TRAM-TRAIN SYSTEMS, AN ANALYSIS OF FRAME CONDITIONS FOR IMPLEMENTATION

Dr. Guillaume de Tilière, BG Consulting Engineers
Olivier de Watteville; BG Consulting Engineers
Jean-Daniel Buri, EPFL-LITEP

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Dr. Guillaume de Tilière
BG Consulting Engineers
Lausanne, Paris

Phone: +41 21 618 17 27
Fax: +41 21 618 11 12
email:
Guillaume.detiliere@bg-21.com

http://www.bg-21.com

Jean-Daniel Buri
EPFL-LITEP
Lausanne

Phone: + 41 21 693 24 31
Fax: +41 21 693 50 60
email: jean-daniel.buri@epfl.ch

http://litep.epfl.ch/

Olivier de Watteville,
BG Consulting Engineers
Lausanne, Geneva

Phone: +41 21 618 17 39
Fax: +41 21 618 11 12
email:
olivier.dewatteville@bg-21.com

http://www.bg-21.com

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Abstract

First tram-train systems have been implemented two decades ago, followed by a lot of studies about the opportunity to implement such systems on several places in Europe. Some projects such as Karlsruhe and more recently Lyon West, Strasbourg and Mulhouse show that the concept of Tram-Train is in fact integrating a lot of things which are commonly not always well understood: If this concept corresponds to a technical system or product, it is also addressing specific needs in term of network design and service offer. More often, this last point has not been very well taken into consideration in most implementations. This is why a good definition of the system pertinence and a proper analysis of some key conditions for proper implementation are required in order to make such a concept accurate.

This research is therefore addressed to planners and decision makers in order to clarify these parameters and frame conditions. Moreover, authors will also integrate in the analysis operational and organisational aspects: Rail operation around cities is often managed by different entities: on one hand the urban perimeter with the operator in charge of the city public transport, on the other hand the main rail operator in charge of railway network in the agglomeration. The tram train is therefore a technical system crossing this frontier, and requiring a proper coordination. This creates technical issues on the existing networks to be overcome, and organisational issues to be dealt with in parallel. These technical and organisational aspects shall be analysed and balanced in term of investments and risks with the potential benefits of such system (optimised performances for urban area).

The paper will provide an assessment of the various projects implemented so far with the ex-post analysis of successes and failures. Authors will also use their recent studies, with the various parameters which are taken into account in mutli-criteria analysis required for decision-making in such projects.

Such factors ill be classified and ranked, and will provide the basis for the elaboration of the spectrum of conditions where such systems are relevant

Authors will then conclude on the way to improve the transport offer on such a market segment, with a better definition of border conditions such as organisational aspects, technical constraints, interoperability and standardisation issues.

Keywords

Tram-train, Rail transit systems, light rail.

On the front page: first run test of the Mulhouse Tram-Train set, on 24/11/2009

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1. Introduction

In guided transportation systems, functions between tramways, light rail or rail systems have always been clear, each responding to a specific demand, based on trip distance or distance between stops.

With the concept of tram-trains introduced in Karlsruhe in the late 1980's and commissioned in 1992 for its first line, a new mixed concept appeared: the benefits of regional rail traffic providing to its customers an end service in the city center with short distance stops without any change of mode.

Since then other projects were implemented and with the new trend of strengthening the transport supply in agglomerations, some public actors or operators are thinking about the best way to optimize their networks.

Would the tram-train fit to their strategy?

In the current trend, the concept shall be clarified because tram-train is not only a matter of buying some new and nice rolling stock. It is a system concept, integrating also the offer design and the infrastructure.

This paper aims to provide some guideline for apprehending such a transportation system, which integrate some functions which are usually split. The article defines and underlines, with references to several case studies, what are the main parameters to be analyzed in order to make the right choices for such a system implementation.

2. Tram-train: concept and definition

2.1 Designed for a specific need

Among all aspects characterising a public transport network, the rupture imposed by the change of mode from regional to urban networks remains a problem for a lots of users. Agglomerations worried about the development of their public transports are always working to improve such connections, and transfers. The concept of Tram-train comes from the idea to avoid such a rupture, keeping also all characteristics of the regional railway mode (higher commercial speed and inter-stations) in one hand, and of the tramway mode in urban area in the other hand (thinner connection thanks to closer inter-stations, but with a lower commercial speed).

The city of Karlsruhe was the first to implement the Tram-train concept in 1992, by connecting physically the tramway network with the regional rail network with a single and common rolling-stock.

2.2 Definition of a tram-train

The Tram-train is a vehicle derived form the tramway, able to run on tramway lines in city centres and on the regional rail network in order to connect without discontinuity the stations located in peri-urban areas with the city centres.

The offer allowed by such a transportation mode can therefore be wider and provide a more efficient connection of the whole network, especially in combination with other classic tramway lines.

