New users will, however, only 'discover' public transport if offered certain incentives.

It is being increasingly recognized that the vehicles used by local public-transport operators represent a true marketing factor, and they are being exploited as such. Many examples have already shown that the introduction of new operational concepts is particularly successful and may lead to quite considerable increases in the number of passengers carried if new vehicles are brought into service at the same time. By their very external appearance, new passenger stock already looks attractive to potential passengers; Deutsche Bahn's ICE is an excellent example of this.

However, the basic demands that passengers place on local public transport go beyond attractive-looking vehicles. Ready availability is important for them, as are punctuality, speed, safety, good connections and, above all, comfort. Passenger comfort has been increasingly enhanced since the early 1970s, with the introduction of continuously-regulated transmission controls (choppers, three-phase technology), more and better information systems, more effective heating and ventilation and, in isolated cases, even full air-conditioning. Increasing comfort in all these ways has meant, however, installing additional items of technical equipment, which, in turn, has led to higher vehicle masses — in some cases, very considerably so. Higher purchase prices and maintenance costs have also been the result. The other side of the story, however, is that fully electronic control systems are making it possible to recover electricity, and that means energy savings of up to 30 % or so.

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The central objective can be summed up in a few words: we must aim to construct economic vehicles for short-distance public transport that offer passengers a high degree of comfort, but which call for only modest capital outlay and whose operating and maintenance costs are low. Industry is indeed facing a big challenge!

'Providing passenger comfort' means that the travelling public must feel as 'safe and sound' as possible during their journey in order to counteract the reticence that some people have about using public transport, since some of them might well be inclined to express the view that a car in a traffic jam is, nonetheless, still a car and it is much more comfortable than an overfilled tram, thanks to its telephone, its stereo and its air conditioning. The comfort of a modern urban-railway vehicle includes not just jolt-free acceleration and braking but also a comfortable seat to sit on, a pleasant general atmosphere, comprehensive and readily comprehensible information systems and a heating/ventilation system that really works or, alternatively, full air conditioning.

2 Introduction of Low-floor Technology

Half way through the 1980s, it was recognized that having to negotiate several steps to board or leave a tram was a problem likely to deter potential users. The answer to emerge was the idea of low-floor vehicles. Not only do they make it much easier for passengers to board and alight, but passenger turnaround times are reduced. (A number of localities have opted for a different solution, that of making platforms higher. They include Stuttgart, Hannover, Bielefeld and the whole metropolitan-railway network in the German state of North Rhine-Westphalia). Putting the low-floor idea into practice led to a first series implementation in 1987 in Geneva, with vehicles that had a low floor over 60 % of their length and were supplied by a consortium consisting of Düwag, VeVey and ABB. The height of the floor is 480 mm above the top of the rails.

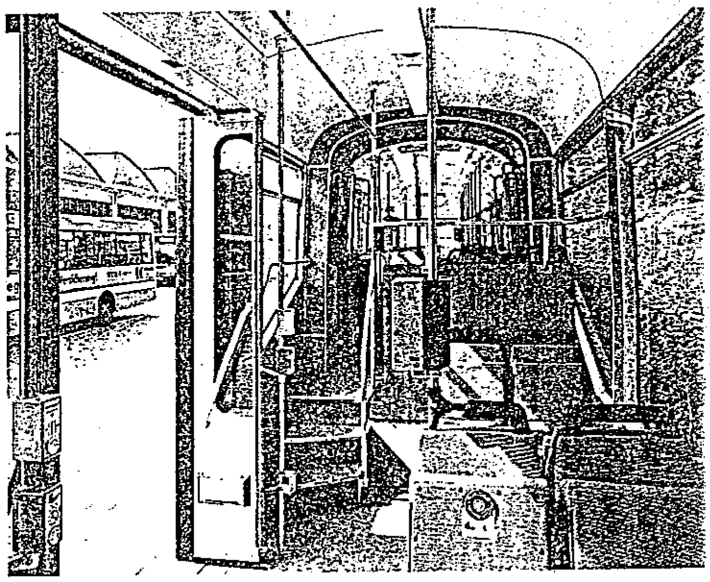
A truly new epoch also started in that same year — 1987 — when GEC-Alsthom/De Dietrich presented a vehicle to run in Grenoble that had a floor height of only 350 mm at all its entrances. From that time on, the whole railway-vehicle industry became involved in an extraordinary development competition — that is still as intensive as ever today, ten years later.

