Revitalization of Indonesia Railway Sector

Rebuilding Rail Based Public Transport System

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Urban Transport in France: The Tramway Revival

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Introduction

Interest in Light Rail Transit (LRT) as a viable urban transportation system has been growing worldwide since the late 20th century. Although there is no definite difference between trams and LRT systems, the latter is an evolved tramway system-tracks are often segregated from other traffic, cars run faster, and everyone has easy access due to level boarding.

Since the beginning of 1970s, France has developed a significant programme of urban transport networks and systems for the major metropolitan areas: a specific policy in favour of investment in urban public transport has been promoted by all local governments in France.

In 1971, a new transport tax was created in the Paris region and it was extended in 1973 to all cities with more than 20,000 inhabitants. This tax is levied on companies with more than 9 workers. The tax rate varies locally from 1% to 2.5% of the payroll. The revenue is used to fund in investment and operation of urban public transport. In 2006, the transport tax revenue for France totalled more than 5.3 Billion Euros, divided into 2.7 Billion Euros in the Paris region and 2.6 Billion Euros for the other 260 Urban Transport Organizing Authorities UTOA. The economic justification for the tax is the important role of the public transport that plays an important role in the employment market, especially because employers will have more possibilities to find better jobs if there is an efficient public transport network.

At the same, organizing authorities UTOA were created by the local boroughs, and they have responsibility for urban public transport in the cities. UTOA were ratified by legislation in 1981, and received the transport tax revenue and spend it based on the following responsibilities:

- Organization of public transport in cities
- Creation and management of transport infrastructures
- Regulation of transport services (volume, fares)
- Development of information systems

The 261 UTOA now in existence have important funding and operations at their disposal, and have boosted the development of many public transport networks.

1. New Public Transit Networks

There are three main reasons explaining the renewal of public transport in France:

- the idea that public transport is necessary and that a system based on the car cannot fulfil the challenge of growing mobility
- the availability of new funding dedicated to public urban transport investments and operations
- the creation of new metropolitan authorities in charge of urban public transport organization.

So at the beginning of 70s, only Paris had a metro network consisting of 13 lines and the first section of the first Regional Express Network's line. No other French city had a metro; only three tramlines remained in Lille, Marseille and St Etienne. All other public transit networks used buses or in some cases (Limoges, Lyon, St Etienne, Grenoble, etc.), trolleybuses.

The situation in 2008 is significantly different both for metro and light rail networks. Six UTOA areas are served by a metro: Paris, Marseille, Lyon, Lille, Toulouse and Rennes. Nineteen cities with Île de France have developed thirty nine lines of a LRT or modern tramway: Nantes, Grenoble, Bobigny, Strasbourg, Rouen, Lille, Montpellier, Orléans, Lyon, Caen, Clermont Ferrand, Bordeaux, T3 Maréchaux, Mulhouse, Nancy, St Etienne, Marseille, Valenciennes, Nice et Le Mans. Caen, Nancy and Clermont – Ferrand had decided to build a rubber-tyred tramway system. The different plans of surface guided systems are outlined in this communication.

2. The "renaissance" of tramway in France

From 1966 onwards, tram systems were operating in only three cities in France, Lille, Marseille and St Etienne. However, the "car only" solution has shown its limits and the 1973 oil crisis encouraged a slow change in mentalities. In early 1975, the Secretary of State for Transport[1] instructed eight cities in France to develop tram network projects. But it was Nantes, not one of the eight cities, which was the first to inaugurate a new tram line in early 1985, followed by Grenoble in 1987, with a key innovation copied in all subsequent projects, namely the low-floor tram. With the Île de France joining the club in 1992, a tram system boom began. By the end of 2007, 19 tram networks (with 3 trams on tyres lines) were operational in France and the first "tram-train" system in France interconnected to an urban transit network is slated to be commissioned in Mulhouse in 2010.

As one of the European countries that gradually abandoned many of its traditional tramways after the Second World War, France was able to start afresh when the new wave of light rail transit (LRT) began to be created in Europe through the introduction of segregated alignments and new rolling stock. At the same time, many other countries were embarking on reconstructing and modernising their existing networks.

The "fresh start" approach, coupled with some specifically French initiatives and conditions, such as a local transport tax on business (the versement transport), and the demographic fact that France has relatively few large cities for a country of its size, has arguably made the Gallic nation the most successful in Europe in terms of medium-capacity, rail-based public transport.

The first reason is that the French approach has endowed light rail with a role that goes well beyond that of simple public transport to encompass an integrated approach to transport, urban regeneration and generally returning the streets to the people instead of the motorcar.

A report on French light rail produced by consultants Semaly and FaberMaunsell for a British public transport authority condensed the reasons for the undoubted success of French light rail as "money, commitment, and planning". The report added: "French cities also combine the introduction of a tramline with the opportunity to pedestrianize their city centres, to reorganise the local road network and hierarchy and--some might say, most importantly--to restructure the underlying bus network to support, not compete with, the tramway."

The second one is the local public transport tax, which can be up to 1.75% of the payroll of a public or private company employing more than nine people, levied since the early 1980s. It provides a constant and guaranteed flow of money that in a city like Lyon with a population of 1.4 million can reach 145 million [euro] each year.

Furthermore, French demography favours light rail, as does the concomitant reduction in construction costs compared with heavy metros. This is reflected in the fact that France has but three heavy metros in Paris, Lyon, and Marseille, plus three light metros in Lille, Toulouse, and Rennes. Light rail vehicles operate in 19 networks, projects are under construction in 10 others with Paris where there are 5 lines around the city under construction, and others are planned or being considered in at least four more.

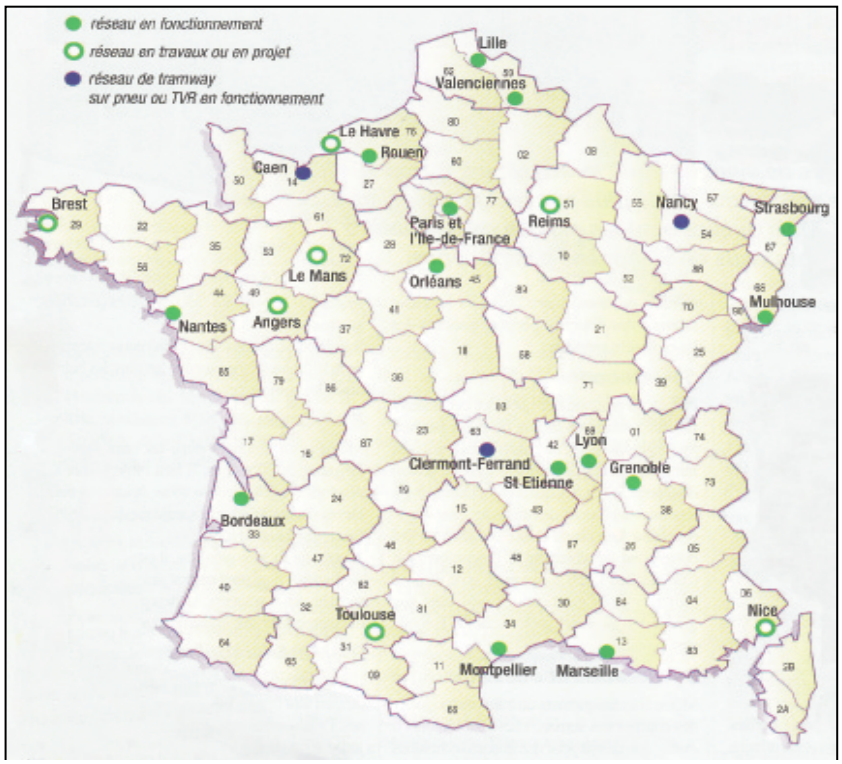
[1] Marcel Cavaillé sent a letter to the mayor of 8 cities: Bordeaux, Grenoble, Nancy, Nice, Rouen, Strasbourg, Toulon and Toulouse asking them after justifying the choice of a modern tramway, to realize designs of tram network. 6 months later he launched an international competition about definition of a new electric guided passenger transit vehicle able to ride in mixed traffic or in a separate right of way.

3. New light rail transit systems in France

The new LRT systems are as follows according to the date of the first opening in 1985:

- **Nantes**, 570,000 inhabitants in the urban transport perimeter, was the first city to adopt a new LRT system with three lines (37.9 km with 79 stations) carrying 225,000 passengers per day and serving the metropolitan area. A fourth line with a low demand (18,000 passengers a day) was opened in 2006 with a busway operated with 20 natural gas articulated bus on 7 km. Currently, a tram- train project using SNCF tracks on part of the line is under project (64 km, order for 7 Citadis Dualis, 1st stage opening in 2009 then 2013).
- **Grenoble**, 400,000 inhabitants in the urban transport perimeter, is served by four lines (35.4 km with 75 stations) carrying 200,000 passengers per day and several extensions to A, B, D lines, a new tram-train project for the line E will open in 2013 in a first stage. The network could reach 50 km before 2020.
- **In the Paris region**, 11 million inhabitants in the urban transport perimeter, two suburban T1 & T2 LRT lines (Saint Denis, Issy/La Défense) and a urban line T3 (in Paris along the Maréchaux South Boulevard) and a tram-train line T4 (Aulnay-Bondy) are operated by RATP (33.4 km with 59 stations carrying 300,000 passengers per day and SNCF for T4 line (8 km with 11 stations) carrying 35,000 passengers per day.
- **Strasbourg**, 500,000 inhabitants in the urban transport perimeter, is served by five lines (54.09 km with 101 stations) carrying 250,000 passengers per day: severe competition between the automatic light rail VAL and LRT caused a politically difficult decision in Strasbourg, but the LRT was chosen as a method to remove the car from the city centre (pedestrian zone and streets). The Urban Communauty of Strasbourg CUS also decided to build a tram-train F line a 1st stage could open in 2009 with urban tramways then a link with SNCF track will open for a tram-train operation.
- **Rouen**, 420,000 inhabitants in the urban transport perimeter, is served by 2 lines, line 1 with an LRT (15.1 km with 31 stations) carrying 63,000 passengers and TEOR lines 1,2 and 3, the Rouen East-West Transport (TEOR), operated with a rubber-tyred wheels vehicule called Civis. Length of the lines is 25.6 km with 41 stations served by 38 Agora articulated buses fitted with optical guidance carrying 30,000 passengers per day. The optical guidance system pulls the vehicles to within 50 mm of the platform offering barrier – free access to all passengers and eliminating the need for wheelchair ramps, etc.
- **Lille**, 1.2 million inhabitants in the urban transport perimeter, is served by two lines of tramways (17.84 km with 36 stations) carrying 32,000 passengers per day: the tracks and the rolling stocks were renewed between 1991 and 1994, this network was opened in 1904. Since 1983, Lille is served by another system, an automatic light rail VAL: 2 lines 45 km long, carrying 80 M passengers in 2006. It is the first implementation in May 1983 of the fully-automatic unmanned guideway or VAL system.
- **Montpellier**, 400,000 inhabitants in the urban transport perimeter, is served by two lines of tramways (35 km with 60 stations) carrying 200,000 passengers per day whose 150,000 on the first line. A third line (20 km with 30 stations) is under construction and must open in 2010.
- **Nancy**, 200,000 inhabitants in the urban transport perimeter, is served by one line of tramways on tyres (11 km with 28 stations) carrying 45,000 passengers per day. A second line is under design with probably trolleybuses.
- **Lyon**, 1.2 million inhabitants in the urban transport perimeter, is served by three lines of tramways (40 km with 63 stations) carrying 170,000 passengers per day. The urban community is served also by four metro lines (two conventional, one rack-and-pinion, one fully automated, D line unmanned, computer-controlled system. The Lyon's metro with a total of 29.5 km with 44 stations carries 160 M passengers in 2006.
- **Caen**, 250,000 inhabitants in the urban transport perimeter, is served by three lines totalling 15.7 km with 41 stations whose 16 are fully completed and served by 38 Agora buses fitted with optical guidance: the optical guidance system pulls the vehicles to within 50 mm of the platform offering barrier-free access to all passengers.

