OVERGROUND RAPID TRANSIT SYSTEMS (BRT/BHLS OR TRAMWAYS) IN FRANCE: SCOPE OF APPLICATION AND POLICY CHOICES

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ABSTRACT

The last three decades have seen the return of tramways to major urban areas in France. These systems have become widely popular due to their performance and their urban requalification potential. The use of such systems continues to grow, including in average-size urban areas. At the same time, the “Bus with a High Level of Service" (BHLS) concept is also growing in popularity. The BHLS is a rapid transit system inspired by the U.S. Bus Rapid Transit (BRT) with its “system approach” but adapted to the French context : narrow streets, high density, street sharing and mass transit function already delivered by metro or tramway. As with tramway, the BHLS includes more than just a rolling stock but also a specific infrastructure and some operating conditions that guarantee a high level of service.
Whilst the financial situation facing local authorities is leading to a streamlining of investments, some average-size urban areas are questioning the economic suitability of tramways, especially where the BHLS is able to meet demand (less than 2,500-3,000 pass./hour/direction). Therefore, the “tramway vs. BHLS" debate rages on in the technological and political spheres, as well as among local residents, despite the fact that there is a clear difference between the two systems in terms of cost, capacity, urban integration, etc.
After an international review on semantics on rapid transit systems, the aim of the paper is to detail the strengths and weaknesses of tramway and BHLS in the French context. Using regulations, technical characteristics, simple economics and experiences, the paper draws the conditions under which each system is suitable. This work is based on recent CERTU studies on the question of rapid transit systems, and on French and European research on the BHLS concept, including the findings of a European COST Action led by CERTU, which includes practitioners and researchers from 14 European countries (www.bhls.eu).

Keywords : Tramway, LRT, Bus, Bus with a high level of service, BHLS, France

INTRODUCTION

As travel practices and attitudes change, public transport must also adapt on an ongoing basis, with innovative developments in both technological and organisational terms. In the 1980s, the French government took steps to reintroduce tramways into French cities (Nantes in 1985, Grenoble in 1987 and Rouen and Strasbourg in 1994), involving a number of urban redevelopment projects. The "air quality" act passed in 1996 used urban travel plans (PDU) to rethink urban mobility, resulting in numerous tramway projects. With support from central government and increasing concerns about living environments, tramways began to be developed in most French important conurbations.

Gradually, questions began to be asked about the relevance of tramways for medium-sized conurbations (fewer than 300,000 inhabitants), particularly in terms of the cost/demand ratio. The idea of "intermediate systems", halfway between a bus network and a tramway began to be mooted, driven by a groundswell of technological innovation: the *TVR*[1] by Bombardier, the *Civis* by Irisbus, the *Translohr* by Lohr, the *Phileas* by Advanced Public Transport Systems (APTS) and so on (Soulas, 2003).

Whilst these new systems have not always lived up to their promises, researchers and operators are now turning to America and Bus Rapid Transit (BRT) systems.
Based on local experiences - *Trans-Val-de-Marne (TVM)* in the Île-de-France, *Transport Est Ouest Rouennais (TEOR)* in Rouen, *BusWay*® in Nantes, etc. - this approach resulted in 2005 in the french concept of Buses with a High Level of Service (BHLS), which places the bus at the heart of a real transport "system" and restores its positive image (Babilotte and Rambaud, 2005). The increasing influence of the BHLS since 2006 (Rabuel, 2009) and the return of the role of central government in funding for public transport have driven the move towards public transport systems that use dedicated lanes (TCSP[2]), which now form part of local and national sustainable development policies. The enthusiasm for public transport places the question of the choice of system back at the heart of a complex and delicate debate involving technical experts, elected representatives and citizens.

TERMINOLOGICAL CLARIFICATIONS

A few terminological clarifications are required when discussing TCSP systems. Time, history and changing attitudes result in different visions of urban transport systems.

In France, there are three main groups of urban TCSP systems based on regulatory considerations

In France, the emergence of "guided systems on tyres" in the late 1990s engendered a certain amount of confusion in terms of semantics. In particular, the incorrect use of the term

[1] *Transport sur Voie Réservée (TVR)* also known as Guided Light Transit (GLT) in English
[2] The term "Transport collectif en site propre" (TCSP) – literally *Dedicated lane public transport* – refers in France to a mean of public transport system that mainly uses land area assigned specifically to it, and operating with rolling stock ranging from buses to metros. As it is a French concept adapted to the national history and culture, the acronym TCSP will be used all along the paper.

"tramway on tyres", driven by political communications, has prompted a number of received ideas about capacity, performance, attractiveness and conditions for the implementation of the system (regulations). In the wake of this, the BHLS has emerged as a deliberately flexible concept.