Building further on the Geneva and Grenoble examples, numerous versions of vehicles have been developed, it being generally considered that the maximum height for a low-floor section should not exceed 350 mm above the rails. The percentage of low-floor space in the passenger area grew steadily to reach about 70 % of vehicle length. So far, all these vehicles still had classical power bogies with pairs of wheels rigidly fastened to each others by means of axles. One of the next developments concerned the running gear in the low floor area itself; both two and four-wheel solutions are to be found and some manufacturers opted to reduce the size of wheels, whilst others introduced free wheels. The technical details have been amply described elsewhere and are not the subject of this article.

On account of the need to create space for axles and also because there are limits to the extent to which wheels can be made smaller, partial low-floor vehicles need to have standard or intermediate floor heights above their power bogies; the floor

Fig. 1a: Modern vehicle with low floors throughout: the Variotram as ordered for Duisburg

Fig. 1b: A low-floor middle section as ordered for Mannheim. Steps linking it to the conventional part impede the flow of passengers



here has to be at least 600 mm above the rails. This necessitates incorporating a step — in many cases, even several steps — between the area above the bogies and the low-floor section(s).

The construction of completely new vehicles with low floors over part of their length is not the only activity that has been going on. An number of older existing vehicles have been modernized with the insertion of additional low-floor sections; the Germany cities of Mannheim and Duisburg are typical examples (Fig. 1). A particular technological advance for urban-railway vehicles then came in Cottbus. Existing Tatra rakes were lengthened by the addition of a central vehicle made of glass-reinforced plastic built by Schindler Waggon and with running gear comprised of free wheels from SIG. The same technology has now also been ordered for 28 vehicles operated by the BVB in Basle. It is still too early to pass any definitive judgement on how well this sort of system is going to fare on short-distance public-transport vehicles.

Fig. 2: Four-section 100 % low-floor tram as supplied by Adtranz to Bremen's municipal public-transport enterprise

3 Development Objective: Vehicles with Low Floors Throughout

The idea of simply moving the steps from the vehicle entrance or its near vicinity to somewhere inside it met with considerable reticence in a number of places, so — even at a very early stage — the following development objectives were formulated for future trams and/or metropolitan-railway vehicles:

- ▷ low floors over the whole length of the vehicle
- ▷ floor heights of 350 mm or less
- ▷ no steps inside the vehicle
- ▷ no pedestals underneath seats.

Reaching these objectives is going to call for innovative solutions as regards both the mechanical parts and the systems of electrical propulsion. These are going to have to be at least as good as conventional solutions in terms of reliability, safety and costs.

The German association of public-transport operators — VDV — started working very actively at an early stage to assist low-floor vehicles in making a breakthrough as quickly as possible. It was back at the end of the 1980s that a number of leading operators and the German rail-vehicle industry formed a syndicate to develop the VDV low-floor urban-railway vehicle. The object of the exercise was to come up with a standard class of vehicle with a low floor throughout, which could then be constructed at a low price in large numbers for several different operators.

