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Dynamics of LRT growth: Karlsruhe since 1975

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The public transport system of Karlsruhe, in particular its innovative services on jointly used heavy rail lines, has received substantial attention throughout the past 20 years. The discussion of the system and of its development has been rather limited in the past, mostly highlighting technical aspects. This paper provides an overview of the development, including the urban development, of the region and of the funding system. The ridership and financial development of the operator is documented in detail. Three case studies focus on the integration of the system development in the general political process of the region and demonstrate the limitations of the operator under its current ownership structures.

1. Introduction

Transport planners, in particular European ones, consider the city of Karlsruhe and its public transport system as an example of things done correctly, a nearly unqualified success story (Wyse 1990, Griffin 1992, Drechsler 1996). The purpose of this paper is to balance these accounts with one that addresses both the overall context of the developments in Karlsruhe as well as the development of the public transport system, including its ridership and financial development.

The structure is as follows. The next section briefly describes the structure of the city. It is followed by a description of the national/regional-funding framework under which the system has developed. The main section summarizes the development path of the system, which is supplemented by three particular project histories in the following section. The final section looks forward and discusses in particular both the challenges of the Regionalisierung of regional/suburban rail services and of the international possibilities for the concepts developed in Karlsruhe.

2. The city

The metropolitan area of Karlsruhe has today ~550 000 inhabitants (metropolitan area: at least 50% of commuters work in the core area; core area: daytime density ~500 persons/km^2 or more inbound than outbound commuters), of which the core contributes 350 000 and city proper 275 000 inhabitants (Stadt Karlsruhe 1995) (figure 1). This catchment area has not changed dramatically over the past 50 years (Christaller 1933). The population distribution follows the expected patterns of post-war development. The city was reconstructed after the Second World War following the original structure mainly along the east–west axis, which was supplemented with new developments to the north and south, both of public housing and single-family

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residences. In the early 1970s suburban growth started in earnest with the attendant losses of residential population in the core areas (figure 2). The growth continues in the suburban areas, while the city has been able to balance most of the recent population

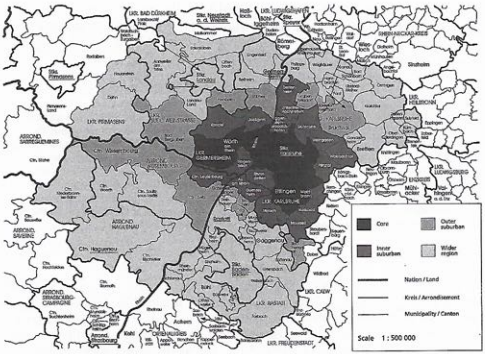

Figure 1. Metropolitan area of Karlsruhe, 1995. [*Source*: Stadt Karlsruhe (1995) p. 17.]

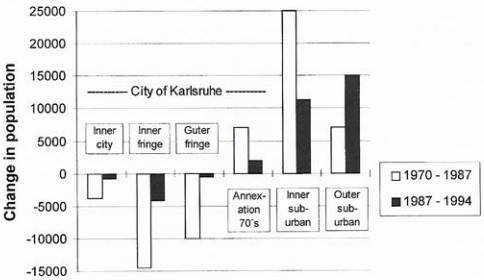

Figure 2. Population development in the Karlsruhe metropolitan area, 1970–94. [*Source*: Stadt Karlsruhe (1995) p. 27.]

losses through the massive immigration of the early 1990s (East Germans, Germans from the former Warsaw-Pact countries, refugees from the former Yugoslavia, etc.).

This overall distribution of change describes the typical situation of a metropolitan core city that needs to maintain its catchment area and to stifle or slow down the development of competing regional shopping/entertainment centres that could draw on the dispersed population of the outer ring. This is particularly urgent in Karlsruhe given its already small catchment area due to the vicinity of competing centres of equal rank (Mannheim/Heidelberg 60 km, Stuttgart 90 km and Strasbourg 90 km) and of lower rank (Pforzheim 30 km, Offenburg 80 km) (Christaller 1933). The public transport policy is part of these attempts.

3. Funding rules

Major transport infrastructures in German cities are funded on a matching grant basis involving the Bund (federal government), the federal Land and the municipality with funds mainly raised through a dedicated levy (0.054 DM/litre), which is part of the national fuel excise tax. The law regulating the fundable types of investment, the Gemeindeverkehrsfinanzierungsgesetz (GVFG), has been amended a number of times since it was first passed in 1971 (Muthesius 1994).

The municipalities can fund both public transport and road construction with these funds, which are channelled through the Länder, with each Land receiving a share of the total according to formula, while the federal government retains a share for large projects. Within each Land the projects are ranked according to cost–benefit criteria, which are calculated according to different guidelines for road and public transport projects. The funds available can only be used if the city can provide the matching funds. It is therefore crucial for a city always to have projects submitted in the hope that higher-ranked projects elsewhere cannot go ahead due to local funding problems there. The matching ratios have changed over time, but in general the proportions have varied $\sim 50:35:15$ for Bund, Land and city, which provides a very strong incentive for the cities to favour capital-intensive projects. Rolling stock has become eligible only within the last decade (table 1).

The operating deficit has to be funded from local funds. In many cases the cities consolidate their public transport firm with their gas, water and electricity supplier within a joint-stock company framework to use the public transport losses to offset surpluses elsewhere. This form of cross-subsidy is coming under increasing pressure

Table 1. Public transport investments eligible under the GVFG.

