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Light Rail or Automatic Guided Transit

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Abstract

The quality and attractiveness of urban public transport has been improved by several technological innovations over the past twenty years. Operating conditions have been transformed, with improved safety and flexibility ; adaptation to the needs of passengers and operators can be ensured owing to the possibilities offered by automation. Light rail and automatic guided transit systems present intermediate characteristics between those of buses riding on shared right of way and those of conventional metros on segregated right of way, from the point of view of investment costs, Light Rail Transit can also, more and less, offer similar service and operating costs. In this paper, the two types of new transit systems operated in France for more than fifteen years : Light Rail and Automatic Guided Transit are presented[2].

1. Light Rail Transit

In 1975, there were around 300 urban tramways networks in the world. Nowadays, this had grown to more than 400 networks of Light rails or streetcars operating in 50 countries on all the continents. More than 100 lines are under studies all around the world.

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2 LRT, presented here is the Nantes network system which is in service for twelve years;
AGT, or fully automatic system, presented here is the VAL of Lille which is in service for fourteen years.

Source : SEMITAN, Métro léger de Nantes

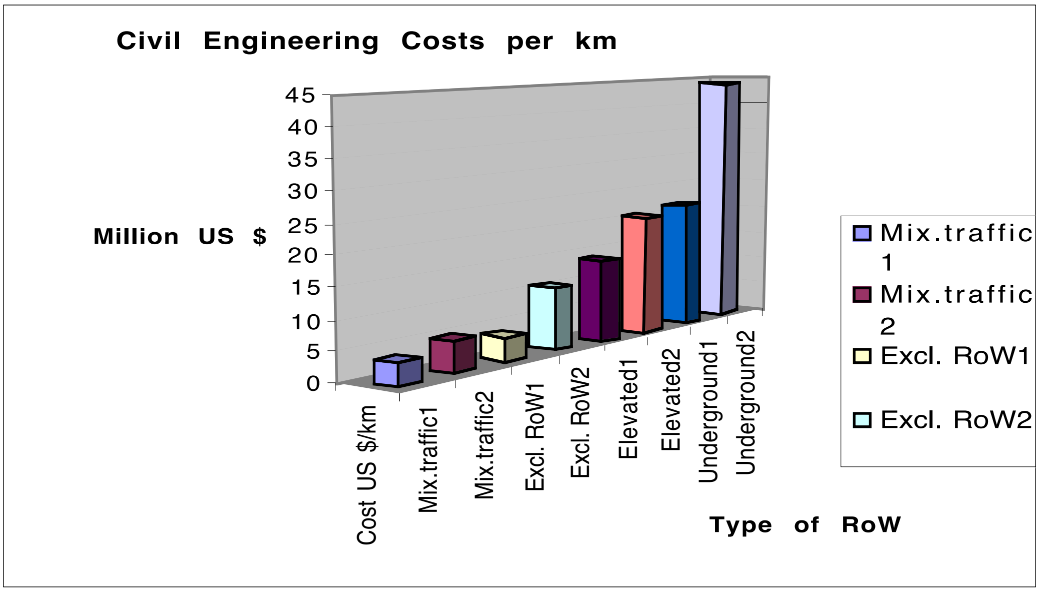
1.1 Infrastructures of Light Rail Transit

Urban transit systems use only a minimal area of ground for parking and maximise the capacity of the running lanes, they have a smaller impact on space uptake and the environment. The quality of service and capacity of light rail transit systems will depend on the type and size of the public transport vehicle, the means used to establish right of way segregation and the degree of segregation in town centres. When there is no land in the centre of the city, it becomes necessary to implement big public works by putting the tracks underground, which results in the loss of some advantages of Light Rail Transit, from the investment point of view.

1.2 The choice of type of right of way and investment

We imagine the influence of the choice of a type of site on the total investment of the Light Rail Transit system. This choice also influences the offered capacity at peak hours. Histogram 1 below shows some civil engineering costs of Light Rail Transit (per km of double track without rails and energy) according to whether part of the line is on surface, underground or elevated.