Although it has to be admitted that it has

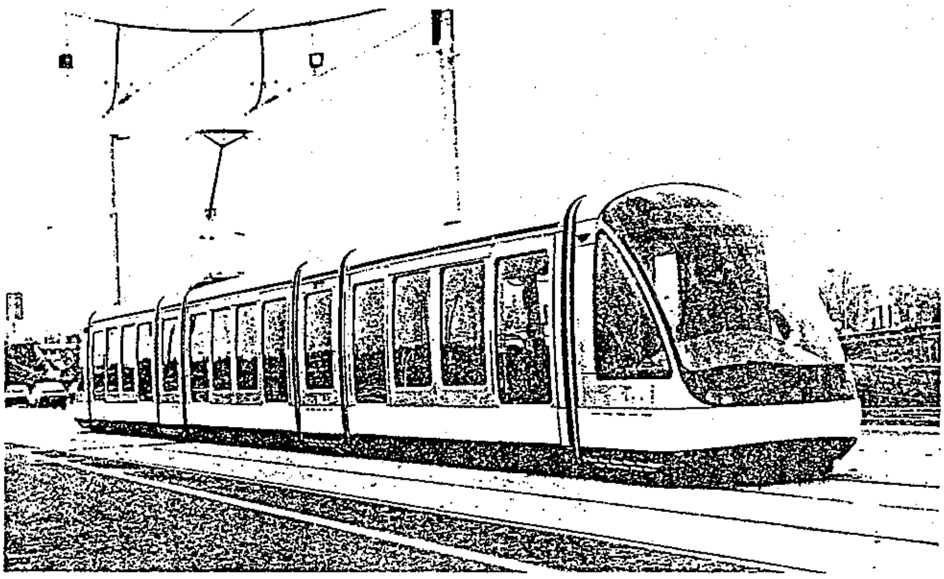


Fig. 3: The Eurotram that Adtranz has built for Strasbourg

not proved possible to implement the whole catalogue of development objectives, many of the essential details that have emerged in the course of this project have had an extraordinarily fruitful impact on the further development of vehicles.

One of the factors that became clear at a very early point in time was that the key to success in achieving a 100 % low-floor vehicle lay in its transmission system. Should it be one of the requirements for the floor to remain low above the transmissions too, one way of achieving this is through having powered running gear with two or four free wheels that both satisfy a carrying function and a provide safe wheel and/or track guidance. Alternatively, it is possible to use cardan transmissions, such as those implemented on the 'Bremen class', the first 100 % low-floor vehicle to be presented in Germany (Fig. 2). A number of further intelligent alternatives have been developed since then.

If, however, we take a close look at all the 'low-floor' vehicles ordered in recent years then only around 40 % of them have low floors throughout. The majority of such new vehicles have low-floor areas accounting for up to around 70 % of their total length. The reason given for this is that vehicles with only partial low floors are able to continue to make use of proven conventional transmission systems (Fig. 3)

Now, the fact is that when bogies are used, it becomes impossible to avoid a least one step inside the vehicle — as has already been explained. This is, at the very least, a minor nuisance for the average passenger and a major hurdle for the

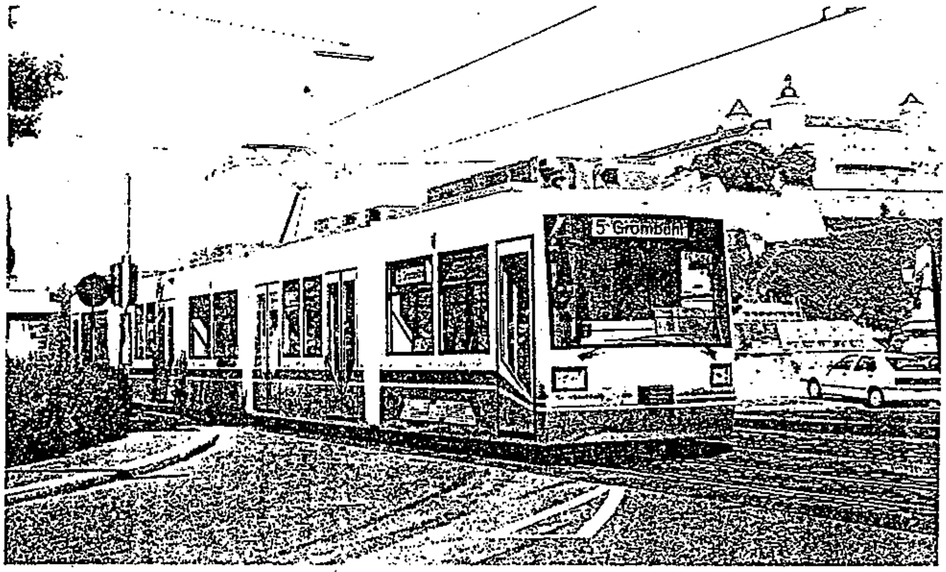


Fig. 4: A 100 % low-floor articulated vehicle as operated by Würzburg's public-transport enterprise: model GT-N, built by GEC-Alsthom/LHB

handicapped, and is more likely to detract from safety than enhance it. The elimination of such steps is without doubt beneficial for passengers — and meeting their expectations is the overriding objective of short-distance public-transport operators.