Eligible from	Category
	Grade-separated rail public transport alignments
	Bus lanes
	Central bus stations
	Central maintenance and storage facilities
	Park + Ride facilities
1988	Purchase of standard- and articulated buses
1991–95	Rehabilitation of public transport facilities in the former East Germany
1992–95	Rehabilitation of rolling stock in the former East Germany
1992	Stops
1992	Purchase of rail rolling stock

Source: Muthesius (1994).

with the deregulation of the European energy markets and other EU initiatives and it is unlikely to last much longer (Aberle 1997).

The buoyant finances of Karlsruhe, especially in comparison with other cities of same size within Baden-Württemberg, the Land concerned (Mannheim, Heidelberg, Freiburg, Ulm), have allowed a sustained investment programme in the past, as matching funds could nearly always be made available. The same applies to the funding of the operating deficits (see below).

4. Network development since 1975

4.1. *Initial situation*

At the beginning of the war Karlsruhe had four public transport systems: the standard-gauge local street car system with a bus system supporting it with feeder services; a metre-gauge Lokalbahn (local train service) connecting Durmersheim in the south and Spöck in the north, and the metre-gauge Albtalbahn connecting Karlsruhe with Ettlingen, Bad Herrenalb and other villages to the south-east. The two train systems had peripheral alignments within the city: the Lokalbahn ran through the Kriegsstrasse just south of the centre and the Albtalbahn ended near the main station ~1 mile south of the centre.

Three of the four systems were reconstructed after the war: street car system, bus system and Albtalbahn, while the Lokalbahn was closed down by 1953, partially to accommodate the increasing road traffic on the Kriegsstrasse. Not only was the streetcar system rebuilt, but also it was expanded during a period when most European cities closed down their streetcar systems. The expansion brought the streetcar to the new residential areas built after the war to the north-west and north-east of the city centre. The bundling effect of the urban structure through the strong east–west axis, which also included the main shopping street, allowed the system to offer superior service at reasonable costs. This competitive advantage was enhanced further when the street car remained at-grade in the now pedestrianized (1972) central part of the east–west axis, the main shopping area of the region, served by all but one street car lines including the Albtalbahn.

In addition, the city acquired the majority of the shares in the Albtalbahn and maintained it as a separate legal entity. The Albtalbahn was integrated into the street car system by changing the gauge to standard and by connecting the systems at the old terminus, the Albtalbahnhof. The trains on the Albtalbahn were run as a street car within the city limits according to the Strassenbahnbetriebsordnung (BOStrab) (LRT/tram operations regulation, including design parameters) and as trains according to Eisenbahnbetriebsordnung (EBO) (heavy rail operations regulation, including design parameters) outside city limits. The rolling stock was adapted to conform to both set of regulations and the drivers were certified for both as well.

The recent history of system of expansion and of the consolidation of the Albtalbahn, the recent GVFG offering new funds and the acceleration of peripheral growth both within the city, but especially in the suburban ring, facilitated and encouraged further growth of the system. In addition, the organizational structure involving at the time the Verkehrsbetriebe, the city-owned operator as part of the city administration (VBK), and the Albtalbahnverkehrsgesellschaft (AVG) as a Plc (Ltd), but managed as one entity opened managerial opportunities not available elsewhere, in particular with regards to the development of investment projects. The recent history not only encouraged the operator, but also the city, which was willing to continue the funding of the expansion and further modernization of its successful operator.

4.2. *Development since 1975*

The internal dynamics of the expanding operator, the changes in the population distribution and an inherent local street car bias required the further expansion of the street car system. The bias expressed itself in a consistent preference of the travellers for a street car service in comparison with prior bus services beyond the identifiable service qualities, as well as in the economic advantages of distributing the overheads of the system across a larger system and more services. The continuing growth of car ownership in the region and the larger share of peripheral customers forced the management to improve the service beyond the sheer expansion of the network. The quality and image had to be improved to maintain the momentum of the operator. The absence of serious plans for underground construction and services allowed the Karlsruhe management team to concentrate their efforts on the conversion of a traditional street car operator into a modern light rail system, defining such a system in the process.

Table 2 details the various network extensions and, where known, changes in ridership associated with the opening of the rail service in comparison with earlier bus services (figures 3 and 4). Table 3 summarizes the development in terms of number of lines, kilometres served and track operated. The network growth follows the population to the north-west (Haardtbahn to Hochstetten), the south-west (Mörsch) and the east (Bretten). The new dual-systems vehicles and interconnections between heavy-rail and urban systems permit a range of new integrated services to further destinations: east (Pfinztal, Pforzheim), south-east (Baden-Baden), north-east (Menzingen, Eppingen, Odenheim; October 1998), west (Wörth; September

Table 2. Network and service extensions 1975–97.