Histogram : 1 Civil engineering costs of LRT



Source : (Kühn,1997), (Kühn,2001), valeur 2002 1 US $ = 1 Euro

1.3 Operation speed

The operation speeds of a Light Rail Transit is generally lower than those of an Automatic Guided Transit for several reasons like the delays due to the traffic conditions, the waiting time in front of the lights at the cross-roads, the limitations of the speed due to the insertion problems of the track have a bad influence, the stop time, the order speed (desired speed) reached is lower than those reached on long inter-station links.

1.4 Operating frequency and quality of service

The frequency of passage depends on several parameters such as the vehicle's monitoring speed, the braking ratio, the level of safety, the response time of the braking-acceleration system, the station, the stop time which depends on the number of boarding-alighting passengers, and the random conflicts along the line .

This frequency also depends on the signalisation : on the surface, the Light Rail adopts the sight seeing driving, near the cross-roads the lights are influenced or directly controlled by the trains in the frame of the priority which is generally given to them. In the underground sections, they generally use automatic block signals, completed by automatic emergency braking, devices controlling the trains going through the signals and controlling the speed, in case of a behaviour engaging the safety : there is a reduction of the flow in relation with those permitted with running at sight, this heterogeneity of flow results in an obligation to foresee regulation devices when there is a common underground section in the city centre.

Light Rail operating systems can be made with the help of operational control systems allowing postponement of departures according to frequency[3] and to give

[3] Generally in France the frequency between two trains at the peak hour is 4 to 5 minutes and 7 to 10 minutes at off-peak hours.

the drivers the necessary information to regulate their speed in relation to the scheduled trip times. Thus, thanks to the separated ROW[4], the priority at signalised junctions, the adapted signalisation to the type of running site, LRT can offer quality of service with regularity, punctuality, and safety comparable to that of the metro since the investments would be important.

1.5 Capacity

At peak hour, with an interval of 4 minutes the offer can be of 2600 phd[5] [6] the operation can be done by multiple units of up to 2 units that brings the capacity to 5200 phd. To obtain more capacity we must reduce the interval that is to say improve the signalisation, the segregation of the site in relation to the general traffic and increase the number of cars per train.

2. Automatic Guided Transit

Since 1981, about twenty automatic urban transport of conventional type systems are under operation in actual urban centre services and several systems are planned or under construction. In all the cases, these are systems running on segregated right of way, fully automated, with quite different vehicle characteristics.

The application of fully automated driverless operation to the new transit systems is the consequence of a research of technical performances (high speeds, reducing intervals between trains, increasing safety) not possible with manually operated trains. Indeed, at the peak hours on the urban metro of Paris and other networks in the world, most of the lines have been manually operated for twenty years yet automatically at least at peak hours, that is to say at those where operation must be the most efficient and where drivers would have to apply more concentration than humanly possible.

The user benefits from the high frequency brought by full automation, avoiding long waiting times in station. This quality gives further attraction to public transport. In addition, this high frequency also can be obtained at off-peak hours by cutting trains between peak and off-peak hours which brings operation supplementary flexibility. High frequency of passage has another advantage on civil engineering costs of transit systems : at equal capacity the light rail (TFS[7] type) running with 3 unit trains every 4 minutes offers a capacity of 7800 phd., the AGT (VAL type) running with 1 unit train with an interval of 72 seconds offers a 8000 phd. capacity. In the first case the platform length is 90 m, in the second case the platform length is 26 m.

The innovations brought to the traditional modes of transport system have greatly spurred the improvement of the networks productivity. The rapid progress of technologies linked to the electronics and computing leads to increased gains in productivity bestowing on the public transport networks a growing tendency to automation.

The objectives to minimise the costs of a mean of transport, adapted to a demand whose importance and structure normally justify a metro, all by giving to users a high service quality have permitted to define for Lille the small gauge of VAL's system, its short passing headway at the peak hour and the technical and

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4 ROW : Right of Way

5 phd : places per hour per direction

6 At a normal load a LRV (Grenoble type) carries around 175 pass. and 240 pass. (6 pass./m^2).

7 TFS : Tramway Français Standard

economical necessity to conceive its automatic integral control.