One of the reasons that many transport undertakings are still showing reticence regarding new running-gear technology is that it has 'not yet been fully tested operationally'. It would be necessary for it first to be subjected to relatively long periods of testing to prove its reliability, safety and wearing properties under the many different types of conditions met in practice. At the time of writing, this has now indeed become the case for some of the systems offered on the marketplace.

To begin with, wheel hub motors incorporating gearboxes had serious teething troubles, and one of the most frequent causes was loss of oil. Gearless versions of wheel hub motors have, however, also been developed. Such a transmission is no more expensive than the conventional drive acting on an axle. In terms of mass, the gearless wheel hub motor is superior to the transmission with transverse motors (in that its mass is only around 70 % of the latter). It must also be borne in mind that wheel hub motors fulfil other functions too that require additional parts on conventional transmissions (e.g. hollow shafts, control-rod couplings, wheel bearings). Having dealt with all the arguments presented so far, this brings us to the next objection, that of the higher unsuspended masses. However, this phenomenon only starts to become a problem at speeds in excess of around 120 km/h, i.e. much faster than metropolitan railways ever run. Practical experience has already shown that urban-railway vehicles with wheel hub motors are capable of performing better than models with conventional transmissions as regards smooth running, noise emitted on bends and the amount of wear on wheels and rails. In addition to the wheel hub motor, a number of other interesting ideas have been proposed for powering vehicles with low floors throughout (Fig. 4).

4 Prospects

So far, nine different types of vehicle with 100 % low-floor designs have been ordered

100 % Low-floor vehicles for tram and urban-railway networks (as at 01.03.97)

Type of vehicle	Manu-facturer	First delivery	Number of orders/options	Where deployed	Height of floor (mm)	Width (mm)	Gauge (mm)	Remarks
Articulated	Adtranz	1989	407 / 181	Augsburg, Berlin, Braunschweig, Bremen, Frankfurt an der Oder, Jena, Mainz, Munich, Nuremberg, Zwickau	350	2300	1000-1435	UD/BD; in its further-developed form, pedestals have been eliminated; available as 3 or 4-section units
Eurotram	Adtranz	1994	67 / 20	Strasbourg, Milan	350	2400	1435	BD
Variotram	Adtranz	1993	51 / 65	Chemnitz, Duisburg, Sydney, Helsinki	350	2300-2650	1000-1435	UD/BD; all-wheel drive possible; wheel hub motors
Combino	Siemens	1998	12 / 36	Potsdam	290	2300	1435	UD/BD; two-wheel longitudinal drive; bolted aluminium bodywork
ULF	Siemens	1995	36 / 116	Vienna	205	2400	1435	UD; radially controlled portal running gear; one vertical drive per wheel
'R'	Siemens	1993	40 / 60	Frankfurt am Main	350	2350	1435	BD; wheel hub motors
Tram 2000	Bombardier	1995	51	Brussels	350	2300	1435	BD; wheel hub motors
Cobra	Schindler Fiat-SIG	1999	6 / 11	Zurich	350	2400	1000	UD; free-wheel running gear; GRP body shell
GT-N	GEC Alsthom/ LHB	1996	20	Würzburg	350	2400	1000	UD; all-wheel drive; wheel hub motors

UD = Unidirectional vehicle / BD = Bidirectional vehicle

in Western Europe, and total orders stood at 683 on 01.03.97; moreover, options have been taken out for a further 497 units (Table 1). In addition to all the types of vehicle listed in Table 1, further concepts have also been presented or are in the process of being developed:

- ▷ Bombardier is developing its Cityrunner, which is to be fitted out with wheel hub motors (Fig. 5);
- ▷ VeVey is propagating its Urbos, a vehicle that avoids the use of pedestals under seats and that can be planned with a certain degree of flexibility, thanks to the modularity of its design both along its length and across its width;
- ▷ GEC-Alsthom's programme includes the Citades system, that can be put together in different ways to produce a whole family of vehicles. Transmission is by means of wheel hub motors (Fig. 6);
- ▷ Yet another vehicle concept is being drawn up for the Blackpool Project. However, details have not yet been made public.