Since 2007, Certu has put forward a new classification of "urban TCSP systems" which has been discussed in working groups involving the Directorate-General for Infrastructure, Transport and the Sea (DGITM), the French Association of Public Transport Authorities (Gart), the French Public Transport Association (UTP), the French National Institute for Transport and Safety Research (Inrets) and the State Agency for Mechanical Ropeways and Guided Transport systems (STRMTG). This classification distinguishes between systems on the basis of two regulations:

- French decree no. 2003-425 relating to the safety of guided public transport (GPT)
- articles R. 311-1, R. 312-10 and R. 312-11 of the French Highway Code and the by-law of 2 July 1982 relating to passenger public transport, as amended by the by-law of 18 May 2009

Some guided systems are subject to both regulations insofar as the guidance system is non-physical (such as the *TEOR* in Rouen and the Phileas of APTS in Douai) or physical but not permanent (the *TVR* of Bombardier in Nancy and Caen). Their rolling stock, considered as road vehicles, is therefore limited in terms of size by the French Highway Code (24.5 m long and 2.55 m wide, excluding wing mirrors). The Translohr produced by Lohr Industrie and implemented in Clermont-Ferrand, however, is guided permanently by a central rail. It is therefore only subject to the regulation on guided public transport, in the same way as the metro and tramway are.

Three categories of urban TCSP systems can be distinguished on the basis of regulatory and technical considerations: the metro, tramways and Buses with a High Level of Service (BHLS).

Metro

The metro is a permanently guided TCSP system characterised by a fully grade-separated infrastructure (no crossroads, platforms inaccessible to (non-travelling) pedestrians, bicycles and motor vehicles). It generally runs underground or on a viaduct. It is operated with a block system. It may be automatic either driverless or not, attended or unattended. A distinction is made between heavy-rail metros and light-rail metros, such as the Véhicule Automatique Léger (VAL) – *Automatic Light Vehicle* used in Lille, Toulouse and Rennes..

Tramway

The tramway is an on-road guided TCSP system that always follows a given trajectory, running on one or more physical rails. This category therefore includes the *Translohr,* "Tramway on tyres" system developed by the manufacturer Lohr, a guided system on tyres

distinguished by the fact that it is physically and permanently guided by a rail. This means that it is not covered by the French Highway Code, particularly in so far as the size of its vehicles is concerned.

Figure 1 : The “tramway on tyres” Translohr in Clermont-Ferrand (source: Certu)

Bus with a High Level of Service (BHLS)

The BHLS is a TCSP system characterised by the use of road vehicles limited to 24.5 m in length and 2.55 m in width by the French Highway Code.
By taking a comprehensive approach (to rolling stock, infrastructure and operating conditions), the BHLS can offer a continuously higher level of service than conventional bus routes (in terms of frequency, speed, span, regularity, comfort and accessibility). This is close to the level of service offered by French tramways. The bus is considered here in its widest sense: it may be guided (using a physical or non-physical guidance system) or non-guided, and powered by fossil fuels or electricity, or use a hybrid power system. BHLS systems that use trolleybuses (such as the C1/C2 in Lyon and projects in Saint-Étienne, Valenciennes and Nancy) will therefore be referred to as “trolleybuses with a high level of service”. The *TVR* from Bombardier, a guided system running on a central rail that is subject to the provisions of the French Highway Code, is therefore classed as a guided BHLS. The *Phileas* from APTS, which is currently being developed, should also be included in the guided BHLS category, subject to the vehicle being authorised in France by the relevant authorities.

Figure 2 : the guided BHLS TEOR in Rouen (source: Communauté de l'agglomération rouennaise)

This classification highlights a different approach in terms of the regulations, depending on the nature of the guidance system:

- permanent and physical for the metro and tramway
- partial, non-physical or non-existent for the BHLS

It also emphasises the notion of capacity, which remains an important criterion in the choice of a TCSP system:

- its permanent guidance system and fully grade-separated infrastructure offer great prospects for the metro
- to a lesser extent, tramways owe their extensive capacity to the dimensions allowed by a physical, permanent guidance system. Their capacity is limited, however, by operating conditions (crossroads management) and the length of platforms.
- the speed and frequency of a BHLS system can be identical to those of a tramway. The dimensions of its rolling stock, and therefore its capacity, however, are limited by the French Highway Code.

DLPT classification	Tramway		Guided BHLS				Non-guided BHLS
System	**Rail-based tramway**	**Translohr**	**Bombardier TVR in Caen**	**Bombardier TVR in Nancy**	**APTS Phileas in Douai***	**Bus with optical guidance**	**Conventional bus**
Type of guidance	2 load-bearing rails	central rail	central rail	central rail	computerised with correction using magnetic sensors	optical	
Guidance class	physical	physical	physical	physical	non-physical	non-physical	
Use of guidance	permanent	permanent	whole commercial run (not to/from depot)	part of commercial run	permanent (except in degraded mode)	permanent (except in degraded mode) or occasional	none
Subject to GPT regulations	yes	yes	yes	yes	yes	yes	no
Subject to the *Code de la Route*	no	no	yes	yes	yes	yes	yes

* planned

Table 1: classification of TCSP systems (source: Certu)

Different approaches in different countries

The French view of tramways is still closely linked to the historical situation where they have been dismantled after the Second World War[3]. Their reintroduction, which began in 1985, is based on stringent requirements in terms of service level (they now run almost exclusively in dedicated lanes) and their accompanying urban development projects (Gouin, Rabuel and Varnaison-Revolle, 2009).