Opening	Type	Segment	Length (km)	Ridership growth (%)†
10/75	b	Langensteinbach–Ittersbach	9.0	30
11/75	a	Klinikum–Nordweststadt	2.3	20
10/79	b	Nordweststadt–Neureut	3.0	80
10/80	a	Eckener Strasse–Rheinstrandsiedlung	2.1	21
9/86	a	Weinbrennerplatz–Oberreut	3.6	48
9/86	b	Neureut–Leopoldshafen	6.0	73
6/89	a	Leopoldshafen–Hochstetten	4.3	100
9/89	a	Rheinstrandsiedlung–Mörsch	3.6	215
12/89	c	Leopoldshafen–Kernforschungszentrum	2.2	
11/91	a	Extension to Mörsch Merkurstrasse	1.9	80
9/92	a, b, d	Durlach–Bretten/Gölshausen	23.8	470
4/94	a	Oberreut–Badeniaplatz	0.4	
5/94	b	Bruchsal–Bretten	21.0	278
9/96	b	Bruschal–Ubstadt–Menzingen	19.2	120
9/96	c, d	Karlsruhe Hbf–Baden-Baden	32.0	
6/97	b	Bretten/Gö]shausen–Eppingen	20.5	100
6/97	b	Karlsruhe Europaplatz–Pforzheim	31.4	
9/97	a, c	Karlsruhe–Blankenloch Nord	10.7	
9/97	a, b, d	Karlsruhe Europaplatz–Wörth Bürgerpark	12.6	
10/98	b	(Bruchsal)–Ubstadt–Odenheim	10.8	

†Immediately after opening, further growth has since occurred.

[a]New construction; [b]New service including major improvemens of existing track; [c]New service on existing track; [d]Interconnection between LRT & heavy rail.

1997), north-east (Blankenloch; September 1997). Further extensions and new services are planned on both new and existing right-of-way in the north-east (conversion to an LRT-service on the line to Heilbronn and building an LRT-line within Heilbronn) and the south (extension in Rheinstetten on 1 km of new line; consideration of a new urban line within Baden-Baden and Rastatt and of LRT-like services in the Murgtal south of Baden-Baden).

The design aim of the lines has been to maximize the use of existing right-of-ways while maximizing the access of the population to the new lines. In the case of the line

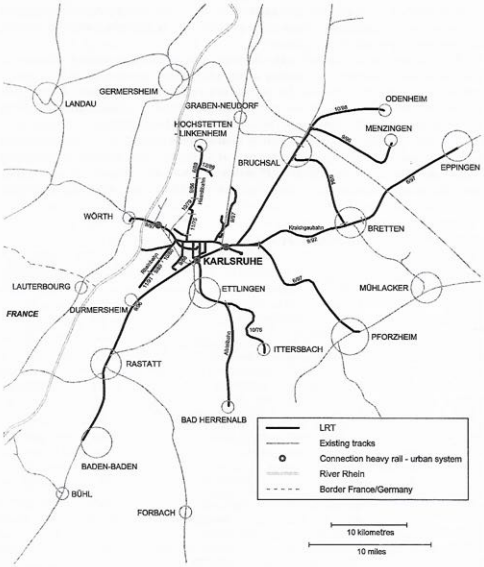

Figure 3. Network development—city and region—since 1975.

to Bretten, for example, eight new stops were built along the existing right-of-way. In the case of the Haardtbahn the existing right-of-way was too far from the villages served and, as a result, a new alignment was built, for example, through Leopoldshafen to achieve the access necessary for the success of the line.

The reuse or joint use of existing right-of-way required substantial negotiations and technological innovation. In the case of the Haardtbahn, the Bundesbahn handed the alignment over to the AVG, but it retained the right to run a limited number of diesel freight trains. In the case of the line to Bretten, the AVG had to develop a new type of vehicle conforming to the electrical and the security systems of both the railway and the LRT-systems (see below).

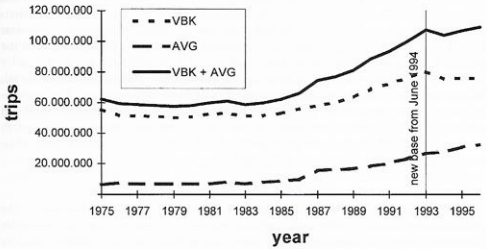

Figure 4. Development of ridership VBK and AVG, 1975–96. [*Source*: Brandl (1996), p. 42.]

Table 3. Development of the LRT system in the city and region of Karlsruhe.

	Number of lines		Length of lines (km)			Length of section (km)		
Year	VBK/ AVG	DB AG	VBK/ AVG	DB AG	VBK/ AVG	Rented from DB AG	For charge to DB AG	DG AG's own
1975	1[1]	—	39	—	39	—	—	—
1979	1[1]	—	51	—	51	—	—	—
1983	1[1]	—	60	—	60	—	—	—
1991	1	1	60	31	60	—	—	31
1992	2	1	89	31	66	—	21[2]	31
1994	4	2	125	63	66	—	57[3]	63
1996	4	2	145	63	86	21[2]	36[4]	63
1997	6	—	263.5	—	117	40[5]	93[6]	—

[1]Line A (since 1993 S1/11) is calculated as one line. [2]S4 Grötzingen-Oberausstrasse – Bretten-Gölshausen. [3]S4 like ([2]), S3 Karlsruhe Hbf – Bruchsal, S9 Bruchsal – Bretten. [4]S3 and S9 like ([3]). [5]S4 Grötzingen-Oberausstrasse – Eppingen. [6]S3 and S9 like ([4]), S4 Karlsr.Albtalbf. – Baden-Baden, S5 Pforzheim – Söllingen and Maxau – Wörth.

Source: Riechers (1997), p. 31.

The extension of the network was complemented by a comprehensive upgrade of the urban system through a conversion of most of the network from at-grade running to vertically separated right-of-ways, priority at signal controlled intersections, the widening of lateral distances between the track axes to accommodate modern and wider vehicles, the modernization of the rolling stock, and, in particular, the acquisition of low-floor vehicles. New maintenance facilities and offices were built as well.

In addition, Karlsruhe introduced in 1983 a heavily discounted transferable season ticket that could be acquired as a monthly or as an annual season ticket. The structure of the timetables and of the lines was adjusted periodically to match the new alignments and patterns of demand.