Nearly all the classes of vehicle mentioned in Table 1 are already operational, a number of them (such as Adtranz's GTN) have already reached quite considerable numbers, and some of them have already also covered impressive distances (Figs. 7, 8).

It is quite clear that there will be a shake-out amongst the multiplicity of models on offer at present. The decisive criteria for the success of vehicles are likely to be the following:

- ▷ running properties
- ▷ wear on running gear and track
- ▷ reliability
- ▷ life cycle costs.

Fig. 5: Cityrunner — a modern tram developed by Bombardier

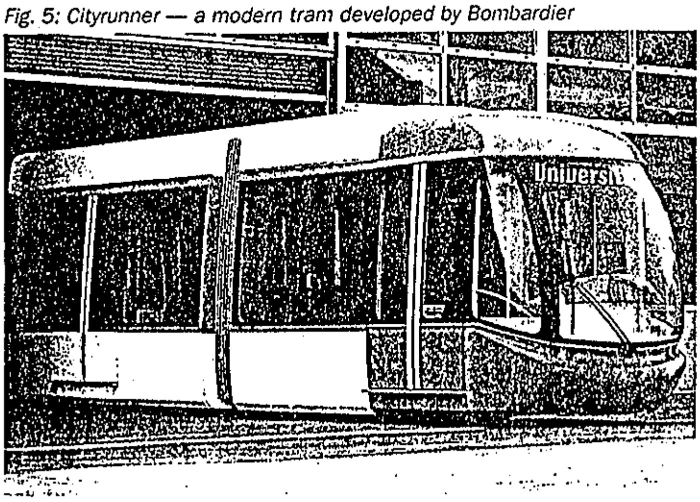
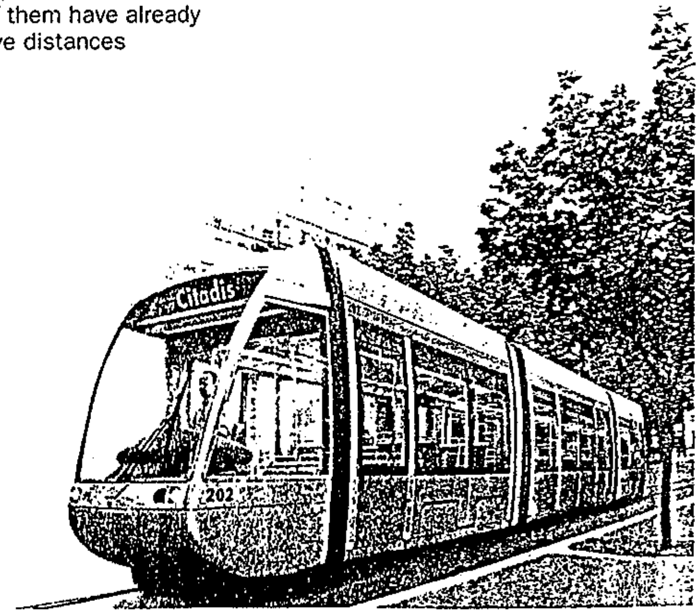


Fig. 6: Urban-railway cars belonging to the Citades system manufactured by GEC-Alsthom



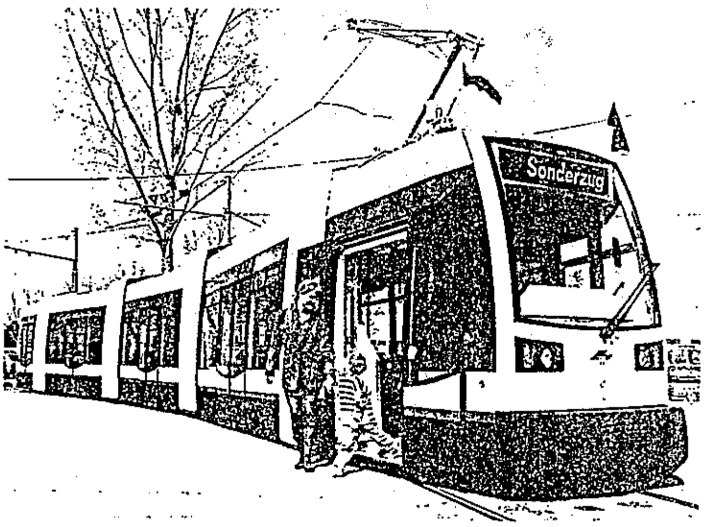


Fig. 7: An ultra-low-floor (ULF) tram as operated by the Wiener Verkehrsbetriebe (Vienna). Supplier: Siemens SGP