- **Orléans**, 300,000 inhabitants in the urban transport perimeter, is served by one line of tramway (17.9 km with 24 stations) carrying 45,000 passengers per day. A second line CLEO (11.8 km with 25 stations) is under construction and due to open in 2011.
- **Bordeaux**, 700,000 inhabitants in the urban transport perimeter, is served by three lines of tramways (43.7 km with 78 stations) carrying 140,000 passengers per day. A fourth line, line D is under design.
- **Saint-Etienne**, 400,000 inhabitants in the urban transport perimeter, is served by two lines (11.54 km with 35 stations) carrying 60,000 passengers per day.
- **Valenciennes**, 400,000 inhabitants in the urban transport perimeter, is served by two lines (18 km with 26 stations) carrying 35,000 passengers per day. A second line (14 km with 23 stations) due to open in 2011.
- **Marseille**, 1 million inhabitants in the urban transport perimeter, is served by three lines of tramways (1st stage 16.5 km with 42 stations) opened in 2007 carrying 100,000 passengers per day. The city is also served by two lines of conventional metro 19 km with 25 stations carrying 70 M passengers in 2006.
- **Mulhouse**, 250,000 inhabitants in the urban transport perimeter, is served by two lines (12 km with 24 stations in 1rst stage) carrying 50,000 passengers per day. A second stage for 2010 is under construction; the network (totalling 20 km with 38 stations) could carry around 100,000 passengers per day.
- **Clermont-Ferrand**, 300,000 inhabitants in the UPT, is served by one line of tramway on tyres Translohr STE4 (14 km with 31 stations) carrying 40,000 passengers per day. An extension of 2 km due to open in 2009 and a second line is under design.
- **Le Mans**, 200,000 inhabitants in the urban transport perimeter, is served by one line of tramway opened in 2007 (15.4 km with 29 stations) carrying 50,000 passengers per day.
- **Nice**, 500,000 inhabitants in the UTP, is served by one line of tramway opened in 2007 (8.7 km with 21 stations) carrying 70,000 passengers per day. A 1st extension of 4.5 km is under construction for 2010, a second line of 15 km going to the Airport is under design and due to open in 2013.



Legend: Green operating tram network – Green & white under-design or under construction network- Black tram on tyres under operation Source: Connaissance du Rail de Juillet 2008

Figure 1: The map of localization of LRT network under operation, under construction or design, and LRT on tyres networks

Seven more cities and Paris region (Châtillon – Viroflay in IdF, Villejuif – Athis-Mons in IdF, St Denis – Villetaneuse in IdF, St Denis Sarcelles in IdF), have already decided to build LRT lines: Angers, Brest, Le Havre, Reims, Toulon, Toulouse and Douai, the later using a tramway on tyres system called Eveole (Phileas in Eindhoven). The Eveole vehicle has an electronic lane assistance and precision docking system, which can be used on routes specifically prepared for this purpose. In these routes, a trail of magnetic reference markers will be laid in the road surface.

3.1. Network's line with a demand around 100,000 passengers per day

Among the 19 tramways networks under operation in France we can classify 10 lines that carry every day around 100,000 passengers or more per day:

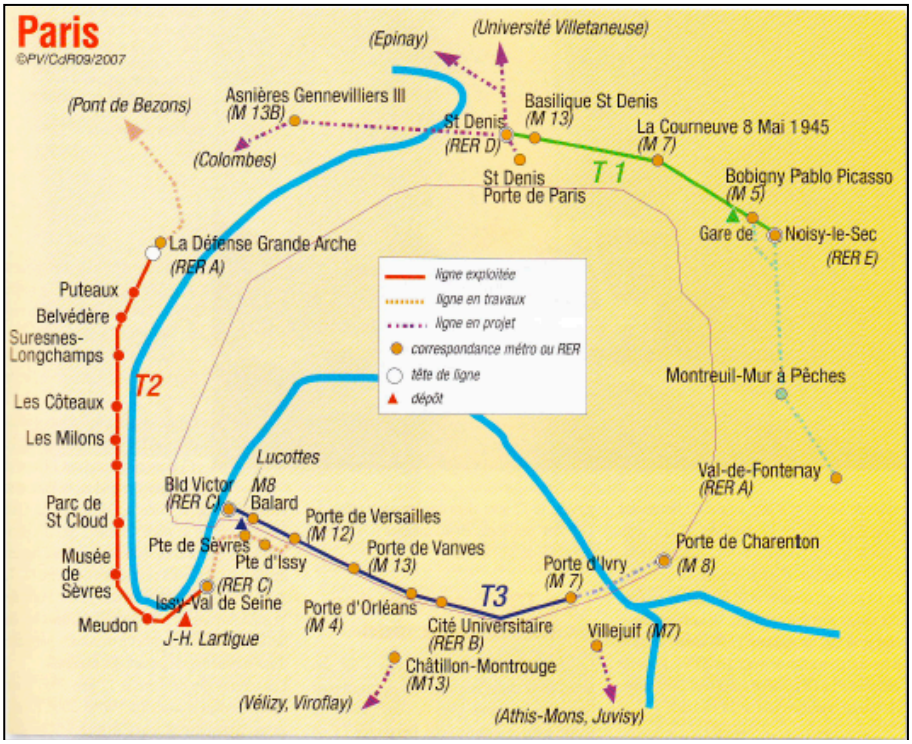
- in Grenoble: line A, Lyon: line T1, Montpellier: L1, Nantes: L1, L2, Paris Ile de France: T1, T2, T3, and Strasbourg: Lines A & D, B & C.

Network / Line	*Traffic pas/day*	*Offer at PH*	*Tram capacity*	*Tram number for km with 2 tracks*	*Line Cost M€/km*
Grenoble LA	90,000	2610	174/275	2.77	25.72
Lyon T1	80,000	2400	201	1.90	24.78
Montpellier L1	140,000	3600	300	2.17	28.91
Nantes L1	90,000	3540	236	2.04	17.41
Nantes L2	112,000	3885	259	1.93	29.32
Paris T1	100,000	2610	174	2.94	32.55
Paris T2	80,000	6870*	2x229	2.30	16.46
Paris T3	100,000	4560	304	2.66	39.16
Strasbourg A&D	116,000	5760	288	1.74	37.8
Strasbourg B&C	104,000	5400	270	1.74	26.00

Source: Connaissance du Rail Juillet 2005 n°286-287 et Octobre-Novembre 2007 n° 316-317- L'année 2006 des transports urbains Gart- 2002, Gart. Website of Transport Authorities of each city- STIF- RATP.

Table 1: 10 lines of LRT carrying 100,000 passengers per day

Nota: * This line must carry in 2009, 30,000 passengers per day more



Source: Connaissance du Rail n°286-287

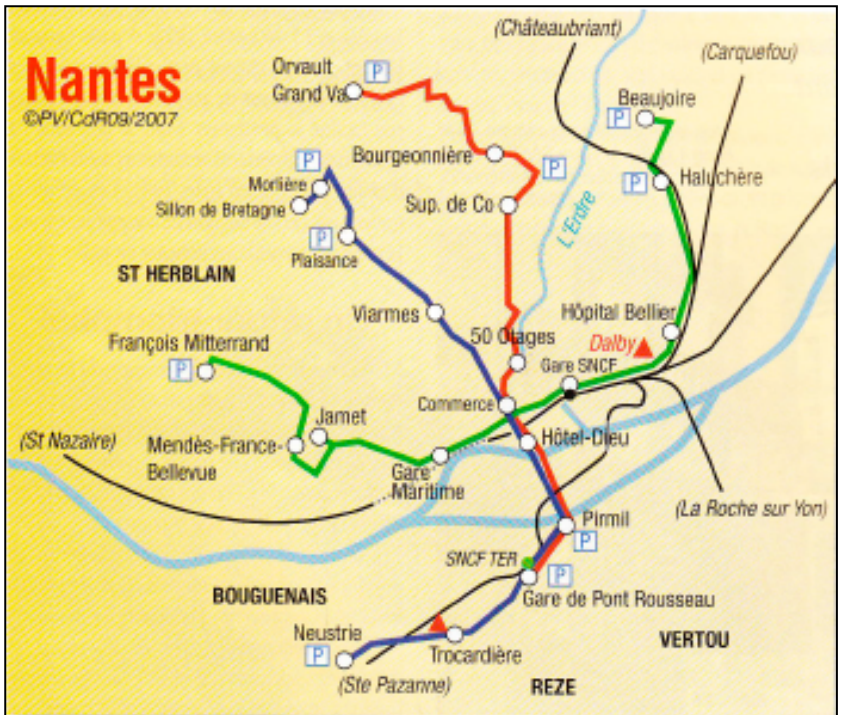
Figure 2: The main tramway 's lines under operation in Paris with the scheme of extensions: T3 must be extended on 14.2 km long to Porte de La Chapelle near Porte de Paris for 2012.

