Big builders face uncertainty as system cars dominate the market

Harry Hondius reviews developments in the tram and LRV sector for the past 12 months

3366

HOW MUCH LONGER will the big systems integrators stay in the light rail and tram-building sector? Order volumes are still running well below the minimum of 500 cars a year needed to sustain the current production capacity of the various Western manufacturers. The past 12 months have seen a number of plant closures, and more are to follow. At the same time, some smaller companies are starting to make more of the running, and new players are emerging.

My analysis of the market published in MR02 p53 showed that tram and LRV production did not add significantly to the profitability of the big companies' transport divisions, and I believe that this still holds true. Indeed, I doubt whether true profitability can ever be achieved. The volumes are too small, there is still too much innovation on offer, and the individual wishes of the customers are still too dominant.

At Siemens, CEO Heinrich von Pierer is still the darling of the shareholders – 'don't retire, stay' they shouted at the last annual general meeting. But with his sharp eye for shareholder value, it would not be surprising if Siemens decided to pull out of light rail altogether. Whilst there are still some existing orders to be completed, this would not be a bad time for Siemens to stop if it wished. Competition is fierce, and there is not enough work for all the manufacturers. Kinki Sharyo has eroded the once dominant position in the USA held by Siemens-Duewag, and in Europe the company's light rail business looks likely to be hit badly by bodyshell problems with its Combino cars (p60).

Stadler's entry into the LRV field, two 24 m Forchbahn units coupled back to back

Siemens Transportation Systems had already taken steps to rationalise its carbuilding activities, announcing on August 1 2003 that it would merge its Light Rail and Heavy Rail divisions into a single Mass Transit business unit. STS France will keep VAL 208, and SGP remains a legally separate company with plants in Wien and Graz.

The closure of Siemens' Carson steel LRV bodyshell plant in California was reported in RG 4.04 p169. With the Avanto LRV relying on subcontracted modules, assembly can take place in Sacramento. If any US customers want further steel cars to the existing designs, STS will subcontract the bodyshells to the SuperSteel plant in Schenectady.

Industry developments

Siemens is not alone in grappling with overcapacity, low order levels and pressure on prices. On October 7 new President Philippe Mellier unveiled Alstom Transport's third reorganisation in two years. This divided the world market into four regional 'customer-focused' businesses, supported by a single Operations Group running the factories and seven worldwide 'functional support teams'.

Alstom says it remains committed to serving the LRV and tram market on an international basis. Cars will still be built in France (Aytré and Reichshoffen), Spain (Barcelona), Italy (Savigliano) and Germany (Salzgitter). But Alstom will close its Preston traction equipment factory in the UK, and end new construction at the Washwood Heath plant in Birmingham.

On March 17 Bombardier announced the closure of seven plants over the next 18 months (RG 4.04 p181). Last November, the President & CEO of Bombardier Transportation Pierre Lortie left suddenly after 12 years with the group. Bombardier Inc President Paul Tellier expressed dissatisfaction with the division's organisation and results.

Lortie's post has been split, with the former head of Alstom Transport André Navarri as President and Wolfgang Tölsner as Chief Operating Officer facing the task of streamlining Bombardier Transportation and defining clear responsibilities. One fundamental change is that the Industrial Division has been abandoned, and each factory will form

Table I. Market share of low-floor trams supplied or ordered up to April 15 2004 (Western suppliers)

Mechanical parts	Orders	Options
Siemens TS	1 426	139
ex Duewag various models	687	18
Combino	481	60
NF8-12	106	61
SGP ULF	152	–
Bombardier Transportation[1,2]	1 394	253
GTxN	466	4
Eurotram	151	–
Variotram	120	97
Incentro	48	6
Cobra	74	22
Vevey	73[1]	–
BN Brugge	45	–
DWA Bautzen	142	49
DWA Bautzen LF2000	136	37
BWS Wien Cityrunner I	18	–
BWS Wien Cityrunner 2	121	38
Alstom[1]	1 035	263
TSF 1 (Nantes)	46	–
TSF 2 (Grenoble type)	116	–
Citadis	501	170
T 2000 (Brussels)	51	–
Vevey	20	–
LHB	126[3]	48
Fiat Ferroviaria various	105	–
Ferroviaria Cityway	70	45
Ansaldo + Breda + Firema	274	65
AnsaldoBreda Sirio	226	65
Breda	24	–
Firema	24	–
Socimi	42	–
CAF	24	–
LFB	2	–
Total	4 197	720

1. Includes 46 middle-floor cars
2. plus 60 trailers 3. Plus 30 trailers

Table II. Market share of low-floor and middle-floor LRVs ordered by April 15 2004

Mechanical parts	Orders	Options
Bombardier Transportation	515	78
Kinki Sharyo	246	70
Siemens Transportation	218	30
AnsaldoBreda (Firema)	148	–
Alstom	37	16
Stadler	13	–
Total	1 177	194
Electrical Equipment	**Orders**	**Options**
Bombardier	351*	60
Vossloh Kiepe	323	–
with Elin motors	*78*	–
with Alstom motors	*176*	–
with Skoda motors	*69*	–
Alstom	216	16
Siemens	148	30
AnsaldoBreda	48	–
Toshiba	24	18
Kinki Sharyo	67	70
Total	1 177	194

* 83 with Alstom motors

Siemens/Kiepe R100-3 or NF8 car for the Rheinbahn operation in Düsseldorf

part of a product division.

The LRV division, headed by Walter Grawenhoff, now controls the plants at Wien and Bautzen, which has effectively taken over the market leadership from the former Duewag works in Düsseldorf. A great variety of cars are produced there, including Classic cars, LF2000, Incentros, Variobahnen, Eurotrams and the De Lijn cars. LRVs and Cityrunners are built in Wien, but Bombardier's aim is to be as flexible as possible. Bogies come from Siegen, and propulsion from Mannheim, but rarely from Västerås.

On February 12 Tellier told *Handelsblatt* his top priority was to earn money. Although the LRV division is profitable, in his eyes it does not belong to Bombardier Transportation's core business. So he is open to offers. He is also looking to settle out of court with DaimlerChrysler in the long-running dispute over the Adtranz purchase.

It is clear that while the big companies go from one reorganisation to another, the smaller companies like CAF are growing. With orders for 80 high-floor LRVs in Pittsburgh and Sacramento, CAF has made inroads into Siemens' US territory. Brussels has ordered a new series of metro cars, which have LRV characteristics, and CAF is also one of the serious contenders to supply 52 dual-system cars for Randstad Rail.

Newcomer Leipziger Fahrzeug-Betriebe has launched an initiative to assemble low-floor trams in the Leipzig tramways' workshops, and Skoda is making small inroads with its Astra cars in Portland, Tacoma and Cagliari. Stadler too may enter the tram business, further eroding the position of the big builders.

Order levels too low

In the 12 months to April 15 2004, a total of 404 new cars were ordered from the Western suppliers. This is better than the annual average over the last 10 years, which was 228 trams and 88 LRVs, a total of 316, but still less than the benchmark 500 cars. This year's total comprises 248 low-floor trams (Table I) and 86 low-floor or middle-floor LRVs (Table II), together with 70 high-floor LRVs. Of these, 134 trams are replacements for older vehicles, and the rest are for new networks or extensions.

In the tram field, Bombardier is market leader with 81 orders, followed by 75 for Siemens, 60 for Alstom, and 17 each for AnsaldoBreda and CAF. For the second year running, Kinki Sharyo leads the LRV sector with 67 low-floor and 20 high-floor cars, followed by AnsaldoBreda with 50 high-floor cars.

Table III shows that Bombardier is the absolute leader in terms of electrical equipment for trams, followed by Alstom, Siemens, Kiepe, Ansaldo and Elin.

