3458

Individualism obscures the low-cost grail

Low-floor car deliveries continue at a high pace, but cuts in financing mean that new orders are fewer and options are only being taken up slowly. This has sparked a race to develop a new range of low-cost vehicles with a host of technical innovations, even before all the current designs on order have entered service

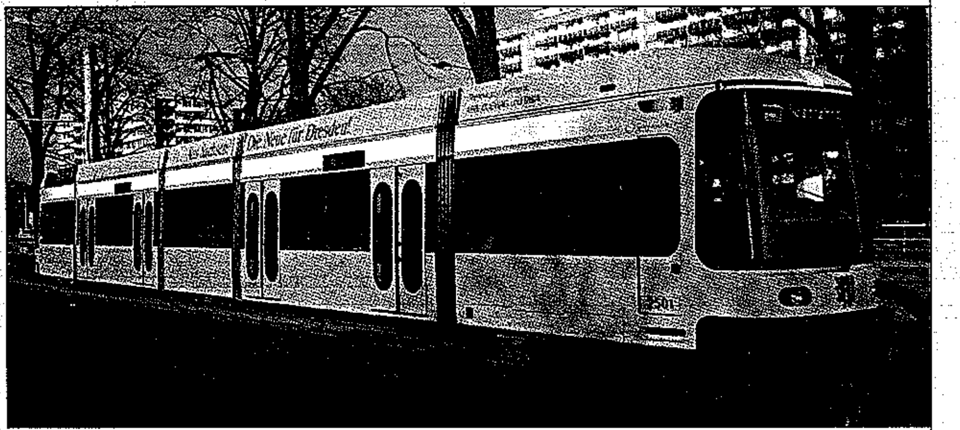
Harry Hondius, MSc (Eng)

IT IS BECOMING increasingly apparent that a cold wind is blowing through public transport financing. More and more operators are being required to do more with less money. Operating efficiency must be improved and revenue increased by offering a more attractive service. But at the same time the capital available for investment is falling.

Germany's GVFG laws, which in some states provided a 50% subsidy for new rolling stock, will almost certainly be cut to a lower proportion from 1997 onwards. At the same time, European tendering rules have started to open up the market to a certain extent, which has had a sobering effect on prices.

A great many modern low-floor trams are now in operation, giving their operators satisfactory service. The introduction of low-floor technology was relatively easy with small wheel bogies and single articulated cars. Multi-articulated cars were initially more troublesome; some hunted, and the EEF-wheelsets showed that a far higher precision level in manufacturing was necessary. And as we learned with the AEG all-low-floor cars, successful prototypes do not automatically mean successful series cars – it is vital not to change too much.

Never before have tram designs reached such a level of technology giving smooth acceleration and high comfort for the passengers. But these goodies do not come cheap. Never has the individualism of operators been so paramountly demonstrated as in the last 10 years, with as a consequence, unnecessarily high initial costs, high spares costs and duplicated teething troubles.



Dresden's NGT6-DD 30 m cars from the 'Sachsentram' consortium (Duewag/DWA/Siemens/Adtranz) have four articulations and 88 seats, with a low-floor height of 350 mm. Floor level is 600 mm above the motor bogies, which are firmly attached to the end modules and cannot turn, minimising the need for wheelboxes in the interior

Common procurement seems to be one of the most difficult things to achieve, despite the fact that it was succesfully practised by Edmonton, Calgary, San Diego, Denver and others. Even the courageous initiative of the Nordic Tramway Committee (RG 4.95 p204) has so far not lead to any common orders.

As an example, after years of forced Tatra standardisation, Berlin, Chemnitz, Dresden, Leipzig, Magdeburg and Rostock have between them ordered 281 cars with options for 288 more. But these are in batches of 120 (+80), 1, 40 (+43), 55 (+70), 25 (+95) and 40, and each batch is mechanically totally different. The only commonality is found with the motor bogies in Rostock and Leipzig, and the electrical equipment for Rostock, Dresden and Leipzig – and also partly by Magdeburg.

In France, Grenoble, Paris and Rouen have together ordered 101 nearly-identical DC-motored cars – the second-series Tramway Standard Français (TSF2). But the metre-gauge systems in St Etienne and Lille bought quite different cars, as did the standard-gauge line in Strasbourg. We have yet to see what Montpellier and Orléans will choose.

Bochum, Brandenburg, Erfurt, Halle, Mülheim, and Oberhausen bought 62 identical cars. But the Halle Type 2 cars with AEG equipment have four-pole Siemens motors, because AEG prefers four-pole motors – even though Halle Type 1 cars have six-pole Siemens motors. The Erfurt Type 2 cars have ABB equipment, which means that although the cars look identical, everything inside is different.