Paris T3: The project the most expensive in this table, is the Tramway T3 (called Marshals' Tramway) in south of Paris were the problems of urban insertion cost around 5 to 10 M €/km, because an ambitious program of landscape around 45 meters wide was realized by the City hall of Paris on the Marshal's boulevard for the insertion of tramway T3: pavements of quality, specific urban furniture for stations and along the line, trees, catenary's poles and public lights. The track of tramway is covered by grass on two third of its linear. Moreover a specific workshop was build near one terminus of the line T3; the investment is integrated in the T3 line's cost. The number of vehicle per kilometre of double track is high 2.66 so the energy powers of under-stations must be well dimensioned and so more expensive.

Strasbourg A&D: The important cost of Strasbourg's lines is explained by a tunnel 1200 m long under the railway station and an highway for line A and some public works for C, D lines stopped during one year waiting for a new Public Purposes Declaration (DUP).

Strasbourg B&C: For second line, the cost is decreasing since the tracks are on surface and the workshop is already built.

Paris T1: this is the first new line of tramway built in high dense quarters of north suburb of Paris with a common workshop with the metro, civil engineering constructions, with 3 tramways per km of double track, an architectural urban insertion (Chemetov Architect), these facts explain why the cost is just above the range of 20-30 M€/km.

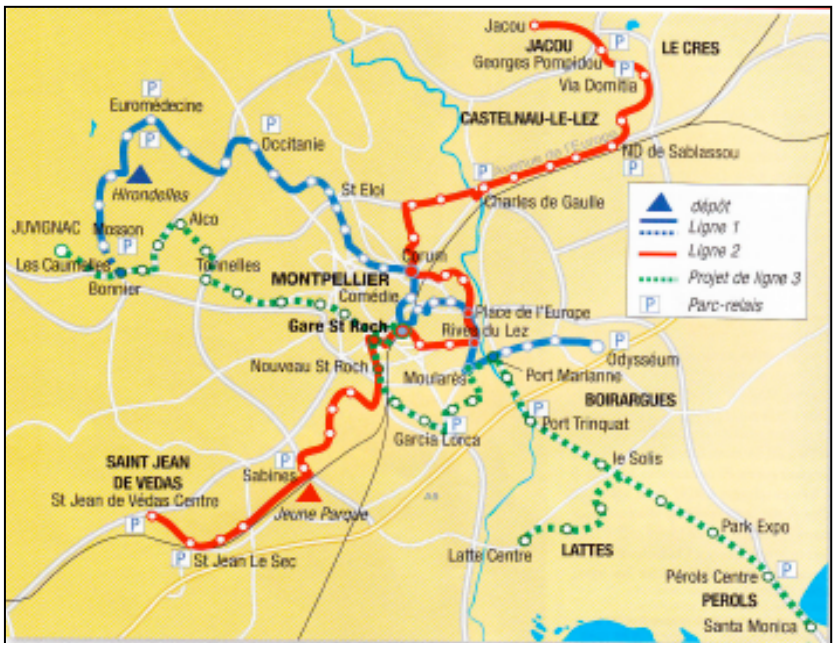


Source: Connaissance du Rail n°286-287

Figure 3: The Line L1 is going partially along the SNCF railway right of way outside the center of the city; the Line L2 is going through the center from south to north.

Nantes L1: this is the first line opened in 1985, it was constructed near the city center partially on a former railway platform so with a minimum of public works, with a workshop but the cost is only 17.41 M€/km val. 2007 with 2 vehicles per km of double track in the first range 20 to 30 M€/km.

Nantes L2: this second line goes through the center of Nantes, on a former busway in the south part but big public works were made in the center all around the tracks platform on the public right of way for convivial pedestrians prospects.



Source: Connaissance du Rail n°286-287

Figure 4: The main line T1 under operation in Montpellier carrying 140,000 passengers with Citadis 401 of a 300 spaces unit capacity with 4 standees per m².

Montpellier L1: the first line bears the overcost of changing 28 Citadis 302 in 28 Citadis 401 by adding two cars to each tram, the cost of the workshop, 4 park and ride, important public works in the CBD and a number of vehicle per kilometer of double track superior to 2.

Paris T2: this line is built on a former railway line like Nantes L1 without civil engineering construction so the cost is under the range 20 to 30 M€/km.

Grenoble L A&B: this line is the first line built with full accessibility from the platform in the station to the low-floor vehicles, for its extension some bridges were constructed above national railways and an highway: the cost is in the mean range 20 to 30 M€/km.

Lyon T1&T2: these lines are the first ones of the tram network built in the city center with a tram workshop: the cost is in the middle range 20 to 30 M€/km.

We calculate the number of tramway per km of double track to see the link between infrastructure cost and the capacity of the line (Strasbourg has 38 km of double tracks and 54.09 km of lines). This table1 allows us to distinguish the cost ranges into 15-20 M€/km, 20-30 M€/km and above 30 M€/km.

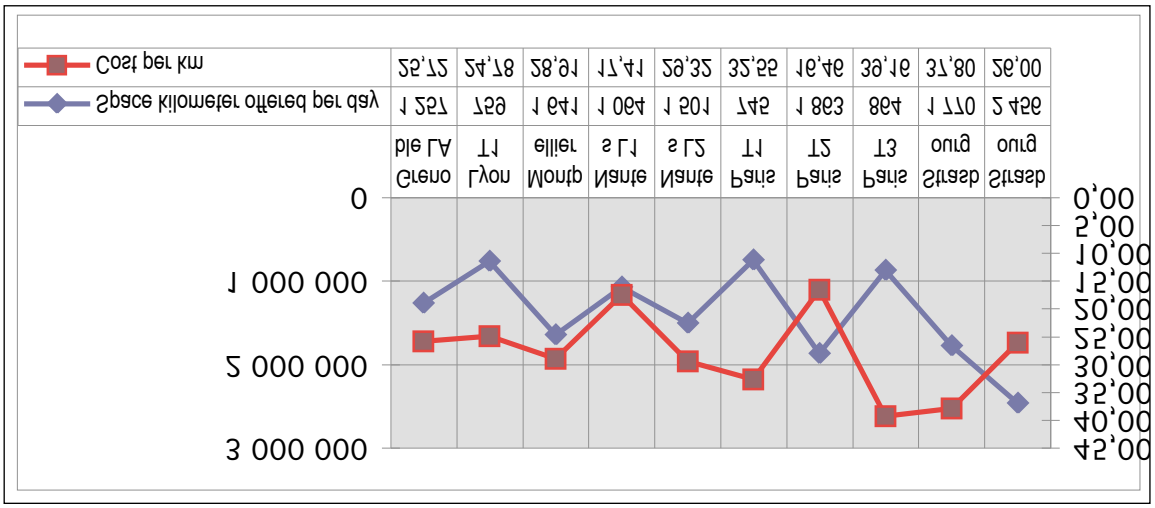


Figure 5: Cost per kilometer and spaces kilometer offered per day of the main 10 tramway's lines under operation in France

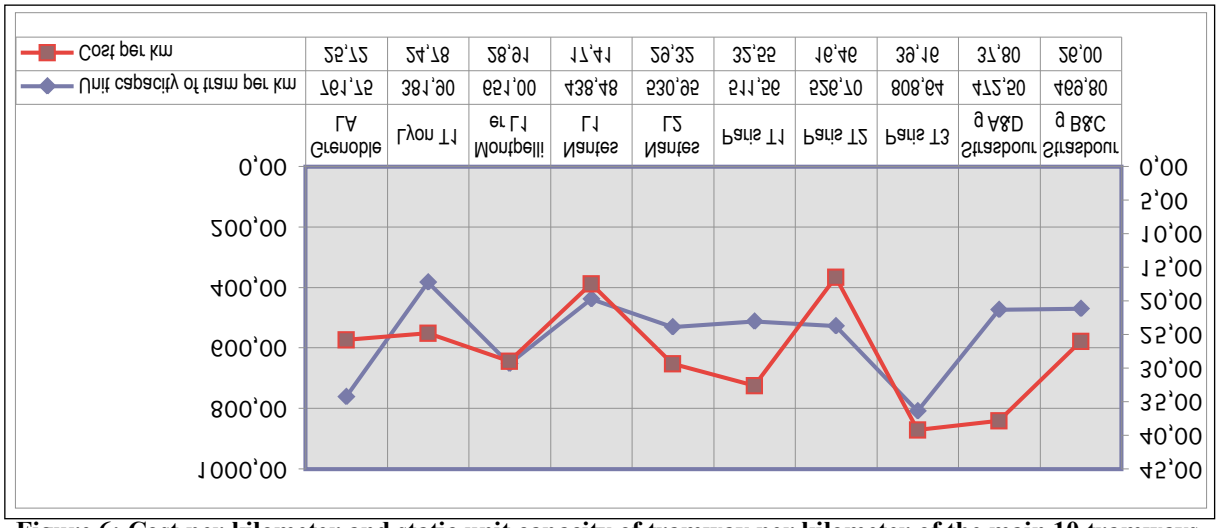


Figure 6: Cost per kilometer and static unit capacity of tramway per kilometer of the main 10 tramways lines under operation in France

3.2. Network's lines with a demand around 50,000 passengers per day

Among the 19 tramways networks under operation in France we can classify 10 other lines which carry every day around 50,000 passengers, the threshold to study a tramway's project to replace the buslines by tramways, is from 30,000 passengers per day, generally in France:

- in Bordeaux: line A, line B; in Caen: line T1; in Clermont-Ferrand: L1; in Le Mans: L1; in Marseille: T1,T2; in Montpellier L2; in Nancy: L1; in Nice: L1; and in Rouen: L1.