The start of the Karlsruher Verkehrsverbund (KVV) in 1993 consolidated the achievements of the past 20 years by extending the reach of the system even further. The KVV offers uniform through-ticketing for all users, discounting of season tickets, in particular for suburban users, and coordinated time-tables throughout the region. The dual-systems vehicles developed for the line to Bretten are used to offer an S-Bahn-like service to most centres in the region (Baden-Baden, Wörth, Bruchsal, Rastatt, etc.) some running exclusively on Bundesbahn right-of-ways (Karlsruhe – Bruchsal, Bruchsal-Bretten). In the case of the service to Baden-Baden, Pforzheim and Wöth, further interconnections between the urban and the heavy rail system built at the Albtalbahnhof at Grötzingen and in Knielingen respectively now allow through-services into the centre of Karlsruhe.

4.3. *Ridership change and economic MOEs*

The buzz, the innovation and service expansions and improvements have generated enough ridership and political support to sustain the developments described above. Unfortunately, the statistical analysis of the changes and the evaluation of the measures implemented is not of the same quality.

The aggregate figures given in table 4 for ridership change, for example, do not allow the separation of the various effects operating when a new rail line replaces an existing bus service: improvement in services (headways, service times, comfort of the vehicle), changes in pricing due to the new operator (in a number of cases the AVG/VBK replaced bus services of private operators or the Bundesbahn/Bundespost), changes in the patterns of the feeder services, discontinuation of direct services to the city centre, the image effect of rail services, etc. In addition, very little is known about how the numbers were derived in detail, i.e. issues of comparability of before-and-

Table 4. Ridership change on the line to Bretten.

	Estimated annual ridership		
Type of day	Before	After	Change (%)
Weekdays	488.000	2064.000	420
Saturdays	39.000	263.000	680
Sundays	6.200	227.000	3670
All	534.000	2555.000	480

Source: AVG and ABB Henschel (1993), p.5.

after situations, duration of reference periods, timing of the reference periods, etc. This cannot be blamed on the operator for whom it is enough to know that prior ridership expectations were surpassed in all cases leading to a faster build-up of demand and services than anticipated. Consistent with the patterns of the AVG, a substantial portion of that demand is leisure and weekend traffic, in particular on the line to Bretten (table 4).

Even the best study (Socialdata 1995), which was undertaken for the evaluation of the line to Bretten, leaves many questions unanswered. The main questions from a planning point of view are the extent of any modal shifts or, in general, the generation of 'new' public transport trips. The Bretten study gives some indications about the answers to these questions (table 5). The study involved repeated 1-day cross section/panel travel surveys in two villages along the line (Grötzingen inside the city limits, which had previously been well served with buses to the old street car terminus in Durlach, and Jöhlingen, outside the city, which previously had been badly served by regional rail services and some buses).

In the case of Grötzingen, the 'existing' users have increased their usage, while only a small share of new users was added (this interpretation of 'old' and 'new' users is very tenuous for repeated cross-section surveys. A full panel analysis of the data would be required to identify user classes — those staying, those joining, those leaving). The increase in public transport usage derives mostly from earlier walking and cycling trips, also associated with an increase of trips into the area served by the LRT-system. In Grötzingen, new trips by existing public transport users should be the main source of ridership growth. In the case of Jöhlingen, both modal shift from car to public transport and a more intense use by the prior users explains the ridership growth. The relative importance of the new public transport demand in comparison with modal shift effects will depend on the location of the new service and the prior conditions, but trip generation will always be present. The estimate for the line as a whole was that 40% of users were prior car users, drivers or passengers. These new trips are consistent with the suburban settlement pattern as they reflect the old ties of the new residents to their old social networks and as they reflect the current distribution of shopping

Table 5. Effect of the line to Bretten.

	Grötzingen		Jöhlingen	
Variable	Before	After	Before	After
Public transport trips/person and day	0.3	0.4	0.2	0.3
Share of public transport users/day	15	16	12	17
Public transport trips/public transport user	2.0	2.2	1.8	1.9
Modal shares (all trips; area served by LRT):				
walking and cycling	31;14	32;8	33;3	34;2
motorcycle and car driver	42;49	40;50	46;64	42;54
car passenger	16;17	14;17	13;14	11;11
public transport	11;20	14;25	8;19	13;33

Source: Socialdata (1995), pp. 6, 7.

and entertainment facilities in the region (there are many shopping centres in the region, but none functions as a full-scale mall, i.e. includes extensive food and movie/entertainment facilities). The LRT supports suburban growth while maintaining the centrality of Karlsruhe.

4.4. *Overall patronage and modal share*

The overall growth in ridership has been impressive (figure 4), in particular after 1983, the year of the introduction of the transferable monthly/annual season ticket, which is replacing rapidly other ticket types (figure 5). This dominance together with the importance of the 24-h ticket makes the interpretation of the figures difficult. It is notoriously difficult to estimate the number of trips undertaken with season tickets and the authors know no special studies for Karlsruhe. There is a rich stock of general knowledge about these numbers, but the development in Karlsruhe makes it likely that the figures as stated overestimate the true ridership to some, unknown, extent. The lower cost of the discounted and transferable season makes it attractive to users with fewer than the traditionally assumed numbers of trips, lowering the average number of trips/season. The same is true for the very rapid market penetration of the season, which reflects the purchase of the ticket by a fair number of users for which the ticket is not strictly economical, but instead is convenient and consistent with the personal self-image.