In the LRV sector the two builds of cars for London's Docklands, plus the Birmingham, Manchester and Sheffield fleets – 157 cars in total – have nothing in common bar the 1435 mm gauge and 750 V DC supply. All these cars and their equipment had to be specially designed and the start of operations was often hampered by 'prototype troubles'.

Table 1. Electrical equipment for low-floor trams ordered to April 1 1996

Supplier	Total	DC chopper	VVVF inverter	GTO inverter	Bipolar inverter	IGBT inverter
Adtranz	889					
ABB	(517)[1]	69			408	40
AEG (Germany)	(213)	25		1		187
AEG (US)	(159)	34		25		100
Siemens	344	14		269		61
GEC Alsthom	248	162		51		35
Elin	152					152
Kiepe	112			112		
Ansaldo	71	54				17
Holec	45		45			
Marelli	2	2				
Tatra	1	1				
Total	**1864**[1]	**361**	**45**	**458**	**408**	**592**

1. Includes 46 middle-floor cars

Chopper: DC motors with GTO thyristor chopper controls

VVVF: Three-phase AC motors with variable-voltage, variable-frequency thyristor controls and intermediate voltage circuit

GTO: Direct Pulse-Width Modulation using air-cooled GTO-thyristors

Bipolar: Direct PWM with three point water-cooled bipolar transistors

IGBT: Direct PWM using Insulated Gate Bipolar Transistors in three point air-cooled (Adtranz) or two-point water-cooled (Adtranz, Elin, GEC Alsthom, Siemens) or air-cooled arrangement (Ansaldo, Siemens)

LOW COST CARS

It is becoming clearer that a degree of simplification – if not standardisation – of low-floor car designs is desirable. Industry has amassed a great deal of experience with the present designs, which we could see paving the way for the emergence of a few 'low-cost' vehicle types. The biggest problem is that operational requirements place severe demands on tram technology. What is already clear is that simply putting bus technology on rails is no way to create a valid low-cost rail vehicle. The rubber tyre is a magnificent and so forgiving intermediary between street and vehicle! Steel-on-steel, in combination with low floors, groove rails and a stop-and-go service is a much tougher environment.

It is vital to design something that should be sturdy and reliable, and produce low life-cycle costs. But this concept will only be successful

Table II. Market share of low-floor trams supplied or ordered up to April 1 1996

Mechanical parts	Orders	Options
Siemens Verkehrstechnik		
Duewag	501[1]	452[2]
SGP	152	
Adtranz		
AEG	407	217
ABB (Variotram)	35	20
ABB (Eurotram)	26	
GEC Alsthom		
TSF 1 (Nantes type)	46	
TSF 2 (Grenoble type)	116	
T 2000 (Brussels type)	51	
St Etienne type	20	
LHB	204[3]	
Breda	125	
Vevey	73[4]	
Bombardier Eurorail	45	
Firema	43	15
Socimi	35	
Fiat	30	
Tatra	1	6
Total	**1910**	**710**

1. includes 15 trailers 2. includes 44 trailers
3. includes 30 trailers 4. includes 46 middle-floor cars

if the industry sticks to a strict pricing regime for its standard cars, whereby all extras will be clearly identified and will have to be paid for. Operators, too will have to constrain seriously their desires for individuality in designs, even down to pooling their purchases.

Electrical developments

The last 12 years have seen the end of chopper controlled DC drives, and the coming of air-cooled GTO inverters controlled first by 16 bit and now 32 bit microprocessors. But the last series of trams with GTO inverters has already been ordered. Water-cooled three point bipolar transistors have fullfilled their promises, and new designs will all have air- or water-cooled Internal Gate Bipolar Transistors in a two-point execution (Table I).

All the manufacturers have now switched to this technology, which is compact and efficient, with few components. It offers a high rate of regenerative braking, and above all is electrically 'DC-silent'. Traction motors are available for 4000 and 6000 rev/min, with water or air-cooling, and either four or six pole versions. There is also a clear tendency towards fully-suspended drives.

It is becoming very clear that hub motors, either gearless or driving through gears, will not be easy to adapt to low-cost vehicles – due mainly to the complexity of the designs and the number of components involved. Added to that is a high unsprung weight, varying from 16 to 20kg per kW of motor power, which makes the cars liable to create vibrations in houses adjacent to street tracks. By contrast, modern bogies from Adtranz, Duewag, LHB and Bombardier with fully-suspended motors and brake disks all offer an unsprung weight of around 4·5kg per kW.

Generally, 32 bit microprocessors with full diagnosis have become standard. Electrical equipment prices are also tending to fall.