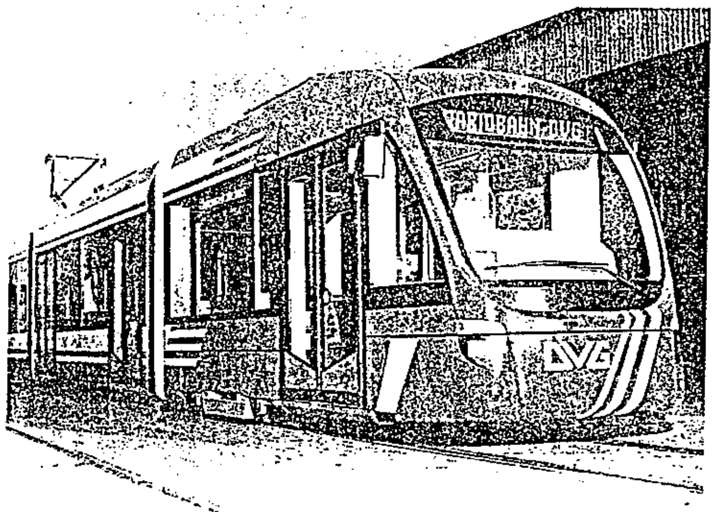


Fig. 10: Adtranz's Variotram as run by Duisburg's municipal-transport enterprise

Despite that, it is most unlikely that there will ever be a single standard class of vehicle. There are several reasons for making such an assertion: above all, the different operating conditions from one locality to the next and the degrees of freedom regarding vehicles that are dictated by the various networks of scheduled services. In short, the real demand is for customized solutions.

One tool that can be of great help is a catalogue of unified operator requirements. However, it should not unduly specific, and a good example of such a catalogue is the one drawn up by the VDV for light-weight, low-cost, low-floor vehicles complying with the German technical regulations on tramways ('BOStrab'). In order to be able to cope with the various needs expressed, a number of manufacturers have built their vehicles on modular principles — such as those already introduced for the Variotram — and these can be used to put together any desired configuration of vehicle.

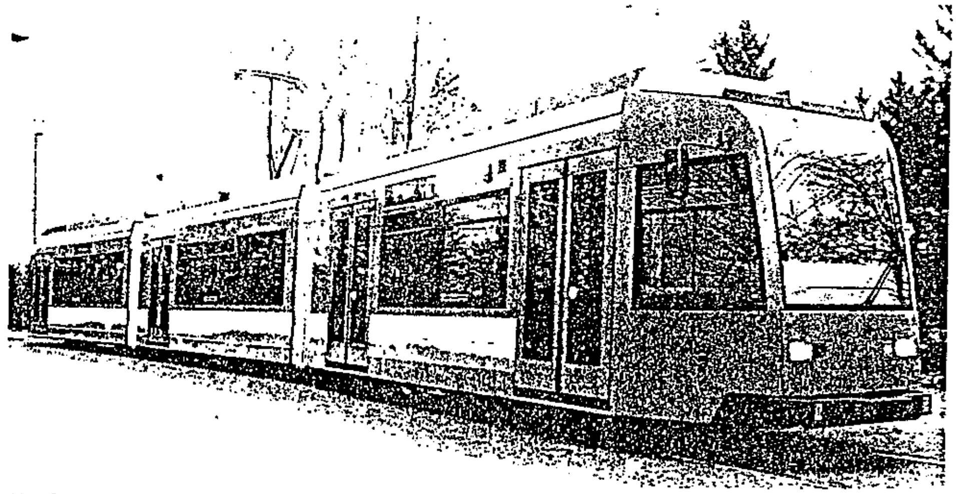


Fig. 8: A class 'R' 100 % low-floor tram as operated by the public-transport utility in Frankfurt am Main. Supplier: Siemens/Duewag