This type of driverless automation on board, has given place to particular technical solutions which would not be the same for other metros manually operated : ie. the landing doors on the platforms, the numerous redundancies of certain equipment items allowing to guaranty a very high availability without need of an immediate human intervention and the necessity to highly develop the means of monitoring and communication.

Source : MetroPlanet, SMAT, Métro de Toulouse

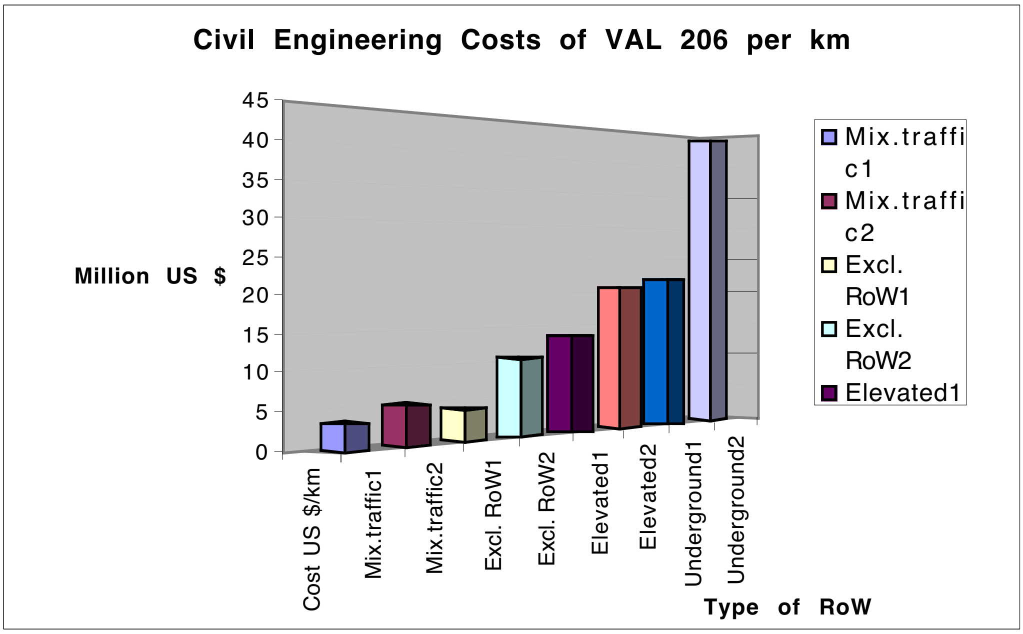
2.1 Infrastructures of Automated Guided Transit

The Automated Guided Transit systems have to run on segregated right of way. Then we understand all the benefits of reduced geometrical size and very short headways : a comparative analysis comparing the civil engineering costs depending on the adopted transit systems allowed us to verify that the construction costs are linked to the vehicles gauge of systems and that for an equivalent capacity, the civil engineering costs (tunnel and underground stations with the cut and cover method at a superficial level) of VAL 206 are lower by 8% to 17% than these of Light Rail for 7000 to 20000 phd. capacities, with 60 seconds headways for the VAL and 90 seconds for the LRT. For a deep tunnelling construction carried out with a Tunnel Boring Machine (TBM), the differences of civil engineering costs of Val 206 and Light Rail are between 17 to 31% less for the VAL 206 at 7000 to 20000 phd. capacities. (Kühn F., 1992)

2.2 Site type and investment

From different implemented projects in France we find that civil engineering costs (not including the track) are in a range of prices such as shown in the Histogram 2 below :

Histogram 2 : Civil engineering costs of VAL 206



Source : (Kühn, 2001); valeur 2002 1 US $ = 1 Euro

2.3 Operation speeds

Automatic guided transit can be well-adapted to the track characteristics and adopts a monitoring speed depending on the lengths of interstations, and acceleration-deceleration (tyres vehicle) allowed by the motorisation of the vehicles. The stop times in station are programmed, the dead time is suppressed, the high level commercial speed, around 35 km/h in relation to a submitted conflicts transit system, is optimised and respected. This high speed reduces the necessary number of vehicles to carry the same amount of passengers at peak hour : thus, with a 35 km/h commercial speed we must use a fleet of 34 Val 206 rolling stocks to carry 7000 phd. on a 10 km line; with a 20 km/h commercial speed we must use a fleet of 51 Light Rail rolling stocks (TFS type) that is to say 50% more.