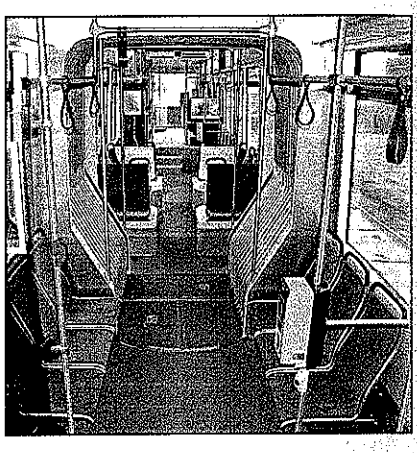
This year's orders have brought the total number of low-floor trams ordered to 4 197, of which 1 583 or 38% can be classified as system cars (Table IV). Of the 248 trams ordered in 2003-04, 158 are system cars. Most recent orders are for 100% low-floor vehicles, with only 28 for partial low-floor versions. Interestingly, Paris and Sevilla have joined the ranks of cities ordering 2 650 mm wide trams.

Table V shows that the larger operators are still able to order at relatively low prices. But there are important differences compared to MR02 p56. Amsterdam and Rotterdam ordered 2 400 mm wide Combino and Citadis 302B cars for 21 000 and 18 170 €/m² respectively, whilst this year similar 2 400 mm cars for Strasbourg, Zürich, Budapest and Düsseldorf show price increases of up to 40%!

As a general tendency, suppliers will try to push their prices up if they can. One-off designs like the metre-gauge tram-train cars for Alacant (p19) are extremely expensive. US prices are also high compared to continental Europe, reflecting the requirement for higher buffing loads and the Buy America regulations.

Centre sections

Although Alcan Altenrhein has stopped making the wrapped GRP intermediate low-floor sections that GBM, Mittenwalde, used to install in various types of high-floor cars, the concept is not dead. Alcan has sold the technology to Czech builder Variel AS in Zrucnad-Sazavou. Variel is supplying 10 shells for GBM to fit into KT4D cars for Tallinn, bringing the series total to 164.



The smart interior of LFB's Leoliner. Note the steps between the low and middle-floor sections

The Dallas Area Rapid Transit board was due to approve on April 13 a programme to retrofit its fleet of Kinki Sharyo LRVs with 9·4 m low-floor centre sections, which will extend each car to 38·8 m. This will cover the 95 cars now in service, plus the additional 20 which were ordered last June for delivery in 2005-06 at a cost of $58m. The aim is to eliminate lineside wheelchair lifts and increase capacity, with two three-section cars offering the same number of seats as three two-section LRVs (RG 4.04 p190).

A prototype steel-framed glass fibre bodied 'C-car' was completed by Kinki Sharyo in 2002 and put into service last year. It has one set of doors on each side, and end steps leading up to the high floor A and B sections. The leading end is supported on the existing centre bogie, and another unpowered bogie is used under a second articulation.

Expected to cost around $1m each, the production C-cars will also be built by Kinki Sharyo. The company is looking for a plant in the Dallas area to assemble both the new LRVs and the centre sections. DART expects to order around 40 low-floor LRVs for new routes, but without the C-cars, it would have to buy up to 100 new two-section LRVs.

Table III. Electrical equipment for low-floor trams ordered by April 15 2004

Supplier	Total	Chopper	GTO inverter	Bipolar inverter	IGBT inverter
Bombardier	1 574	–	–	–	264
ex Adtranz	*358*	–	–	–	*358*
ex ABB	*577*[1]	*69*	–	*382*	*126*
ex AEG (D)	*351*	*67*	*1*	–	*283*
ex AEG (US)	*24*	–	*24*	–	–
Alstom	939	–	–	–	–
Alstom F+UK	*689*	*162*	*51*	–	*456*
Alstom-Parizzi	*145*	–	–	–	*145*
Alstom-NL	*105*	–	–	–	*105*
Siemens	831	14	276	–	541
Kiepe Elektrik*	361	–	127	–	219
AnsaldoBreda	280	54	–	–	226
Elin	205	–	–	–	205
Ingelectric	7	–	–	–	7
Total	4 197[1]	366	479	382	2 970

1. Includes 46 middle-floor cars.
* 127 cars with Alstom, 126 with Skoda and 51 with Siemens motors

The Siemens Avanto S70 for Houston has an interior typical of US LRVs; this is the low-floor section

Part low-floor cars

In Category A2, cars on two driven and two non-driven bogies, AVG/VBK has ordered four more GT8-100D/2SM cars from Bombardier and Siemens; bodies will be built by Fahrzeugtechnik Dessau for assembly at Uerdingen using bogies from Siegen. This will bring the total number of dual-system tram-train cars in the Karlsruhe region to 114 (79 medium-floor and 35 high-floor), of which one high-floor car has been destroyed by fire. The 100th car was delivered recently.

FGV of Valencia has ordered nine tram-train LRVs from Alstom Spain for use on the metre-gauge Alacant – Altea section of the Alacant – Dénia line, which is being electrified at 750 V DC rather than 1·5 kV DC. The cars resemble Bombardier's Saarbrücken design, in that the outer sections rest on the centre module, which runs on two bogies. Both outer sections have partial low-floors (Fig 1).

The welded steel car is 36·5 m long and 2 550 mm wide, running on bogies with a 2 m wheelbase and wheels of 720 and 660 mm diameter. Designed for a buffing load of 600 kN, the car weighs 57·5 tonnes (or 617 kg/m²), and is powered by 120 kW motors, which give a ratio of 14 kW/t; three of the four bogies are motored. There will be 99 seats and space for 204, with a pair of

Interior of the Bombardier Swift K car for Minneapolis, looking from the low-floor section to the high-floor area at the car end