2.3 Constraints to be integrated

2.3.1 Contraints related to existing infrastructure

Before planning a tram-train in an agglomeration, the existing infrastructure networks shall be analysed. If the agglomeration has already a regional rail infrastructure in one hand ("RER" network like), and the other hand a tramway infrastructure in city centres – which is usually the case in Switzerland – the tram-train will run on those two types of infrastructures, which don't present the same characteristics. The differences could be of several types:

Gauge and free profile:

The rail profile is always superior or at least equal to the tramways' one, as well as the so called RER lines (Swiss norms also specifying the normal gauge – 1435 mm) is superior to the one of most tramway networks (metric line of 1000 mm). This usually constitutes the main barrier for the implementation of tram-trains in Switzerland. An alternative exist, with the implementation of one of the two networks with a third rail, but this remains costly and heavy to implement.

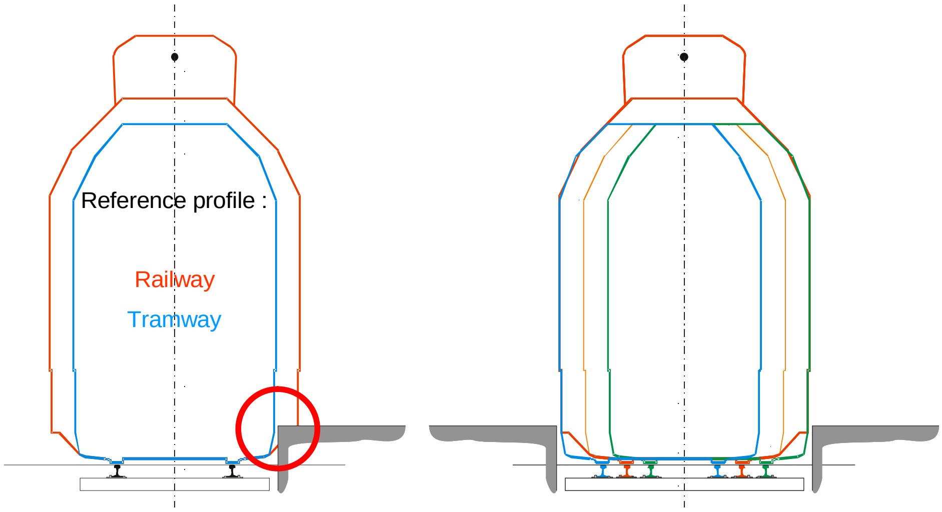

Figure 1: Differences of profile: tramway and railway networks *(source: EPFL-LITEP)*

Figure 2: Kassel's solution to solve free profile issues in stations *(source: EPFL-LITEP)*

Wheel profile:

The wheels' flange designed for railways are deeper and larger than the ones of tramways. Therefore this implies specific measures in the case of mix traffic, in order to avoid any derailment at crossing sections: usually both infrastructure and rolling stock shall be adapted in consequence.

Length and Height of platforms:

The question of platforms is a recurrent one of all tram-train studies and projects. Train floors cannot be always at the platform level if the platforms are not at the same height. Generally railway platforms are at 55 cm (except for RER in Paris with 92 cm), and generally 20 to 30 cm in cities for tramways. One must also notice that in Switzerland it is forbidden to use railcars which floor is below the network platforms. This would de facto imply to design tram-train with relatively height floors to be compatible with rail platforms and a retractable footboard in order to allow an easier access for the city-centre or urban connection. However, regarding the equity of access for people with reduced mobility, the new Swiss law ("Lhand" law), will impose from 2023 a vehicle access without any stair (100% floor to floor access). This will therefore constitute an additional strong constraint for the Tram-train designers.

The other issue that might be critical is the limitation of platform length in city centres. In most of cities, platform's lengths are limited to 40 or 50 m. In such cases, if the demand is growing fast due to an attractive offer, the capacity of the system for its regional offer will be affected unless the frequency could not be rise sufficiently. This aspect shall be analysed seriously, as it can drastically changes economical benefits of investments in comparison to RER projects where train-sets can easily reach 200 to 250 m, and in some cases 400m.

Power supply:

Railway networks are usually equipped with high voltage alternating traction currents (for instance CFF norm = 15 kV, $16^{2/3}$ Hz), whereas tramway networks are most of the time powered lower direct current (600 or more frequently 750 Vdc). This difference can be handled through bi-current rolling-stock, which additional costs are now reduced by a better standardization.

Safety systems:

Railway networks are always equipped with elaborated safety systems (signalling), based on block systems with automatic control systems. Tramways are based on circulations based on "on sight" drive following road driving procedures. Tram-train systems shall therefore be equipped with both systems, with drivers trained in consequence for operation in urban areas and regional rail lines.

Transition areas:

For tram-train concepts where a connection to the railway network is planned, a specific area must be designed for the handling of transitions (power supply and signalling), allowing train-sets to go from one network to the other (see figure below for the example of a study of a tram-train line, operating on the Sytral tramway network in green and the RFF rail network) for Lyon-Givors.