City / Line	*Traffic pas/day*	*Offer at PH*	*Tram capacity*	*Tram number for km with 2 tracks*	*Cost line M€/km*
Bordeaux A	56,800	4500	300	1.75	31.72
Caen	40,000	2300	135	1.52	18.30
Clermont - Ferran	40,000	3400	170	1.57	21.95
Le Mans	50,000	3300	220	1.49	23.81
Marseille T1	44,600	3060	204	2.36	31.76
Montpellier L2	52,000	1696	212	1.21	25.78
Nancy L1	45,000	1620	135	2.27	17.08
Orléans L1	45,000	2640	176	1.23	21.19
Nice L1	70,000	3240	216	2.29	39.41
Rouen L1	63,000	3000	175	1.85	54.19

Source: Connaissance du Rail Juillet 2005 n°286-287 et Octobre-Novembre 2007 n° 316-317- L'année 2006 des transports urbains Gart- 2002, Gart. Website of Transport Authorities of each city- STIF- RATP.

Table 2: 10 lines of LRT carrying around 50,000 passengers per day

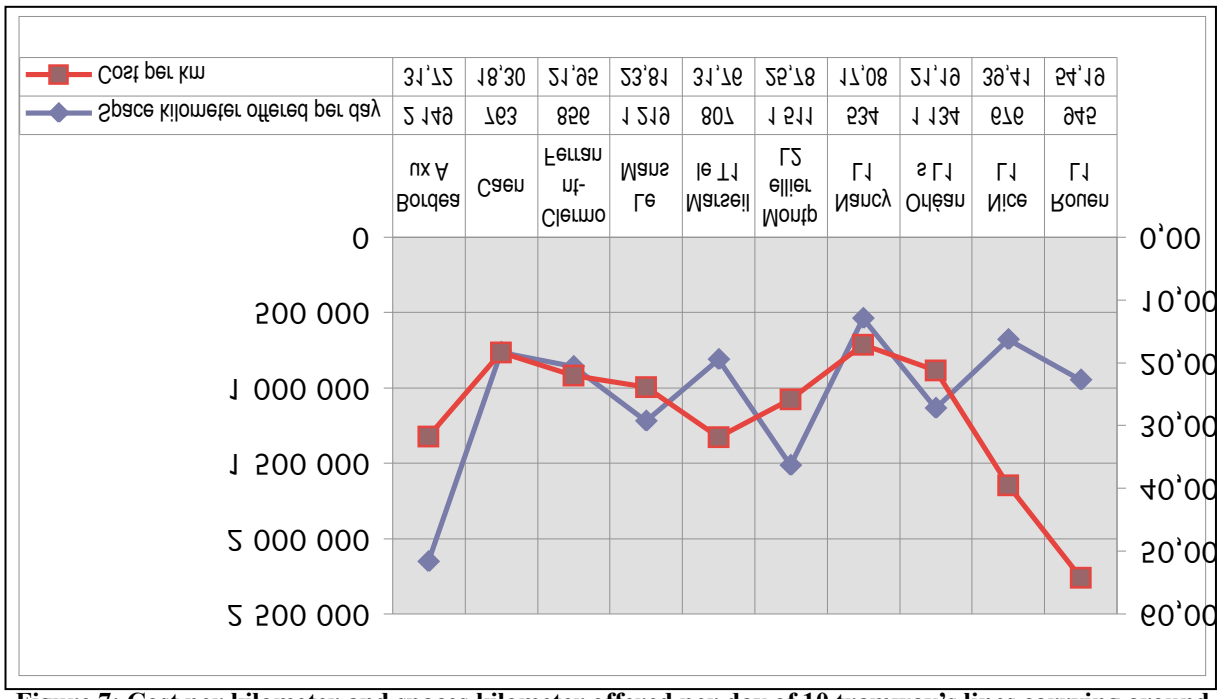


Figure 7: Cost per kilometer and spaces kilometer offered per day of 10 tramway's lines carrying around 50,000 passengers par day under operation in France

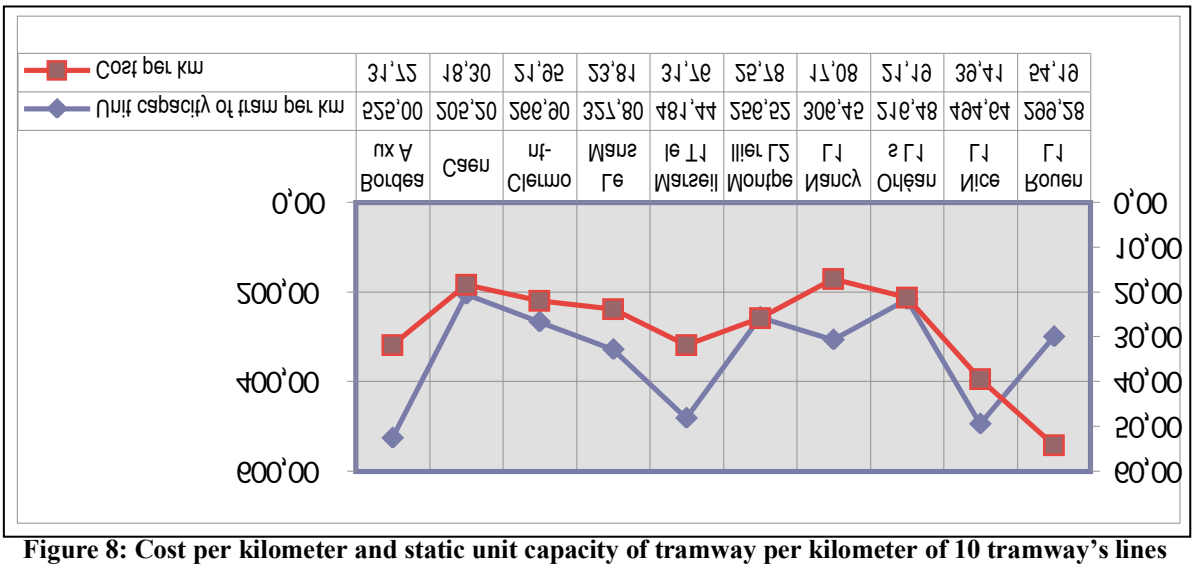


Figure 8: Cost per kilometer and static unit capacity of tramway per kilometer of 10 tramway's lines carrying around 50,000 passengers per day under operation in France

Bordeaux A: the cost of Bordeaux's A line is explained by the fact that it includes the workshop, the rolling stocks equipped for the ground electric alimentation (1.5 ME per double km), this cost is just above the range of 20 to 30 M E / km

Caen L1: it is a first line of tramway on tyres under operation in France, TVR, which offers 2300 spaces per hour per direction, its cost 18 M € /km is under the range of 20 to 30 and it is around the cost of Paris T2 and Nantes L1 which were built on a former railway right of way. This system is limited by the vehicles 24 m long and the number of 20 vehicles per hour and direction that is to say 2700 spaces/hour/direction or 55,000 passengers per day.

Clermont-Ferrand L1: it is the third line of tramway on tyres operated in France, a difference with the first lines of Caen and Nancy (vehicule of 24.5 m long max.) is that this system is a module, narrow gauge (2.20 m wide) with several length, 25 m for STE3, 32 m for STE4 39 m for STE5). The cost is in the low of the range 20 to 30 M € /km.

Le Mans: it is the first line (generally with an overcost around 5 ME/km) built without the subsidy of State, suppressed in 2003 (30 ME), so the master of works tried to obtain the best low prices during the public works bid and the choice of urban insertion and surface's treatment was made in a sober style manner. The result is a cost in the low range 20 to 30 M € /km / km.

Marseille T1: it is the first new line built, so the cost include an overcost of around 5 ME compared to a second line or extensions of a first line, and the fleet is sized up to carry up to 100,000 passengers per day, there are 2.36 vehicles/km versus 1.49 in Le Mans.

Montpellier L2: this line goes along a former railway track (around 25% of the line's length) where tram's second line has only a single track what is a constraint for the headway which is 7 min 30 sec. That is to say a low offer of 1700 spaces/h/dir. So the cost of 25.78 M € /km which is high in front of the offer can be explained by the big number of civil engineering constructions on this line.

Nancy L1: it is the second line of tramway on tyres under operation in France, TVR, which offers 1620 spaces per hour per direction, its cost 17.08 M € /km is under the range of 20 to 30 M € /km and it is around the cost of Caen first line, Paris T2 and Nantes L1 which were built on former railway right of way. This system is limited by the vehicles 24 m long and the number of 25 vehicles per hour and direction that is to say 1620 spaces/hour/direction but the headway of 5 minutes could be reduced to 3 minutes or an offer of 2700 spaces / hour / direction.

Orléans L1: its cost is in the low of the range 20 to 30 M € /km, the offer with 1.23 tram per km is low but with the second line under construction, the offer will increase with 1.44 tram per km.

Nice L1: like Bordeaux this network choose a specific vehicle with batteries to go through two sections 435 m and 485 m without catenaries, it is the first line built in the city with an overcost around 5 ME and like the line T3 there is an overcost of 5 to 10 ME for a rigth of way's treatment of several tenth meters wide with modern art public furniture. The number of vehicle per kilometre of double track is high 2.29 vs 2.66 for T3 line.

Rouen L1: The overcost of this line came from the civil engineering costs of one tunnel (1700 m long) and 5 underground stations under the CBD, opened 3 years late after of the 1 stage opening.

3.3. Remarks

Among the lines that carry around 100,000 passengers and more per day we find three categories of lines:

- the lines with a cost range between **15 to 20 M€ per km** which are built on former railway lines outside the centre to much urbanized (Nantes L1, Paris T2),
- the lines which are the first of a network (overcost around 5 M€ / km) generally serving the center of the city with a cost range between **20 to 30 M€ per km**,
- the lines with a specificity like 3 vehicles per km of double track, public works like bridges, tunnels, underground stations, modern art works, street remodelling on wide surface with all kind of pavements on the public right of way beyond the tramway's tracks, have a cost above **30 M € per km**.

Among the lines which carry more or less 50,000 passengers but among them some are increasing their frequentation up to 100,000 in some years with the network's effect, we find three categories of lines:

- The lines with a cost range between **15 to 20 M€ per kilometer** which are operated by tramways on tyres like in Nancy, Caen and Rouen (TEOR),
- the lines which are the first of a network (overcost around 5 M€ / km) generally serving the center of the city with a cost range between **20 to 30 M€ per km**: with a tram on tyres (Clermont – ferrand) in the low of this range
- the lines with a specificity like in Bordeaux using a ground level power supply system, rather than the traditional overhead contact system (OCS), Nice has a vehicle with batteries for going through two wide beautiful places, and Rouen with an underground of 2000 m long and 5 stations.