Volume dictates prices

As I have remarked in previous articles, the price of modern low-floor cars is influenced significantly by the size of the orders, with small batches attracting a significant premium. A comparison between two similar LRV designs for Köln and Karlsruhe clearly shows up the contrast in the price structure, reflecting the relative order size: 120 against 20, as well as the technical differences. Even when adjusted as if it were equipped in the same way, the Karlsruhe car works out around 20% more expensive per m² but 4% cheaper per seat.

The Köln order is one of the two big deals that are currently making the running for large-volume prices; the other is a build of 118 Duewag/Kiepe cars for Düsseldorf's Rheinbahn. Re-calculated for a 'standard' width of 2300mm, the bi-directional KVB car works out at DM3m / 28·4 x 2·3 = DM45930 per m². The 27·5m long Düsseldorf car at DM2·78m works out slightly cheaper at DM43950 per m². Also in the same range is an 83-car order for Dresden, at DM43000/m².

By comparison, a typical 45 m² articulated diesel bus costs around DM580000 or DM12900 per m². This is just 30% of the relative price of a modern tram. The only way for operators to achieve low life-cycle costs for good quality modern trams is to purchase new cars together, to a common design, and thus get the order volumes up.

Orders slow down

Looking in detail at developments in the market over the past 12 months, there has been a marked slowdown in the rate of new orders.

Table III. Market share of low- and middle-floor LRVs ordered by April 1 1996

Mechanical parts	Orders	Options
Adtranz	21	10
Bombardier Eurorail	163	53
Firema	15	
Siemens Verkehrstechnik	91	
Total	**290**	**63**
Electrical equipment	**Orders**	**Options**
Adtranz	41	10
Ansaldo Trasporti	15	
Kiepe (Elin motors)	68	
Kiepe (GEC Alsthom motors)	95	53
Siemens	71	
Total	**290**	**63**

If we compare the orderbooks for low-floor trams and LRVs reported in the past three issues of *Developing Metros*, we can see that the total has been rising by an average of around 200 cars a year, including 10 trailers. In 1993 the global orderbook stood at 1308 cars and 384 options; in 1994 it was 1467 plus 893, whilst in 1995 the figures were 1661 and 850. Another year on and the total number of orders has grown to 1910, but the options have fallen to 710 (Table II).

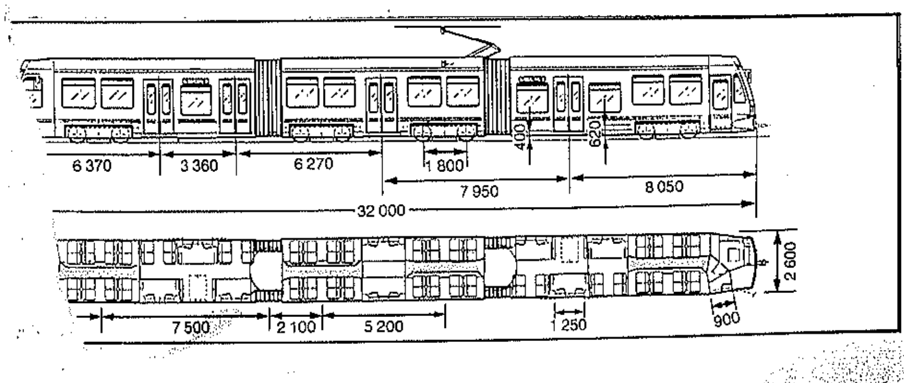
Around 1100 cars have been delivered so far, leaving about 800 cars to be built, with options for another 700. Of these 800 cars, 150 are ULF cars for Wien, to be delivered in batches of 18 from 1998 onwards, and 95 are part of a bigger order from Magdeburg which has been halted, with no indication when deliveries will resume. Of the 240 cars ordered in the last 12 months only 82 were new orders, whilst 158 came from existing options.

Of the 10 groups or firms listed in Table II, only five currently have trams under construction: Siemens Verkehrstechnik at Düsseldorf, Wien (SGP) and DWA Bautzen (which is doing work under contract from Duewag); Adtranz at Berlin and Nürnberg, GEC Alsthom at Salzgitter (LHB) and Aytré; Breda at Pistoia; and Firema at Stanga.

Orders for low-and middle-floor LRVs grew from 192 cars plus 80 options in 1994 to 214 plus 93 in 1995 and 290 plus 63 in 1996 (Table III). This is an average of 50 cars per year for four mechanical suppliers. Siemens won orders to build 74 high-floor LRVs for Los Angeles (later cut to 52) and 14 more for Tunis, whilst Goninan is supplying 20 to Kowloon – Canton Railway Corp for Hong Kong's Tuen Mun network. Duewag and Adtranz are to build 20 B80C (chopper) double-articulated cars for Dortmund, which must surely be the last new chopper cars to be ordered. Only 20 high-floor trams have been ordered; more Type 7s for Boston's MBTA from Kinki Sharyo to augment the present fleet.