This transition requires a neutral area (see figure below), located in the junction of the two networks, which localisations constraints is not always easy, especially in urban areas

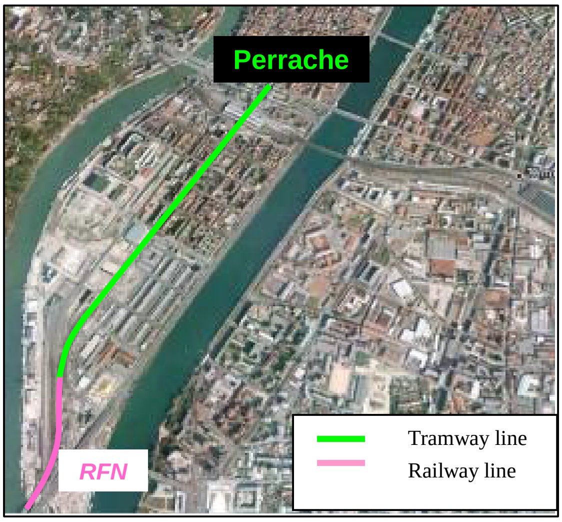

Figure 3: Tram-train study for Lyon-Givors

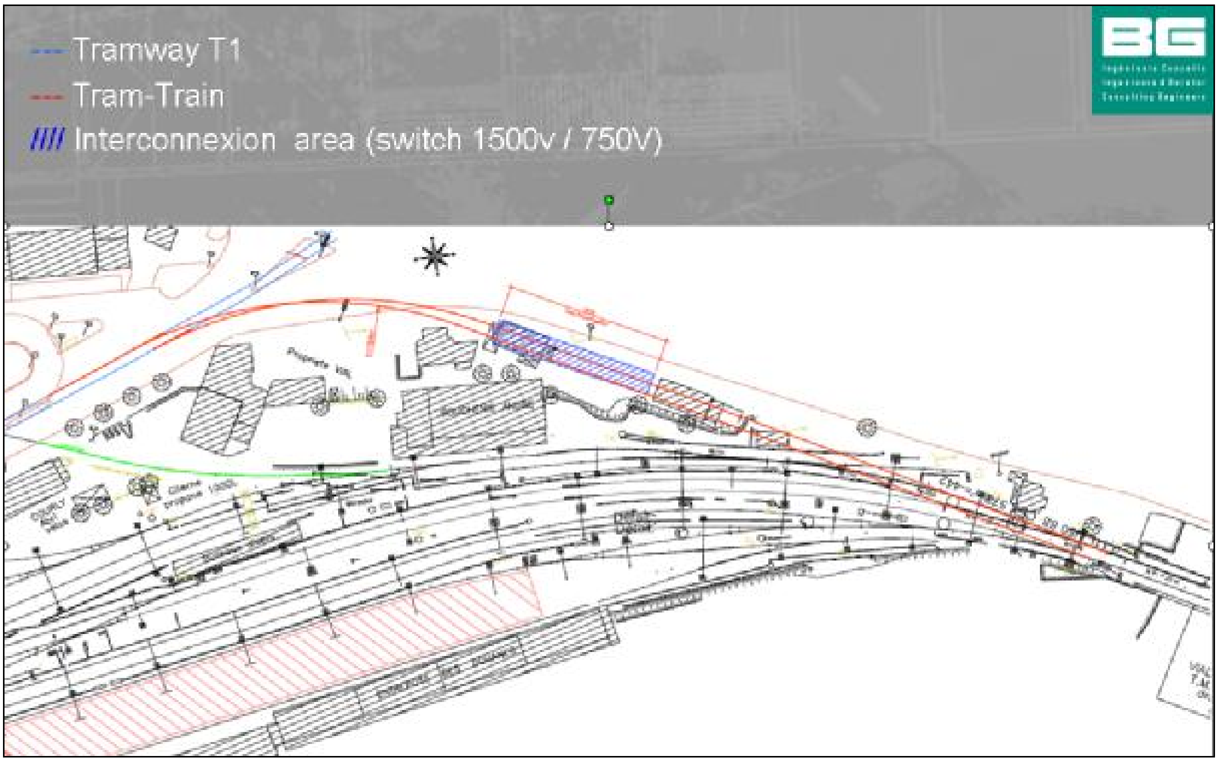

Figure 4: Tram-train transition area, example of Lyon-Givors study

This figure shows the example of the implementation of the transition area between RFF network and the Sytral Tramway network in the South of Lyon. Such an area allows to:

- Switch from the rail signalling (KVB here) to the tramway signaling system
- Switch of power supply 1500 V / 750 V
- Ensure through predefined buffer time the RFF schedule for tram-trains entering on RFF network, as tramway circulations can always be subject to delays due to the road traffic jam.
- In several countries like France and Switzerland, the Change of circulation direction is required from the right for the tramway network to the left for the rail network (except for projects done in Alsace and Lorraine).

This example of Lyon-Givors study is a good example to underline some other key issues driving the choice for system implementation: the operation constraints related to traffic in city centers in one hand, and a regional rail network in the other hand.

2.3.2 Operation Constraints

Scheduling and delay management:

The way a tramway system is operating is very different from railways. When the network is well developed, schedules are more given by frequencies than by regular schedules. Tramways are inserted in the traffic in a first in first out principle. This makes the reliability of schedules in city centres more difficult to respect, especially due to the influence of road traffic jam on tramways.

In the case of railways, scheduling is extremely important, especially for the lines where capacity is an issue. Therefore the transition zone described above is also used from the operation point of view as a stop area with some reserve in order to limit the impact of potential delays on the railway line and ensure the integration of the tram-train in the right scheduled window.