Table IV. System tram cars ordered up to April 15 2004

System	Type	Firm orders	Gauge mm	Length m	Width mm	% low floor	Power kW	Delivery date
Alstom	**Citadis**	**501**						
Montpellier	401	30	1 435	40·9 B	2 650	70	(1)	1999-02
Orléans	301	22	1 435	29·9 B	2 320	70	4x140	2000-01
Dublin	301	26	1 435	29·7 B	2 400	70	4x140	2001-02
Dublin	401	14	1 435	40·9 B	2 400	70	(1)	2003
Lyon	302	47	1 435	32·4 B	2 400	100	4x120	2000-02
Melbourne	202A	36	1 435	22·7 B	2 650	100	4x100	2001-02
Bordeaux	402	56	1 435	43·9 B	2 400	100	6x120	2002-06
Bordeaux	302	14	1 435	32·8 B	2 400	100	4x120	2002-06
Rotterdam	302B	60	1 435	31·2	2 400	100	4x100	2002-04
Barcelona	302	37	1 435	32·5 B	2 650	100	4x120	2002-04
Paris	302	26	1 435	32·2 B	2 400	100	4x120	2002-04
La Rochelle	302	1	1 435	32·4 B	2 400	100	4x120	2001
Grenoble	402	35	1 435	43·7 B	2 400	100	6x120	2005-06
Mulhouse	302	20	1 435	32·5 B	2 650	100	4x120	2005
Valenciennes	302	21	1 435	33·2 B	2 400	100	4x120	2005
Strasbourg	402C	35	1 435	45·0	2 400	100	6x120	2005-06
Paris	402	21	1 435	40·0 B	2 650	100	6x120	2006
Alstom Ferroviaria	**Cityway**	**70**						
Torino	–	49	1 445	34·0 B	2 400	100	12x41	2002-03
Torino	–	6	1 445	34·0 B	2 400	100	12x41	2001
Messina	–	15	1 435	22·5 B	2 400	100	8x41	2002
Siemens	**Combino**	**481**						
Prototype	–	1	1 435	26·5 B	2 300	100	4x100	1996
Potsdam	–	16	1 435	30·5	2 300	100	4x100	1998-01
Augsburg	–	41	1 000	41·9	2 300	100	6x100	2000-04
Freiburg	–	18	1 000	42·0 B	2 300	100	6x100	1999-04
Basel	–	28	1 000	42·9	2 300	100	6x100	2000-02
Hiroshima	–	12	1 435	30·5 B	2 450	100	4x100	1999-02
Erfurt	–	7	1 000	30·5	2 300	100	4x100	2000
Erfurt	–	29	1 000	31·5	2 300	100	4x100	2002-05
Erfurt	–	12	1 000	20·0	2 300	100	2x100	2002-04
Nordhausen	–	2	1 000	19·1	2 300	100	4x100	2000-01
Nordhausen	–	2	1 000	20·0	2 300	100	4x100	2002-03
Nordhausen	–	3	1 000	20·0 B	2 300	100	4x100	2002
Nordhausen	–	3	1 000	20·0 B DE	2 300	100	4x100	2004
Amsterdam	–	151	1 435	29·2	2 400	100	4x100	2001-04
Amsterdam	–	4	1 435	29·2 B	2 400	100	4x100	2002
Melbourne	–	21	1 435	29·9 B	2 650	100	4x100	2002-04
Melbourne	–	38	1 435	20·0 B	2 650	100	4x100	2002-03
Bern	–	15	1 000	30·5	2 300	100	4x100	2002-04
Ulm	–	8	1 000	30·8	2 400	100	4x100	2003
Verona	–	22	1 435	20·0 B	2 300	100	4x100	2004
Poznan	–	14	1 435	29·2	2 400	100	4x100	2004
Tagus South	–	24	1 435	33·0 B	2 650	100	4x100	2005
Alacant	–	10	1 000	31·5 B	2 400	100	4x100	2005
AnsaldoBreda	**Sirio**	**226**						
Prototype	3C2	1	1 445	17·5	2 400	100	2x106	2002
Sassari	5C3	4	950	27·0 B	2 400	100	4x106	2002
Milano	7C4	58	1 445	35·0	2 400	100	4x106	2002-04
Napoli	3C2	22	1 445	18·5 B	2 400	100	4x106	2004
Milano	5C3	35	1 445	25·0	2 400	100	4x106	2004-05
Göteborg	5C3	60	1 435	29·4	2 650	100	4x106	2004-05
Athens	5C3	35	1 435	32·0	2 400	100	4x106	2004
Bergamo	5C3	14	1 435	29·8 B	2 400	100	4x106	2004
Firenze	5C3	17	1 435	31·7 B	2 400	100	4x106	2005
Bombardier	**Incentro**	**48**						
Nantes	AT5/6L	33	1 435	36·4 B	2 400	100	8x45	2000-01
Nottingham	AT5/6	15	1 435	33·0 B	2 400	100	8x45	2003
Bombardier	**LF 2000**	**136**						
Dessau	NGT6	10	1 435	21·0	2 300	45	4x85	2000-01
Dresden	NGT12DD	24	1 450	44·6	2 300	56	8x85	2003
Halle	NGT6	30	1 000	21·0	2 300	45	4x85	2003-05
Frankfurt/Main	NGT8 'S'	60	1 435	30·0 B	2 400	62	4x95	2003-04
Leipzig	NGTXXL	12	1 458	44·6	2 300	56	8x85	2005
Bombardier	**Cityrunner**	**121**						
Linz		21	900	40·0	2 300	62*	6x100	2001-04
Lodz		15	1 000	29·5	2 300	62*	4x100	2001-02
Eskesehir		18	1 000	29·5	2 300	62*	4x100	2004
Genève		21	1 000	42·0 B	2 300	62*	6x100	2004-05
Brussels		27	1 435	31·9 B	2 300	62*	4x100	2004-05
Brussels		19	1 435	43·2 B	2 300	62*	6x100	2005
Total		1 583						

1: 4 x 140 and 2 x 120 kW motors. B = Bi-directional
* ramped floors give these cars the impression of 100% low-floor.

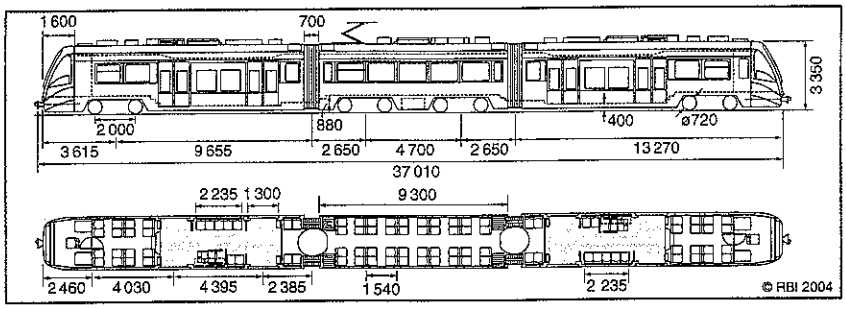
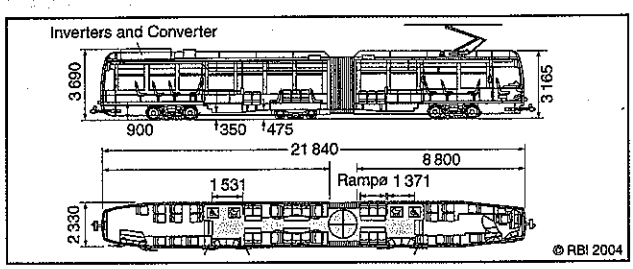


Fig 1. Alstom metre-gauge tram-train car for 750 V DC operation on the Alacant – Dénia line

1 300 mm wide doors on each side of the outer sections. Floor height at the entrances is 400 mm. The centre section and the areas above the outer bogies have a floor height of 800 mm. Top speed will be 100 km/h. The cars will be built in Spain, with IGBT inverter drives from Charleroi and motors from Ormans.

Stadler has delivered the first 600 V/ 1·2 kV DC Forchbahn cars (MR02 p54), which represent the firm's entry into the LRV market. The 24 m long 2 400 mm wide metre-gauge cars will run back-to-back in pairs. Wheels are 680 mm diameter, with Västerås supplying one inverter per driven bogie. With two 100 kW inverters from Traktionssysteme Austria per driven bogie, total rating for a train is 800 kW, or 11·5 kW/t. A pair of cars weighs 69·4 tonnes, or 602 kg/m²; top speed is 80 km/h, and the units have railway-style air brakes.

Fig 2. The two Leoliner part low-floor cars have been developed by the LFB joint venture between Siemens and LVB in Leipzig



Innovative venture

A new initiative emerged last year in Category B1, covering cars on bogies with small wheels. LFB, the joint venture of LVB and Siemens which runs the tram workshops in Leipzig, has built two articulated cars, similar to the original Vevey Genève Be4/6 cars of 1984-88.

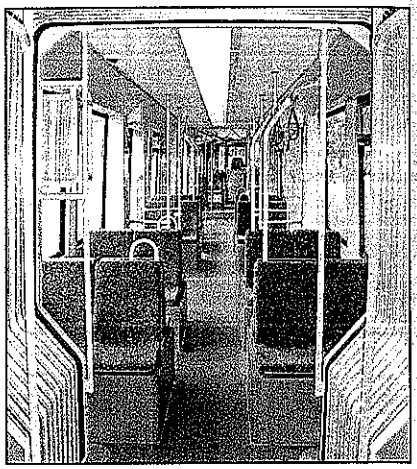
LVB had already modernised a number of its Tatra T4 car bogies with primary suspensions. LFB took two of these bogies, which have 700 mm diameter wheels on a 1 900 mm wheelbase, and increased the rating to 65 kW using VEM-built AC motors on each axle. A new centre bogie has been developed from the small-wheeled bogies used under LVB's 56 NGT8 cars and 38 trailers; this has a 1 600 mm wheelbase and 550 mm wheels.