Of the 1910 low-floor trams ordered, 41·7% are 100% low-floor (798 cars including 45 trailers). Of these, 464 (58·1%) are being built by Adtranz, which dominates that sector. Leading suppliers of the 1112 cars with 10% to 70% low-floors are Duewag (445 cars, 40%), GEC Alsthom (336 cars, 30·2%) and Breda

ig 1. The Firema/Ansaldo SL95 middle-floor-car r Oslo Sporveier with all axles driven. Floor ight is 400mm at the doors and 620mm in the t of the car; it seats 96



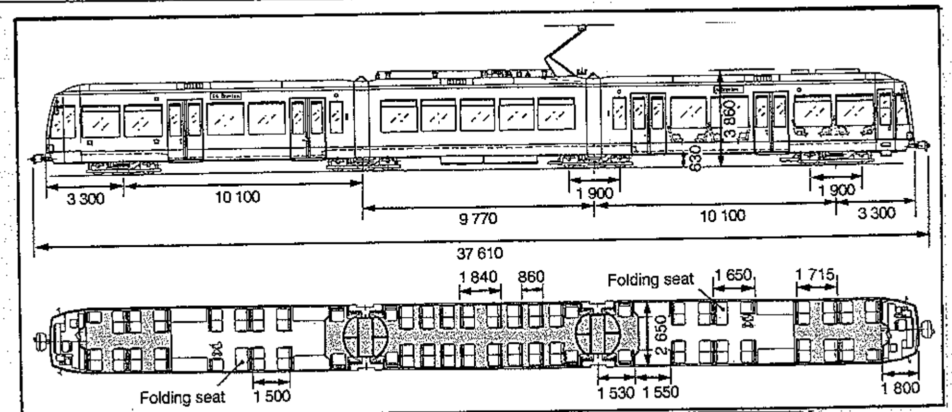


Fig 2. The 100 seat Adtranz/Duewag dual-system car for AVG/VBK in Karlsruhe has a floor height 630 mm at the entrance level and 880 mm above the bogies. A 200 mm deep folding step at 370 mm above rail covers the space between the car and the platform to simplify boarding

(100 cars, 9%), leaving 20·8% to be split between the other six manufacturers.

INDUSTRY DEVELOPMENTS

The merger of AEG Schienenfahrzeugtechnik and ABB Transportation into Adtranz (RG 2.96 p85) has created a giant rolling stock supplier that dominates the public transport sector. Inheriting four tram product lines, Adtranz becomes the leading supplier of electrical equipment and second in mechanical parts. Its future 'centre of excellence' for trams and LRVs will be at Nürnberg, home of the most important production line, the AEG (ex-MAN GHH) plant, which has 407 cars on order and options for a further 217. Other Adtranz products are the ABB Variotram, with 35 orders and 20 options, and the Eurotram, of which 26 are in service in Strasbourg.

Adtranz is also involved with the Cobra car developed by Schindler and SIG, the latter now being part of Fiat-SIG Schienenfahrzeuge AG, in which Fiat has a 60% stake. This may be a valuable opening for SIG, as the long-promised development of the Italian tram and light rail market could take off in the next few years.

Another international grouping formed in the past year is Matra Transport International, owned jointly by Siemens and Matra's French parent the Lagardère group. One of the four reasons given for the creation of the joint venture is to market Duewag low-floor trams in France. A forthcoming merger of sub-suppliers may bring together SAB Wabco, Thyssen-owned BSI and Davies & Metcalfe to form one company.

50 TO 65% LOW-FLOOR CARS

Analysing the latest car orders and design variants, these can be grouped into the categories which I defined in RG 11.91 p797, and have used in subsequent articles.

In **Category A**, the total has increased to 159 with the first Scandinavian order for middle-floor trams; Oslo is buying 17 from Firema/Ansaldo (Fig 1). The 32m long, 2600mm wide bidirectional trams will have an aluminium body with all axles motored. The 680mm diameter wheels are driven by IGBT inverter controlled AC motors, giving a high power-to-weight ratio of 18kW/t. 35% of the floor length is 400mm above rail, and the rest 620mm. The predicted weight is 557kg/m², and the price works out at 43600DM/m².

Karlsruhe's AVG/VBK group has ordered 21 more dual-system (15kV 16⅔ Hz/750V DC) middle-floor all-steel cars from Adtranz, bringing the number of **Category A2** cars to 61. These will have a Duewag body and interior, with Siemens transformers and rectifiers (RG 8.95 p475). The 36570mm long cars (Fig 2) will have entrances at 630mm and the higher sections at 880mm. The Adtranz end-bogies will have 125kW AC motors, giving a power-to-weight ratio of 8·72 kW/t and a weight of 559kg/m². Top speed is 100km/h, whilst the price works out at DM46950/m².