The ridership success is visible, in particular, in terms of average annual person trips on VBK services, which has continuously risen since the mid-1980s, to reach ~220 trips/person a year in the service area (figure 6). (This figure is an underestimate, as the trips made on AVG services within the VBK service area are not included.) While the popular success continues, the VBK has come under financial pressure in recent years (figure 7) with the deficit increasing rapidly and the cost – recovery ratio slipping since 1991, although it has been stabilizing recently.

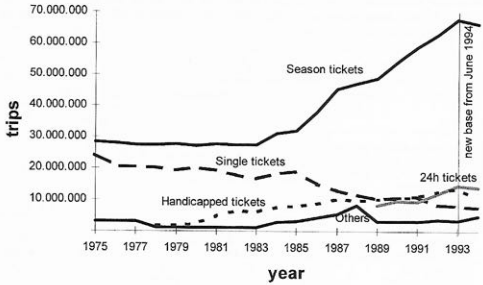

Figure 5. Ridership VBK by ticket type, 1975–94. [*Source*: Brandl (1996), p. 44.]

Comparable figures are not available for the AVG. The productivity of staff has increased through the use of larger vehicles and the extensive use of trains with two or three vehicles, especially on longer-distance services (figure 8), but ridership per seat/km is stagnant or falling due to the generous service provided, especially during off-peak periods (figure 9). The financial pressure on the VBK will increase as the finances of the city will deteriorate further due to the long current recession in Germany, the restructuring of public budgets in general and the losses due to the out-migration of middle-class residents. In addition, there is regulatory pressure to

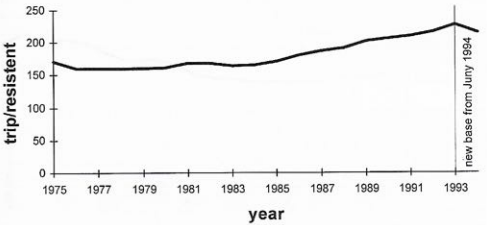

Figure 6. Development of annual person trips by VBK, 1975–94. [*Source*: Brandl (1996), p. 43.]

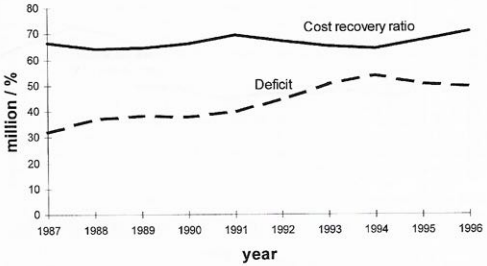

Figure 7. Annual deficit and cost recovery ratio VBK, 1987–96. [*Source*: Brandl (1996), p. 46.]

end the cross-subsidies between energy supply and public transport, which is institutionalized through a holding company in Karlsruhe and which offsets profits and losses across all firms. The AVG is in a better position as it is dealing with suburban communities whose finances are in general better and who are keen to obtain new LRT service and are therefore willing to pay for those services (Socialdata 1993a). Equally, the regionalization of rail services (see below) opens up new possibilities to lower overhead costs through expansion of services.

In spite of the dramatic ridership growth, the overall modal share in the Karlsruhe has not changed dramatically in recent years (Socialdata 1993b). The

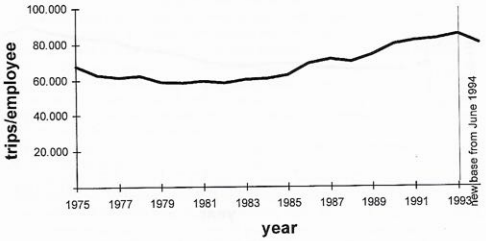

Figure 8. Passengers/employee VBK, 1975–94. [*Source*: Brandl (1996), p. 48.]

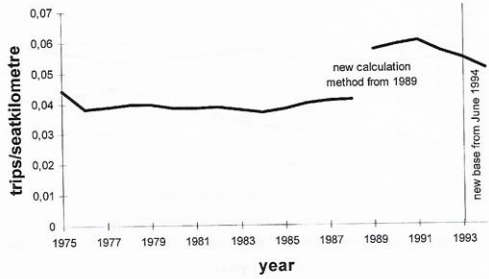

Figure 9. Passengers/seat kilometre, 1975–94. [*Source*: Brandl (1996), p. 47.]

share of public transport has increased from 13% (1982) to 16% (1992), while the share of the car has remained constant, with the gain for public transport stemming from car passengers (1%) and walking (2%). Cycling increased its share from 13 to 17% over the same period. The public transport system jointly with the expansion of cycling has been able to contain the growth of car use, but not massively to reverse it. This is a special achievement as car ownership continued to grow steadily to ~500 per 1000 inhabitants (1994) over this period (Stadt Karlsruhe 1997).

5. Getting it done, or not

The progress made in the Karlsruhe region and reported above seems very smooth from the outside and creates the image that the public transport operator can move ahead without restrictions. The three lines discussed below have been selected as a counter image as they all show how the operator and its plans are embedded into the political process of the region and the city. Success paves the way, but it does not remove all obstacles. The discussion is based on Havranek (1996), Schafferer (1996) and Stuefer (1996).