The resulting uni-directional Leoliner (RG 1.04 p8) is 21·8 m long and 2 300 mm wide (Fig 2). The front section is carried on a motored bogie, and is articulated to the rear part which is supported by the small-wheel bogie and a second motored bogie (Bo'+ 2' Bo'). The two IGBT inverters and the static inverter have come from Vossloh Kiepe.

Floor height is 900 mm above the powered bogies, and 475 mm over the centre bogie, sloping down to 350 mm at the two 1 200 mm wide doorways. There are also high-floor entrances front and rear, 1 200 and 700 mm wide respectively. Three steps connect the 350 mm and 900 mm high areas. In total, 50% of the car length is low-floor. The weight is 27 tonnes or 537 kg/m².

Leoliner is intended as a lower-cost alternative in the 20 m length category, where low-floor cars are particularly expensive. It might interest cities which have a stock of good Tatra bogies, and thus might find buyers in Poland, where between 1979 and 2003 no fewer than 3 368 four-axle 105N and 805N cars with similar B3 bogies went into service.

The first car was unveiled in Leipzig on December 16 last year. If the initial tests are successful, LVB is looking at ordering between 26 and 52 Leoliners. The LFB board will have to decide this spring whether to built a new assembly hall for future production, although the LVB Managing Director says that three tram suppliers have shown interest in building Leoliners in partnership with LFB.



Interior of Bombardier's Classic LF 2000 bogie car for Frankfurt/Main, with four seats across a width of 2 400 mm

Category B2 covers cars with driven bogies and articulated intermediate section(s) running on trucks with individual wheels. Delivery of the Kinki Sharyo/Alstom low-floor cars to VTA San José has begun, releasing 29 high-floor cars from 1986-87 which have been sold to Salt Lake City for US$652 000 each (p38). The new light rail line in Houston, which opened on January 1, will have a fleet of 18 Avanto S70s from Siemens (RG 10.03 p618).

The 15 Avanto cars ordered by SNCF for the Aulnay – Bondy line east of Paris (p15) are also taking shape. These have corrugated articulations developed by Hübner, and a front end with retractable automatic couplers supplied by Scharfenberg as a complete module. Final erection will take place at Lohr Industrie in Duppigheim, France. In this case, Siemens is effectively acting as project manager, assembling parts fabricated elsewhere.

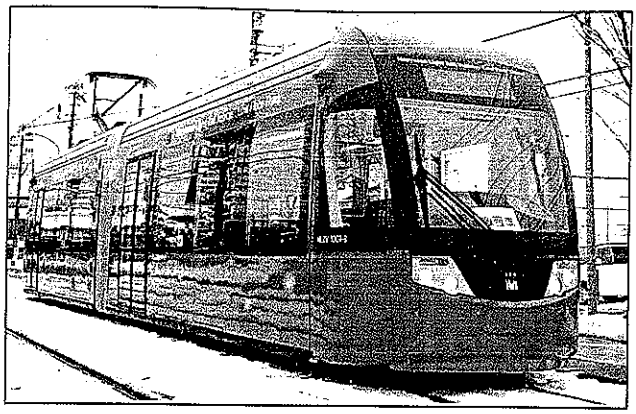
Minneapolis has started taking delivery of its 24 US/Mexican built Swift cars from Bombardier (p28). This is a heavier version of the K4000 (Swift K) family already running in Köln, Stockholm, Istanbul and Croydon.

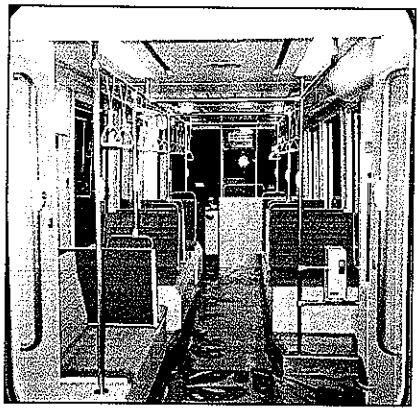
The largest order in Germany went to

Table IVb. System middle and low-floor LRVs ordered up to April 15 2004

System	Type	Firm orders	Gauge mm	Length m	Width mm	% low floor	Power kW	Delivery date
Bombardier	K Type	83						
Stockholm	A 32	22	1 435	29·7 B	2 650	65	4x120	1999-03
Den Haag	A 32	6	1 435	29·7 B	2 650	65	4x120	2003
Istanbul		55	1 435	29·7 B	2 650	65	4x110	2003-04
Siemens	Avanto	44						
Houston	S70	18	1 435	29·4 B	2 650	60	4x140	2003
San Diego	S70	11	1 435	26·4 B	2 650	60	4x140	2004
SNCF	25 kV AC/ 750 V DC	15	1 435	36·4 B	2 650	70	4x160	2004
Alstom	RegioCitadis	37						
Kassel	15kV/600V	18	1 435	36·5 B	2 650	67	4x150	2004-05
Kassel	DE/600V	10	1 435	36·5 B	2 650	67	4x150	2004-05
Alacant	Tram-train	9	1 000	37·0 B	2 550	n/a	6x140	2005
Total		164						

B: Bi-directional cars. DE: supplementary diesel-electric drive
1: For use on Rijn-Gouwe pilot line between Gouda and Alphen





The Bombardier/ Niigata GT4N-K Minicentro for Takaoka (left) has a much simpler interior (right) than the earlier Momo version in Okayama (MR 03 p59)

Bombardier/Kiepe, with Köln ordering 69 K4500 cars (Fig 3), a middle-floor derivative of the K5000 (MR03 p61). This is a completely new air-conditioned car; it looks like a K4000, with which it is able to work in multiple, but all the detail dimensions are different.

Köln's experience with the K5000 has blown away the illusion, once widely-propagated, that you could get a pre-tested car from Wien or Wildenrath and simply drive it away. Thus KVB has arranged for a pre-series delivery of five K4500 cars, which will be thoroughly tested before the remainder are delivered.

Dortmund invited offers for more Stadtbahn B cars, but did not find the bids acceptable. Instead, it has bought 15 older cars from Bonn, built in 1975 and now replaced by K5000s (RG 8.03 p482). Ready for service, the reconditioned B cars will cost just €600 000 each.

Late last year Valley Metro Rail in Phoenix selected Kinki Sharyo to supply 36 part-low-floor LRVs with options for 39, whilst Seattle's Sound Transit has gone to the same builder for 31 cars and an option for 31 (RG 1.04 p8). Basically similar to the new San José cars, they will be built in Japan and assembled locally in Arizona and Washington to meet Buy America rules. These orders reinforce the dominant position that Kinki Sharyo has now built up, with a total of 246 low-floor LRVs. Charlotte, North Carolina, has selected Siemens as its preferred supplier for a fleet of 16 Avanto part low-floor cars, with an option for a further 25. These cars will be 27·8 m long and 2 650 mm wide, weighing 44·2 tonnes (613 kg/m²) and cost US$3·3m each, or US$36 474/m².

Multi-articulated cars

Category B2A covers multi-articulated cars running on trucks with medium-height floors above the driven trucks and low-floors above the non-driven trucks. So far De Lijn has ordered 39 cars from Siemens and Bombardier, well on the way to the total of 47 cars planned for the second batch. An extra 10 cars have been ordered to cope with anticipated traffic levels during reconstruction of the Antwerpen ring road.

Delivery of the different Variotrams for the four Rhein-Neckar operators (Mannheim, Ludwigshafen, Heidelberg, and OEG) has been completed (RG 11.02 p671). These cars have good riding qualities and are relatively quiet.

In Category B8, Bombardier Bautzen has sold 252 laser-cut, spot-welded, corrosion-resistant steel cars, of which 136 can be characterised as system cars. Kassel has taken delivery of 22 uni-directional and 10 bi-directional cars, whilst Essen has 34 and Schwerin 30; another 20 will be delivered to Bremen. Bombardier now calls these its 'Classic' design. The LF2000 system car has won orders from Dessau (10), Halle (30), Dresden (24), Leipzig (12) and Frankfurt (60). To this can be added 26 similar cars for Krakow in Category B2.