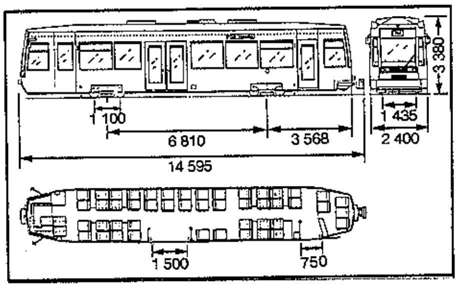


Fig 4. Düsseldorf's Rheinbahn is the second company after HEAG of Darmstadt to purchase 100% low-floor trailers. The floor level of this Duewag design is 350 mm; 16 out of the 49 seats stand on boxes

Mittenwalder Gerätebau, Schindler and SIG have fitted a prototype low-floor intermediate section between the two halves of a Cottbus KT4D car, using a shell made from wrapped glass-fibre composites (RG 5.96 p250). The shell is bolted to a steel frame, and runs on two BSI single trucks with individual wheels steered by a radial linkage from the articulation centres. DVG in Duisburg has ordered 30 low-floor intermediate sections from Duewag to enlarge their GT8NC-DU cars to GT10NC; it is expected that ultimately all 45 cars will be so equipped.

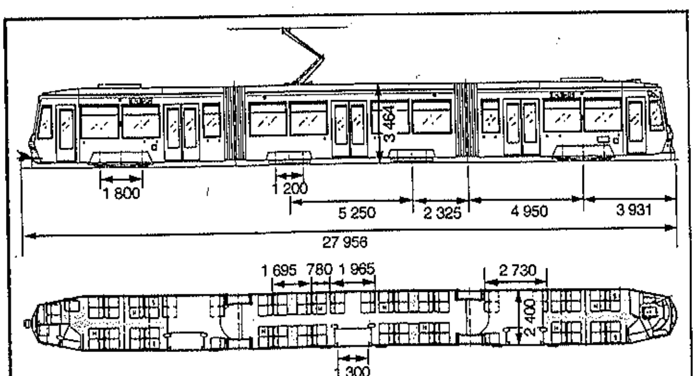


Fig 3. The LHB/ Adtranz metre-gauge cars for Darmstadt have 81 seats. The central floor level is 350 mm above rail, and the areas over the bogies are at 587mm

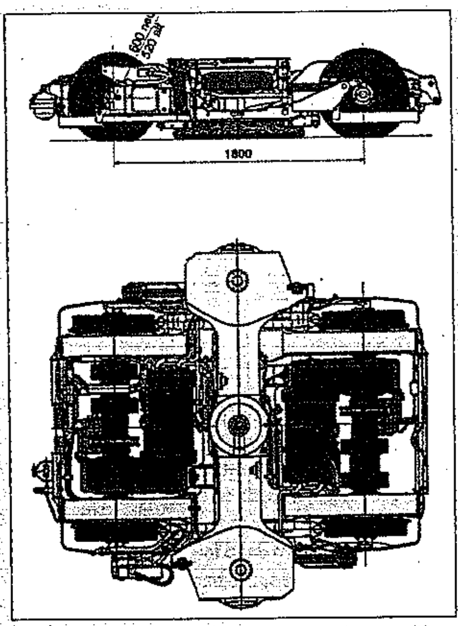
In **Category B**, Leipzig increased its order to 55 whilst HEAG of Darmstadt has ordered 20 metre-gauge cars (Fig 3) from LHB and Adtranz. Directly derived from the Magdeburg standard-gauge design, these 27780mm long cars are 2400mm wide, and seat 81. Car weight will be 493kg/m², and power-to-weight ratio 11·6kW/t. Equipped with IGBT inverters, they are priced at DM50375/m².

The total number of cars in **Category B1** is now 288, including the 30 trailers for Darmstadt, which were supplied by LHB and Adtranz in 1993-94. GEC Alsthom received an order from St Etienne for 20 cars, which will be nearly identical to the 15 existing low-floor cars; Vevey will supply the bodyshells and small-wheel bogies, whilst Duewag will provide the monomotor power bogies and articulations.