The issue of available capacity on networks:

If mix traffic could be a very good opportunity, one must ensure that the capacity level of the rail and tramway networks allow operating efficiently the tram-train system. If one of the two network begins to be saturated, then the opportunity to split the tramway and rail functions shall be analysed, if the impacts on schedule and operation stability is too high and affecting negatively the demand.

2.3.3 Organizational and institutional aspects

Collaboration between different organisation

Usually, in most agglomeration the functions and services between the rail system and public transport in cities is separated and managed by different organisations and administrations.

As tram-train systems are mixing both functions, studies and projects are gathering more actors. This means that for all decision making process or for the operation of such a system, a strong collaboration is required from these actors.

This also implies that institutional and organisational aspects shall be integrated early in the studies and the analysis. Moreover, such a project shall therefore be surrounded by a favourable political climate, as well as by a significant cooperation between the actors of the city and the region.

Common operation and processes

Railway networks are always equipped with elaborated safety systems (signalling), based on Tram-train is merging city and regional interests and therefore requires a strong coordination of the city operator and the regional operator. Usually they have their own personnel, prescription, accounting systems. With such a tram-train system, processes are redefined as both technical systems and organisations (training, supervision etc) are managed globally for regional and urban needs.

2.4 Characteristic of tram-trains rolling-stock

In most cases, tram-train lines were developed on existing infrastructures, and the rolling-stock aimed to be adapted in the maximum to the infrastructure.

Main differences in characteristics between Tram-trains and other guided transport systems for agglomerations are the following:

	Tram	Tram-Train	light train (ex GTW Stadler) [1]	Regional train (ex: FLIRT Stadler)[1]
Maximal speed [km/h]	70	100	115 / 140	160
Acceleration [m/s^2]	1,1	1,1	0.7	1,2
Vehicule width [m]	2,3 – 2,65	2,4 – 2,65	2,65	2,88
Floor Height[mm]	300-400 / 650	400 / 650	885 / 1045*	600 / 1120
Multiple Units	Possible	Possible	Possible	Possible
Capacity per single composition (passengers)	220-310	220-240	396	360
* Floor at 1045 mm, front doors at 885 mm. Followed by two steps of 185 mm coming to 515 mm.				

Table 1: Synthesis of rolling-stock characteristics: Tram, tram-train and light rail
(source: adapted from M. Chatelan, EPFL-LITEP)

Specifications and norms:

The differences between the various concepts of rolling stock such as metro, tramways, light rail or urban rail is defined by the definition of functional needs, and the technologies and design, who support it. But accompanying the technological evolution, the related norms and standards associated to each type of concept lead also to some safety constraints or levels that makes also investments or operational costs more or less expensive.

If the various technologies and systems are also mainly driven by customer requirements and needs, more and more the mandatory standards or norms are influencing the products. This global trend of standardization allows to benefit from larger volumes for manufacturers, and then in a second run from better prices for the customers. However, sometimes higher standards implied by the evolution of norms are also pushing prices up.

Such entry data are determining ranges such as the weight and power of trains (specification related to crash-tests, cooling systems, acceleration performances) and therefore have de facto

[1] stadlerrail.com

impacts on the production costs (investment, operation costs related also including the maintenance).

If for city transport systems such as metro and tramways, norms are less harmonized than for railways, the tram-train remains in some cases bounded with less constraints in term of norms than the urban and regional railcars. For examples: for tram trains, norms would be for instance revised in France, with a first IN norm related to Tram-train systems, which first draft version was produced end 2009. In this one, two examples can be mentioned to illustrate the impact of mandatory norms on technical designs:

- Trainset structure resistance for longitudinal traction: for instance, according to German norms, 600 KN against 1500 KN for standard rail trains.
- Front window resistance projectile 35 m/s instead of 60 m/s
- collision Resistance - respecting DIN 5560 only

It is clear that the debates surrounding the definition of norms and the pressure exercised by national operators to push these norms closer to their standard rail standards (or even fully compliant) have serious impacts on the design and the costs of the system.

3. Current experience and reference projects

3.1 Main studies

It is interesting to notice the evolution of the tram-train studies since two decades, depending on their initial concept and to analyze for which type of cities or agglomerations they were planned. It is also important to notice how their integration in the public transport network was planned, and especially see in this context if there were already some other guided transport systems or not.

3.1.1 First generation of studies: looking for an ideal implementation

As underlined in the study of van der Bijl & Kühn 2004, the first generation of studies were based on the first Kahrlsruhe concept, but with probably too much optimism on the way to implement such a system, or at list on the real constraints associated to it.

The first table below draws the main studies, done up to 1997, the first generation of tram-train studies. Mapping theses studies shows that such a system was thought to be implemented in medium cities, from 100'000 to 300'000 inhabitants. Application cases where mostly focused where no other tramway or RER were in operation.