At 44·57 m, the Dresden and Leipzig cars are the longest in operation at present (p5). The vehicle is in fact a longer version of the Cobra using bogies rather than trucks. Three sections are carried on bogies, of which two are driven, connected by wheel-less sections and Hübner double corrugated bellows, standard for the LF2000 family.

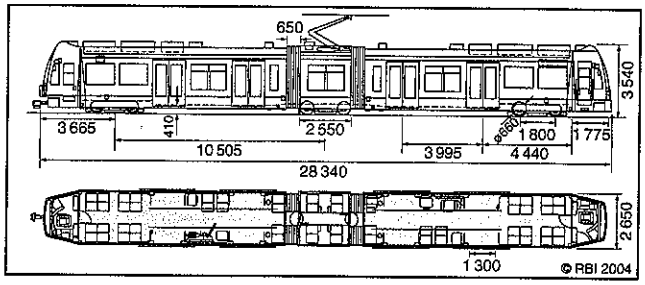


Fig 3. The K4500 to be delivered to KVB by Bombardier and Vossloh Kiepe has conventional axles in the truck under the central articulation

Dresden's DD12 follows the pattern created by DVB for its earlier DD6 and DD8 cars in Category B2A. The car has a floor height of 365 mm at the entrances, and in the middle car and wheel-less parts, with a 598 mm height above the driven bogies. Five 1 400 mm wide doors give a door width to car length ratio of 155 mm/m. Bogie wheelbase is 1 800 mm, and the wheels are 600 or 520 mm diameter.

The eight fully-suspended 85 kW motors are fed by two air-cooled Duo-inverters, each inverter feeding two motors in one bogie. The force-ventilated car has Mitrac controls and is equipped with a FAGA static inverter. There are 107 seats and space for 153 standees at 4/m². The DD12 has excellent riding qualities and is reasonably quiet. The similar Leipzig XXL car is only 2 200 mm wide at the entrances, to suit the existing platforms.

The last 12 months also saw the start of delivery of the 60 eight-axle cars for Frankfurt/Main (RG 11.03 p690). This is a further and more luxurious

Table V. Published prices of tram and LRV orders placed in 2003-04

System	Type	Orders + options		Length m	Width mm	Price per car	Price per m²
Trams							
Paris	Citadis 402	21	49	40·0 B	2 650	€2·58m	€24 393
Zürich	Cobra	68	22	35·9	2 400	€2·23m	€25 922
Strasbourg	Citadis 402C	32	12	45·0 B	2 400	€2·81m	€26 007
Brussels	Cityrunner	19	10	43·2 B	2 300	€2·08m	€20 096
Brussels	Cityrunner	27	10	31·9 B	2 300	€2·4m	€20 206
Düsseldorf	NF8 *	15	61	30·0 B	2 400	€2·07m	€20 703
Budapest	NF12	40	0	53·0	2 400	€3·76m	€29 404
Leipzig	NGTXXL	12	12	44·6	2 300	€3·33m	€32 617
Alacant	Combino	10		31·5 B	2 400	€2·7m	€35 715
Sevilla	CAF/Elin car	17		31·3	2 660	€2·74m	€33 031
LRVs							
Karlsruhe	GT6-70D/N	15		20·7	2 650	€2·03m	€26 736
Los Angeles	P 2550	50	100	27·0 B	2 660	$1·0m	$41 020
Phoenix		36	39	27·4 B	2 660	$1·19m	$43 088
Seattle		31	31	29·0 B	2 660	$1·6m	$46 060
Alacant	Tram-Train	9		37·0 B	2 660	€4·1m	€54 603

B. Bi-directional car

Barcelona has started test running with its first 2 650 mm wide Alstom Citadis 302 cars for the TramBaix project. Interior height inside the articulation is 2 010 mm (below left)

development of the Kassel car, albeit with only three passenger doors, equivalent to 152 mm/m. The car is fully air-conditioned, and has double-glazed windows plus a satellite-based information system. It is 30·3 m long and 2 400 mm wide. Floor height is 370 mm between the doors and 580 mm above the driven bogies.

The four 100 kW motors come from VEM, and are fed by two Duo-inverters, with each inverter feeding a single motor. Transtechnik supplied the two static inverters for the auxiliaries. As with the Dresden cars, the noise level on good ballasted flat-bottomed track did not exceed 71 dB(A) at 70 km/h.

These bogie vehicles represent an important segment in the market. More and more customers are not convinced by the curving qualities of multi-articulated 100% low-floor cars. For them the LF2000 offers a welcome alternative, with riding qualities as good as a classic tram.

All low-floor cars

So far 461 GTxN cars have been built to the MAN (now Bombardier) design, of which one was destroyed by an accident in Augsburg. In Japan, the 1 067 mm gauge network in Takaoka has signed a deal with Niigata Engineering for six GT4N-K 'Mini-centros', bringing the class total to 466.

They will be similar to the Momo car delivered to Okayama (MR03 p59) but with a less luxurious interior. The first was delivered in December 2003. Three cars will use parts that Bombardier supplied to Niigata for more Okayama cars; this potential purchase has been cut to two. Kumamoto is interested in buying two GT4Ns, and another Japanese town might order seven more GT4N-Ks from Niigata.

München is considering buying between three and 19 more cars (GT8N-2). If ordered, these would be built at Bautzen with Siegen trucks.

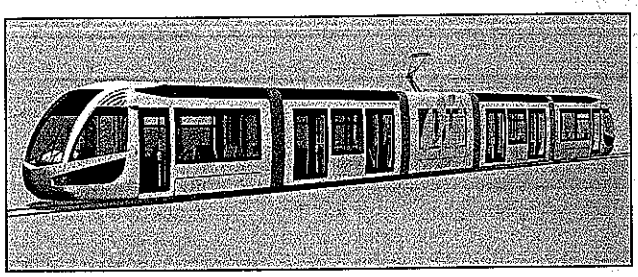
The Siemens-Kiepe NF series of cars for the Rheinbahn in Düsseldorf continues to evolve. Jokingly known as the 'Felzino' after the Rheinbahn Managing Director Dr H Felz, the 2 400 mm wide aluminium car has an Alcan alu-grip body with tapered sidewalls and small-wheeled end bogies, running on Combino trucks, of which two are motored. After receiving 36 NF10 and 15 NF8 cars instead of the 86 originally planned, Rheinbahn has now ordered 15 bi-directional NF8s. Suitable for tunnel use and fitted with Albert couplings for multiple operation, these will form the first part of a planned fleet of 76 cars.

BKV of Budapest has ordered 40 NF12s, which at 53 m will be the longest trams ever built. They will have a 2' Bo 2 Bo Bo 2' wheel arrangement, but no dimensions are available, even six months after the order was placed.

On July 16 last year, VBZ of Zürich confirmed its order for a further 68 Cobra cars from Bombardier and Alstom Transport, based on experience with six prototypes. The deal was finally signed on October 1, but the price originally agreed in 1996 could not be held. It was increased by 10% to SFr3·4m per car, but the suppliers said they expected to make no profit at the higher level. Out of the SFr233m total, Bombardier will get SFr190m and Alstom the rest for the bogies. The cars will be delivered between 2005 and 2009.

It seems unlikely that anyone else will order further Cobras, apart perhaps from Verkehrsbetriebe Glatttal, which will connect with VBZ at Oerlikon. Since 1996 all the other large metre-gauge operators have selected their preferred designs. The Zürich procurement was accelerated in 1999 when Adtranz threatened to close Pratteln works, and VBZ increased its commitment from six cars and an option for 11 to a total of 75. Of these, 63 were ordered in one batch in an effort to keep Pratteln open. Ironically, Bombardier has now confirmed its intention to close the plant by the end of 2005; the cars will be assembled at Villeneuve instead.