Following a period of nearly a hundred years during which the external appearance of the tram changed but slightly, the introduction of low-floor vehicles has also been accompanied by turbulent developments in styling that have put a totally new 'outfit' on the good old tram. Nothing short of an out-and-out styling competition is leading to ever more modern external appearances, borne out by a number of eloquent examples, such as the Variotram, the K 4000, the Eurotram, the Combino (Fig. 9) and the Citades. All these endeavours are helping to make trams look more attractive and — more important still — helping them lose the stigma of being old-fashioned (Fig. 10).

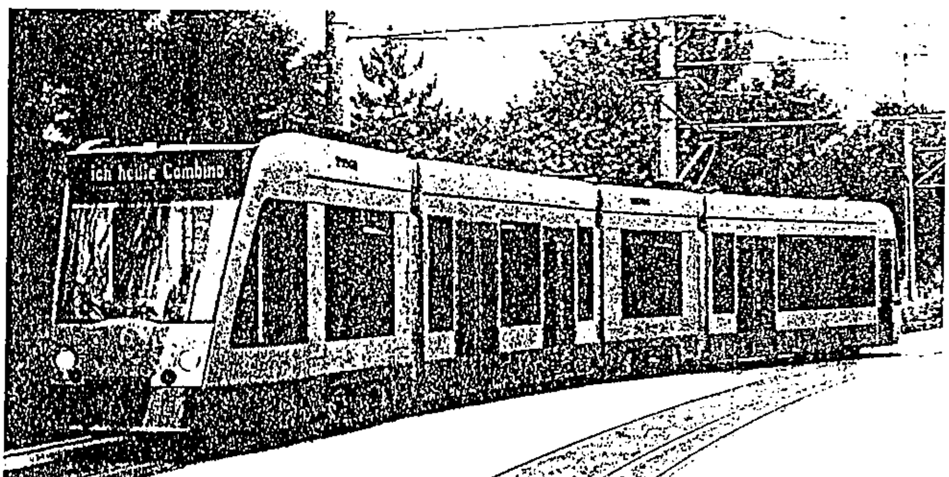


Fig. 9: A Combino type low-floor tram as supplied by Siemens Duewag

There is no sign of a slackening in the zeal

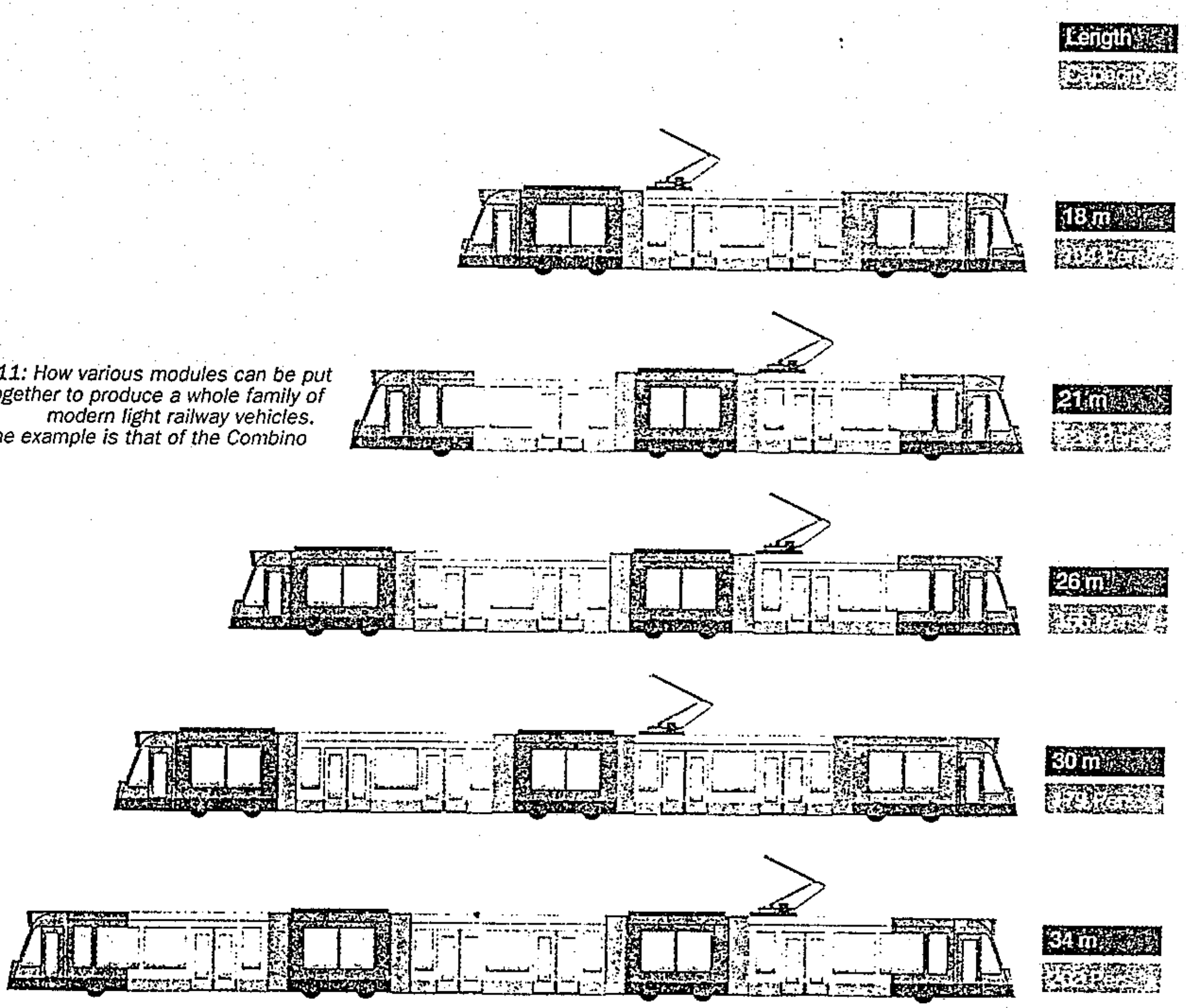


Fig. 11: How various modules can be put together to produce a whole family of modern light railway vehicles. The example is that of the Combino

to develop low-floor vehicles for short-distance public transport. Vehicles with low floors throughout will continue to gain ground. Such a trend will, however, take a certain time. A very similar phenomenon was also observed when three-phase technology was introduced for urban-railway vehicles, but it too finally came to be regarded as state of the art some considerable time ago.

New technologies are also being increasingly used in the manufacture of vehicles:

- ▷ adhesive bonding systems are being used for side-wall and roof panelling;
- ▷ glass-fibre reinforced plastics are being used for moulded front ends;