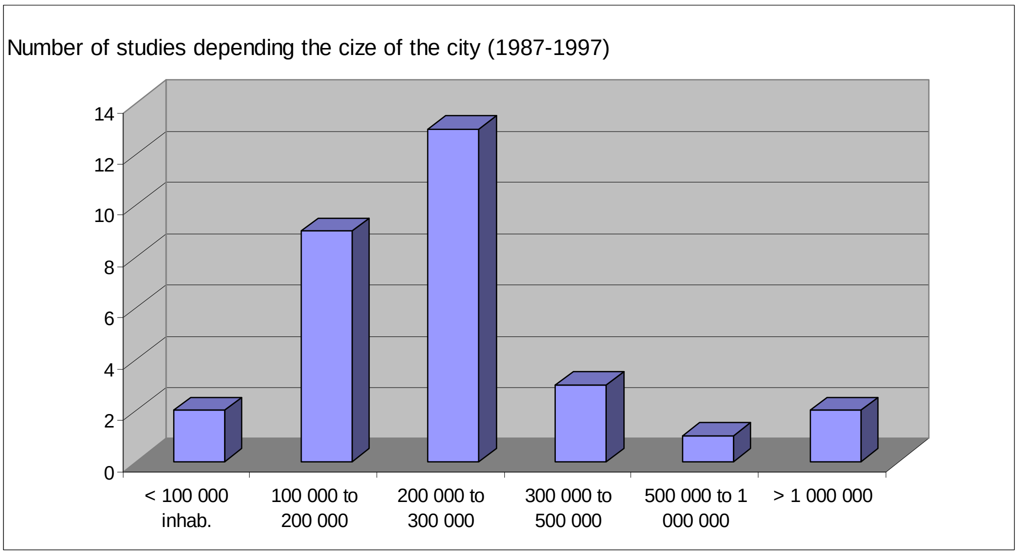

Figure 5: Tram-train studies and the size of agglomerations (up to 1997)

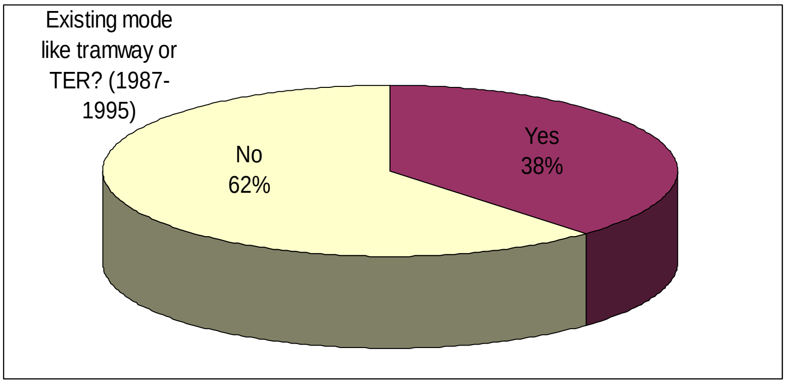

Figure 6: Tram-train studies depending on TC offer (1987-1995)

City / Region		Population city	Population Region	Existing tramway	Gauge	Other high quality rail mode	Dates of studies	Remark
Aachen	D	280 000	630 000	no			1992-1997	
Braunschweig	D	245 000	346 000	yes	1100			standard gauge envisaged
Bristol	UK	410 000		no				abandoned
Cardiff	UK	285 000	950 000	no				
Chemnitz	D	270 000	600 000	yes				
Dresden	D	480 000		yes				Study only on one corridor
Glasgow	UK	650 000		no				
Ile de France	**FR**		**8 100 000**	**yes**		**RER**		First projetc with tangential functions, connecting suburbs, connecting d'Aulnay-sous-Bois / Bondy. Commercial operation since 2005
Geneva	CH	150 000	300 000	yes	1000			
Graz	AU	240 000	400 000	yes				
Hamm	D	180 000		no				
Heilbronn	**D**	**122 000**	**415 000**	**no**				Also due to the Karlsruhe (sharing of the maintenance center for railcars)
Kassel	D	195 000	550 000	yes				
Kempten	D	60 000		no				
Kiel	D	250 000	500 000	no				
Leiden-Alphen-Gouda	NL	260 000		no				
Ljubljana		260 000	360 000	no				
Luxemburg	**Lux**	**77 000**	**400 000**	**no**				project modified, current studies don't plan to connect the city center.
Maastricht-Heerlen-Kerkrade	Nth	267 000		no				
Nedway Metro/Kent	UK	290 000	340 000	no				
Mulhouse	**FR**	**110 000**		**no**				In commercial operation in 2010
Nottingham	UK	275 000	875 000	(no)				tramway planned at that time, but not in service
Osnabrück	D	170 000	36 000					
Paderborn	D	130 000	270 000	no				
Portsmouth-Gosport-Fareham	UK	180 000		no				
Rostock	**D**	**250 000**	**350 000**	**yes**		**S-Bahn**		
Salzburg	AU	140 000				(yes)		Light rail system, but not desserving the citycenter
St. Polen	AU	50 000	145 000	no				
Sunderland	UK	300 000						
The Hague-Rotterdam	Nth	1 170 000		yes				
Ulm	D	110 000	4 400 000	yes				
Vienna	AU	1 550 000		yes		S-Bahn		Study only on one corridor
Average Population		285 030						
Average Population (without cities > 1M Inhab.)		215 677						

(source: adapted from Vander Bill & Kuehn 2004 and updated)

Table 2: Synthesis of tram-train studies (1987-1997)

At that time, tram-train systems were therefore seen as potential system to develop new services. It was seen as either new build projects, or also frequently as a way to reuse old rail infrastructures that were no more or less in use.