After delivering a handful of 70% low-floor trams, CAF has now entered the 100% market, with an order for 17 cars from Sevilla Metro. These bi-directional cars will be 31·2 m long and 2 650 mm wide (Fig 4), with a floor height of 350 mm, dropping to 300 mm at the entrances. The underframes will be assembled from corten steel, and the walls and roof from stainless steel.



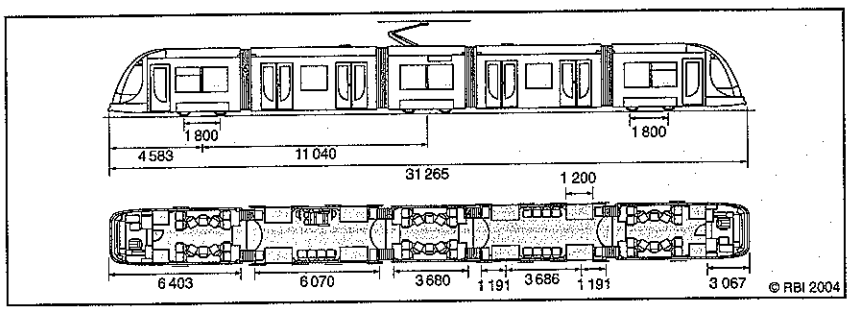
Alstom is supplying a variant of its Citadis 302 design for use in Valenciennes

With a wheelbase of 1 800 mm and 590 mm diameter wheels, the end trucks will be driven by two double motors arranged longitudinally in a common housing suspended from the frame. Each 70 kW motor drives a single wheel via a conical hypoid gear. The frame has a rubber/steel primary suspension and a steel coil secondary, and all wheels are fitted with brake discs. An Elin Duo-inverter will feed the two motors on one side of one truck. Two auxiliary converters rated at 64 kVA will feed the air-conditioning, which demands 2 x 39 kW plus 4·7 kW for each cab. The cars will carry 54 seated and 146 standing passengers. Maximum axleload is 12 tonnes.

Citadis heads the system cars

Alstom Transport's Citadis family has become the leading system car, with sales and firm orders now totalling 521 vehicles. As this issue went to press,

Fig 4. CAF's entry into the 100% low-floor market is a 31·3 m car for the Sevilla metro



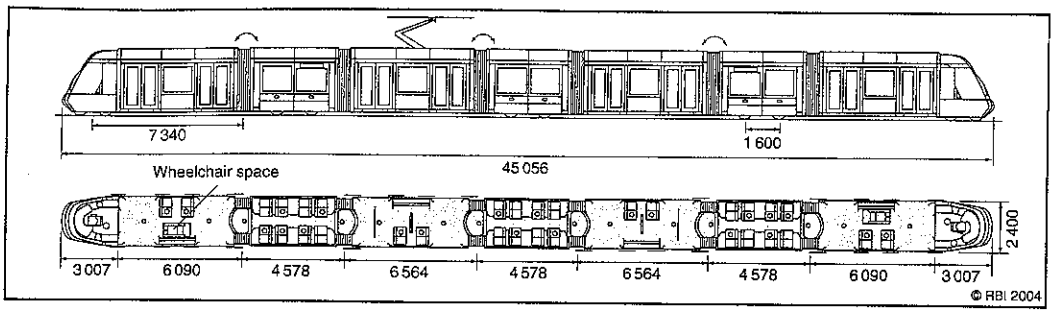


Fig 5. Alstom's Citadis 402C for Strasbourg is a variation of the standard design with new double-door end modules running on small-wheeled bogies

Alstom announced that Tenerife had ordered 20 Citadis 302 cars for €50m, which are not included in the tables.

In the past year Alstom has won an order from RATP for 21 Citadis 402 cars, 2 650 mm wide, as part of a deal covering 70 cars for new tram lines around Paris. Valenciennes increased its order for 2 400 mm wide cars by four, switching from 17 Citadis 301s to 21 Citadis 302s which are 4 m longer. And CTS of Strasbourg has ordered 35 cars to a new model designated 402C.

There is no further official news about the tentative order from Jerusalem announced in December 2002 for 69 Citadis 202A cars, identical to Melbourne's 22·5 m cars.

The Citadis all low-floor trams, designed for a buff load of 200 kN, can be split into four basic models.

• The 302 and 402 cars now total 280, of both 2 400 and 2 650 mm width. They ride on three or four Arpège trucks without primary suspensions, with 590 mm diameter wheels and a 1 600 mm wheelbase, powered by 120 kW motors. Floor height is 350 mm. The 26 Citadis 302 cars for RATP have a buff load of 400 kN.

• There are 36 Citadis 202A cars for Melbourne's Yarra Trams. These 2 650 mm wide cars with straight sides ride on two 1 850 mm wheelbase Solfège trucks with primary suspensions and 610 mm diameter wheels powered by 105 kW motors. Floor height is 360 mm.

• The Citadis 302B cars are 2 400 mm wide with straight sides. They run on three 1 870 mm wheelbase Corrège trucks with 610 mm diameter wheels. Electrical control is arranged by side, with 100 kW motors driving the outer wheelsets longitudinally. Floor height is again 360 mm. Orders from Rotterdam have brought this series to 60 cars.

• The new 402C design for Strasbourg will be 45 m long and 2 400 mm wide (Fig 5), inspired by the Felzino NF cars. It is in many respects a classic five-module Citadis 402 car with 6 x 120 kW motors. But the wheel arrangement is 2' Bo Bo Bo 2', with the two new end modules running on small-wheeled bogies, almost identical to the Magdeburg design. Wheelbase of the end bogie is 1 200 mm, and the wheels are 410 mm diameter. The car is designed to carry 76 seated and 224 standing passengers.

Alstom initially offered its Italian Cityway design for Strasbourg, but then discovered that the city's politicians liked the NF model and the proposal was adapted accordingly.

Of the 501 Citadis cars ordered, 92 in Montpellier, Orléans and Dublin are of type 301/401. Another 313 are of the 302/402 family running on Arpège articulated bogies with no primary suspension apart from the resilient wheels. This combination requires perfectly round wheels, softly supported track, and optimal grinding of the rails. Lyon was the first city to adopt Citadis 302s, and no complaints have been heard so far.

Bordeaux is the second city to choose the 302, but here there is the complication of the APS third-rail current collection (RG 2.04 p.87). Given the fact that French overhead wiring is generally very light, due to the high number of substations, it seems regrettable that such a complex system has been adopted. Teething troubles are as expected – trams running onto third rail sections with their pantographs up, objects caught under the trams short-circuiting the third rail, and now all 981 contact switch boxes have to be replaced, delaying the opening of Lines B and C. It may be that Bombardier's experiments with supercapacitors (RG 11.03 p744) might be a better way to bridge short gaps in the overhead wires.

Indeed, when Nice announced on March 14 that it proposed to order 20 Citadis 302 cars for €2·85m each, it said they would have high-capacity nickel-hydride batteries for use in Garibaldi and Messina squares, where there will be no overhead wires, rather than install APS.

Barcelona has now started test running with its first Citadis 302 cars. Rotterdam's first Citadis 302B was delivered on November 15 2002, and five were officially put into service on August 25 the following year. The cars have been well received by the public. One car will eventually be equipped with a CCM flywheel to save energy.

