2090

Prices under pressure as tram boom subsides

Harry Hondius MSc reviews low and middle-floor tram and light rail developments over the past year, and finds that the glut of rolling stock orders is running out. High production volumes have not brought the lower prices that are essential if established operators are to justify replacing their ageing fleets

AS WAS TO BE expected, and probably even feared, the stream of orders for new low-floor trams has slowed down considerably. Only 160 vehicles were ordered in the last 12 months – and 59 of these were options on earlier contracts. The problem is simple; many cities have no money available for new vehicles, and must get by with modernising their existing fleet. High-floor tram business was also rare in 1994. San Francisco Municipal Railway increased its contract with Breda and General Electric from 40 to 52 cars, and Debrecen ordered 11 vehicles from Ganz Hunslet.

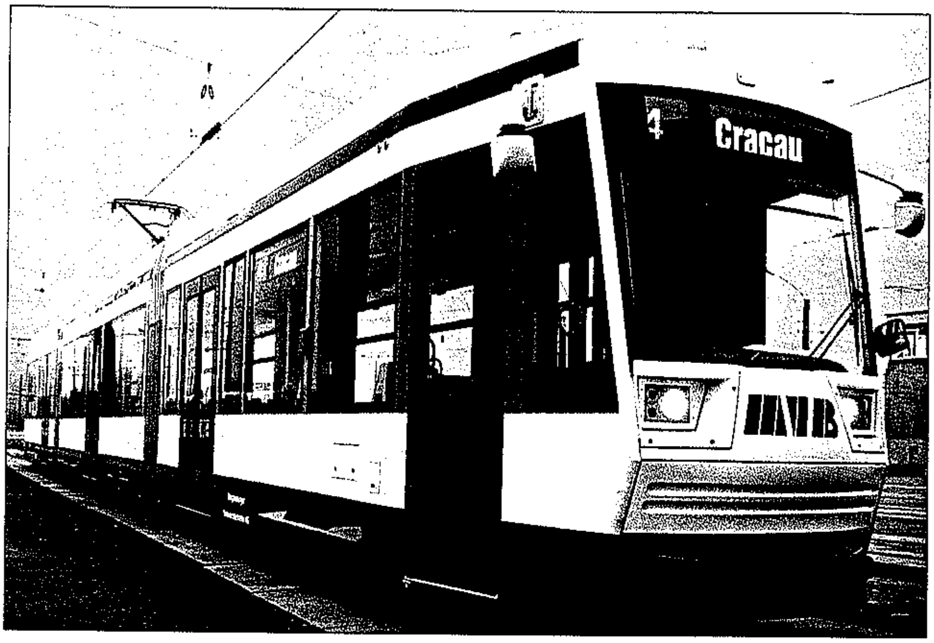
Orders for high-floor LRVs remain healthy, and well in line with the average output of around 160 cars/year achieved over the past 20 years. But there is a fundamental change coming along. In the past, all these LRVs were being ordered for new systems. Now we are seeing the first orders for replacement cars.

Largest contract was for 144 six-axle LRVs for Hannover, 23·7 m long and 2650 mm wide. LHB, Duewag and Siemens will deliver these between 1996 and 1999. Duewag and Siemens have started supplying 39 AC-motored type U4 cars 24·5m long for Frankfurt.

In the low- and middle-floor LRV category, there were orders for just 7 more Duewag/Siemens cars for Portland, Oregon, and 15 dual-voltage LRVs for Saarbrücken (p62), which will come from Bombardier Eurorail's Wien works with Kiepe Elektrik equipment.

CAPACITY CRUNCH COMING

In order to cope with the mini boom of orders in 1993-95, many suppliers invested heavily in their production facilities. Duewag, the leading manufacturer, modernised its Düsseldorf works and farmed out work to other factories in the Siemens group: MAK in Kiel built the Bonn low-floor cars, whilst Duewag's Uerdingen works supplied low-floor cars to Heidelberg and high-floor cars for Bielefeld. AEG completely revamped its old MAN GHH shops in Nürnberg and also began building trams at its Hennigsdorf works near Berlin. ABB is rebuilding its Waggon Union site in Berlin.



Magdeburg's MGT8D 60% low-floor cars from LHB and ABB have 12 seats standing on 225 mm high boxes, leaving a 675 mm wide corridor

This investment is reflected in recent delivery rates. Over the 10 years to the middle of April 1994, some 460 low and middle-floor cars had been delivered. Add to that 600 high-floor trams, and deliveries average around 100 per year. However, just 12 months later some 740 low-floor cars have been delivered, indicating that output shot up last year to over 300 cars (Tables I and II).

With the lack of contracts in 1994-95, the industry is eating through its order books with considerable speed. Very soon this output will have to slow down to much lower levels, and much of the expensively-acquired plant will find itself under-utilised again.

The biggest upset in the industry during the last 12 months was the end of the partnership between ABB Henschel and LHB, with GEC Alsthom Transport purchasing 51% of LHB shares and leaving Preussag with 49%. In one fell swoop, GEC Alsthom acquired the considerable light rail expertise that LHB has assembled over the last 20 years, making it the second player in the tram market.

However, this news was totally overshadowed by the annoucement in mid-March that moves were under way to merge the ABB and AEG transport sectors to form ABB Daimler Benz Transportation. If this merger goes through, it will almost certainly lead to a reduction in the range of low-floor car types now on offer from ABB and AEG.