Düsseldorf's Rheinische Bahngesellschaft has ordered 15 trailers from Duewag and Kiepe, with an option for another 44 (Fig 4). These will work with 59 of the 118 articulated motored trams ordered to the same principles (cut from 138 when the trailers were ordered). The trailers are 12595mm long and 2400mm wide, with 49 seats. The price is DM33700/m² or DM22448/seat. This works out at 20% less than the DM42170/m² or DM38600 per seat for the motor car. For an extra DM9·1m, the Rheinbahn bought 1451 extra seats at a unit cost of DM6271 – half the price of a bus seat.

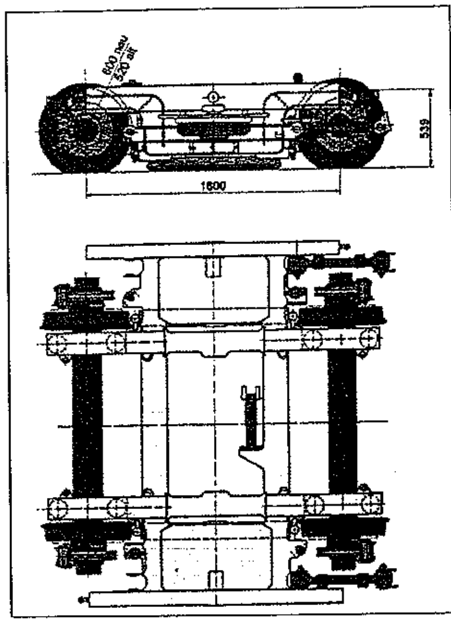
Duewag and Kiepe are currently delivering the Rheinbahn's welded all-steel motor cars, which are designed for operation in multiple as well as with the trailers (RG 2.96 p62). The leading Scharfenberg coupler can be retracted longitudinally when not in use, and the front covered automatically.

In **Category B2** the first Dresden 6NGT-DD cars (p23) have been delivered, bringing the total to 451 cars. A 1450mm gauge version of the 64 metre-gauge cars now in service in Mannheim and Ludwigshafen, they are being built by DWA Bautzen under Siemens' man-



Left: Fig 5. The latest Karlsruhe dual-system LRVs use Duewag's SM bogie, fitted to all standard and metre gauge part-middle-floor cars. The suspension consists of rubber/metallic primary springs, and secondary air springs. The weight of the car is transmitted via a friction disc that dampens the rotation movement. The forces are transmitted by a kingpin. Yellow: frame and bolster. Red: axles. Green: fully suspended AC motor and gears. Orange: fully suspended brake disc and gear. Blue: air springs and side linkage between frame and bolster, vertical and horizontal shock absorbers

Right: Fig 6. The VBK cars use a carrying bogie directly connected to the 'articulation car' as in Valencia, Mannheim, and Dresden. The primary suspension is by rubber springs, with air bag secondary suspension. Yellow: bogie frame. Red: portal axle with individually turning wheels. Orange; four disc brakes. Blue: air-springs and linkage to the car, allowing only 1° of movement, vertical and horizontal shock absorbers



agement, and fitted with Duewag bogies. A Siemens SIBAS32 microprocessor system controls Adtranz AC motors. The Knorr secondary suspension is of a new hydro-pneumatic design. The cars are reported to be extremely stable and free from hunting movements. Weighing 497 kg/m², with a power-to-weight ratio of 11·4 kW/t, they work out at DM43 000/m².

Firema and Ansaldo have been chosen to supply 15 LRVs for the Midland Metro line between Birmingham and Wolverhampton. The end sections are almost identical to the Oslo cars, but the articulated centre section is shorter, giving a 50% low-floor area at 350 mm above rail. 24 400 m long and 2 600 mm wide, the car seats 58, weighs 550 kg/m² and has a power/weight ratio of 11·6 kW/t.

Another design about to be delivered is the first of the Siemens SD600 cars for Portland, Oregon (RG 2.96 p98). Although due for dispatch in February, the first of these is now expected to arrive in Portland during June.

KÖLN – KARLSRUHE CONTRAST

Köln is about to take delivery of the last of its initial 40 Series 4000 LRVs from Bombardier Eurorail and Kiepe (RG 6.95 p342), and KVB has exercised an option for a second batch of 40 – with another option for 40 still available. They have very similar dimensions to the 20 unidirectional LRVs delivered to VBK in Karlsruhe by Duewag and Adtranz (RG 8.95 p475). It is interesting to compare the two designs. Both came out heavier than calculated: KVB 498 kg/m² instead of 458 and VBK 489 kg/m² against 452. The powered bogies are quite similar to Duewag's standard middle-floor design (Fig 5).

The main differences start with the central articulation, which is only 1200 mm long in the KVB cars compared to 3220 mm for the VBK car. The trailing bogies, which are firmly attached to the articulated sections, are also of very different conception (Figs 6 and 7). The interiors too are completely different (below). The Karlsruhe car is a classic all-steel welded body, with a middle-height floor of 610 and 407 mm and an entrance 340 mm above rail. The Köln car has floor levels at 400 and 580 mm, meaning that all platforms had to be raised to 350 mm.