In other countries, particularly in northern and eastern Europe, the tramway has remained above all a transport tool. Its performance varies depending on the configuration chosen: from tramways caught up in the traffic on the model of the old American *Streetcar*, to those that run through tunnels on some sections. Nonetheless, tramways do share some characteristics across Europe: most run on the roadway and their dedicated lanes are relatively “permeable”. The German term for "tramway”, in fact, is *Straßenbahn,* which suggests the idea of a “railway in the road” By contrast, when light rolling stock (such as that operated on tramways) is used in the form of a metro system (i.e. grade-separated lanes that are inaccessible to other users), the term used is *Stadtbahn*. The same idea of a “light metro” system is found in the American term “Light Rail Transit” (LRT), which has become widespread throughout the world. It exists in a variety of different forms. Whilst in the United States the term LRT refers to both light and conventional metro systems, the term is sometimes used, incorrectly, to encompass “European tramways”.

As far as buses are concerned, the terminology used firstly expresses the different contexts in different continents. In the majority of European cities, the requirements for high capacity are already met by suburban trains, metro and tramways. The BHLS (Bus with a High Level of Service) can therefore adapt to the number of users, whilst retaining the main advantages of the tramway and its philosophy in terms of integrating into often narrow streets. Conversely, the concept of BRT and the legendary projects associated with it (e.g. in Bogota and Curitiba) regularly come back to the need for high capacity, which can result in significant divisions in the urban landscape (e.g. systems that use 2x2 dedicated lanes, grade-separated junctions, pedestrian footbridges, bus convoys, etc.). This *Full-BRT*[4] system seems to be becoming more widespread in numerous major cities in developing countries and conveys only a partial image of BRT. In the United States, in fact, the BRT concept is broader (Finn, Heddebaut and Rabuel, 2010), incorporating *BRT-Heavy* (the equivalent of the French BHLS) and *BRT-Lite*, which corresponds to initiatives to revitalise bus routes such as the *Lianes* in Dijon or the *Chronobus* in Nantes. This last category is primarily based on lines with high frequency and span, with ad hoc developments at certain black spots (e.g. queue jumping, bus lanes, priority at traffic lights).

[3] Except for tramways in Saint-Etienne and Lille, and tramway no. 68 in Marseille (now dismantled following the decision to create a new tramway network, the first section of which entered into service in 2007).
[4] Term used in the United States to describe very high-capacity BRT systems.

WHICH TCSP SYSTEM TO CHOOSE? A UNIVERSAL QUESTION TO WHICH THE ANSWER IS CHANGING OVER TIME

The question of which TCSP system to choose is often a matter for debate. Whilst public transport now plays an important role in political discussions, it is also a question that resonates with citizens, associations, enthusiasts, the press and others. It translates differently depending on the country, city and time.

In the United States, the debate between BRT and LRT is an old one and subject to significant levels of lobbying. The first BRT projects came about as the result of studies carried out in St Louis and Washington in the 1950s (Levinson and *al.*, 2002). These were quickly compared to LRT systems. This continues to be a topical question (Vuchic, 2005) and still revolves around the same arguments:

- In North American cities, the primary role of public transport is to respond to the needs of commuters travelling between the Central Business District (CBD) and their home in the suburbs[5]. Given its flexibility and limited cost, a BRT system can be operated in a way that meets these requirements more effectively, for example by limiting feeder services and offering more rapid direct services in addition to routes where buses call at every stop.
- Defenders of LRT systems emphasise their level of service, capacity, attractiveness[6] and potential to structure the environment they run through.

In Europe, responsibility for the choice of TCSP system generally falls to a single urban transport authority, which first defines requirements (routes, capacity, etc.) and then the resources needed to meet them (type of system). The British Isles are the main exception to this rule. Bus deregulation in Great Britain and the separation of responsibility for buses and tramways in Ireland are both obstacles to an integrated, comprehensive approach. In these circumstances it is difficult for tramways to gain a foothold.

In France, the discussions about TCSP systems focused initially, in the 1980s, on the choice between the VAL, which first entered service in 1983 in Lille, and the tramway (revived in Nantes in 1985). Both systems have very different characteristics in terms of performance, integration into the urban landscape, and costs. There was intense debate in the large provincial conurbations that wanted their city to have a TCSP system (primarily Strasbourg, Toulouse, Rennes and Bordeaux). Between 1994 and 2003, the French government played an active role in the debate by supporting the development of the tramway over the VAL, through more advantageous subsidy levels and ceilings.
With tramways spreading to conurbations of fewer than 300,000 inhabitants from 2001 onwards (Montpellier and Orléans) and the recent emergence of the BHLS, the debate is now focusing on surface TCSP systems. Unlike the choice between the VAL and the tramway, the choice between the tramway and BHLS forms part of a shared vision in terms

[5] Conversely, in Europe, public transport uses the potential resulting from a concentration of passenger numbers and is playing an increasingly important role for reasons other than travel between home and work.
[6] A study carried out by the National BRT Institute (NBRTI) nonetheless shows that a high-performance, visible BRT can have as positive an image as an LRT (Cain and *al.*, 2009).

of service level and integration into the urban landscape. Tramways and BHLS systems, however, are complementary and each is appropriate in different situations.