Table III shows market position of the vari-

Table I. Market share of low-floor trams supplied or ordered up to April 1 1995

Mechanical parts		Orders	Options
Duewag		422	500
GEC Alsthom	46(1) }		
GEC Alsthom/De Dietrich	115 }	396	4
Bombardier Eurorail	51 }		
Linke-Hofmann-Busch	184(2) }		
AEG		323	290
SGP Verkehrstechnik		152	
Breda		125	
Vevey Technologies		73(3)	
Bombardier BN Division		45	
Socimi		35	
ABB		33	50
Fiat		30	
Firema		26	
Tatra		1	6
TOTAL		**1661**	**850**

1. Includes all Nantes cars, of which 34 were fitted with low-floor centre sections in 1993
2. Includes 30 trailers
3. Includes 46 middle-floor cars

Table II. Market share of low- and middle-floor LRVs ordered by April 1 1995

Mechanical parts		Orders	Options
Bombardier Eurorail		123	93
Duewag		91	
Total		**214**	**93**
Electrical equipment		**Orders**	**Options**
Kiepe (Elin motors)	68 }	123	93
Kiepe (GEC-A motors)	55 }		
Siemens		71	
ABB (1)		20	
Total		**214**	**93**

1) ABB has also equipped 46 regional railway cars in Switzerland

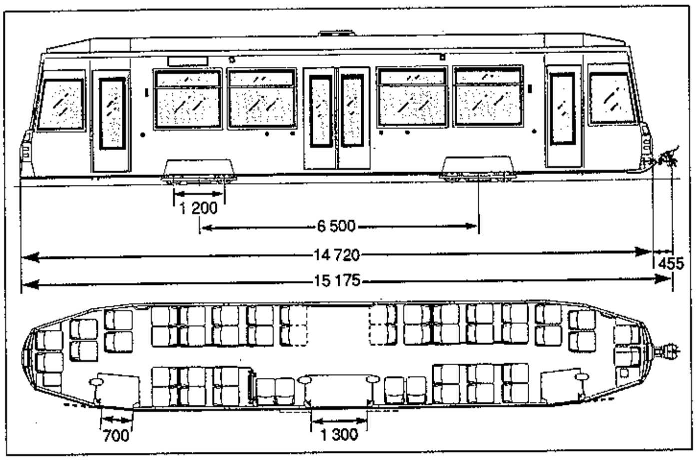
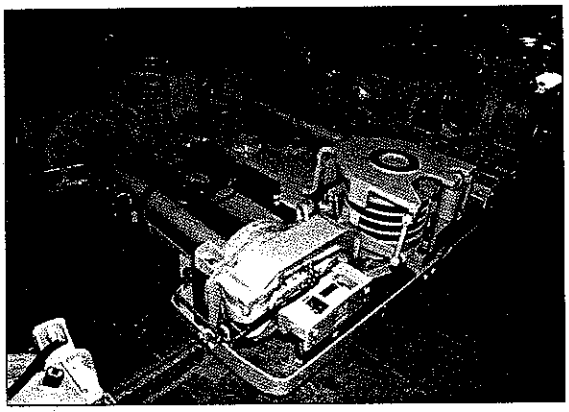


Fig 1. Darmstadt's small-wheeled trailer from LHB and ABB has 48 seats. The LHB carrying bogies are almost identical to those on the Magdeburg car (below left), with 410 mm wheels and direct links from axle to frame. Primary suspensions are steel-rubber laminate, whilst the secondaries are coil springs in series with rubber elements



ous electrical suppliers, and the technologies that are being used.

TECHNICAL ADVANCES WITH MIXED RESULTS

It is very clear that building trams is a specialist skill. Only those firms continuously engaged in the business will progress systematically.

A significant pointer to success is equivalent vehicle weight, expressed as kg per square metre of floor space. The most experienced tram builders generally achieve the lowest vehicle weights. In 1941 Schlieren and BBC (now Schindler and ABB) set a new standard with the first truly modern trams for Zürich, at 450 kg/m². By around 1960 the lightest trams were around 400 kg/m², but now the best low-floor cars are only just below the level achieved in 1941. Of 1631 low- and middle-floor trams ordered, just 42 weigh less that 450 kg/m². Another 144 are around that benchmark, but no less than 579 (or 35% of all orders) are heavier than 500 kg/m². The majority of cars weigh between 450 and 500 kg/m².

So what has the industry learnt so far from the adoption of new technology?

- New car types are initially too often heavier than calculated, even when made by the most experienced builders.
- Primary springing is an absolute must for trams, especially for those running on grooved rails. So is the presence of resilient wheels.
- Although the ride quality of the EEF single-axle trucks has proved very acceptable, the two-axle bogie is generally very difficult to beat in coping with the deficiencies of tram tracks – which alas are more common than desirable.
- Hub motors seem technically capable of withstanding the tough operational conditions, but have proved unsuitable for running on tracks without solid foundations. On lighter track structures, their high unsprung weight may lead to significant vibration.
- Even when prototypes have apparently been thoroughly tested, series-built cars incorporating small changes can show disturbing deficiencies which need considerable time to remedy.
- Sceptics of water-cooled traction equipment can probably be convinced of their advantages by looking on the roofs of the latest cars for Rostock, Magdeburg and Mannheim. These have neat and compact arrangements that can be remarkably silent. The fully-suspended 6000 rev/min motors have proved to be equally silent. This is an area where real progress has been made.

Table III. Electrical equipment for low-floor cars ordered to April 1995

Supplier	Total	Chopper (a)	VVVF (b)	Direct PWM inverters GTO (c)	Bipolar (d)	IGBT (e)
ABB	429(1)	69	—	—	360	—
Siemens	326	14	—	252	—	60
AEG	294					
AEG	(146)	25	—	1	—	120
Westinghouse	(59)	34	—	25	—	—
Kiepe	(89)	—	—	89	—	—
GEC Alsthom	227	161	—	51	—	15
Elin	152	—	—	—	—	152
Ansaldo	54	54	—	—	—	—
Holec	45	—	45	—	—	—
Tatra	1	1	—	—	—	—
Marelli	2	2	—	—	—	—
TOTAL	1530(2)	360	45	418	360	347