The Köln design combines an interesting

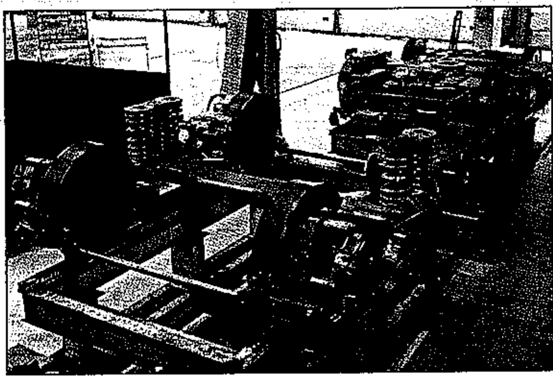


Fig 7. Bombardier Eurorail carrying bogie for the Köln LRVs. The wheelsets are connected to the cast steel frame by swing links and horizontal rubber primary springs. The small 'articulation car' rests on secondary steel springs, with vertical and horizontal shocks. There are disc brakes on the outside. The bogie frame is linked on the side to the 'articulation car'. A motor bogie is seen in the background

The interior of the Karlsruhe LRV (below) has 90 seats; none stand on wheel boxes and the step between the two floor heights is 203 mm. Provision is made for ticket sales by the driver. In contrast, the Köln LRV (below right) has 70 seats and a smaller interior step of just 180 mm. No tickets are sold in the car

mix of construction techniques. It has a mild steel bottom plate with a stainless-steel frame riveted to it, onto which aluminium outer plating is then glued. The roof is a riveted aluminium frame covered with stainless steel plates, whilst the cab end is a welded steel fabrication, bolted to the bottom plate. All parts including the nose are pre-cabled as far as possible and pre-equipped with air piping; they are prefabricated in Wien and shipped by container to Brugge, where final erection takes place. The bogies are built in Belgium. The floor consists of glued wooden panels, and the roof of sandwich panels.

Both cars have a Duewag interior. They are equipped for multiple operation, with Scharfenberg couplers on the VBK vehicles and BSI on the KVB sets. In both cases the couplers can be turned sideways and covered automatically when not in use. The riding qualities of both vehicles is good, but the central part of the KVB car is definitely noisy. In contrast, the interior noise level of the VBK car at 60km/h is one of the lowest ever recorded: 67dB(A) in the A and B sections and 70dB(A) in the articulated C section. It virtually glides over the grooved rails in the heart of Karlsruhe!

ADTRANZ KEEPS THREE DESIGNS

In RG 11.95 p773 I reviewed the latest developments with the AEG low-floor design, notably in Berlin. At that time 304 of the first-generation (1A)'(A1)'(A1)' version had been ordered, along with 283 options. Mechanically identical are the 70 GT6Ns for München and 14 for Nürnberg, which have two Siemens GTO inverters. The Berlin cars are also the same, but have three AEG IGBT inverters and are equipped for multiple-unit operation.

Almost identical are 12 metre-gauge cars for Zwickau and 8 for Frankfurt-an-der-Oder; these have three AEG IGBT inverters but a (1A)'(1A)'(1A)' wheel arrangement. There are also bi-directional versions for Jena (19) and Mainz (16). The Augsburg, Braunschweig, Jena, and Mainz cars all have the same nose, but Braunschweig has a (1A)'(1A)'(A1)' configuration. All future GT6N and GT6M cars will be arranged (1A)'(A1)'(A1)' as standard. Another derivative is Bremen's four-section GT8N which has a (1A)'(1A)'(1A)'(1A)' wheel arrangement, GEC Alsthom motors and two Kiepe GTO inverters.

Following the experience in Berlin, all standard-gauge cars will be equipped with Voith or Hurth limited-slip differentials to unlock the individually-driven wheels once the difference of the couple exerted on the two driven wheels exceeds a certain value. The metre gauge bogies have been made more flexible in the longitudinal plane.

Unfortunately, the cost of building these stainless-steel cars is beyond the reach of many cash-drained operators looking for low-cost options.