2.4 Operating headway and service quality

The adopted headways on Lille's first line at the peak hour are between 72 seconds (60 seconds is a possible interval at the hyper peak -hour on the 1st line) and 3 to 6 minutes at off-peak hours and by night. This short headway allows a service quality that cannot be offered by Light Rail subjected to traffic jams. The AGT has also the regularity of a metronome, and a high degree of flexibility. We measure on VAL's operation during 99.7 % of the time a running regularity at one second near. Automation allows for substantial adaptability ; thus when there is a drift of peak hour with abnormal crowding, a remote control signal from the central control room allows the injection of several trains without the time needed to organise drivers, to oversee the staff, to plan the operating schedule, etc. The operator adapts better to the users demand, which brings to the transport user another service quality. (Frémaux D., 1993).

2.5 Capacity

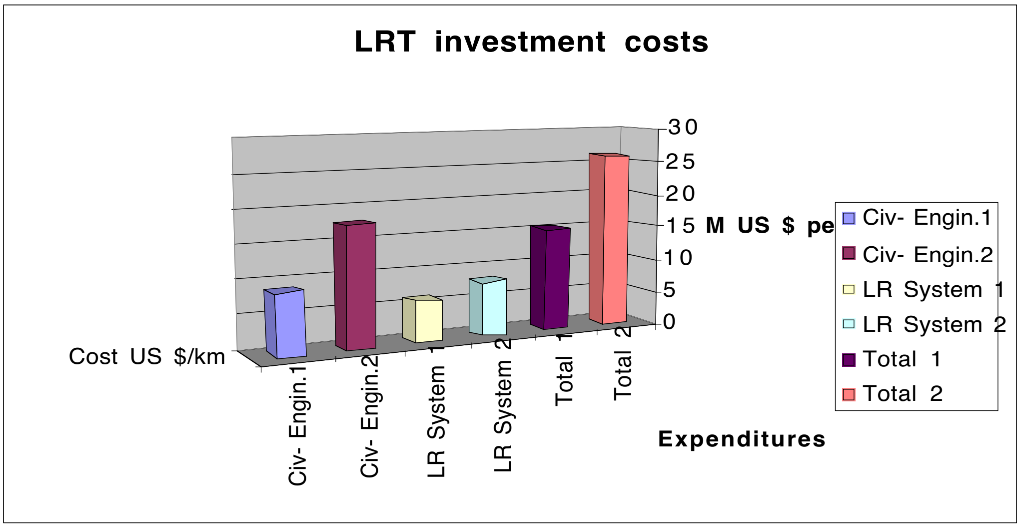
At the peak hour, with a minimum headway of 60 seconds the supply[8] can be of 9600 phd., and increases until 19200 phd. with a two-car train at a normal load and 26160 phd.(excep.load).

3. Comparison of 2 systems : the LRT and the AGT

3.1 Investment costs

From ten recent projects of LRT (111 km) in France the investment costs of each system have been evaluated. The costs are in a range of prices such as shown in the Histogram3 below:

Histogram 3 : LRT investment costs



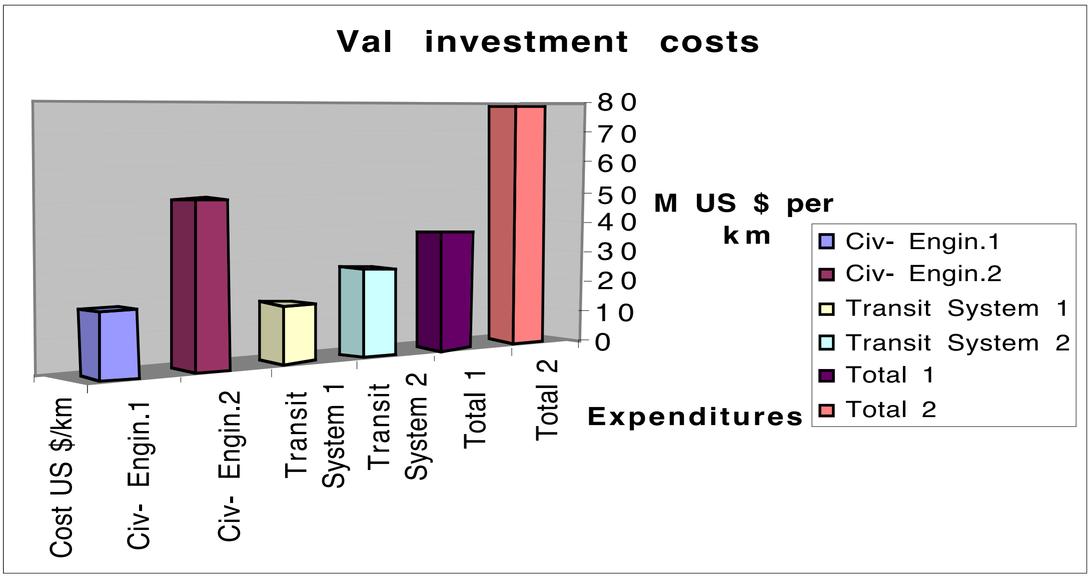
Source : (Kühn, 2001), (Kühn, 2002); valeur 2002 1 US $ = 1 Euro

The cost range of "Civil Engineering and Appended Expenditures " can be explained by the variations of the construction and on the workshop which is built either for the line, or the future network or merely enlarged. The cost range of "Light rail system" comes from the variation of the necessary supply, the fleet and the electric power that must dispose the system .

As for VAL system, 5 lines under operation in France totalling 72 km allows us to give the cost of civil engineering and the cost of the specific equipment linked to the integral automated system control and the rolling stock. These costs are in a range of prices such as shown in the Histogram 4 below:

[8] At a normal load a VAL 206 car type carries around 160 pass.(4pass./m^2) and 218 pass. (6 pass./m^2) at an exceptional load

Histogram 4 : VAL investment costs



Source : (Kühn, 1997), (Kühn, 2001); valeur 2002 1 US $ = 1 Euro

The cost range of "Civil Engineering" comes from the percentage of underground works : thus, 3 lines with 80% of their length in tunnel, one line with 90% of its length, at last one line with 40% of its length in tunnel.

The cost range of"Transit system" can be explained by the number of trains/km operated on each line : thus, 2 lines operating 3.17 trains/km (Lille), 1 line with 2.98 trains/km (Toulouse), 1 line with 1,7 trains/km (Rennes), at last 1 line with 1.11 train/km (Orly).

The Light Rail lines are designed to supply of around 2500 phd. with one-car trains, the VAL's lines are designed to supply 9600 phd. with one unit trains.

The commercial speed of Light Rail is around 18 to 20 km/h in France while the commercial speed of VAL is 32 to 35 km/h, this being principally due to the necessary segregated right of way to operate an Automatic Guided Transit.

Definitively, these above costs show that on average among several lines :

- the equipment linked to the integral automated system control and the rolling stock of an AGT as the VAL has a cost equal to double up to triple that of the equipment linked to the Light rail system and its rolling stock cost, for the first system the supply is 9600 phd. and for the second the supply is around 2500 phd.

- the civil engineering has a cost for the VAL's system equal on average to the double up to the triple that of LRT civil engineering cost. 40 to 90 % tunnelling construction of a VAL line compared to only 10 % tunnelling construction of LRT line.

3.2 Operating Costs

From a comparative analysis of French Metros operating costs we take the operation costs of Lille's metro for the year 1986 (after 2 full years of operation of the first line 13.3 km long with 38 one unit trains), for the year 1988 (61 trains), for the year 1990 (2 lines of 25.3 km long under operation with 83 trains), for the year 1995 (2 lines of 28.6 km long under operation with 83 trains) and for year 2000 (2 lines of 45 km under operation with 143 trains) the amount of supplied passenger places-km, of annual trips with the corresponding costs for the year considered are represented in the table 1 below in Francs & Dollars (without general and structural expenses, and taxes).