4. New urban transit systems

All new systems aim to improve the efficiency of the service offered to passengers and to reduce total costs (infrastructure and rolling stock investment cost, and operation costs). The main technical innovations have been applied to the new LRT systems.

4.1. Modern tramway networks

The system conceived and realized for the first time in France, in Nantes, was a new mode of transport even if its inspiration's sources were multiple and it took in the example of foreign networks. Innovation consisted not only in creating a surface metro adopting a separated right of way excluding car traffic, but also in integrating harmoniously the transit system equipped of light rail rolling stocks and of more recent techniques of control (priority to traffic lights, information to passengers in real time…) to the city.

The care taken from this first realization to the public space, totally rethought of the better efficiency benefits for all urban functions and a urban landscape and this became the characteristics the most notable of the tramway "at the French manner". The tramway technology (electric traction, elastic wheels, standard rail and groove rail) that had progressed of a notable manner, essentially in the Germanic world, authorized to insert this system in the more contrasted urban environments, from highway's platforms to the history burdened city's centers.

In Île de France, the Paris Metropolitan Area, the tramway's development finds its origin in a relative failure of an ambitious program of busways conceived in 70's. Busway's developments struggled to make consensus. Highly consumer of space, they do not seemed to be able to bring sufficient counterpart, neither in term of service improving, neither in term of requalification of urban centers. With the notable exception of TVM[2] busway, conceived at once as a system, the busways stayed under discontinuous developments sometimes punctual and without effects truly sensitive on the attractiveness of public transport.

In 1980, the Institute of Development and Urbanism of Île de France region, IAURIF, suggested the project of a modern tramway on an axis of bypass Saint Denis – Bobigny. It was the beginning of a project with an eventful genesis. The consensus between the actors of the project did not establish easily including at local level. It is here that the tramway showed its originality. It brought to the project altogether the capacity to seduce and the capacity to compel. The novelty of the system and above all its "urbanity" seduced: it is more comfortable, more silent, more "ecological" and more sparing of space than the bus. It suggests stations instead of stops.

The track with groove rails harmonizes with quality surfaces (paving stones, grass…). The constraint, it is those of "all or nothing". Every one knows that contrary to a busway, the project can be realized only in its whole. All is then in place for a political debate of high intensity. It was what knew Saint-Denis – Bobigny project, like the most of all French tramway's projects. The impacts of St Denis – Bobigny Tramway, put into service on July 1992 between Bobigny and La Courneuve surprised. The forecast level of traffic, a long time contested by some experts, was reached in some months then widely exceeding.

The imbalance peak hour – off peak hour, as usual high on the bus of the suburbs, became blurred with the tramway. Today traffic stays dense all day long. Frequent and easily opened tramway became a kind of "moving walkway" in the city.

The capacity to merge into the city while offering a quick and frequent service is at the origin of the choice of elected members of Hauts de Seine on account of tramway for the improvement of the rail line Issy-Plaine – Puteaux that became line T2 in 1997. Success went well beyond previsions because the forecast traffic of 24,000 passengers / day reaches today 80,000 passengers / day. These successes contributed to do of the Plan 2000 – 2006 contract in Île de France, the "tramway's contract Plan". Sixty-six kilometres of tramway project were the subject of a joint agreement of the State, the Region and the concerned Departments. Three operations, T3 line Marshals tramway, T1 continuation in

[2] TVM : Trans Val de Marne

Noisy-le-sec and the line T4 (tram-train of Aulnay-Bondy) are today under operation and meet the expected success.

In some years, it is a real network that takes place. This development can equip large suburb territories with a high level-of-service transport system: T3 at the Paris and suburb's boundary and T1 and T2 in the near crown.

4.2. Different rolling stocks

The early rolling stock, constructed by Gec-Alsthom (the former Alstom constructor) for the 1st Nantes line, consists of 2.3 m wide articulated carriages consisting of two light chassis on three bogies. It can carry 168 passengers with 60 seated. The later 29.40 m long articulated carriages have low floors (340 mm over the top of the rail) and a higher capacity (174 with 58 seated). The first example was followed by Grenoble - its first line entered into service in 1988, and the second line in 1990. Then it was adopted on the lines of T1 St Denis Paris, Rouen and Paris T2 Issy – La Défense. Soon Lille's network adopted the low floor Breda Tramway. Then Strasbourg adopted the Eurotram with very large windows and a panoramic driver's cab at the both ends. It is an articulated vehicle, 33.3 m long, 2.40 m wide on four bogies of which three are powered, offering 240 spaces with 66 seats: the floor is a single-level flat floor, 340 mm over the top of the rail. This rolling stock is very popular.

However, building tramway lines has become more and more expensive, both due to the very small numbers of rolling stock and to the high cost of incorporating the system in the urban infrastructure (special pavements, landscaping, street remodelling, etc.). To get an overview of the cost of the 39 lines under operation in France nowadays, have a look at the table in the annex of this report.

5. New Research & Development Programs

In an attempt to lower the cost of an LRT line, a number of R&D programs have been developed.

5.1. Citadis

Alstom has developed a new LRT system called CITADIS based on two main innovations: lighter bogies requiring shallower track beds, and a modular concept for carriages allowing more choices (number of cars and doors, types of windows).

Source: Connaissance du Rail n°286-287 (cliché: Yves Allain)

Figure 9: Citadis 302 in front of the Railway station of Valenciennes

After 10 years of production, the Alstom's Citadis has overpassed the threshold of 1000 tramways sold worldwide. In October 2007, 25 cities were operating tramways Citadis and 50 cities had a project under design for the next 3 years.

Manufacturer	***Alstom***				***Bombardier***		
Model	***TFS classic/modern***	***Citadis 301***	***Citadis 302***	***Citadis 403***	***Eurotram***	***Incentro***	***Flexity Outlook***
Length	29.400 m	29.866 m	32.41-32.85 m	45.056 m	33.1-43.0 m	36.422 m	32.500 m
Width	2.300 m	2.320 m	2.400 m	2.400 m	2.400 m	2.400 m	2.400 m
Floor height (mm)	Extreme: 875 center: 345	Center: 350 mm bogie motor: 600 mm	350 mm	350 mm	350 mm	350 mm	320 mm
Nomber of bogie motor	2	2	2	3	3/4	2	2
Number of bogie porter	1	1	1	2	1	1	1
Doors	4 +2 driv.cab.	8 doors	8 doors	16	12/16	12	12
Capacity	Seats: 54+4 Total spaces : 174(4p/m^2) 252(6p/m^2)	Seats:40 Total spaces : 176(4p/m^2) 261(6p/m^2)	Seats:48/64 Total spaces: 170/200(4p/m^2) 255/272(6p/m^2)	Seats:64 Tot.spaces: 288(4p/m^2) 400(6p/m^2)	Seats:66/92 Tot.spaces: 230/256(4p/m^2) 275/370(6p/m^2)	Seats:72 Tot.spaces: 239(4p/m^2) 394(6p/m^2)	Seats:44 Tot.spaces: 160(4p/m^2)
Traction motor	separate D.C. current 1 x 275 kW	asynchronous three-phase current, auto-ventilated 2 x 170 kW	asynchronous three-phase current, water cooling 2 x 175 kW	asynchronous three-phase current, water cooling 2 x 175 kW	asynchronous three-phase current 4 x 26.5 kW	asynchronous three-phase current, water cooling 4 x 45 kW	Cooled air 4 x 115 kW

Table 3: Characteristics of tramways generally operated in France (source: from the manufacturers)

5.2. Flexity

Bombardier has developed a new LRT system called Flexity with 4 versions: Outlook, Classic, Swift and Link.

The Flexity-Outlook is the new generation of the integral low floor Eurotram of Strasbourg, Milano and Porto. The Flexity-Outlook has been ordered by Bruxelles, Genève, Graz, Linz and Marseille.

Source: Connaissance du Rail n°286-287 (cliché P.L.)

Figure 10: Flexity Outlook in Marseille

The Flexity-Classic has conventional bogies, a steel structure and a partial low-floor, this version was ordered by Dresden, Francfurt, Leipzig, Cracovie, etc.

The Flexity-Swift is designed for express services on former railways: it was adopted in Koln, Croydon, Istanbul, Rotterdam and Stockholm.

The Flexity – Link is adopted as a tram-train operation; it is under operation in Sarrebrück.

5.3. TVR, Translohr, Civis and Phileas

Another program consists of the so-called Intermediate Transit System, an intermediate system between a bus and a guided LRT. All three types developed several years ago consist of articulated cars on tyred axles with electric motors on wheels, but guided in different ways. They were tested on a 1400 meters long track in South of Paris, which is a part of a busway with curves and gradients under operation called Trans Val de Marne.

Since 2002, Nancy and Caen adopted the TVR of Bombardier ANF, Spie Enertrans: its guidance system clings mechanically to a central rail.

Source: Connaissance du Rail n°286-287 (cliché Yves Allain)

Figure 11: TVR of Nancy in St Jean the main street

Since 2006, Clermont – Ferrand put into service the Translohr STE4 developed by Lohr-Industrie: the cars, guided mechanically along a central rail, are available in a narrow width of 2.20 m and different lengths, 24.5 m, 31.5 m and 39 m. due to a modular concept with 3 or 5 axles. The floor is completely flat (340 mm over the rail) with a capacity ranging from 138 to 202.

Source: Connaissance du Rail n°286-287 (cliché P.L.)

Figure 12: Translohr STE4 on Jaude's Place in Clermont Ferrand

The third system, named CIVIS, has been developed by Iribus (the former Renault VI) Siemens (the former Matra Transport International). The guidance system is based on an image processing system following two painted lines on the road. Very wide tyres from Michelin spread the load on the road. Caen adopted the CIVIS for a second line TEOR, the optical system was adapted on Agora buses.

A fourth system called Phileas in Eindhoven and Evéole in Douai has been developed by APTS (former DAF trucks). The Phileas vehicle has an electronic lane assistance and precision docking system, which can be used on routes specifically prepared for this purpose: electronic guidance system is based on permanent magnets installed in the lane. Moreover there exists a system using the ultrasounds at the stops to ensure the determination of distance, which allows the vehicles to make the exact positioning in diagonal direction

5.4. Tram-Train

A tram-train is under operation in Sarreguemines France and Saarbrücken Germany since late 1997. It uses normal railway tracks and specific tramway rails. In Île de France near Paris between Aulnay and Bondy, the T4 tram-train line 8 km long is opened since November 2006. Other different projects are under construction in Mulhouse (2010) and Strasbourg (2009), under consideration in Nantes and Grenoble.