RELEVANCE OF SURFACE TCSP SYSTEMS AND SELECTION PROCESS

The process that leads to the choice of a TCSP system can be very complex. It takes time, research, consultation and a high level of involvement from decision-makers in relation to some highly sophisticated technical aspects. It is primarily based on the six themes discussed in the rest of this article. The process may involve several iterations, going back and forth between these themes: the choice of the most appropriate system is not always immediate.

The long-term view (20-30 years) of the development of conurbations and public transport/TCSP systems

Long-term strategies regarding the location of housing, employment and services, together with changing travel expectations and behaviours, can modify the balance of transport needs and transport provision within an urban area. They may also themselves be influenced by transport policy. As a result, the development of TCSP networks (systems, routes, general organisation of public transport) must anticipate these phenomena as effectively as possible based on a long-term, comprehensive view.

As far as the approach to building long-term public transport networks is concerned, several lessons can be learned from feedback from the first cities with TCSP systems:

The first TCSP route should not be the only focus of attention

To ensure that the effect is sustainable, the improvement in service level must continue over time (e.g. by developing other TCSP lines, improving the bus network, etc.) and the urban transport authority must have room for manoeuvre by thinking of the long term. In addition, the first TCSP route should not automatically try to serve all the major facilities that generate traffic if this involves using a winding route that limits speed and is costly (initial investment and operating cost). It may, however, be a step in the development of a network of lines with a high level of service.

TCSP systems form part of a broader network that provides support for them

They should not be the sole focus of attention. The most positive effects in terms of public transport mobility are seen where the parallel conventional bus system performs well (e.g. in Nantes, Strasbourg and Rennes) (Certu, 2007). This is even more the case when TCSP systems only serve a little part of the conurbation.

Bus to TCSP feeding do not have to be systematic

Organising a bus network purely to serve the tramway has its limitations, as proven by the experience of the first tramway line in Orléans in 2001. Although this type of operation ensures a minimum level of traffic on the tramway line, it does not in any way guarantee a "TCSP effect" across the whole of the network. In addition, it can lead to connection difficulties, particularly in the outbound direction, if buses do not run frequently enough. It may be preferable to offer users a wider range of options, for example a high-performance feeder system and a city-centre bus system with a properly "meshed" network. This concept of "optional transfers" has been implemented in Rennes, Lyon and Le Mans, amongst others.

The problems of capacity in TCSP systems must be anticipated

The problems of capacity must be anticipated in order to avoid difficulties in the medium term (operational problems, irregularity, reduction in commercial speed, poor image for the service). In particular, the logic of concentrating TCSP routes around a main central hub may be a matter for debate. In addition to the problems of operating the actual lines (three lines converge at the "Commerce" hub in Nantes), these configurations create pedestrian flows that are difficult to manage in confined spaces (such as "Homme de Fer" station in Strasbourg).
Local authorities therefore need to take this aspect into account in planning future projects (e.g. tramway "ring routes" such as line E in Strasbourg and the development of a "meshed network" in Nantes).

Several French networks have now incorporated the concept of "meshing"in developing their TCSP networks

The purpose is both to respond to travel requirements more effectively and to anticipate problems of capacity. This approach has been developed either to complement the existing TCSP network (e.g. extension of line E of the tramway in Toulouse and line C in Grenoble) or alongside the first TCSP lines (such as the tramway project in Dijon).