5.1. *Extension to the Rheinstetten*

The start of the procedure to obtain a line order in 1976, i.e. the legal permission to build the new line to the Rheinstrandsiedlung, was the occasion for the municipality just south, Rheinstetten, to request that it is to be involved and consulted in the overall public transport planning for this part of the region. First discussions and assessments identified the extension of the street car as an LRT line as the preferred option within a year, but the detailing of the alignment, the need to identify the funding sources and the delays to the line to the Rheinstrandsiedlung slowed further progress quickly after that. In February 1979, the final legal hurdles for the line to the Rheinstrandsiedlung were cleared and Rheinstetten reacted by approving the necessary budgets for the line in the hope that its line should operate by 1982 (assuming no legal challenges by individual residents affected by the line).

At this point the line was hijacked by the administration of Karlsruhe that tied its approval of the line to the agreement of Rheinstetten in four issues, of which three were unrelated to the line. The city requested that Rheinstetten should pay for most of the capital costs of the line and make an ongoing contribution to the operating deficit of the line. The other conditions were a change in the water price paid by Rheinstetten for water provided by Karlsruhe, approval of the runway extension of the local general aviation airport and a promise not to obstruct the plans for building a motorway connector through Rheinstetten, which is of primary benefit to the city. Rheinstetten refused the last three demands outright as extortion. It took another 5 years to resolve these issues. A court finally adjudicated the change in the water price. The runway extension and the motorway connector were removed from the discussion through the effects of the second oil-shock in 1981 that substantially raised environmental awareness and made these projects temporarily unacceptable in any case.

While the conflicts between Rheinstetten and Karlsruhe were resolved by 1984, the approval of the line within Rheinstetten could not be taken for granted as the preferred line involved a substantial change in the street networks of the villages forming Rheinstetten. It was only after a positive referendum in August 1986 that final negotiations could be initiated, which clarified the distribution of costs between all parties by November 1986. The line order was granted in August 1988. The first

part of the line was opened in November 1989, while the opening of the second part, in 1991, was delayed by the line order process. Further regulatory proceedings have delayed any further extensions until recently.

The history of this line illustrates clearly how the city is trying to lever its public transport system for unrelated business. The crass nature of the attempt resulted in its defeat, but it shows the potential never-the-less. The 13 years between the first discussion and the opening of the first part of line also warns against excessive optimism for the speed with which ideas can be converted into reality, even in Karlsruhe.

5.2. *Dual-system-vehicle and the line to Bretten*

By the early 1980s the success of the AVG to the south and the successful extension to the north-west (Haardtbahn), partly on converted heavy rail right-of-ways and the internal growth dynamic of the firm, justified the search for future expansion opportunities. The growth of the villages along the Pfinztal and in the direction of Bretten (Kraichgaubahn) (~35 km to the north-east) defined an attractive corridor for a suburban service. Unfortunately, the Bundesbahn was not willing or able to develop this corridor as it was handicapped by old rolling stock and its network structure, in particular by the fact that its terminus at Karlsruhe main station is too peripheral within Karlsruhe to be attractive to many commuters or shoppers. The ridership trend was downwards. In addition, the Bundesbahn did not want to relinquish the line to Bretten completely as it had done with the Haardtbahn, as it was operating longer-distance services on the line. It also did not want to lose the remaining operating revenue from the line. Still, it was clear that through-services to the centre of Karlsruhe were required to increase ridership, which implied vehicles operating both on heavy rail as well as on LRT tracks. While the AVG had long experience with operating both as a LRT as well as a railway, it was doing so on a line without other traffic (ignoring its own diesel freight services on its lines), which allowed common safety and electrical systems. In the case of the Kraichgaubahn, it was clear that any operation would be under mixed traffic, i.e. both LRT-suburban services and heavy rail regional services. Mixed services were considered at the time to be technically impossible and undesirable with regard to safety (i.e. due to the weight differences between the lighter LRT-vehicles and the heavier heavy-rail sets). The precondition for the service was, therefore, both the development of a suitable technology and the political agreement of the communities along the line.

The political process was protracted as the players involved, Karlsruhe, Bretten, Walzbachtal (Walzbachtal is the legal entity encompassing the villages along the line, which still retain their individual character within this frame), the Landkreis Karlsruhe (Landkreis can be translated as 'county', but the responsibilities are structured differently: it is an administrative level that provides the joint services, which its constituent villages and small towns cannot provide (e.g. hospitals, specialist schools), and it administers for the Land certain agendas (e.g. environmental protection, public transport regulation etc.); it is funded by a levy on its villages and small towns), AVG, Bundesbahn and the funding agencies at Land and federal level had to be brought together. First discussions started in 1983, but the final contract was not signed until October 1988. Issues were the allocation of costs for track and rolling stock between the parties, in particular Bretten and Walzbachtal, the allocation of revenues between AVG and Bundesbahn, and the

exact alignment of the line. The discussion about the alignment was finally resolved in February 1989 when the city council of Karlsruhe agreed to the interconnection of the urban and suburban system at the main line station in Durlach. It was agreed at the time that the AVG receives all revenues from the services, but that it has to pay track fees for the use of Bundesbahn alignment.

The technological development started in earnest in 1986 with funding from the German Ministry for Research and Technology. Initial tests included both a two-system vehicle, able to run under both the urban and heavy rail electrical system, and a vehicle with an additional battery supply for the heavy rail portion of the line. After the initial tests only the two-system vehicle was pursued and developed further. The further development included the installation of a heavy-rail compliant safety system (INDUSI ATP) and of a new type of wheel profile capable of running safely both on urban and heavy rail track and switches. The use of INDUSI overcame the safety concerns, as this system automatically assures safe distance between trains. Otherwise the vehicle employs only one type of system, e.g. the horn complies with railway regulation, while the brake complies with street car standards. Certain compromises were made with respect to the acceleration capabilities to keep the weight of the vehicle under control. The vehicle as such is a modern LRT-type vehicle with regards to seating, passenger comfort, passenger information, size of windows, etc., and also weight. The vehicles were ready by 1991 and as mentioned above are not only being used on the line to Bretten by the AVG, but also generally by the Bundesbahn for suburban services around Karlsruhe. They were in many ways the prototype for the new generation of light heavy rail vehicles that have come onto the market in the 1990s and which combine in essence lower weight, higher passenger comfort, better acceleration/deceleration with one man-operation for heavy rail lines.