Source: Connaissance du Rail n°286-287 (cliché P.L.)

Figure 13: Tram-Train Avento of Siemens adopted on T4 line

Source: H.Dahl, 2004

Feature \ *Vehicle*	***TVR Bombardier***	***TRANSLOHR Lohr Industrie***	***CIVIS Irisbus***	***PHILEAS APTS bv***	***CITADIS Alstom***
Guidance technique	Monorail (Mechanical)	Monorail (Mechanical)	Optical (Immaterial)	Magnetic (Immaterial)	Rail track
Bimodal abilities	Yes, depending on the version	No	Yes	Yes	No
Bidirectional abilities	Yes, in guided version	Yes, in guided version	No	No	Yes
Types	1 version	STE3, STE4, STE5	2 versions	3 versions	Several
Length(s) (m)	24,5	24.5, 31.5 and 39	18 and 19.5	18, 24.5 and 26	29 to 45, 2 x 29
Weight (empty) (t)	26	17.7, 28.5, n.i.	18.4, 19.5	15.23, 19.65	40
Weight per meter (t/m)	1,06	0.772, 0.904	1.02, 1.0	0,93 and 0,90	1.38
Unit Capacity (4 p/m^2)	131	138, 170 and 202	103 and 115	103, 129 and 141	212
Static/ dynamic gauge (m)	2.50 / 2.8465	2.20 / 2.505	2.47 / 2.65	2.54 / 2.785	2.32 / 2.62
Single / double DKE[3]	2.8465 / 6.14	2.805 / 5.46	2.95 / 6.46	3.085 / 6.498	2.92 / 5.69
Floor's Level (mm) / if kneeling	350	280 / 200	340 / 250	340 / 270	350
Propulsion	Electric /diesel-electric system	Electric, charge batteries for autonomy	Electric, also through Diesel or Gas	Electric, through Diesel or Gas	Electric
Catenary	Yes	Yes	Yes, depending on version	No	Yes
Manoeuvrability	Following rail or steering front wheels	Following rail or steering front wheels	Front wheel steering	Wheel steering on each axle (computerized)	

Table 4: Features overview of five guided public transport systems

[3] DKE: developed kinematic envelope

6. Current Trends of Light Rail

The tramway revival in France and other countries is not up to date or a fashion; three reasons explain this continuous expansion:

A. For carrying potential flows of 2000 to 5000 passengers per hour per direction, the tramway is the public transit mode the most adapted.

Trying to carry the same flows by buses is not impossible but this costs more. Operating cost of the space per kilometer offered PKO is on an average twice more expensive for bus than for tramway. The question of vehicles capacity is an essential question but little mentioned. An articulated bus line on a separate right of way of tramway type costs a little less in investment, but to carry 3000 passengers in one hour on a given section we need:

- 27 articulated buses (110 spaces with 4 passengers / m2)
- 10 trains of tramway type Montpellier Citadis 401 (300 spaces with 4 pas. / m2).

B. Tramway is an exceptional tool of renewal

On the contrary of the busways and metros, the projects of tramways oblige to handle the public space from one front to another front including crossed places. For example, at the beginning of the first three projects of Nantes, Grenoble and T1 of St Denis, this aspect was considered as a constraint but rapidly adapted by elected representatives as a strong point and a lucky.

To understand that the tramway is an exceptional tool of urban renewal we have to ask ourselves to whom benefits the expenses realized:

- for the system, the benefit is limited to the customers,
- for the urban landscape, the benefit is stretch to all those who frequent the site.

C. Tramway is a tool well known to fight again the car expansion

The main political strong point of tramway is the main reason of his eviction: the tramway was removed because it embarrassed the car and we put it again because it embarrasses the car.

The tramway is today the best tool to solve this contradiction:

- removing the cars of a street, if the street does not fill with pedestrians, nobody will understand why and the cars will return quickly.
- replacing them by rails (with bonus grass) and this decision is understood.

The main advantages of LRT are its commercial speed, its capacity, its attractiveness to car users and a number of qualitative factors, which are called "image". LRT is not only seen as a means of transport, but also a tool of urban design and improvement of public space. LRT also has the important advantage of running on electricity. LRT is non-polluting mode at the point of use. There is now considerable evidence that LRT attracts car users.

Surveys of passengers on new LRT systems in France, Canada and UK have shown that although the majority of passengers were drawn from other public transport, around 15 to 20 per cent formerly made their journeys by car, with about the same number making new journeys. In the right location, LRT can be very successful and can justify its costs.

7. The life cycle cost of tramway and urban bus

Across an example, the figures of Montpellier for the year 2003 presented by the general manager of the operator of Montpellier's network TaM, we try to show how the LCC and in final, the ratio receives/expenses is positive for the tramway and only 39% for buses.

PHYSICAL DATA	**TRAMWAY** (1 line – 15 km)	**URBAN BUS** (15 lines)
Rolling stocks	30 trains	149 buses
Vehicle km 2003	1 613 000 km	5 882 000 km
Spaces km offered 2003	450 100 000 spko	470 700 000 km
Carried passengers 2003	24 600 000 pass.	19 200 000 pass.
	INVESTMENT	(In Million Euros)
Compared investment cost (out of city beautifying)	317 ME	103 ME
Annual deadening	On 23 years 14.0 ME	On 16 years 6.3 ME
Yearly financial expenses	At 5 % 8.0 ME	2.4 ME
	ANNUAL COST 2003	
Investment cost	22.1 ME	8.7 ME
O&M costs	14.2 ME	28.4 ME
Total (investment + O&M)	**36.3 ME**	**37.1 ME**
	2003 **RATIOS**	
Cost / SpKO (Inv + O&M)	8.0 Cents E	7.9 Cents E
Cost / passenger	1.47 E	1.93 E
O&M cost / passenger	0.58 E	0.58 E
R / E (without invest. cost)	101 %	39 %
R / E (invest+ O&M)	39 %	31 %

Source: M. Le Tourneur, "Le développement du Tramway en France" Journée ATEC du 3 Juin 2004, Ppt.

Table 5: Comparison between investment and operating costs of tramway 1st line and 15 bus lines with data of 2003 in Montpellier

8. The success of Light Rail transit

After the recommendations of Prof. Vukan Vuchic in "Livable Cities", and the guidelines of UITP about the "Light rail for liveable cities", we list the main parameters, which characterize the light rail transit.

8.1. Capacity

Investment costs are high (we saw in above chapters, costs are between 15 to 40 M € per km according to the localization and the level of spaces offered), and thus the challenge is to develop the right mode in response to the right transit need.

Light rail is the ideal mode for carrying between 3,000 and 11,000 passengers per hour and per direction.

8.2. Speed and regularity

LRT, thanks to their high performance, light rail vehicles accelerate quickly and can attain good service speeds. With a segregated right of way and priority at traffic lights' crossings, which make light rail congestion free, LRT has a good average commercial speed (which depends also of the length of inter-stations and the real priority at traffic lights).

Measures to reduce dwell times at stops (e.g. stepless and gapless boarding, wide doors, tickets sold off the vehicle) increase speed and regularity and also improve the accessibility of the system.

8.3. Reliability

Congestion-free transit is regular and hence reliable. Thanks to this reliability, high frequency time tables at peak hours can be designed, obtaining better passenger flows. Light rail can also operate when adverse meteorological road conditions such as snow or ice affect road traffic.

8.4. Environment-friendly

LRT produces no emission at street level with electric traction. Modern traction equipment allows regeneration of breaking energy and consequently considerable energy saving if the operation of vehicles is organized on the line (vehicles braking and vehicles accelerating in the same time and the same electric section).

LRT is a relatively silent transit mode and rolling noise and vibration can be attenuated further by good maintenance of vehicles and tracks. Floating slabs under the rails can attenuate vibrations, "green" track reduces noise even more (grass-covered).

8.5. A positive image for the city

LRT can be fine on the aesthetic point of view and gives a strong positive image to the city. Extensive experience shows that customers' response is more enthusiastic than with improved bus system.

Using LRT contributes positively to the social dimension of a city, improves the quality of life and makes it more liveable.

8.6. Impact on urban life

Light rail schemes are not only transit projects, but also city projects. In contrast to bus routes, light rail tracks are permanent and highly visible. Light rail is thus a strong long-term political commitment of the authorities in favour of public transit.

LRT contributes to the regeneration and modernisation of urban centre and to the development of new areas. It attracts real estate development and the creation of new housing, new offices and shopping centres along its path. It increases the value of existing real estate as well.

Light rail systems encourage the compact and dense development of towns and cities and avoid unnecessary urban sprawl, increasing their efficiency.

8.7. Impact on the overall transit situation

Success of LRT depends on a well-thought redesign of the existing public transit lines, as feeders to light rail lines, to make the structure more visible, integrated, understandable and consequently user-friendly. It will lead to an increased use of public transit, and consequently has a positive impact on the modal split.

8.8. Development by stages

The development of a LRT could be planned and executed in several stages, providing benefits to its clients and operator from the early beginning of the project. Initial street running operation or "basic" rolling stocks could reduce high initial capital costs and attract private partnership with a reduced risk of overspending or prolonged start of operation. Hence, below the critical capacity threshold, buses or other intermediate transit modes could be more appropriate, securing capabilities for introduction of light rail at some later stage.

Other parameters of course, should be added to the list above as comfort, accessibility and ease of use, safety and adaptability.

9. Future developments

9.1. Technology

Over the last 20 years, low floor technology, AC chopper control and modular vehicle design concept have been widely introduced. Trends for the near future will include the introduction of composite materials, and measures leading to lower energy consumption and simpler maintenance.

Current collection at ground level or batteries may improve light rail's visual aspect in historic city centres (e.g. Bordeaux, Nice, Angers, etc.). Complementary to "classic" or French Standard light rail, new and innovative "intermediate" forms of guided transit are becoming available. Several types of "tramways on tyres" are under operation in France (in Nancy, Caen, Rouen, Clermont–Ferrand) and under construction in Douai.