1) Includes 46 middle-floor cars
2) Electrical supplier for Boston's 100 Breda cars has not yet been chosen
a) DC motors with GTO thyristor chopper controls
b) Three-phase AC motors with variable-voltage, variable-frequency thyristor controls and intermediate voltage circuit
c) Direct pulse-width modulation using air-cooled GTO thyristors
d) Direct PWM with three-point water-cooled bipolar transistors
e) Direct PWM using Insulated Gate Bipolar Transistors in three-point (AEG and GEC Alsthom) or two-point (Siemens) arrangement

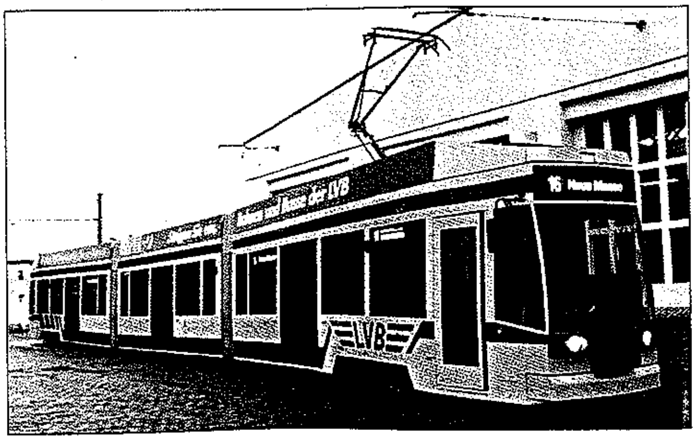
VEHICLE DEVELOPMENTS

Table IV gives the main technical data of all car designs ordered since 1984, using the categories defined in RG 11.91 p797.

Category A remained stable at 142 vehicles, including the 34 out of 46 Nantes cars which have low-floor centre sections. The Freiburg GT8MNZs, of which 16 are in service, are remarkable vehicles with excellent riding qualities and low noise levels – probably the ultimate in classic tram technology. With all axles driven and 48% low-floors, they have four wide entrances just 290 mm above rail. The eight 185 mm steps on both sides of the four bogies form no obstacle to passenger movement in practice. In the LRV category, the Nantes cars also exhibit excellent riding qualities.

Turning to **Category B1**, the first of 25 Magdeburg cars was delivered by LHB/ABB in December 1994. Whether the remaining 95 cars in the order will actually be delivered, and if so when, is at present unclear. These cars have classic bogies, with ABB's new standard electrical equipment. Fully-suspended 6000 rev/min water-cooled motors are controlled by four three-point water-cooled bipolar transistor PWM inverters, directly connected to the 600 V DC system.

The first Duewag-ABB 61% low-floor cars were delivered to Leipzig last December; these have a middle-floor height of 560 mm above rail



GEC-Alsthom's TSF cars for Rouen have doorway flaps bridging the gap between the 280 mm high platform and the 350 mm car floor for wheelchair and pram users

Wide articulations give a spacious feel to the interior of the Duewag/ABB design for Mannheim and Ludwigshafen; a 210 mm step connects the 390 mm low floor section to the higher ends

Single front and rear doors give access to the 587 mm middle floor part through a 237 mm interior step. Three double doors at 300 mm open onto the 350 mm low-floor sections. Only 12 out of 71 seats stand on boxes. The small wheel bogies are nearly identical with those of the 30 trailers delivered to HEAG in Darmstadt during 1994.

The Darmstadt trailer car (Fig 1) is an excellent 100% low-floor design, offering 48 seats, of which 16 stand on boxes. The riding qualities and general noise level are impeccable.

The first low-floor car for Leipzig was delivered in December 1994 – these are being built by Duewag, with ABB and Siemens equipment and small wheel bogies designed by Vevey (photo opposite). The Leipzig car uses Duewag's fully-suspended motor bogie and ABB's standard electrical equipment, in line with the latest Freiburg and Magdeburg types. Siemens' SIBAS 16 electronic controls are fitted. Leipzig has increased the size of the order to 35 cars, with eventual plans to bring the fleet up to 50. After that, a shorter version is envisaged, with a possible series of trailers under consideration.

In **Category B2**, Breda landed the biggest order of the year with a US$215m contract for 100 Type 8 trams to replace Boston's troubled fleet of Boeing Vertol cars. Breda will also be responsible for adapting MBTA's Kinki Sharyo Type 7 high-floor cars for multiple-unit operation with the new design. The Type 8s will have a fully-fledged high-floor entrance and two low-floor exits (Fig 2), similar to the designs for Torino.

Grenoble has ordered a further batch of Tramway Standard Français cars from GEC Alsthom, bringing their total fleet to 53. The 15 extra cars will be the first of the type to have AC drives. In total 115 TSF cars have now been ordered, of which the 100 DC-motored versions used in Grenoble, Paris and Rouen are almost identical.

Rouen's first two Metrobus routes opened in December 1994 (RG 10.94 p653). The 28 TSF cars have been specially adapted to tunnel conditions. Nearly all the electrical equipment is neatly stored on the roof and protected by Neerman-design covers. This Rolls Royce of modern trams will be further improved by the use of individual three-phase AC motors, which will allow the end high-floor sections to be lowered into the middle-floor range, reducing the height of the internal stairs.

Mannheim, Ludwigshafen and the Rhein-Haardtbahn have started to take delivery of their family of multi-articulated cars from Duewag (RG 12.94 p783), which use the standard ABB electrical package. Thanks to the wide articulations, the interior is roomy (above right), like the ABB Variotram. The air-sprung trucks give an excellent ride on straight track, but curvature causes a pronounced sideways oscillation.

These cars have a front door at 350 mm above rail, with a 250 mm interior step up to the middle-floor section. The central area is at 390 mm above rail, and the 210 mm steps leading up to the end sections do not cause any hindrance to interior movement. The multi-articulated format allows 2400 mm width on a system that has only been able to run 2200 mm wide cars before.

Although three of the Rhein – Neckar companies have ordered a total of 69 cars, the fourth operator in the group, OEG, has opted to buy six metre-gauge versions of Variotram from ABB Henschel (Fig 3). These will have conventional bogies, and will be the same width as OEG's existing cars.