Combino deliveries continue

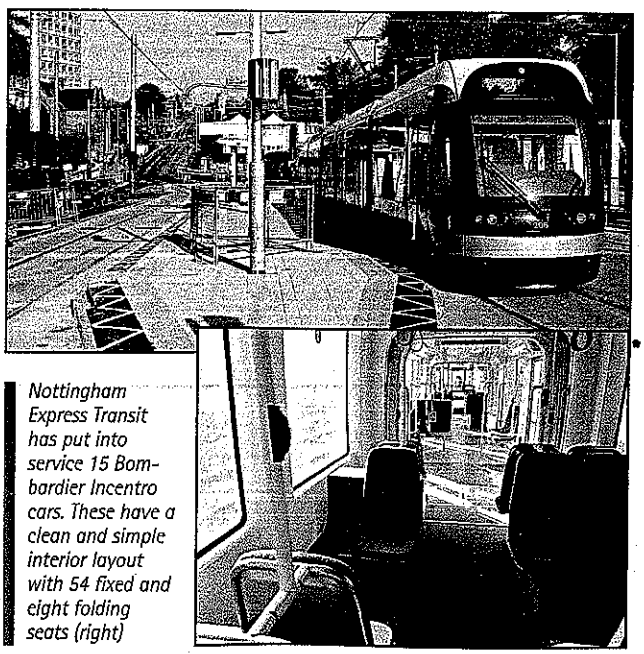
Despite the latest technical problems (p60), Siemens has received firm orders for 481 Combinos and 106 NF cars, totalling 587 cars of which well over 400 have been delivered. The latest order from FGV is for 10 cars destined for the new tram system in Alacant. Delivery of five-module cars for Melbourne has started. And well over 100 Combinos are now in service in Amsterdam, allowing massive withdrawals of the Schindler cars from the early 1960s.

Ulm has received its eight Combinos and converted completely to low-floor operation (RG 7.03 p418). One of Nordhausen's cars was used for demonstrations in Gmunden, Austria, and a three-module Melbourne car was briefly shown in Kaohsiung, Taiwan (RG 2.04 p70). In May 2004, three hybrid three-module Combinos equipped with a diesel generator will enter service in Nordhausen (MR02 p59). They have received EBA approval to operate through services over the HSB line to Ilfeld.

Bombardier variety

Now known as the Outlook C series, Cityrunner was developed by Bombardier Austria, which at the time owned 26% of ELIN EBG Traction. The 2 300 mm wide Austrian system car was designed to provide a low-floor car with conventional axles. The first order was for 21 cars of 40 m for the 900 mm gauge network in Linz (MR02 p55), followed by 15 metre-gauge 30 m cars from Lodz; these are all in service.

The next delivery will be 18 cars for Eskisehir in Turkey, which are nearly identical to the Lodz design but have



Nottingham Express Transit has put into service 15 Bombardier Incentro cars. These have a clean and simple interior layout with 54 fixed and eight folding seats (right)

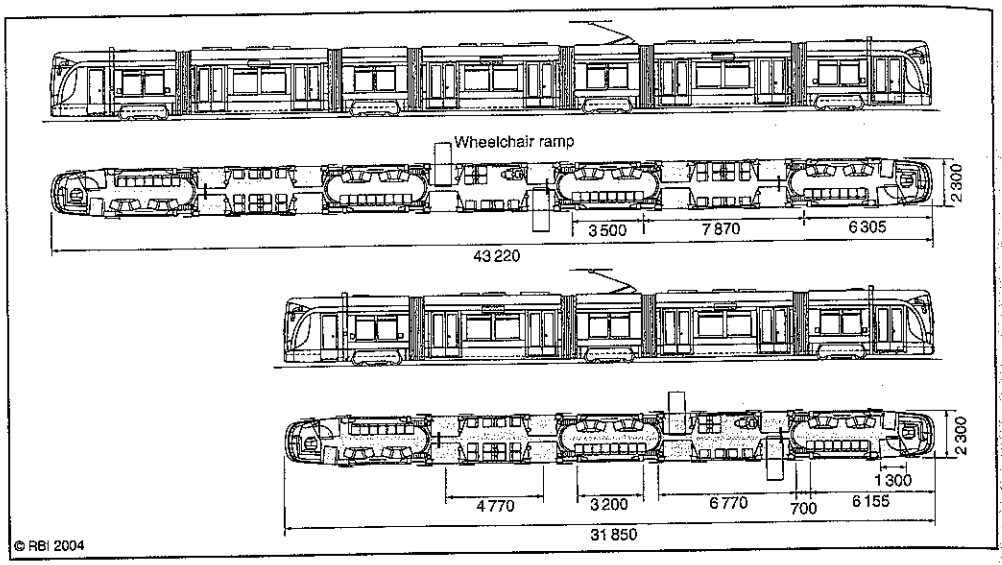


Fig 7. Brussels has ordered two versions of the Bombardier Cityrunner (Outlook C Series)

Bombardier air-cooled traction equipment from Mannheim and VEM motors. They have been tested for a buff load of 400 kN. The first car has run trials on OEG tracks between Mannheim and Edingen, and the ride quality at 70 km/h was very good. At that speed on ballasted flat-bottomed track the interior noise level did not exceed 71 dB(A). The Hübner double-corrugated bellows help. The excellent primary suspension and silent running of the non-driven bogie give the car the performance quality on straight track of a classic bogie car. Total weight is 34 tonnes or 501 kg/m².

TPG of Genève, which has ordered 21 bi-directional cars, 42 m long, hired two 30 m cars from Lodz to help ease capacity problems, whilst gaining experience with the Cityrunner design at the same time. Another success for Bombardier is the order from Brussels (RG 12.03 p771), covering two batches of bi-directional cars (Fig 7). There will be 27 T3000 cars of 31·8 m, weighing 37·9 tonnes and 19 cars of 43·m weighing 51·1 tonnes; both designs work out at 518 kg/m².

Nantes has exercised part of its option for further Incentro cars, ordering 10 cars to be built at Bautzen, Siegen and Mannheim. With the original order for 23 and 15 cars in Nottingham, this brings the Incentro fleet to 48.

March 9 saw the start of revenue service in Nottingham, after a long period of test running and driver training during which the attractive trams showed their excellent riding characteristics. The 2 400 mm wide cars

Combino in trouble

WITH THE mileage operated by its Combino cars increasing, Siemens has unhappily run into unexpected problems with torsion resistance of the bolted aluminium bodyshells. There are now more than 400 Combinos and NF8 and NF10 cars with similar bodies in service, so structural changes to these cars are likely to mean high costs.

The problem was officially announced at the end of the quarter to December 31 2003, when it was revealed that Siemens Transportation Systems' profits had fallen from €68m in 2002 to €32m in 2003. Siemens warned that the problem could lead to further financial charges in the coming quarters, and with a subsequent announcement in mid-March (RG 4.04 p186) leading to the complete withdrawal of all cars that had run more than 120 000 km, the final cost could well exceed €200m.

The problem appears to have arisen from the greater length of the car bodies and distance between the trucks. In a classic high-floor tram, the bodies are around 14 m long and the spacing between bogie centres is typically between 6·2 and 6·4 m. Articulated cars with shared bogies maintained this spacing, so for a 25 m car the three bogies were 6·2 m apart, leaving a 3 m overhang at each end. In the 27 m long Stadtbahn B the distance between bogie centres was 10 m. Only small torsion forces were transmitted from one bodyshell to the other.

Multi-articulated cars like Variotram, Citadis 302/402, Sirio and Combino are very different. As Fig 6 shows, in a 31 m Combino car Part I (TM1 + S1 + LM) has a length of 17·5 m resting on two trucks. The distance between the truck centres is 11·4 m. The lower articulation bearings are of the ball-type, whilst the upper bearings allow movements around the vertical axis. Hung to this is Part II (S2 + TM2), 13·5 m long, resting on one truck. Between S2 and TM2 the articulation is the same as between the other sections, but between S2 and LM there is an articulation that allows movements in the vertical and transverse directions. The articulations are solid structures.