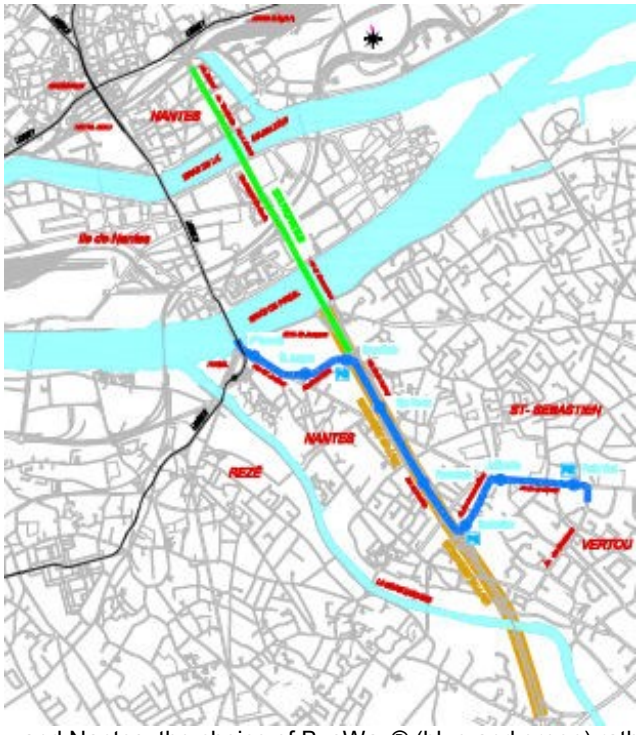

Figure 3: between Vertou and Nantes, the choice of BusWay® (blue and green) rather than a new section of tramway (blue) is starting to "mesh" the city centre whilst relieving congestion on the existing tramway (grey) (source: Nantes Métropole)

The question of the long-term overall organisation of networks is a major issue. Some networks have anticipated this aspect as part of their thinking (e.g. Nantes and Strasbourg for the last few years, and Dijon). Others will be forced to do so by circumstances. This is the case in Bordeaux, whose short-term (2012-2013) TCSP projects essentially involve extending existing tramway lines that are already overcrowded. The discussions that took place at the time the outsourcing contract for the system was renewed highlighted these weaknesses. In the short term, the new operator suggested using *Lianes* based on the Dijon model in order to increase the attractiveness of buses as a complement to the tramway. At the same time, the city has incorporated these elements in its discussions on the development plan for the TCSP network for 2020-2030.

TCSP service-level targets

Tramways and BHLS systems can provide the same level of service in terms of frequency, span, speed and regularity. It all depends on the traffic conditions. The differences stem from levels of comfort, accessibility, and image which are better with the tramway, although developments around buses (design, guidance systems, etc.) have led to numerous improvements.

Comfort

Rail-based, guided transport systems offer better levels of comfort for passengers (better stability for passengers who are standing). Modern rail-based tramways are relatively quiet

except for screeching where bends are too tight. In this respect, vehicles on tyres have an advantage but, in general terms, sharp bends should be avoided for reasons of speed.

Accessibility

Single-path guided systems (e.g. rail-based tramways, *Translohr* and *TVR*) offer optimal levels of accessibility both in terms of the platform/vehicle interface and inside the vehicle itself. Horizontal and vertical gaps are less than 3 cm on all doors. There is not yet any feedback on the *Phileas* BHLS, which is also a single-path system. Optically guided systems (not single-path) generally offer good levels of accessibility (e.g. horizontal and vertical gaps of less than 5 cm on the most accessible door on the *TEOR* in Rouen).

Image and comprehensibility

Rail-based tramways offer more freedom in terms of choice of materials (paving slabs, grass, etc.) in order to reinforce the modern, high-quality image of the system. Rails make the system easier to understand. Nonetheless, feedback shows that BHLS systems have a high level of potential in terms of image, urban redevelopment and comprehensibility. The *TEOR* BHLS system in Rouen is very popular with users, primarily as a result of the high level of service it offers (the *TEOR* scores 16.2/20 for overall satisfaction compared with 15.7/20 for the tramway).
Ground-level power supply (Alstom APS[7] system in Bordeaux) and on-board battery systems (crossing the Place Masséna in Nice) are now a part of the aesthetic quality of tramway integration. Trolleybuses may also use these types of technique in the short or medium term.

Figure 4: Avenue Alsace Lorraine in Rouen before and after the development of the TEOR (source: communauté de l'agglomération rouennaise)

[7] Alimentation Par le Sol (APS)

Travel requirements and capacity of TCSP systems

The maximum theoretical capacity of TCSP systems depends on the frequency of the service and the capacity of the rolling stock. Capacity is calculated on the basis of a comfort standard of 4 persons per square metre and an optimal service (absolute regularity, trams running every 3 minutes in each direction) and a presupposition on the internal lay-out (seating/standing spaces arrangement). In practice, the capacity of a system is primarily dependent on the conditions in which it was developed and operates. On-board ticket sales, not having priority at traffic lights and failure to keep dedicated lanes clear are all factors that have a negative impact on the regularity and therefore the capacity of a TCSP system.