INDEPENDENT WHEEL CARS

In **Category B3**, a total of 156 cars with EEF wheelsets has been ordered, and the great majority of these have now been delivered. Kassel was the first city to order a follow-on build of EEF vehicles; Duewag has already completed these 10 additional chopper-controlled cars, which have AEG and Siemens electrical equipment. Delivery of the series cars for Rostock is now in full swing (DM94 p14), but the order has been cut back to 40 because the city has only obtained a 15% subsidy and cannot raise the rest of the money. These cars run very silently in curves, an immense improvement over Rostock's old Tatra T6A2 cars.

All 42 EEF-equipped cars for Bochum (DM 93) have been delivered, together with two prototypes for Halle and four for Erfurt. Due to be dispatched shortly are four cars for

Fig 2. Breda's low-floor tramcar for Boston will have 52% low floors

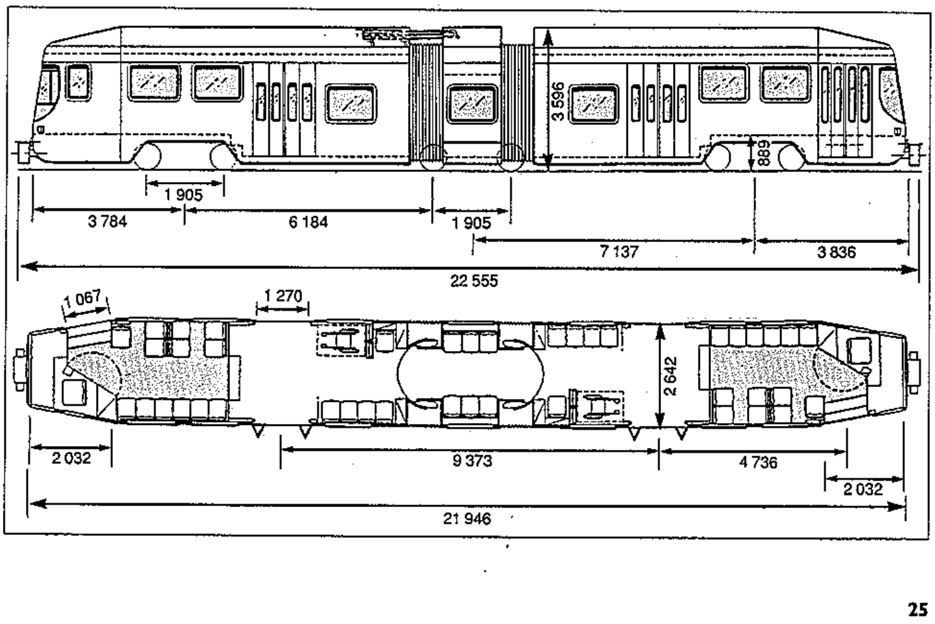


Table IV - Technical details of low and middle-floor trams, LRVs and regional rail cars ordered or delivered between 1984 and April 1 1995