Dual-mode or hybrid drive systems, combined with onboard energy storage devices like batteries or flywheels, will allow circulation beyond the bounds of track and overhead catenaries.

9.2. An affordable Light rail

High investment costs dissuade to begin the planning and construction of a new LRT line. Harmonisation of LRV design, wide constructors bid should result in lower unit prices and a LCC approach should lead to lower operation & maintenance costs.

New financing techniques such as Public Private partnership could help to fund new projects.

LRT can be very appropriate as a complementary mode in wide metropolitan area: for transit within suburbs and for links between different suburbs by avoiding the urban centre where the separate surface right of way is very difficult to obtain.

Tram-trains running on former railways tracks in rural areas and in the suburbs, continuing in the city on urban tramway tracks allow a journey without break in riding between town and suburbs.

10. Conclusion

We saw in this paper that French transit industry has successfully developed since the 1980's, the light rail system even an automatic light rail, the VAL, which is adopted in three cities like Lille, Toulouse and Rennes. Among the 39 LRT lines on 19 networks under operation we find several kind of light rail levels.

Systems in Nantes (1985), Grenoble (1987), and Lyon (2000) were built mainly in-street, with urban renewal and improved beautifying aesthetics of the street as main objectives. Similar to Germany and Switzerland, urban transit in French cities is managed by a single authority UTOA, that has significantcontrol over operations and fare policy. By this measure, France's light rail systems have been more successful delivering frequent, high-quality service that is well integrated with feeder services and the built environment.

All French systems are primarily for local travel within a city or built-up area providing many stops with convenient walk-on access.

LRT is typified by its variety of Right of Ways (RoW), which include:

- 1. a single line (Montpellier L2),
- 2. in-street with traffic (Saint Etienne L4),
- 3. on-street segregated (T1,T2,T3) most of the linear of French LRT,
- 4. various kinds of at-grade but segregated track alongside a road (Lille's tram along the Grand Boulevards of Roubaix Tourcoing) or in median (T3 on the Marshal's Boulevard South)
- 5. Completely separate private RoW, which may or may not be grade separated
- 6. Tunnels or subways (Strasbourg Line A, Rouen L1 and Lille Line 1 & 2).

This flexibility is the essence of LRT.

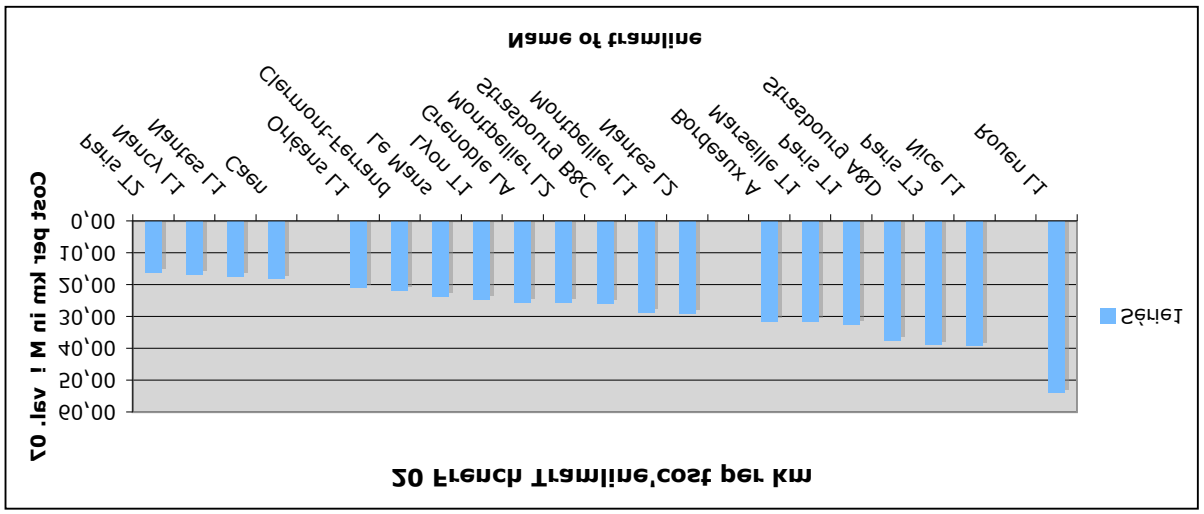


Figure 14: The four range of Tramline's cost per km in M € val 07

In the chapter 3 above, we have made the description of different lines of tramways under operation today in France. Among these lines we distinguished the high flow lines around 100,000 passengers per day and new lines being as yet around 50,000 passengers a day.

We found three categories of lines:

- the lines whose cost is in a range of 15 to 20 M € per km, generally built on former railway tracks in Paris Trans Val de Seine T2 or Nantes 1rst line. We find also in this range the lines of tram on tyres TVR of Nancy and Caen (cf. Figure 14 above).
- the lines whose cost is in a range of 20 to 30 M € per km, we find in this range most of the new lines built on surface these last years, Orléans, Le Mans, Clermont Ferrand (Tram on tyres), Montpellier L1 & L2,
- the lines whose cost is in the range of 30 to 40 M € per km, we find in this range the first lines with a specific equipment i.e for Bordeaux the ground electric alimentation, for Marseille it is 2.36 vehicle / km vs 1.49 for Le Mans L1, for Paris T1 it is also 2.94 vehicles / km and an architectural insertion (cf.Chemetov), Strasbourg A & D it is a tunnel built in the sands of Rhein river, Paris T3 it is also an architectural insertion in Paris Marshal's Boulevard and Nice choosed a specific vehicle with batteries to go through 2 magnificent places.

At last we find a network out of range, the first line of tramway in Rouen (cf. bibliography: 2 km and 5 stations underground costed the same price than 9 km of surface line and 15 stations, the 11.6 km costed 2500 MF or 381 M€ with the economic conditions of 1990).

If we examine the lines in the first range below 20 M€ per km, even if the cost is low the space kilometre offered per day on line T2 and Nantes L1 are respectively 1. 863 M and 1.064 M per day. This offer is of the same level than the tramway of Strasbourg line A & D, Nantes L2, Montpellier 1st line (140,000 passengers per day).

For the tram on tyres of Caen and Nancy the offer is respectively 0.763 M and 0.534 M per day what is correct to carry 50,000 passengers a day.

As it is said in "La Gazette des Communes" (cf. Bibliography), Systra, project manager, indicates that a tramway line costs nowadays around 20 M€ per km without big public works like bridges, tunnel, etc. and specific beautifyings outside the RoW of 6 to 12 meters wide. Extension of a line is generally 25 % less expensive than the former line for which the master of works should pay a workshop and a fleet of vehicle.

For the flows around 20,000 passengers and below the UTAO could choose a project by stage, building a busway and operating a BRT with articulated or sometimes bi-articulated buses for some years. When frequentation will increase enough a project of tramway could be realized.

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City/ UPT inhabitants /Opening	**Line Length** (km)	**Stations**	**Traffic** Pas./day Sps/hour/dir	**Headway** Peak Hour (min.)	**Rolling Stock** Fleet/brand	**Gauge** (m)	**Length Capacity** (m)/(spaces)	**Power** (kW)	**Cost's line** M € HT/ km val economic conditions 2007
Angers 300,000 June 2010	12	1/25	35,000/2895	4'	17 Citadis 302	2.40	32.42 / 193		248 M€ val. 06 or 21.28 M€ val.07
Bordeaux 700,000 Dec 2003	A/19.9	A/41	56,800/4500	4'	62 Citadis 402	2.40	43.99/ 300	6x120=720	1st st: 24.6 km; 678.7 M€ val.03 or 31.72 M€ val. 07 2nd st 19.1 km ; 558.2 M€ val.06 or 30.11 M€ val.07
B May 2004	B/15.4	B/20	55,600						
C April 2004	C/ 8.4	C/17	19,000		12 Citadis 302	2.40	32.85 / 218	4x120=480	
Brest 250,000 June 2012	14	24	45,000/ 2400	5'	20 rolling stocks				298 M € or 21.2 M€/km val. 07
Caen 230,000 Nov. 2002	15.7	34	40,000/2300	210 ''	24 TVR Bomb	2.55	24.50 / 135	300/Dies.200	286 M€ val.07 or 18.30 M€
Clermont Ferrand 300,000 06	14	31	40,000/3400	3'	22 Translohr STE4	2.20	32 / 170	400	290 M€ val 06 or 21.95 M € 07
Douai 200,000 1st stage 2009	12	21	18,000/883 or 1100	7'	10 Eveole 18 m 2 Eveole 24.50	2.55	18 / 103 24.50/129	Hybrid Diesel-batteries	117 M € val 2004 or 10.92 M€ val. 2007
2nd stage 2012	16	24							124.8 M € val 2007 or 7.8 M€
Grenoble 400,000 Sept. 1987	A /12.7	A / 29	90,000 / 2610	4'	53 TFS-2	2.30	29.4 / 174	2 x 275 = 550	A & B 552 M€ val.06 or 25.72 M€
Nov. 1990	B / 9.4	B / 20	59,000						Or 25.72 M € / km
May 2006	C / 9.6	C/ 19	30,000 / 4125	4'	35 Citadis 402	2.40	43.73 / 275	720	450 M € val.05 or 24.06 M€/km val.07
Oct. 2007	D / 3.7	D / 7							
2013	E /18.5								420 M € with Workshop and rolling stocks
Le Havre 280,000 2012	12.5	24	56,000 / 2914	3'30	17 rolling stocks		30 / 170		260 M € val. 05 or 22.05 M€/km
Le Mans 200,000 Nov. 2017	1 / 15.4	1 /29	50,000/ 3300	4' , 8'	23 Citadis 302	2.40	32 / 220	4 x 120 = 480	337 M € val. 2005 or 23.81 M€/km val.07
Lille 1.2 M Mai 1994	17.84	36	32,000 / 3260	3'30 , 7'	24 Breda	2.40	29.9 / 190	410	220 MF val.94 or 19.73 M€/ km val. 07
Lyon 1.2 M T1 Jan. 2001	10.5	24	80,000/2400	5'	57 Citadis 302	2.40	32.416/201	480	T1 + T2 = 515.92 M € val.01 or 24.78 M €/ km val.07
T2 Jan. 2001	14.9	29	70,000/2400	5'					
T3 Dec. 2006	14.6	10	13,000	8', 16'					172 M € val. 06 or 12.3 M € val.07
T4 Jan. 2009	10	18	22,000		13 Citadis				185.3 M € val.06 or 19.08 M €val. 07 o
LESLYS* Sept. 2009	21.7	4	3,000		6 Stadler Tango				100 M € val.06 for 7.1 km or 14.50 M €/ km val. 07
Marseille 1 M T1 Juin 2007	5.9	14	44,600/3060	4'	26 Flexity Outlook	2.40	32.50 / 204	460	1st & 2nd stage 468 M€ (val. 03) or 31.76 M€ val. Jan.07
T2 Juin 2007 2nd stage	5.1	13	42,600						
T3 2nd stage	5.4	12			14 Flexity				
Montpellier 400,000 L1 July 2000	15.2	27	140,000 /3600	5'	30 Citadis 401 3 Citadis 302	2.65 2.65	40.9 / 300 32.51 / 212	6 x 140 = 840	348.8 M€ val. 00 or 28.91 M €/km val 07
L2 Dec 2006	19.8	33	52,000/ 1696	450'',15'	24 Citadis 302	2.25	32.51 / 212		429 M€ val. 02 or 25.78 M €
L3 2010	20	30	60,000		20 rolling stocks				450 M€ val. 02 or 26.77 M €/km val07
L3 bis 2012	5		70,000		23 rolling stocks				120 M €
Mulhouse 250,000L1 May 2006 2nd stage 2010	9 10.97	10 21	25,500 / 3465	4 ', 8 '	20 Citadis 302		32.50 / 231	480	249 M € val 01 or 25.62 M € / km 1st stage
L2 May 2006 1st stage Tram	3	14	22,000		7 Citadis 302				
2nd stage 2010	8.75	17	87,000						
1st & 2nd stage 2012	19.72	38							340.2 ME val. 2001 or 17 ME / km
Tram Train Suburban line 2010	20	18		20 ', 10'	17 bicurrent Avanto	2.65	36.678 / 242	800	1st stage 147 M € for 20 km
Nancy 280,000 2002	11	28	45,000/1620	5'	25 TVR Bombar.	2.50	24.50 / 135	300 /Dies. 150	140 M€ val 98 or 17.08 M€ val.07
Nantes 570,000 L1 Jan. 1985	17.6	32	90,000 3540	4'	34 TFS high floor Alsthom	2.30	29.62 / 236	550	10.4 km Cost 94.34 M€val.1985 or 17.41 M€ val 07 5 km d'ext 52.14 M € val2000 or 13.14 M €/ km val.07
L2 Sept. 1992	16.1	33	112,000 /3885	4'	33 Incentro	2.40	36.40 / 259	8 x 45 = 360	57.6 M€ val. 2004 2.2 km or 29.32 M€ val.07
L3 Aug. 2000	6.4	17	35,000 / 2520	4'					L3 cost :116.2 M€ val.00 or 22.87 M € /km val07