Table 1 : VAL operating costs

LILLE's VAL	1986	1988	1990	1995	2000
P.P.K. x 10^6	643	681	1260	1396	2021
Trips x 10^6	27	29	44	51	62
O & M Costs in MF **in US M$**	65 **9.4**	73 **12.2**	115 **21.1**	155 **29.2**	200 **28.7**
P.P.K. Cost in Francs **in US Cents**	0.101 **1.4**	0.107 **1.79**	0.091 **1.67**	0.111 **2**	0.098 **1.4**
Trip Cost in Francs **in US Cents**	2.40 **34.7**	2.51 **42.2**	2.61 **48**	3.04 **57**	3,22 **46**

Source : (Dtt, 1995), (Dtt, 1990). (Kühn, 1997) & (CUDL, 2001) Nota : P.P.K : Passenger Place-km. with 6 passengers/m^2 - Average value of US$:1 $ 86= 6.93 Francs; 1$ 88= 5.96 Francs; 1$ 90 = 5.45 Francs; 1$ 95= 5.30Francs ; 1$ 2001 = 7,80 Francs **P.P.K : Passenger Place-km. with 6 passengers/m^2**

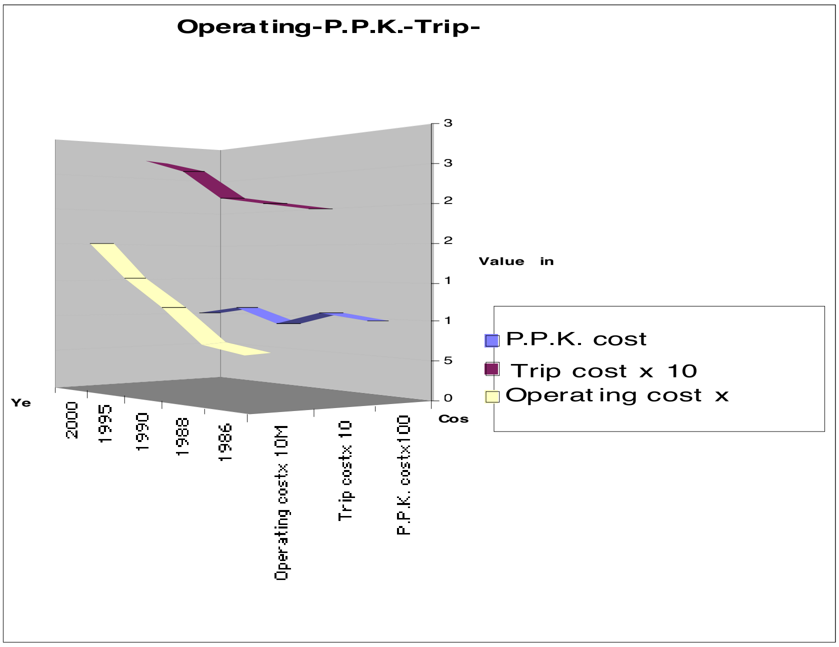
The operating costs of Nantes LRT are gathered for the years 1987 (1 line 10.6 km long with 20 trains), 1990 (after 2 full years of operation of the first line 12.6 km long with 28 trains), for1994 and for1998 (2 lines of 26.8 km with 46 trains), the amount of supplied passenger places-km, the amount of trips carried out by year with corresponding costs (without general and structural expenses, and taxes) are represented in the table 2 below in Francs and Dollars :

Table 2 : LRT operating costs

NANTES LRT	1987	1990	1994	1998
P.P.K. x 10^6	207	250	511	620
Trips x 10^6	13.07	13.26	32,9	35,8
Operating Cos	19.79 MF/3.29M $	21.2 MF/3.88 M $	67,2 MF/12,21M$	86,1 MF/14,66 M $
P.P.K. cost	0.0956 F/1.59Cent	0.0848 F/1.55 Cents	0.131 F/2,3 Cents	0,139 F / 2,36 Cents
Trip cost	1.51 F/24.8 Cents	1.59 F/29.3 Cents	2,04 F/37,1 Cents	2,40 F / 40,9 Cents