The experience of Karlsruhe was a major step, as it allowed following the commercial services and the trend of demand following its network extension. But the enthusiasm following this project opening led to a very poor rate of surviving case, many of them staying just in the best case as sleeping projects.

The main reasons for this could be summarized be the three points below:

- Complex project management, which has not been supported enough by political and institutional conditions (see § 2.3.3 above)
- The technical barriers related to infrastructure mainly (see § 2.3.1 above)
- Negative economical results: Tram-train systems remains specific, and at that time it was not standard products, leading to extra costs in term of engineering and products, in addition to its specificity in terms of operation also.

3.1.2 Second generation of studies: from dreams to reality

This first phase of studies led transportation engineers to rethink the approach and revise the concept to be this time more focused on specific corridors or applications: Tram-train system is very specific, answering to a narrow market window and was definitely not a miraculous solution to improve transport in agglomerations.

New studies and projects started with more emphasis on the accuracy of the offer-demand concept:

- Tram train was then seen to complete existing networks with a new tangential approach like in Ile de France
- It was redefined to be applied on some regional projects for smaller corridors, where the pertinence of the concept was more in ad equation with the real offer–demand level.
- The concept and related products (rolling-stock) were developed with more derivates, using standards platforms in order to provide efficient and cost effectives products (efforts of manufacturers to increase their portfolio with such systems).

This second generation of studies, after 1997, was therefore taking advantages of the first decade of difficult experience of the tram-train concept to find new applications. The fact to have also in parallel a lot of new tramway and RER projects leaded to more comprehension in the right application of each system: This contributed also to have a better understanding of the advantages and limits of each system, as well as their complementarities.

The table below synthesizes the second generation of tram-train studies: (1996-2010)

City / Region		Population city	Population Region	Existing tramway	Gauge	Other high quality rail	Dates of studies
Alicante	ES	285 000		NO	1000		1999
Antwerp	BEL	450 000		YES	1100		
Bayonne	FR	40 000		NO			
Bellfort (Mulhouse)	FR	55 000		NO			
Besançon	FR	117 000		NO			
Birmingham	UK	971 000		YES	1435		
Bordeaux	FR	215 000		(NO)			
Bremen	GER	540 000	850 000	YES	1435		
Cracow	POL	760 000		YES	1435		
Dunkerque	FR	70 000		NO			
Frankfurt am Main	GER	640 000		YES	1435	Bahn / Metro	
Groningen	NTH	170 000		NO			
Grenoble	FR	153 000		YES	1435		1996
Haarlem	NTH	150 000		NO			
Hanau	GER	88 000		NO			
Helsinki (including Espoo)	FIN	780 000		YES	1000	Metro	
Kaiserslautern	GER	100 000		NO			
Liberec	TCH	98 000		YES	1000		
Liège	BEL	185 000		NO			
Lille	FR	185 000		YES	1000	VAL-Metro	
Lyon (including Villeurbanne)	FR	570 000		YES	1435	VAL-Metro	
Lyon-Givors	FR	570 000		YES	1435	TER	2009-2010
Manchester	UK	394 000		YES	1435		
Marseille	FR	800 000		YES	1430		
Munich	GER	1 230 000	1 500 000	YES	1435	Bahn / Metro	
Nancy	FR	103 000		NO			
Nantes	FR	270 000		YES	1435		2005
Nice	FR	340 000		(NO)			
Nordhausen	GER	47 000		YES	1000		
Orléans	FR	113 000		YES	1435		
Palermo	IT	685 000		NO			
Plymouth	UK	244 000		NO			
Rouen	FR	108000		YES	1435		
Saint - Etienne	FR	180 000		YES	1000		2007
Sassari	IT	120000		(NO)	960		
Schwerin	GER	110 000		YES	1435		
Stavanger (including Sandnes)	NOR	165000		NO			
Strasbourg	FR	264000		YES	1435		1997
Tampere	FIN	200000		NO			
Neckar - Alb (Tübingen - Reutlingen)	GER	195000		NO			
Zwickau	GER	102000		YES	1000		
Average Population	0	329 795					
Average Population (without cities > 1M Inhab.)		298 256					

Source: adapted from Vander Bill & Kuehn 2004 and updated

Table 3: Synthesis of tram-train studies (1997-2010)

This new phase was therefore very interesting for transportation engineers in order to redefine in more details the role of these various systems and their pertinence, to see how each system was positioned in term of function and its match to each city and regional network configuration.

Figure 7: Tram-train system in Saarbrucken, the first low-floor tram-train vehicle

Interesting is to observe the increasing interest for smaller cities, interesting by a mix of functions urban/regional and also an increasing interest in modal complementarily.