City and car type	No	Axles	Length mm	Width mm	Floor height (high) mm	Floor height (low) mm	% low floor	Weight empty tonnes	Max speed km/h	Supply voltage V	Power rating kW	Seats	Stand-ees @ 4/m²	Wheel dia mm M	Wheel dia mm T	Gauge mm	Power rating kW/m²	Specific weight kg/m²	Year delivered	Suppliers
Category A	**142**	**Conventional 8-axle cars with low-floor sections up to 50% and floating articulations (except Amsterdam)**																		
Amsterdam 11/12G [(1)(B)]	45	Bo'Bo'Bo'Bo'	25 630	2 350	870	280	9	36·9	70	600	8x38·5 [(A)]	63	90	662	--	1435	8·5	598	1989-91	BN/H
Würzburg GT8/8	14	B'B'B'B'	32 600	2 400	910	310	9·8	42·5	70	750	4x162	78	125	690	--	1000	15·2	543	1989	L/S
Freiburg GT8C	11	B'B'B'B'	32 840	2 300	910	270	9	38·5	70	750	4x150	84	115	690	--	1000	16·6	509	1990	D/AB
Freiburg GT8MNZ [(B)]	26	Bo'Bo'Bo'Bo'	33 090	2 300	560	350	48	38·5	70	750	8x65 [(A)]	84	108	590	--	1000	13·5	506	1993-95	D/AB
Nantes	46	B'2'2'B	39 150	2 300	873	353	16·3	51·9	80	750	2x275	74	178	660	660	1435	10·6	576	(1985)-93	G
Category A2	**40**	**Middle-floor LRVs with low-floor sections up to 50% of the car length**																		
Sheffield [(B)]	25	B'B'B'B'	34 750	2650	880	480	34	46	80	750	4x250	88	150	670	—	1435	21·5	505	1993-94	D/S
Saarbrücken [(B)]	15	Bo'Bo'Bo'Bo'	36 010	2650	800	400	41	53·8	100	750/15kV	8x60 [(A)]	108	132	660	—	1435	8·9	564	1996-97	BE/K
Category B1	**228**	**Cars with 60 to 70% low floors using classic motor bogies, floating articulations and small-wheeled carrying bogies**																		
Genève Be4/6 [(C)]	28	B'2'B'	21000	2300	870	480	60·4	27	60	600	2x150	48	66	660	375	1000	11·1	559	1984-90	V/D/AB
Genève Be4/8 [(C)]	18	B'2'2'B'	30010	2300	870	480	71·6	34	60	600	2x150	73	91	660	375/410	1000	8·8	493	1995	V/D/AB
Bern Be4/8	12	B'2'2'B'	31000	2200	710	350	72·8	34	60	600	2x151	68	109	560	410	1000	8·9	498	1989-90	V/D/AB
St Etienne Be4/6	15	B'2'B'	23000	2100	710	350	59	27·4	70	550	2x140	43	92	560	410	1000	10·2	567	1991-92	V/D/G
Magdeburg MT8D	120	Bo'2'2'Bo'	29410	2300	587	350	60	32·5	70	600	4x95 [(A)]	71	96	590	410	1435	11·7	480	1994-2000	L/WD/AB
Leipzig 8NGT	35	Bo'2'2'Bo'	27800	2200	560	350	61	30·4	70	600	4x95 [(A)]	77	104	590	410	1458	12·5	497	1994-96	D/WB/AB/S
Category B2	**430**	**Multi-articulated cars with intermediate articulation section(s) using independent wheels**																		
French Standard [(B)]	115	B'2 B'	29400	2300	875	345	65	43·9	70	750	2x275	54	120	660	660	1435	12·5	649	1987-96	G/DD
Torino	54	B'2 B'	22200	2300	870	350	56	30	60	600	2x150	51	92	680	680	1445	10	587	1989-90	F/FI/AT
Roma [(B)]	34	Bo'2 Bo'	21200	2300	835	350	54	29·7	70	600	4x100	34	101	680	680	1445	13·4	609	1990-91	SO/AE
Tatra RT6N	1	Bo'2 Bo'.	26280	2440	900	350	63	33	80	600	4x90	45	130	700	660	1435	10·9	515	1993	T
Valencia	21	Bo'2 Bo'	23780	2400	560	350	62	29·7	70	750	4x103 [(A)]	65	91	590	590	1000	13·9	521	1994	D/C/S
Lisboa	10	Bo'2 Bo'	24020	2400	700	350	62		70	600	4x103 [(A)]	65	90	590	590	900			1995	D/C/S
Mannheim [(2)] 6MGT	64	Bo 2 Bo	29200	2400	600	350	65	35	70	600	4x95 [(A)]	85	97	660	590	1000	10·8	499	1994-95	D/AB
RHB [(2)] 8MGT	5	Bo 2 2 Bo	40500	2400	600	350	84	42	70	600	4x95 [(A)]	119	150	660	590	1000	8·1	483	1994-95	D/AB
Dresden 6NGT	20	Bo 2 Bo	29200	2300	560	350	65	32	70	600	4x95 [(A)]	87	97	590	590	1450	11·9	476	1995-96	D/AB/S
OEG [(B)]	6	Bo 2 Bo	32200	2500	630	350	65	38	80	750	4x95 [(A)]	84	100	630	630	1000	10	472	1996	AH
Boston [(B,C)]	100	Bo'2'Bo	21940	2642	889	355	52	39	88	620	4x100 [(A)]	46	98	711	711	1435	10·2	672	1998-2001	BR/?
Category B2 LRVs	**106**																			
Karlsruhe GT6-70D/N [(B)]	20	Bo'2 Bo'	28820	2650	580	390	61	34·5	80	750	4x125 [(A)]	91	100	590	590	1435	14·5	452	1995-96	D/AB
Portland [(B)]	46	Bo'2 Bo'	27140	2654	980	355	66	44	88	750	4x140 [(A)]	72	116	711	660	1435	12·7	611	1995-97	D/S
Köln [(B,C)]	40	Bo'2 Bo'	28820	2650	580	400	65	34·5	80	750	4x120 [(A)]	62	116	630	630	1435	13·9	458	1995-96	BE/K
Category B3	**156**	**Cars with floating articulations and EEF self-steering independent wheelsets under the intermediate section**																		
Kassel 6NG	25	B'1'1'B'	28750	2300	700	350	70	30·2	70	600	2x180	80	105	560	560	1435	11·9	456	1990-94	D/AE/S
Bochum+ [(3)] NF6D [(B)]	79	Bo'1'1'Bo'	28620	2300	560	350	63	32	70	600	4x105 [(A)]	72	100	575	575	1000	13·1	486	1992-95	D/S
Heidelberg MGT6D [(B)]	12	Bo'1'1'Bo'	28930	2300	560	350	63	31	70	600	4x95 [(A)]	74	97	590	590	1000	12·2	465	1994-95	D/AB
Rostock 6NGTWDE	40	Bo'1'1'Bo'	30100	2300	560	350	50	30·4	70	600	4x95 [(A)]	91	92	590	590	1435	12·4	439	1994-95	D/WB/AB/S
Category B4	**34**	**Cars with floating articulations which steer 'single axles' consisting of independent wheelsets**																		
Bonn R1.1 [(B)]	24	Bo'1'1'Bo'	28570	2400	560	352	65	31·4	70	600	4x103 [(A)]	70	98	590	590	1435	13·1	458	1994	D/S
Düsseldorf	10	Bo'1'1'Bo'	27500	2400	560	350	61	30	70	600	4x105 [(A)]	72	93	590	590	1435	14	454	1995-96	D/K
Category B5	**68**	**LRVs with single-axle bogies under the intermediate section, steered by the floating articulations**																		
Wien U-Bahn T [(B)]	68	Bo'1'1'Bo'	26800	2650	530	440	60	34·7	80	750	4x100 [(A)]	58	136	590	590	1435	11·5	489	1993-95	BE/D/K/E

Brandenburg, four for Mülheim and six for Oberhausen. Erfurt has ordered a further five uni-directional cars, which will have ABB and Siemens equipment. The first of 12 bi-directional metre-gauge EEF cars for Heidelberg has been completed by Duewag's Uerdingen works; these have doors on four end corners (photo opposite).

MAK of Kiel has delivered 24 **Category B4** cars to Bonn (RG 10.94 p357). These have 'single-axle' trucks consisting of individual wheelsets steered by the articulations (Fig 4), which gives quite acceptable riding qualities. The same arrangement will be used on 10 uni-directional cars ordered from Duewag by Düsseldorf's Rheinbahn, with options for a further 128 (Fig 5). These vehicles will be about 1 000 mm shorter than the Bonn cars, and will have two doors in the centre section. Designed for multiple-unit operation, they will have Kiepe equipment and traction motors supplied by GEC Alsthom's Ornans works.