- ▷ it is now possible for plastics and bolted aluminium structures to be used for vehicle bodies;
- ▷ in the field of transmission-control systems, it is generally expected that there will be further integration, thanks to intelligent components;
- ▷ increasing compactness is also to be expected for instrumentation and controls;
- ▷ intelligent components (such as doors, heating and lighting) will communicate with each other via data buses;
- ▷ zero-maintenance, easy-to-replace items of equipment are increasingly becoming available;
- ▷ prefabricated vehicle segments will simplify the manufacturing process (Fig. 11).

It is the most favourably priced vehicle that will win the competitive race — provided passengers' desiderata are also adequately catered for. As a rule-of-thumb all the following requirements ought to be met:

- ▷ short delivery times
- ▷ low initial purchase price
- ▷ low life-cycle costs
- ▷ high availability
- ▷ appealing styling, high level of attractiveness
- ▷ generously dimensioned, uncluttered interior design
- ▷ broad aisles between rows of seats
- ▷ wide passage through articulations (no bottlenecks)
- ▷ no electrical equipment inside the passenger saloon
- ▷ no steps and no pedestals
- ▷ low mass
- ▷ low noise levels both inside and outside
- ▷ materials capable of being recycled.

There is still plenty of scope for a further competition of ideas between the manufacturers. It goes without saying that innovative operators are also needed to place orders to implement all these ideas.

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