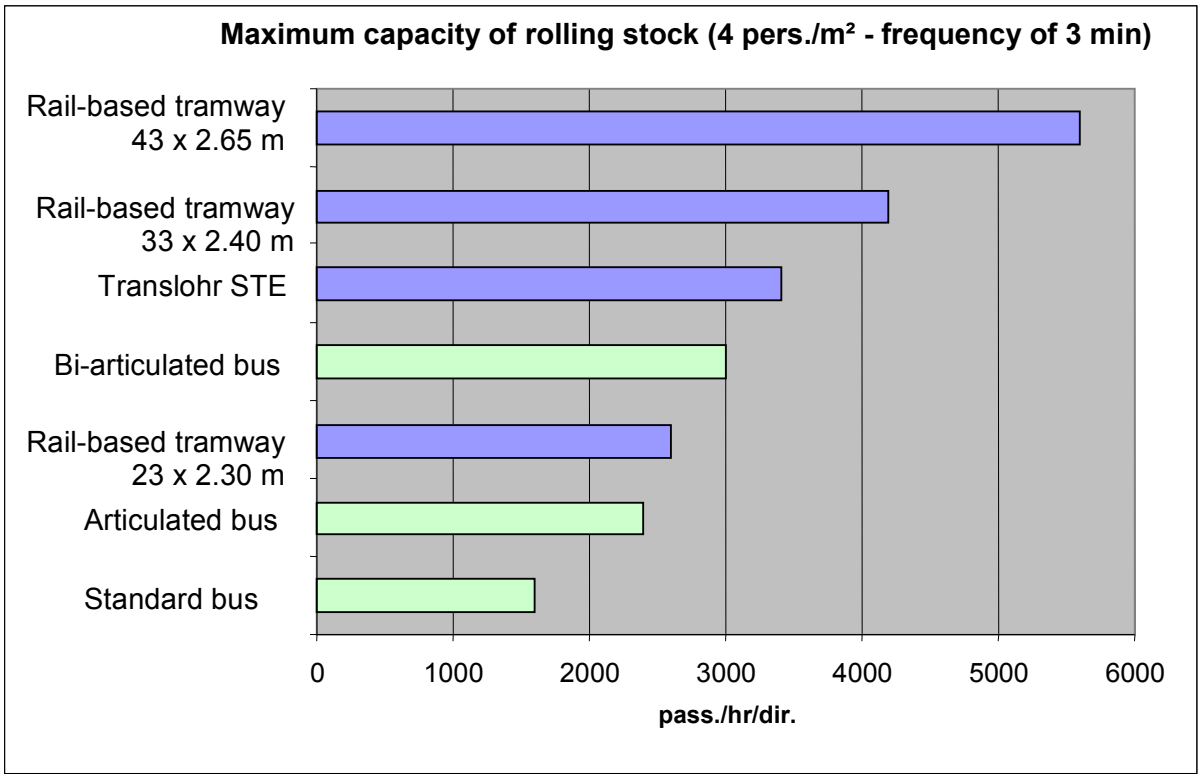

Figure 5 : capacity maximum system capacities source: Certu)

Tramways and BHLS system offer different levels of capacity because of regulations.
BHLS vehicles are in fact limited by the French Highway Code to 24.5 m in length and 2.55 m in width, excluding wing mirrors. Currently, apart from the Bombardier *TVR* in Caen and Nancy, only standard or articulated buses (maximum 18.75 m long) operate in France. In other countries, some conurbations operate non-guided, bi-articulated buses (e.g. the Van Hool AGG 300 in Utrecht and Hamburg, and Hess vehicles in Switzerland and Luxemburg). Manufacturers working in this field are expected to launch new rolling stock in the next few years. Several French conurbations, including Nantes and Nîmes, have shown an interest in this type of vehicle.

Figure 6: Van Hool AGG 300 bi-articulated bus in Utrecht (source: Certu)

By contrast, the dimensions of tram vehicles (whether on rails or tyres), can exceed the limits set by the French Highway Code. These are modular vehicles whose capacity can vary widely from one model to another, depending on the choices made (width, length, internal layout).

Matching capacity to demand is no easy matter, insofar as it is based on long-term traffic forecasts (20-30 years) that can alter as circumstances change. Since 2006, the reduction in purchasing power and an increasing awareness of environmental issues has led to a sharp increase in the use of public transport networks. This is a useful reminder of the strong development potential for urban public transport but requires a certain degree of caution. Recent trends of this kind have not yet bedded down and uncertainty remains even where detailed modelling has been produced.
Nonetheless, French and European experience demonstrates the necessity of allowing for additional capacity. Opting for a system that reaches its limits in terms of capacity as soon as it enters service or shortly afterwards can cause operational problems (e.g. the length of time required for passengers to get on/alight, situations where it becomes impossible to get on, irregular running, reduction in commercial speeds, etc.) These then lead to additional operating costs and convey a very negative image to the population.

Overall cost of TCSP systems

The controversial question of the cost of systems is the subject of large amounts of research, particularly abroad (Deutsch, 2008, Hsu, 2009, Zhang, 2009). In the difficult context of funding for public transport, this topic is often approached in too simplistic a manner and cannot just be summed up as "BHLS systems cost three times less than tramways", as is often heard in France.

For a cost analysis to be relevant, it must:

- take into account not only the initial investment costs but also long-term operating and maintenance costs (resurfacing the running way due to rutting for tyre-based systems, points for tramways, mid-life refurbishment of rolling stock, etc.)
- incorporate the life expectancy of rolling stock
- separate the "transport" part of a TCSP system from "building to building" roadway enhancements, which are independent of the choice of TCSP system
- be part of a long-term economic calculation (Certu, 2002)

Identifying the various investment and operating costs is difficult as these are strategic data for manufacturers and operators. Nonetheless, it is possible to give some orders of magnitude based on feedback from current and planned TCSP systems (call for "urban transport" projects from the Grenelle round-table talks on the environment).