The prototype lightweight low-cost car

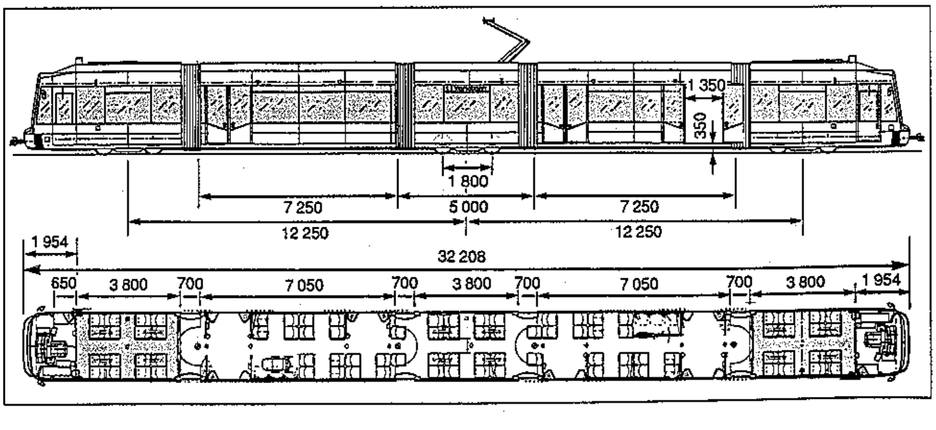


Fig 3. OEG is buying six bi-directional versions of the ABB-Henschel Variotram for its interurban lines around Heidelberg and Mannheim; they have 65% low-floor sections at 350 mm above rail

Table IV - Technical details of low and middle-floor trams, LRVs and regional rail cars ordered or delivered between 1984 and April 1 1995

City and car type	No	Axles	Length mm	Width mm	Floor height (high) mm	Floor height (low) mm	% low floor	Weight empty tonnes	Max speed km/h	Supply voltage V	Power rating kW	Seats	Stand-ees @ 4/m²	Wheel dia mm M	Wheel dia mm T	Gauge mm	Power rating kW/m²	Specific weight kg/m²	Year delivered	Suppliers
Category B6	**1**	**Prototypes with Jakobs (or similar) carrying trucks**																		
Firema VT1 [B]	1	Bo'2 Bo'	21 320	2300	900	350	63	30	72	600	4x80	40	79	690	400	1445	10·7	611	1994	Fi/M
Tram Group		B'1 B'	29000	2400	750	300	65	20	90	600	2x100	80	120	700	700	1435	10	298	?	BTG
Category B7	**25**	**Cars with 100% low floor passenger modules and single sets of independent wheels under the articulations**																		
Prototype VCL [B]	1	B'1'1'B'	22000[4]	2500	950	350	76	24	70	600	2x205[A]	36	94	680	500	1445	17·1	436	1990	BR/AE
Lille [B]	24	B'1'1'1'B'	29600	2400	950	350	76	46	70	750	2x205[A]	50	118	680	500	1000	8·9	647	1993-94	BR/AE
Category C1	**9**	**Prototype 100% low-floor cars based on newly-developed running gear with independent wheels**																		
Bremen GT6N	1	(1A)'(A1)'(A1)'	26500	2300	350	300	100	26·8	70	600	3x84[A]	67	103	680	680	1435	9·4	439	1990	AE/K
München GT6N	3	(1A)'(A1)'(A1)'	26500	2300	350	300	100	29·4	70	600	3x85[A]	64	102	680	680	1435	8·6	482	1990-91	AE/S
Torino	1	Bo'2 Bo'	22200	2300	350	350	100	24	90	600	8x60	55	88	680	680	1445	21·6	470	1991	FI/M
Socimi S350	1	Bo'Bo'	14000	2400	350	350	100	10·5	70	600	8x20	33	49	550	—	1445	18·6	312	1989	SO
Chemnitz 6NGT	1	Bo 2 Bo	30970	2650	350	290	100	36·5	70	750	8x40[A]	79	132	630	630	1435	8·8	445	1993	AH
Wien A ULF197-4	1	1'A'A'A'	23610	2350	197	180	100	31	70	600	6x60[A]	51	100	670	670	1435	11·6	558	1995	SG/E/S
Wien B ULF197-6	1	1'A'A'A'A'1'	34870	2350	197	180	100	42	70	600	8x60[A]	79	152	670	670	1435	11·4	513	1995	SG/E/S
Category C2	**489**	**Series cars based on category C1 prototypes**																		
Augsburg GT6N [5]	11	(1A)'(A1)'(A1)'	26600	2300	350	300	100	29·6	70	600	3x85[A]	60	96	662	662	1000	8·6	484	1993-96	AE/S
Bremen GT8N [5]	78	(1A)'(1A)'(1A)'(1A)'	35400	2300	360	300	100	37·5	70	600	4x85[A]	85	129	650	650	1435	9·0	460	1993-96	AE/K
München GT6N [5]	70	(1A)'(1A)'(A1)'	26500	2300	360	300	100	29·4	70	600	3x85[A]	64	102	650	650	1435	8·6	482	1994-97	AE/S
Wien A ULF197	100	1'A'A'A'	23610	2350	197	152	100		70	600	6x60[A]	51	100	670	670	1435			1997-2005	SG/E/S
Wien B ULF197	50	1'A'A'A'A'1'	34870	2350	197	152	100		70	600	8x60[A]	79	152	670	670	1435			1997-2005	SG/E/S
Würzburg	20	Bo Bo Bo	29110	2400	350	300	100	35	80	600	12x50[A]	80	112	670	—	1000	17·1	501	1996-97	L/AH/S
Category F	**117**	**Cars with hub motored independent wheels or similar, not derived from a prototype**																		
Frankfurt R3.1 [B]	40	Bo'2'Bo'	27200	2350	350	300	100	33	70	600	8x55[A]	59	111	740	590	1435	13·3	516	1993-94	D/S
Brussels T2000 [B]	51	A'1'Bo 1'A'	22800	2300	350	350	100	33·2	70	600	8x44[A]	32	92	640	375	1435	10·6	633	1993-95	G/BN/AC
Strasbourg [3][B]	26	Bo Bo Bo 2	33100	2400	350	350	94	40	70	750	12x26·5[A]	66	144	550	550	1435	8·0	503	1994-95	AL/AE
Category G		**Proposed designs for which components have been tested on a modified car**																		
Cobra 370	—	A'A'A'A'	24460	2300	370	320	100	25	65	600	4x70[A]	59	87	560	—	1000	11·2	444	—	SH/SI/AB
Category H	**46**	**Regional rail cars with classic bogies and 40 to 60% middle or low-floor sections**																		
FART ABe4/6 [B,C]	12	Bo'2'Bo'	30300	2650	900	530	60	42·5	80	1350	4x150[A]	82	70	750	600	1000	14·1	529	1992-93	V/SI/AB
RBS ABe4/8	23	Bo'2'2'Bo'	39300	2650	880	390	50	51	90	1200	4x160[A]	120	140	720	720	1000	12·5	489	1992-93	SH/SI/AB
OSST/ CEV Be2/6 [B]	11	2'Bo 2'	29280	2700	800	350	41	29	80	1200/900	2x160[A]	93	87	720	660	1000	11·0	367	1997	ST/V/SL/AB