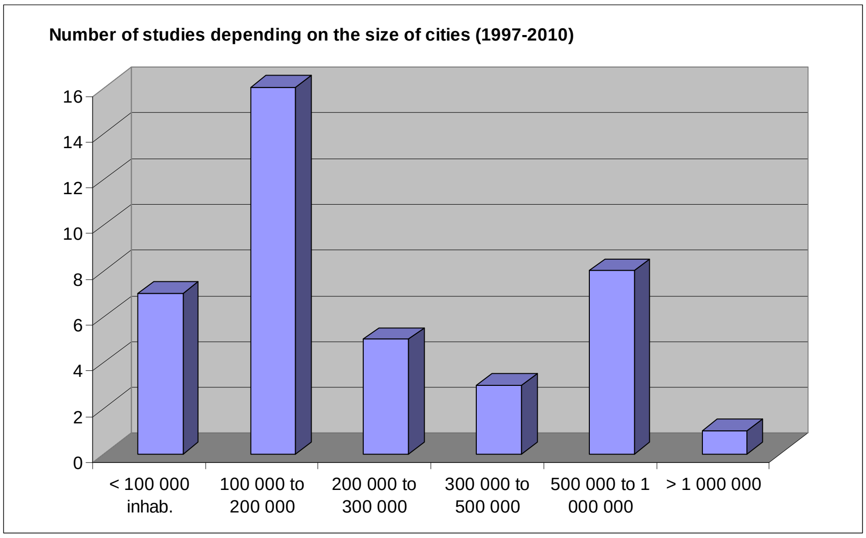

Figure 8: Tram-train studies depending on the size of agglomerations

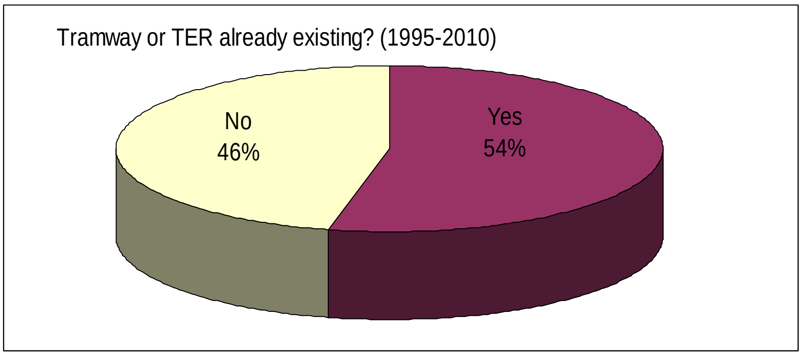

Figure 9: Tram-train studies depending on TC offer

Nowadays, the tram-train is therefore seen as not trivial or simple to implement, with a very narrow positioning in term of function or offer.

3.2 Main Tram-train project references

Tram-train systems; still a narrow market

If tram trains systems appeared in the 1990's and was seen a success at that time with a first implementation done in Karlsruhe in 1992, since then some other experiences have been done but not much, as summarized in the table below.

Commercial operation	City / Region	country	Population city	Population Region	number of kilometre	number of trainset	voltage	Gauge	Mixt traffic	Studies
1992	Karlsruhe	D	291 000		400	122	750 V cc /15 kV dc	1435	no	end 80's
1995	Kassel	D	195 000		122	28	750 V cc /15 kV dc	1435	yes	1990
1997	Saarbrücken	D	177 000			28	750 V cc /15 kV dc	1435		
2005	Aulnay sous bois	FR	82 000		7.9	15	750 V cc /25 kV dc	1435	no	1992
2006	Rotterdam	NL	590 000			54	600 V cc /1500 V cc	1435		
2006	Alicante	SP				9	750 v cc	1000		1999
2000	Nordhausen	D	45 000		8		diesel / 750 Vcc	1000	yes	
2002	Chemnitz	D	250 000		23		750 v cc		no	
2008	Strasbourg	FR	272 000	640 000	40			1435	yes	1997
2009	Lyon West	FR				24	700 V cc /1500 V cc	1435	yes	2007
2010	Nantes	FR	283 000	804 000		24	750 V cc /25 kV dc	1435		2005
2010	Mulhouse	FR	111 000	278 000	13.2	39	750 V cc /25 kV dc	1435	no	1997
	Average		287 000		120.18					