System	BHLS	Tramway (on rails or tyres)
Cost of vehicle (2007 value excl. tax)	€300 K to €900 K	€1.5 to €3 M
Investment costs of a 1st TCSP line – "transport" section including vehicles - (2013 value excl. tax)	€2 to €10 M/km of dedicated lane	€13 to €22 M/km of dedicated lane
Life expectancy of rolling stock	15–30 years	30-40 years
Operating costs of a 1st TCSP line (2008 value excl. tax)	€3.5 to €5 /km	€5 to €7 /km

Table 2: TCSP systems cost data (source: Certu)

Note:
- investment costs for the "transport" section do not take account of road works outside the public transport site, urban amenities or associated developments. They depend primarily on the level of service required and the context (civil engineering structures, depots, etc.)
- the cost of a BHLS vehicle depends on its length and facilities. The value of €900 K for the BHLS relates to a modern articulated trolleybus.
- the *TVR* from Bombardier, which is no longer being produced, and the *Phileas*, which has not currently been authorised for use in France, have not been taken into account in the data shown in the table. Nonetheless, it will be noted that the investment cost of the *TVR* in Caen ("transport" section including rolling stock) was €14M_{2000}/km of dedicated lane and that it had operating costs of €6.5/km in 2003, similar to a tramway. In addition, the cost of the *Phileas* project in Douai was calculated at €7.5M excl. tax_{2007}/km of dedicated lane in the 2007 invitation to tender. The rolling stock was estimated at €1.3M for an 18-metre vehicle.

Integrating a TCSP system into the urban fabric

Integrating a TCSP system into the fabric of the city must be part of a comprehensive approach designed to support alternative modes of transport to the private car. This task is made particularly difficult, however, by the narrowness of the streets in most French cities. The long-term vision for an urban area and its public transport network can sometimes lead to choices of systems and routes that are incompatible with the integration options available.

Tyre-based systems have the advantage of being able to negotiate turns with greater ease, especially when they are guided and follow a single path. It is also important to note that bi-articulated buses may integrate more effectively on curved sections than articulated buses

(e.g. thanks to directional rear axles). However, tramways require less space on curved sections than buses. If high performance is sought (particularly in terms of comfort and speed), TCSP systems should avoid overly winding routes.

Tramways can be integrated into straight sections of street more easily, as rolling stock is not excessively wide (2.4 m for standard trams, 2.2 m for the *Translohr*). Buses, on the other hand, tend to be between 2.5 m and 2.55 m wide, not including wing mirrors (an extra 0.25 m on each side). By having doors on both sides of vehicles (this is the case for all trams in France, as well as for the APTS *Phileas* bus), it is also possible to reduce the space taken up by stations (e.g. using a 4 m wide central platform instead of side platforms, each 2.5 m wide).

System	**Rail-based tram 2.40 m**	**Translohr**	**TVR**	**Phileas (1)**	**TEOR**	**Conventional bus (2)**
Type of guidance	2 load-bearing rails	central rail	central rail	computerised with correction using magnetic sensors	optical	no guidance
Single-path	yes	yes	yes	yes	no	no
Width of running way on straight sections (double lane)	5.6 to 5.8 m	5.4 m	6.2 m	6.5 to 7 m	6.7 to 7.3 m	6.5 to 7 m
Minimum acceptable radius	25 m	10.5 m (on rail)	12 m (on rail) (3)	12 m	12 m (non-guided) 25 m (guided)	11 to 12 m
Width of running way on curves	7 to 7.5 m	6.7 to 7 m	7 to 7.6 m	8.2 to 8.5 m	9 to 11 m	10 to 12 m

(1) as of 1 June 2009, the Phileas system had not yet been approved in France; running-way measurements may therefore be subject to modifications
(2) with no cyclists
(3) feedback from Nancy and Caen shows that it is preferable not to descend below 15 m

Table 3: integration of different TCSP systems (source: Certu and Cete Méditerranée)

With a few exceptions, trams today are designed to be able to cope with gradients of 6% or 7%. With motors on each axle, slopes of 10% could be envisaged; however, this would involve significant modifications that could increase rolling-stock costs. Rubber-tyred vehicles are better equipped to negotiate slopes, with a limit of 13% often set in order to ensure user comfort. Finally, it should be noted that electrically powered vehicles have greater accelerating capacity on slopes.

The use of guided systems for road vehicles is often motivated in technical terms by integration problems. However, the reality is far more complex. While physical guidance systems such as the central rail of the *TVR*, do indeed help reduce the space required by the vehicle, the same cannot always be said for vehicles that use non-physical guidance systems. Regulations on guided public transport impose safety margins which, in straight sections, can cancel out the gains obtained by guidance (this is the case for the APTS *Phileas* system in Douai, for example) or even increase the amount of space required (e.g. *TEOR* in Rouen). Whilst the land take on curved sections may be lower in the case of single-path systems, the guidance system is not always suitable for tight bends (as with the optical guidance system in Rouen).