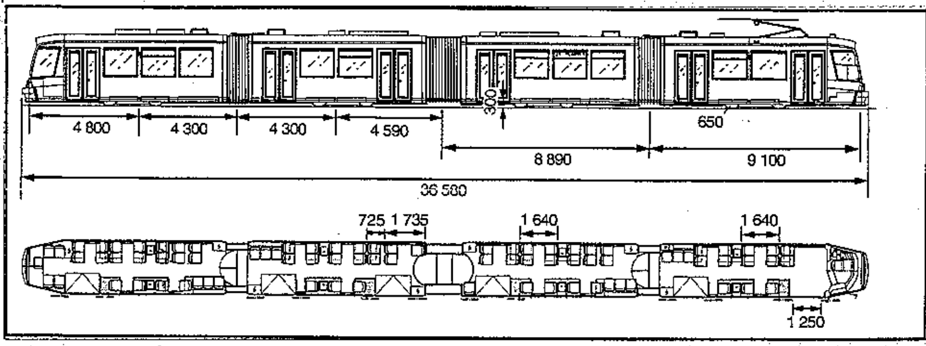


Fig 8. The 'low cost' 80 seat version of the Adtranz (ex-AEG) 100% low-floor car for Nürnberg and München

Furthermore, the distance between seating bays over the bogies was considered by some operators as being too small, at 475 to 490mm. In the latest builds for Bremen and Berlin this spacing has been increased to 550mm.

After so much development and overcoming teething troubles, one would expect Adtranz to start reaping the harvest with major series production. But starting with 26 cars for Nürnberg and 17 for München, an almost completely new tram is being developed (Fig 8). Designated GTN8-2 (standard-gauge) and GTM8-2 (metre-gauge), this design will have a welded aluminium bodyshell assembled from a frame and pre-formed modular profiles. The roof and nose will be formed from a reinforced plastic and aluminium sandwich.

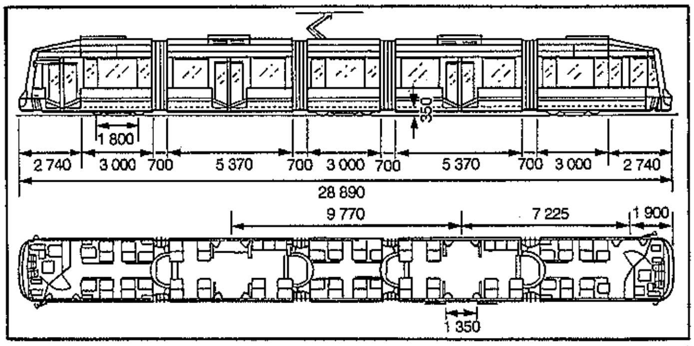


Fig 9. Sydney is buying seven of these bi-directional 100% low-floor 60 seat Variotrams from Adtranz; they have gearless hub motors

In order to give the seats over the bogies more legspace, the wheelbase of the standard-gauge version is being increased from 1850 to 2000mm, although the metre-gauge bogies are unchanged. All cars will have identical Siemens GTO inverter equipment. In order to improve the clearance profile, the cars are formed as two four-axle half-units, which are coupled by a separable articulation derived from the InterCity-Express concept.

At the same time, Adtranz is continuing to develop the Variotram concept – at least for the time being. A 65% low-floor variation is being built for OEG, and 100% low-floor cars with gearless hub motors are on order from DVG in Duisburg (1), and Sydney's Pyrmont Light Rail Consortium (7) (Fig 9).

There are also 20 metre-gauge cars for Helsinki, which were won after a fierce competition with Schindler/SIG's Cobra that also has Adtranz electrical equipment. The Munico test car was demonstrated in Helsinki during the summer of 1995. Rautaruukki will build the bogies and undertake final assembly, using bodies and electrical equipment supplied from Germany. The cars have all wheels driven and will be equipped with IGBT inverters. The reported price works out at DM58870 per m².

As shown in Table IV, the Chemnitz, Duisburg, Sydney and Helsinki 'modular' Variotrams in fact have very little modularity in common. The length of the end modules and the intermediate modules on the Chemnitz and OEG versions are identical, as will be the standard-gauge bogies

Table IV: Adtranz Variotram cars and similar models from other manufacturers

City	Chemnitz	OEG	Sydney	Duisburg	Helsinki	Würzburg	Combino[1]	Cityrunner[2]
Manufacturer	Adtranz	Adtranz	Adtranz	Adtranz	Adtranz	LHB	Siemens	Bombardier
Type	SD	BD	BD	BD	SD	SD	BD	SD
Length *mm*	31380	32200	28020	33780	24000	28810	26380	23300
Width *mm*	2650	2500	2650	2300	2300	2400	2300	2300
End module *mm*	5640	5640	5740	6540	4835	5700	5840	5200
Intermediate module *mm*	7250	7250	5370	7050	3560	6280	7400	4880
Centre module	2800	3600	3000	3800	2800	4850	4040	3090
Power *kW*	8x45	4x95	8x45	8x45	12x45	12x50	4x100	8x45

SD: single direction BD: bi-directional 1. Prototype to be ready in July 2. Design concept