The operation of the line was an immediate success as it was able to attract not only commuters and leisure/shopping travellers to Karlsruhe, but also day-trippers from Karlsruhe who use the line for visits to Bretten and to reach the starting points of their walking and cycling tours in the Kraichgau. The line increased patronage also on the continuing Bundesbahn services, as the total attractiveness of the public transport system improved. Given current services levels, it is now cheaper for the AVG to lease the line. Reversing the original situation the Bundesbahn is now paying track fees for its remaining services.

The development of the vehicle within the 4 years and of the whole line within 8 years is a major achievement, especially given the very substantial technological and regulatory hurdles for the vehicle. It has opened up a new territory for the LRT operators not only in Karlsruhe and Germany, but also world-wide (see below; Ludwig and Kühn 1995). In spite of the obvious attraction of the line, local concerns about funding, accessibility and consumer spending patterns delay the political process, even in this case.

5.3. *Tunnels under the Kaiserstrasse*

The Kaiserstrasse is the central part of the dominant east – west axis. It is the backbone of the pedestrianized major shopping district of the region and of the administrative centre of the region. It is the main destination for urban and suburban travellers to the city. Until today at any one time, all or all but one or two street car/LRT lines use/have used the Kaiserstrasse to provide access to these destinations (A sign of the strength of the interactions: one major department store

specifically relocated its main entrance to bring it closer to the nearest LRT/street
stop.) The traffic density during the peak hours (about one train/min) has beer
concern since the late 1960s, both as a moving/standing wall of trains disturbing
pedestrian traffic in the pedestrian zone, as well as a capacity bottleneck for
system.

Since the early 1970s the city and the VBK have been searching for a solution
this problem in a series of studies, mostly focused on various tunnel syste
following the example of Cologne (see also the pre-Metro of Brussels) that
developed a LRT/street car system which is partially underground. The first ma
study of 1972 was in thrall to the general enthusiasm of the time for undergrou
facilities, especially now that they had become fundable through the GVFG of 19
Even then the consultants recognized that part of the lines had to remain ab
ground, even above the tunnels. The preferred project was not pursued at the tim
the development of the S-Bahn/U-Bahn in Stuttgart pre-empted the funds availa
The operator could now concentrate on the transformation of the system to a LI
system (vertical separation of the track, line extensions, public transport prior
new wider vehicles, increased use of double and triple traction, etc.). The meas
sufficed to solve the problems mentioned above during these years.

The next major study was undertaken in 1989 when the problems identified
become very visible through the success of the public transport system since 19
foreseeable capacity problems given expansion plans, and the pedestrian–t
interactions in the pedestrian zone, etc. The solution identified, which involved
only a tunnel below the Kaiserstrasse but also a tunnel to the main station to
south, collapsed under its own costs when funds were primarily redirected to
Germany after 1990 and funding, in general, became tighter for the cities.

The further expansion of the system necessitated a new study already in 1992
This time the solution tried to minimize construction costs and the size of
underground network in terms of length and number of stations (table 6). The st
had been undertaken by a team formed from the staff of the operator and of the
planning and civil engineering departments. The preferred option essent
proposed to move the suburban/regional traffic (initially two lines) into the tur
but to retain the remaining traffic above ground. The tunnel provided for
possible later extension to the south/main station. Its conclusions were accepte
the city council in 1994. While the city council majority for the first time with st
support of the VBK assumed that the solution would be built, local resistance
up. The resistance focused on the disruption to the pedestrian zone du
construction, the perceived mismatch between the tunnel and the small amour
traffic using it (initially), the operating costs of the tunnel, a general fear of tun

Table 6. Karlsruhe: preferred tunnel solutions.

Year	1972	1989	1992
Number of alternative	5.4.1	4.2	U2
Length (km)	7.8	10.3	2.9
Number of underground stations	13	9	5
Investment costs (DM million, 1992 prices)	485	1530	320

Source: Adapted from Stuefer (1996), p. 56.

the lack of a proper cost – benefit study, doubts about the cost figures provided, the perceived lack of a proper study of the major alternative corridor (an alignment along the Kriegsstrasse, a parallel major urban arterial about 400 m south of the Kaiserstrasse, which is scheduled for redesign, as its traffic function has changed due to the opening of urban motorways further to the south) and a perception that Karlsruhe could not afford its share of the total budget. The finalized design was approved by the council majority in May 1996, but it was rejected in a referendum in October 1996 after a campaign in which the proposers, in particular the mayor and the head of the VBK, did not fully engage relying on their prestige to carry the day.

The defeat of the proposal is an object lesson for an operator that has become too self-assured after many successes to consider all impacts of all proposals properly. It also shows that the citizens of Karlsruhe insist on a system serving them in the first instance with the suburban users welcome but not dominant. This conflict of interest between the city residents and the AVG/VBK, which can only grow in suburbia, and the retailing interests, which need the suburban customers, but fear disruption, is set to fester, until an acceptable solution is found, a solution that is neither too expensive nor too disruptive, but one that still offers the suburban travellers services to their destinations in the core of Karlsruhe.