L4 Busway 2006	7		18,200 / 1650	4 '	20 Bus Citaro	2.55	18 / 110		75 M€ val. 2005 or 11.35 M €/km val.07
Tram-Train 2013	64				7 Citadis Dualis				144 M € val 05 or 2.385 M € / km val.07
Nice 500,000 L1 2007	8.7	21	70,000 / 3240	4 ', 8 '	20 Citadis 302	2.65	33.021 / 216	480	333 M € val.06 or 39.41 M €/km val.07
2nd stage 2010	4.5								890 M € for 2nd stage 26.5 km or 33.58 M € / km val 07
Orléans 300,000 L1 Nov. 2000	17.9	24	45,000/2640	4'	22 Citadis 301	2.32	29.87 / 176	560 kW	301 M € val. 00 or 21.19 M € / km val.07
L2 2011	11.8	25	22,000/ 2640		21 Citadis 302	2.40	32.50 / 231		297 M € val. 06 or 25.98 M € / km val.07
Ile de France 11M T1 St Denis-Noisy Dec 1992	11.9 dont 3	26 4	100,000/2610 9,000	4'	35 TFS-2	2.30	29.40 / 174	550	186 M€ val. 89 pour 9 km et 35 TFS or 32.55 M€ val.07 Ext. Noisy 80.95 M € val. 98 or 35.07 M € / km val. 07
T1Noisy – Val de Fontenay	7.95	15	40,000						279.35 M€ val. 00 for infras, or 44.27 M€07 / km
A1bT13 rd stage Gennevilliers 2011	4.9	10	43,000		9 Citadis				163.73 M € val 06 or 34.41 M € / km val.07
T2 Issy-La Défense July 1997	11.3	13	8 0,000/6870	4'	13 2 unit Citadis	2.40	65 / 458	480	132.9 M € val. 1996 or 16.46 M € /km
Ext.T2 to Porte de Versailles 2009	2.3	3	30,000 / 6870	4'	10 Citadis 302	2.40	32.70 / 229	480	110.59 M € val. 03 or 55.29 M € / km val.07
A1a Ext to Bezons bridge 2011	4.2	7	58,000	4'					276.49 M € val 2005 or 69.84 M€ val 07
T3 Maréchaux Sud 1st st Dec 06	7.9	17	100.000 / 4560	4'	21 Citadis 402	2.65	49.70 / 304	720	267 M € val.02 or 39.16 M € /km val.07
2nd st to Porte de La Chapelle 2012	14.2	22	155,000 / 4560	4'					615 M € val 06 or 44.6 M € / km val.07
A2b T4 Aulnay-Bondy Nov.2006	8	11	45,000	4 - 6'	15 Avanto	2.65	36.36 / 242	800 k	124.23 M€ val. 2003 or 17.84 M € / km val.07
A3c Châtillon-Viroflay 2010 & 12	13.6	21	82,000/3429	210'', 7 '	30 Translohr STE5	2.20	39 / 200		445.7 M € val. 06 or 32.79 M € / km val. 07
A3b Villejuif-Athis Mons 2012	11.2	18	36,000 / 3648	5 '	19 Citadis 402	2.65	49.70 / 304	720	337 M € val 06 or 30.99 M € / km val.07
Athis Mons-Juvisy 2013	3.5								160 M € val. 06 or 47 M € / km val. 07
A3g St-Denis-Villetaneuse Y 2013	8.46	18	55,000 / 3600	3 ' 6'	20 Rolling stocks		180		230.4 M € val. 00 or 33.09 M € / km val. 07
St Denis-Sarcelles 2011	6.6	16	30,000 / 1800	4'	15 Translohr STE3	2.20	25 / 120		215 M€ val. Jan. 2006 or 33.55 M€ / km val.07
Reims230,000 L1 2011	11.2	22	45,000 / 3075	4' , 10'	18 Citadis 302	2.40	32.70 / 205	480	Total cost 342.78 M€ val. 2004 or 34.27 M€/km 07
Rouen 420,000 Déc. 94	15.1	31	63,000 / 3000	210''	28 TFS-2	2.30	29.40 / 175	2x275=550	381 M€ val.90 pour 11.6 km or 54.19 M € / km val. 07
L2 TEOR 2001/06	25.6	41	35,000/2100	3'	38 Agora art. Bus	2.55	18.50 / 105		164 M € val 04 or 7.17 M€ / km val.07
St Etienne 400,000 L4 Dec 1881	9.34	30	35,000 / 4440	2'	35 Alsthom-Vevey	2.12	23.19 / 148	2x140=280	
L5 Oct. 2006	2.2	5	18,000						75.6 ME val.03 or 34.50 M € / km val. 07
Strasbourg 500,000 A Nov. 1994	12.6	22	A&D/116,000 8100	2' , 3 '	9 Eurotram 14 Citadis 403	2.40 2.40	44.10 / 270 45.00 / 288	12 x 28= 336 720	297.75 M€ val. 94 or 37.8 M €/km val.07
B Sept. 2000	14.88	27	B&C/104,000	3 ', 6'	26 Eurotram		44.10 / 270		B&C: 247.7 M€ vaL.99 for 12 km or 26 M€ / km val. 07
C Sept.2000	10.39	21			18 Eurotram				402.54 M€ val. 99 for B ext, C,D,E, 13.5 km or 37.57 M€/km val.07
D Aug. 2007	5.62	11			9 Citadis 403				37.57 M€/km val.07
E Aug. 2007	10.6	20			18 Citadis 403				37.57 M€/km val.07
F Tram train 2009	40			15' 30'					212 M€ val. 99 or 6.89 M € val.07
Toulon 320,000 2011/2013	18	37	50,000	5'	28 rolling stocks	2.40	32 / 200		515 M€ val.03 or 32.36 M € val.07
Toulouse 800,000 LE 2010	10.8	18	30,000 / 3180	4'	18 Citadis 302	2.40	32.70 /212	480	266 M€ val 05 or 26.10 M € / km val 07
Valenciennes 400,000 July 2006	9.5	19	25,000 / 3180	4'	21 Citadis 302	2.40	29.66 / 212	480	1st stage 269 M€ val. 2006 or 29.16 M€ / km val 07
2nd st. Sept. 2007	8.5	7	10,000						2nd stage 69 M€ val. 2006 or 8.36 M€/km

Edition:2/10/08 Source: Connaissance du Rail Juillet 2005 n°286-287 et 2007 n° 316-317- L'année 2006 des transports urbains Gart- 2002, Gart.Website of Transport Authorities of each city- STIF- RATP

Characteristics of 39 tramways lines (19 networks) under operation or 23 lines under design (7 networks) in France

.Nota: the investment costs of projects realized on different years have to be homogenized, so we present the costs on current value 2007, the present value factor is 3% per year.

- Bordeaux: the comparative costs between GPS and catenary is 1.5 M€ / km for GPS and 0.45 M € / km for the catenary val. 2004
- Lyon: LESLYS Light rail going to the Airport from the center of Lyon with T3 line's platform and LESLYS platform on separated Right of way
- Nice: Load of battery for one vehicle 900 kg and equipment 600 kg per Citadis life cycle 5 years. 45 moduli of 12 V each that is to say 540 V with 370 A maximum intensity which represents a maximum power of 200 kW during 13 minutes vs 480 kW for the Citadis traction's motors so the speed is limited to 30 km/h in autonomous mode. The life cycle is estimated to 5 years of operation. The operator asked that the transition between the autonomous and catenary modes should be managed by the driver and not automatically changed