Finally, given the various problems encountered with certain physical guidance systems (higher costs than expected, operational difficulties) and the limits of non-physical systems when it comes to integration, guidance systems now seem to interest local authorities largely because of easier docking and the improved accessibility they provide at stations (this is the case with projects in Metz, Nîmes and Nancy).

Whilst integration studies are often carried out late in the process, it is important to take this aspect into account at the feasibility study stage. In Besançon, the strategic vision for the development of the town and its public transport network, as well as the constraints caused by the meander of the River Doubs, influenced the decision to opt for a TCSP that runs through the central business district. Because this area is so confined, it requires a complex single- lane system that is difficult for buses to negotiate and incompatible with the high level of service required and the desire to "open up" public space. The single-lane solution for buses would not have been able to cope with demand at peak times once the system comes into service. Opting for a tramway has therefore helped to limit integration problems and guarantee that the system will have sufficient capacity over the medium and long term.

Technology and industrialisation

Not all TCSP systems offer the same "manufacturer's warranties" over the long term. Rail-based tramways and BHLS systems based on relatively traditional bus models are solutions that have been tried and tested in France and Europe. The results are a level of competition and economies of scale that encourage their more widespread use.

The new comprehensive "turnkey" guided systems on tyres often rely on a single manufacturer (Lohr, Bombardier or APTS). Whilst the *TVR* has effectively been abandoned by Bombardier, the *Translohr* is continuing to develop in France, Italy and Asia. As far as the *Phileas* is concerned, it has not yet been authorised for use in France and is experiencing implementation problems in the Netherlands and Turkey. Manufacturers have expressed more interest in the simpler and less costly optional optical guidance system and this could be developed further.

Whatever the system used (tramway or bus), research is now primarily emphasising questions of propulsion and the removal of overhead power lines, areas in which rail-based tramway systems already have a head start: examples include APS (ground-level power supply) systems in Bordeaux over more than 10 km, on-board batteries in Nice to cross Place Masséna, and numerous studies currently being carried out by manufacturers[8]. Lohr also offers battery operation for the *Translohr* over short distances (less than 2 km in Padua) and is studying a system of inverse catenaries, however this would presuppose the installation of a large number of posts (which would have to be spaced at distances shorter than the length of the vehicle). As far as buses are concerned, whilst battery-powered systems for short distances seem to be able to be developed quickly, full "wireless" operation will undoubtedly take longer to achieve.

[8] Ground-level power supply system at Bombardier (PRIMOVE project with induction technology) and at Ansaldo (TRAMWAVE project) or supercondensers at Alstom (STEEM project) or Siemens (ITRAS HES project).

Other features

Other features of TCSP systems do not appear to play a decisive role in the final choice. From the point of view of CO2 emissions, the focus on electricity promoted by the French government as part of its policy of financial support for TCSP projects responds to the needs of both tramways and BHLS systems (trolleybuses). As far as noise is concerned, these issues have now been largely resolved, although the problem of trams screeching on sharp bends remains. This problem has prompted designers to opt for routes that are as straight as possible, particularly given that sharp bends also cause rapid wearing on rails and significantly decrease speeds. It seems that the conclusions on the impact of tramways on economic activities (Certu, 2005) may also apply to BHLS systems (studies underway in Rouen). Finally, whilst the work required to develop a tramway system may take longer than that needed for a BHLS (although it depends on the level of service required), this argument does not seem to be decisive in the choice of system.

CONCLUSION

Surface TCSP systems (tramways and BHLS) are high-performance tools available to local authorities to support a policy of sustainable urban transport. Whether it is the first TCSP route to be developed or the extension of an existing network, discussions need to focus on scenarios (route, system, organisation, integration) that form part of an overall view of the public transport network and the development of the conurbation.

An analysis of system characteristics shows that the relationship between cost and demand and integration into the urban fabric are decisive factors in choosing a system that meets the authorities' objectives as closely as possible. Each system is relevant to a greater or lesser extent in a given situation. Nonetheless, the uncertainties hanging over the future of mobility in France (such as the price of oil, the duration and impact of the economic crisis, increasing awareness of environmental concerns, the actual potential for modal shift, etc.) have further complicated the decision over which system will be most relevant in the long term (15 years, 30 years or more!) and impacted the ability of local authorities to fund them.

At the same time, innovation in both technological and design terms is continuing in order to offer urban areas the solutions that are most suitable for their needs: amongst other things, wires are disappearing from historic city centres, the BHLS concept is moving into suburban areas to complement rail services (e.g. the TSPO[9] project in Strasbourg and discussions in Grenoble, Toulouse, etc.), cable transport systems could find a place in urban and suburban environments (project in Grasse) and discussions on a “low-cost tramway” (Besançon project) continue.

[9] Transport en Site Propre Ouest strasbourgeois - *West Strasbourg Dedicated Lane Transport*

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