Notes:

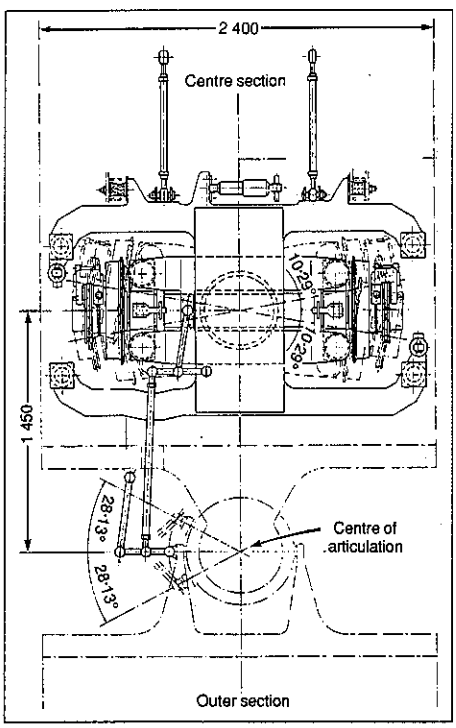
(A) = AC motors
(B) = Bi-directional vehicle
(C) = Middle floor car
(1) Data is for 12G, 11G is essentially the same
(2) Totals for both types includes 14 cars for Ludwigshafen
(3) Total of 79 includes 42 cars for Bochum, 20 identical cars for five other German cities, 5 single-ended versions for Erfurt with ABB/Siemens equipment and 12 for Halle with AEG equipment
(4) 2 x 1700 mm equipment bays within body length
(5) In total, 319 cars of this type have been ordered by 10 German systems
(6) Modular car, 94% of comparable length available for passengers

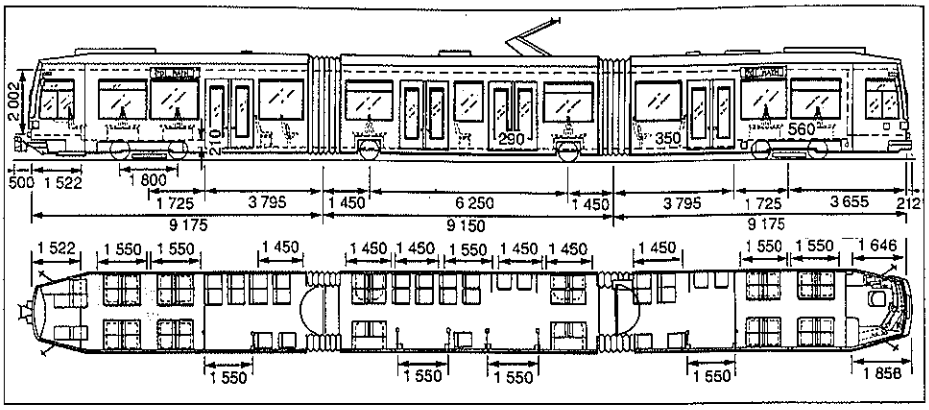
Key to manufacturers:
AB = ABB, AC = ACEC, AE = AEG, AH = ABB-Henschel, AL = ABB Transportation Ltd, AT = Ansaldo Trasporti, BE = Bombardier Eurorail (BWS), BN = Bombardier Eurorail (BN), BR=Breda, BTG = British Tram Group, C = CAF, D = Duewag, DD = De Dietrich, E = Elin, F = Fiat, Fl- Firema, G = GEC Alsthom, H = Holec, K = Kiepe Electrik, L = LHB, M = Ercole Marelli, S = Siemens, SG = SGP, SH = Schindler, SI = SIG, SL = SLM, SO = Socimi, ST= Stadler, T=Tatra, V = Vevey, WB = DWA Waggonbau Bautzen, WD = DWA Waggonbau Dessau

being built speculatively by British Tram Group is now expected to start test running in Blackpool at the end of August.

Lille's Breda/AEG cars (**Category B7**) have been in regular operation for a year now, and are bedding down gradually (RG 10.94 p654). Their riding qualities are excellent in the longitudinal sense, but the absence of primary springs makes them a touch hard in the vertical plane. Noise levels in the Pininfarina-designed passenger saloons are very good, but the ambient noise levels in the driving compartment are considerably higher. The two 1700 mm long electrical equipment com-

The 12 Duewag/ABB bi-directional cars for Heidelberg have 63% low-floors and a middle-height floor 560 mm above rail. They are the first low-floor cars with end doors on both sides





Left: Fig 4. Duewag's latest cars for Bonn and Düsseldorf use single trucks with individually-turning wheels, steered by a radial linkage from the centre of the articulation

Above: Fig 5. Düsseldorf's Rheinbahn has ordered 10 of these 61% low-floor cars from Duewag with Kiepe equipment. The contract includes options for a further 128 vehicles

partments behind the cabs makes the 50 seat cars comparable with a 26200mm vehicle. Although provided with Alusuisse-designed aluminium bodies, they are amongst the heaviest cars to be built.