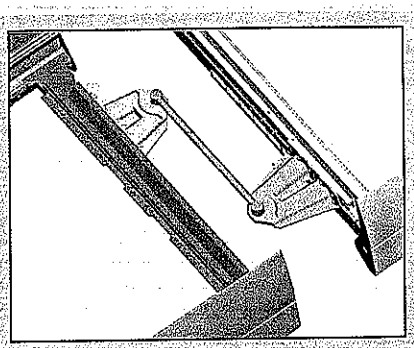
It appears that the torsion forces that this design generates in S-curves are much higher than anticipated, and cause cracks in the square profiles around the articulations. Some bolts have also been damaged. The problem initially appeared on a 42·8 m long car in Basel, and then on other 42 m cars, but only sporadically on the 30 m cars.

In Amsterdam, where the Combinos are operating at speed around many curves, the forces that are produced in the linkages between the truck and the car body are much greater than anticipated, certainly in the rear truck, 28 m from the driver. This is leading to damage at the linkage bearings.

A Freiburg car which had operated for over 200 000 km was taken to the Siemens works in Praha to be dismantled and studied intensively, in order to develop a programme for reinforcing the car bodies where necessary. The upper bearings in the vertical articulations will be strengthened, and a damper will be added to the two-axis bearings to reduce the torsion forces.

As many cars from other suppliers have the same basic configuration, the question arises as to whether similar problems occur with steel bodies. In 1994-95 Duewag delivered 69 steel-bodied cars to the Rhein-Neckar companies, 28 and 38 m long, plus 60 NGT6 cars for Dresden. No problems of this magnitude arose, but in all these cars, as with all designs from other manufacturers, hydraulic dampers are fitted between the car modules, which is not the case with Combino.

It seems clear that this sad development will have severe financial consequences, but Siemens' corporate financial strength should allow it to clear the matter up once and for all. ■



The Combino articulation linkages allow movements in the vertical and transverse directions. The fixed horizontal link (brown) will be replaced by a damper

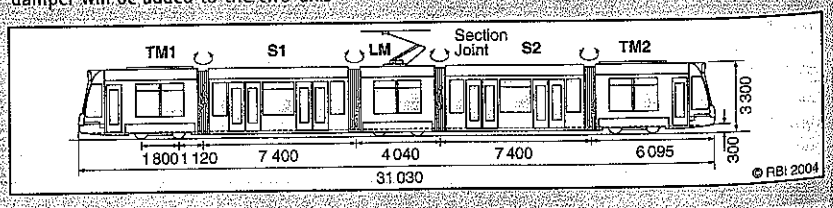


Fig 6. Standard configuration of articulations for a typical 31·2 m Combino Mk II car

are in principle identical to those in Nantes, but the wheel-less sections are 1 700 mm shorter, giving an overall length of 33 m. The drive gears come from Flender; the conical gear now drives the wheel, and the plain gear provides the intermediate link between motor and conical gear.

The Nottingham cars have 54 fixed and eight folding seats, plus space for 143 standees at 4/m². Total weight is 39·2 tonnes, or 495 kg/m². The bodies come from Amadora, bogies from Siegen, traction motors from Wiener Neudorf, and the inverters from Mannheim, with final assembly at Derby.

China's Changchun Railway Vehicles Co has ordered 360 Incentro trucks from Siegen for €37m. These will be used under 120 low-floor cars of Changchun's own design, being built for new tram networks in Changchun and Tianjin. Bombardier's Mannheim plant will supply electrical equipment for 20 cars, and the rest will come from a joint venture between Bombardier and local Chinese partners. The cast steel frame truck is particularly suited for rough conditions and for 2 650 m wide cars. Delivery of European trucks for locally-designed cars is a very interesting 'first'.

Sirio deliveries steady

AnsaldoBreda has now received orders for a total of 225 Sirio cars (Fig 8). Top priority at present is to deliver the 35 cars for the Athens network (RG 9.03 p532), as these must be in service this summer in time for the Olympic Games! This has delayed other deliveries, including the 40 cars destined to replace older vehicles in Göteborg.

All other orders are for Italian cities, including two of the big existing networks. Milano has bought batches of 58 long and 35 short cars (RG 2.04 p66), and Napoli is getting 22. The first of the shorter cars for Milano have started to arrive. Sirio will also be used on three new systems: Sassari (4), Bergamo (14) and Firenze (17). The prototype is now being tested in Napoli in conjunction with Ansaldo's STREAM third-rail current collection system.

Sirio exhibits a high degree of modularity. All cars have single end doors with the exception of Göteborg. Firenze and Athens have two pairs of doors in the wheel-less modules, and the others one set.

SIRIO

225 Vehicles Under Construction
(327 including contractual options)

Delivery			
2003	2-Bo 19,45 m x 2,3 m Passengers 114 (@4p/m²)	**Naples**	**22**
2003	Bo-2-Bo 24,65 m x 2,4 m Passengers 150 (@4p/m²)	**Milan 2**	**35**
2002	Bo-2-Bo 27,12 m x 2,4 m Passengers 151 (@4p/m²)	**Sassari**	**4**
2003	Bo-2-Bo 29,35 m x 2,65 m Passengers 189 (@4p/m²)	**Göteborg**	**40**
2004	Bo-2-Bo 32,0 m x 2,4 m Passengers 221 (@4p/m²)	**Bergamo**	**14**
2005	Bo-2-Bo 31,9 m x 2,4 m Passengers 177 (@4p/m²)	**Florence**	**17**
2003	Bo-2-Bo 32,3 m x 2,4 m Passengers 185 (@4p/m²)	**Athens**	**35**
2002	Bo-2-2-Bo 35,35 m x 2,4 m Passengers 213 (@4p/m²)	**Milan 1**	**58**

Fig 8. Overview of the various orders for AnsaldoBreda's modular Sirio system car

Outlook remains unclear

What will the future bring? It is more and more difficult to believe that it will be possible to maintain a production level of 500 vehicles per year. One of the biggest changes is that the German *Länder* will stop subsidising the purchase of trams. At present, these subsidies vary from 50% to 85%, but in future the operators will be confronted with the full prices for the first time. Similarly, the French government is planning to stop awarding grants for the construction of new light rail networks.

Possible orders may come from Dortmund and Bochum, which want to begin replacing their Stadtbahn M and N cars that are now over 25 years old. The Rhein Neckar tram operators are happy with their new Variotrams, but will they be able to find the funds to purchase the rest of their options for 54 cars? Currently MVV is expected to buy nine, OEG 10 and Heidelberg eight to 12.

Will Wien continue to order ULFs, and will Innsbruck convert its heavily-used trolleybus lines to trams and replace its old Duewag cars? How about the planned new Italian networks? Frankfurt is planning new high-floor LRVs to replace its U2 cars, and Stuttgart wants to increase its fleet of DT cars to operate new extensions.

A number of new tram networks are expected to open in the foreseeable future for which no rolling stock has yet been ordered. These include Glatttal in Switzerland, Marseille, Le Mans, Angers, Palermo and Jerusalem. Planned extensions in Montpellier, Lyon and Bern might also require extra stock.

New light rail lines likely to open in the next few years include the RandstadRail conversion of the Zoetermeer line, and the Rijn-Gouwe line to Leiden in the Netherlands, Tel Aviv, and Leeds and Portsmouth in the UK. The 'big-bang' extensions in Manchester are likely to require more than 50 new cars, and Saarbrücken wants to buy another 16. Tram-train routes are seriously planned in Strasbourg, Mulhouse, Luxembourg, Rostock, Braunschweig and Grenoble.

It looks as if orders might come, but probably much later than expected. But the market for Western suppliers is likely to be further eroded by innovations such as Leoliner, and other locally-manufactured vehicles may also emerge, such as the 70 Djuro Djakovic cars being built for Zagreb in Croatia. ■

A 30 m Bombardier Cityrunner for Eskisehir being tested on OEG's Edingen – Mannheim line

Interior of the AnsaldoBreda Sirio car being delivered to Athens