Table 4: List of tram-train projects in commercial operation

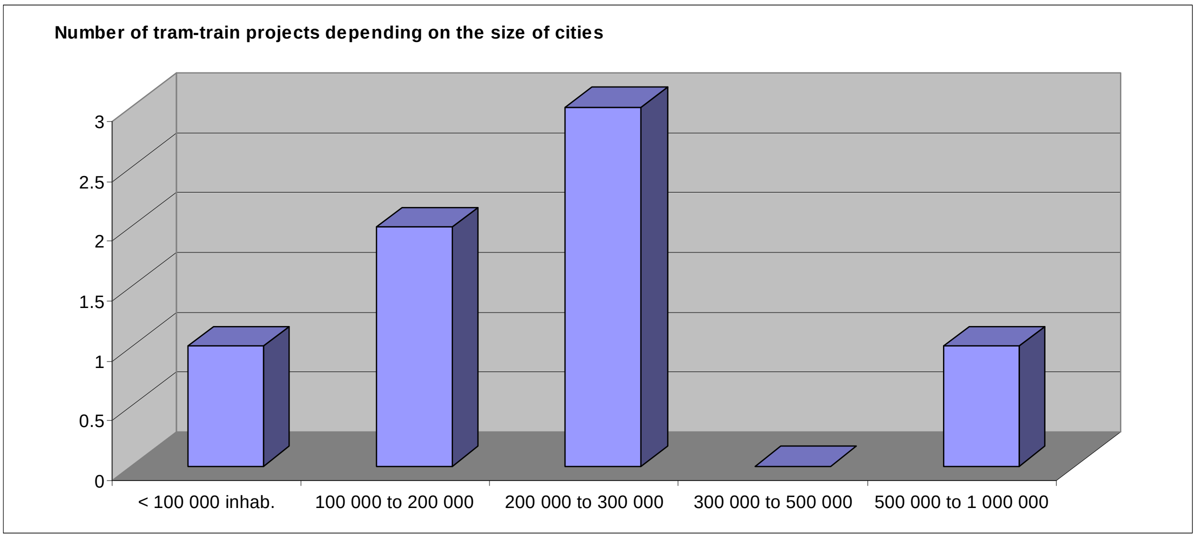

Figure 10: Tram-train studies depending on the size of cities

Implementation projects were designed for specific and narrow corridors, using or rehabilitating old rail lines. They bring passengers in city centres in areas not to close from the central rail stations, or in terminus in peripheral stations such as the "tram-train Ouest Lyonnais". This provides a good improvement of the public transport network structure and creates new leverages through multimodal poles or nodes through a better improvement of the transport network structure.

Each project is a prototype, as the infrastructure characteristics related to tram and rail operation brings much more constraints than other systems. But in this project the technical and organisational environment allowed a proper concept implementation.

These constraints detailed in § 2.3 make the surrounding of such tram-train project so that so far less than 15 applications worldwide in operation, the current projects still provide now. But manufacturers developed technologies, especially form the rolling-stock side so that a much better standardisation rate is allowed, point which could be very important for the improvement of the transportations concept evolution.

Economical aspects, recent experience:

The recent studies and experience shows that operation costs of tram-train systems could be interesting, as pointed out in the table below. However such costs are heavily depending on the cost structure of the operator, and therefore such data could be very different to one operator to the other, and from one country to the other: in addition to the theoretical cost structure, the way to make the accounting and to price the different services is determinant.

Data related to the French experience	Tram	Tram - Train	RER - TER	comments
Average operation costs [€ / km]	7	13.5	18	depends on the organisation of the operator and its cost/pricing structure
Rolling stock costs [M€]	3.3	4.25	7	Investment per trainset

Table 5: some examples of cost comparison for the French market

The economical analysis is very important at the early stage: It shall define early as possible, what are the real impacts of the following key factors:

- Costs of eventual interconnection with the railway line (mix operation), inducing transition area and eventual overpasses (if required depending on the capacity of the railway line at the intersection).

- Maintenance depots: Is there existing depots with comparable rolling-stock which allows synergies? The maintenance strategy, its required infrastructure could also represent significant investments that must be evaluated in the long run.

- Can the demand forecast increase be fully taken into account, or does the tram-train system capacity completely cap this potential (problem of length limitation of stations in the city area).

Depending on such projects requirements, investments costs or limitation in capacity could kill the potential economical benefits of the system attractiveness.

4. Conclusion

Implementing a tram-train system requires first a deep analysis of the technical constraints which are one of the critical aspect or a killing factor, especially on the infrastructure size and the network structure. The simultaneous existence of a tramway and railway network within an agglomeration wishing to develop a tram-train system is therefore not always an advantage as it could multiply the constraints. This probably explains the lack of success of tram-train up to now in Switzerland. But some interests remains as for instance in Fribourg, where politicians asked mid 2010 for a new feasibility study.

In the top killing factors, figure also the organisational and political or institutional aspects: as tram-trains are a mix of city and regional transport service, it usually brings around the table various historical operators and institutions or politicians that must find a consensus. Setting up studies and projects remains something complex in this case in comparison to the other traditional systems (tramway or RER). Such projects require a strong collaboration between the various entities as well as between different operators. It is true that such actors traditionally have their own prerogatives and scope and does not always have the habit to work together, following their own objectives and sometime in competition. But through the increasing numbers of agglomeration projects, this has now significantly evolved, and the degree of cooperation strongly increases.

Tram-train systems are a bit more complex than other transportation modes are they combine two functions: fine connections in centres and regional connections in agglomerations or country-side. As a result it is also more complex and sometime more expensive to be put in place, due to all constraints related to interoperability and compatibility between systems.

Based on all existing projects and especially the one of Karlsruhe, we can say that the pertinence of a tram-train line is based on the three following points:

- Put in relation a city centre with localities of significant size, which internal connections have relatively short inter-distance stops in order to increase the impact of this type of transportation service.
- Benefit from the very competitive trip time between these localities and the city centre, thanks to the performances of the line and the rolling stock.
- Provide to users significant earning time thanks to the direct switch between the "regional rail function" and the "tramway" function in the city without connection changes putting users closer to their destination.

Such a system could also be seen as a transition for cities wanting to take advantage of such a concept, mixing the focus on regional and city traffic. If some years later the traffic in the city centre leads to congestion, the functions could be split again, with a tramway function and a separate urban rail function. In these conditions, the tram-train system could be a very good tool for the transport policy, under the condition it is well designed and if the critical conditions for implementations are well checked, in order to benefit from all the pertinence of this concept.

5. References

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