ALL LOW-FLOORS

Category C now totals 615 cars or 38% of the entire low-floor order book. Wien's SGP/Elin ULF prototype was due to start its test programme in April. The Bremen/AEG design (**Category C2**) is now in full production. Bremen has already received 40 cars, and delivery of 70 series cars to München started last autumn (RG 11.94 p699).

Deliveries to Berlin were halted for a while after four cars had arrived, because of derailments on the 150m radius curve leading to Marzahn depot. A remedy was found by installing a Voith Hydrolock limited-slip differential to uncouple the drive to both powered wheels on each bogie when a certain difference in couple between the wheels occurs, as happens in curves. The torsional couple in the axle that connects both wheels disappears, which has a favourable effect on the lateral stability of the non-driven wheels.

Derailments of the metre gauge cars for Zwickau were cured by making the front non-driven end of the bogie frame less stiff in the lateral direction.

Nürnberg has ordered 26 GT8N cars from AEG to replace its existing six-axle cars and trailers. A build of 12 cars for Braunschweig's 1100mm gauge network is being assembled by LHB; these are equipped with Siemens electronics and AEG motors. LHB is also assembling 20 cars for Würzburg, which will have all wheels driven. These cars will use Siemens hub motors with gears, which will be mounted in ABB Variotram metre gauge bogies.

In **Category F**, Frankfurt has ordered a second batch of R3.1 trams from Duewag and Siemens, increasing its fleet from 20 to 40.

Strasbourg has taken delivery of its 26 Eurotrams from ABB Transportation Ltd (RG 1.95 p13) which enabled a trial service to be introduced on the city's new line on November 27 1994. Full commercial services started on February 27 (p67). Ride quality of the Eurotrams is good, but they are not free from squealing in curves. The drive is silent, which alas cannot be said of the air-conditioning. The 1500mm single-leaf doors open and close too slowly, and are far from silent. The articulations are unusually small for a multi-section car of the Variotram family (below right).

The glass cupola which acts as the driver's cab (photo opposite) is certainly interesting from the design angle; less clear is whether it will prove possible to ensure reasonable climatic conditions for the drivers at all times. The Neerman design fits well into the city, which has been radically rejuvenated to coincide with the construction of the new tramway.

PRICES UNDER PRESSURE

It is clear that Europe-wide bidding and the looming shortage of work for the major tram builders has put prices under pressure. Bombardier and Kiepe set a new low standard in 1993 when the 120 bi-directional 2650mm wide LRVs for Köln were priced at DM37380/m². Early the following year, Düsseldorf negotiated a rate of DM42120/m² for 138 cars from Duewag and Kiepe; these 2400mm wide cars will have GEC Alsthom motors.

It is worth noting that extra width adds virtually nothing to prices, thus the smaller the car, the more expensive the price per m². A 2200mm car is easily 15% more expensive per

Pininfarina's interior design for Lille's Breda trams (below), compared with Strasbourg's Neerman designed Eurotrams (below right)

m· than a comparable vehicle 2 650 mm wide. The same thing also applies for longer versions of multi-section cars. For example, the 64 uni-directional Rhein-Neckar cars being built for Mannheim and Ludwigshafen cost around DM49 000/m², whilst the five 40 500 mm long versions for the Rhein-Haardtbahn work out at DM44 300/m². Rostock is also paying DM49 000/m² for its 40 uni-directional cars.

Small supplementary orders for bi-directional cars of the Bochum type cost DM55 000/m², which is about the same as the Tramway Standard Français and the AEG/ Siemens price for München's 70 cars. Nürnberg's four-module version of the AEG design works out slightly cheaper at DM47 240/m².

Nevertheless, we are not yet seeing the effects of large production volumes working through in new order prices. As discussed at the UITP light rail conference in Amsterdam last September, the only way to get prices down is for different operators to sit down together and order the same car, so that the supplier can benefit from the advantages of production on a larger scale.

The Düsseldorf order is a good example. With a potential build of 138 identical cars, the price comes down to 3 ½ times the price per m² of an articulated low-floor bus. Nevertheless, further savings are needed if tram investment is to be truly competitive. With a nominal depreciation period of 25 years for trams and 10 years for buses, the tram should not cost more than 2 ½ times the bus in order to match the annual depreciation charges.

Driving 'module' of the Strasbourg Eurotrams. All operating controls are mounted in the seat armrests, and video monitors replace mirrors to enable the driver to watch the platforms

OUTLOOK UNCERTAIN

Despite the obvious economies of adopting a range of common vehicles, almost every operator still wants its own variations, even when adopting a design that already exists. Good examples of this are Kassel and Rostock, Bonn and Düsseldorf, Mannheim and Dresden, Valencia and Lisboa, Bochum and Heidelberg. In every case the cars are very similar, but key dimensions or electrical equipment specifications are different, imposing substantial extra design costs.

Where new tram systems are being built, vehicles account for around 20% of the total project cost. The economics of standardisation are relatively less significant. But where even the wealthiest of western cities faces the need to replace vehicles that are often between 30 and 40 years old, incremental costs weigh very heavily indeed.

With public funding for capital projects becoming scarcer in many western countries, and a growing desire to cut the operating subsidies for public transport, cutting the cost of new vehicles by clubbing together with other operators is becoming essential. Otherwise there is an increasingly large risk that major cities may eventually be forced to abandon part or all of their tram systems, simply because they cannot afford to replace their existing fleet! □