The defeat of the tunnel solution initiated the search for new solutions based on new alignments in the Kriegstrasse, south of the Kaiserstrasse. Various alternatives were discussed and evaluated in detail with the disappointing results that none of those developed so far (1998) are either fundable under the rules of the GVFG or feasible in terms of traffic flow and public transport operation. The evaluation was performed with the official cost – benefit methodology Standartisierte Bewertung (Heimerl *et al.* 1988). The alternatives designed so far have not substantially redirected traffic flows away from the Kriegsstrasse through turning prohibitions or road closures. Such solutions will have to be considered unless the tunnel is to be revived.

6. Outlook and conclusions

6.1. *Local*

The Karlsruhe public transport system, urban (VBK) and suburban (AVG) has had an extraordinary successful 20 years characterized by nearly continuous growth and the conversion into a qualitatively new system (LRT and the Karlsruher Model of joint suburban services). The further expansion plans speak of the confidence the region has in the abilities of the operator to deliver superior services. It also puts the operator into an excellent position to benefit from the regionalization of the heavy rail services, under which services are tendered by line or sub-network. With its relatively low-cost base, AVG/VBK should be able to expand into this business, especially given its control of access to the business and service core of the region. It has already started to do so, by taking over a rural/suburban train network north-east of Bruchsal.

The success of the past 20 years could on the other hand become a problem for the future, as it has been achieved with a very small management team under charismatic leadership, but always with the financial backing and general confidence of the city and its leadership. Such structures are prone to mistakes such as the ill-conceived referendum campaign and they are difficult to maintain when the firm reaches a certain size and levels of complexity or when central figures retire or leave. The VBK/AVG combination might be at this point of transition and it is unclear

whether it can achieve an internal restructuring as successful as its restructuring of its network and service.

It is also unclear whether the city wants to support the development of a commercial suburban railway service provider that has to operate in price competition with the Bundesbahn and other providers participating in the tendering market. The commercial risks involved might be judged too high for the city, as the owner of the AVG, the instrument for such a bid. This would be especially true as the expansion into tendered suburban and regional services would weaken the perceived unity of interest between VBK/AVG and the commercial and policy interests of the city as the attention of the management team would be diluted and diverted away from serving the city. In addition, the current level of deficit might not be sustainable for the city when, as mentioned above, the earlier cross-subsidization becomes impossible. Finally, the mixture of the city's role as regulator of the tendering process and as owner of the service provider is unstable in the long-term.

This case study has summarized the development of the public transport system in the Karlsruhe region within its regional and financial context. It has highlighted that the success of the system has not been smooth, but that the system is part of the overall political process of the region and is subject to its limitations. The operator (VBK/AVG) and its owners have now to decide how to react to the development of a commercial market for rail services under regionalization/deregulation. They have also to find a new balance between the interests of the urban and suburban users, in

Table 7. World-wide overview about LRT-systems, using existing railroad tracks.

Status	Type of system Dual-voltage-system	Single-voltage- or fuel-system
Operating	Karlsruhe (Germany), Saarbrücken (Germany)	Buenos Aires (Argentina), Calgary (Canada), Geneva (Switzerland), Kassel (Germany), Köln/Bonn (Germany), Manchester (UK), Newcastle (UK), Nottingham (UK), Paris (France), San Diego (USA)
Under construction	Chemnitz (Germany), Heilbronn (Germany)	Ljubljana (Slovenia), Salt Lake City (USA), Zwickau (Germany)
Planned/under construction	Bremen (Germany), Dortmund (Germany), Geneva (Switzerland), Graz (Austria), Hamar-Elverum (Norway), Kiel (Germany), Köln/Bonn (Germany), Ladshut (Germany), Leiden-Gouda (Netherlands), Linz (Austria), Luxembourg (Luxembourg), Mulhouse (France), Munich (Germany), Oslo (Norway), Regensburg (Germany), Rosenheim (Germany), Rostock (Germany), Salzburg (Austria), St Pölten (Austria), Ulm (Germany)	Aachen (Germany), Austin (USA), Brisbane (Australia), Bristol (UK), Cali (Colombia), Canyon/Ada counties (USA), Cardiff (UK), Kent (UK), Nantes (France), Ottawa (Canada), Philadelphia (USA), Porto (Portugal), Rochester (USA), Sonoma counties (USA)

particular as suburbanization proceeds and the dominance of the city as a destination is diluted in the future.

6.2. *National and international*

The continuous growth of ridership and the expansion of the Karlsruhe system into suburbia has inspired a whole range of studies and projects in Germany and elsewhere, which hope to copy the success (table 7). It should be clear that some but not all of the elements can be copied, in particular the reuse of existing alignments with dual-systems-vehicles. This clearly opens new opportunities for rail-based public transport by providing excellent access to the cores of urban areas without incurring the massive costs of new construction. This opportunity only exists where the old alignments still are near centres of activity (e.g. Saarbrücken, Manchester) or where new centres of activity can be developed (e.g. Portland), where neither holds no success can be expected (e.g. certain parts of the new systems in Los Angeles).

The Karlsruhe experience also suggests that continuous growth and service improvement of the existing system are crucial to overcome the political and technological difficulties inherent in implementing new systems. The spreading of the existing overheads and the existing experiences are powerful arguments. New rail systems in areas where rail has been replaced by bus-based systems will have to overcome this hurdle.

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