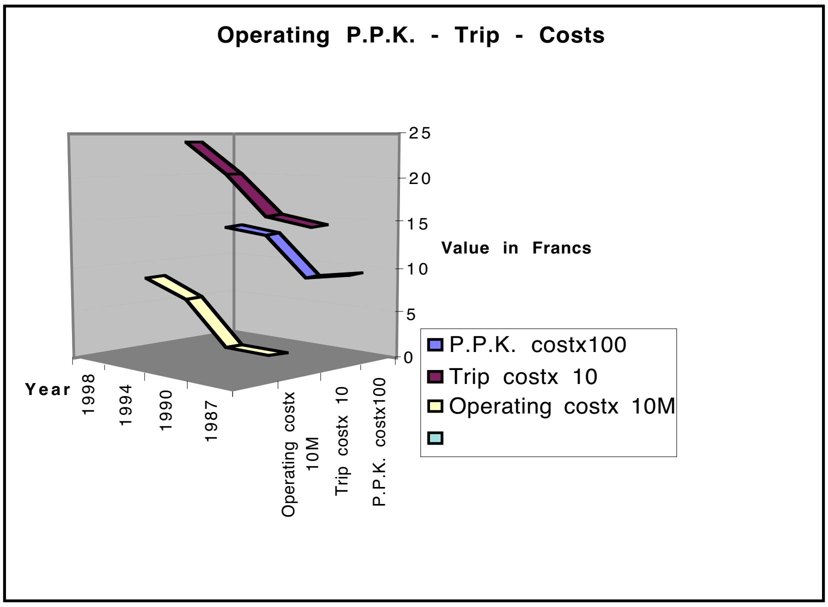
Source : (Semitan, 1987) et(Dtt, 1995) (Dtt, 1999).
Average value of US$: 1 $87 = 6.01 Francs ;1 $90 = 5.45 Francs; 1 $94 = 5.50 Francs.
1$ 98 = 5,87 Francs

Histogram 5 : VAL operating costs



Source : (Dtt, 1995), (Dtt, 1990). (Kühn, 1997) & (CUDL, 2001)

Histogram 6 : LRT operating costs



Source : (Semitan, 1987) et(Dtt, 1995) (Dtt, 1999).

If we compare the level of PPK costs, the PPK VAL cost is around 13 to 68% lower than the PPK LRT cost; as for the VAL trip costs they are between 64 to 12%

higher than LRT trip costs.

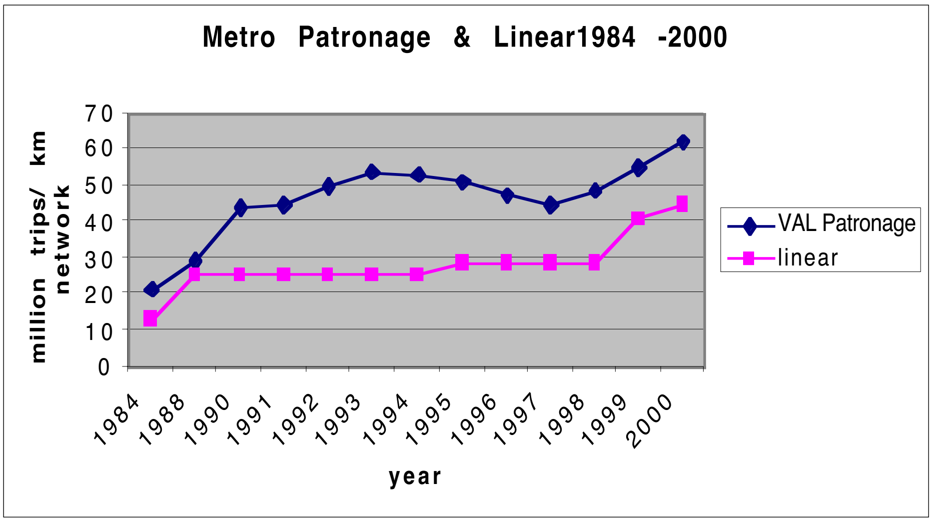
On Lille's network, the productivity per employee was 15542 km.trains in 1986 and increased to 25306 km.trains in 1995 that is to say an increase of 63%.

On Nantes LRT network the productivity per employee is 10417 trains.km in 1987 and increased to 11149 trains.km in 1994 that is to say an increase of 7%.

For each of the 2 networks of urban transport (buses and metro), expenditures and operation's fare income have evolved. The ratios fare income/expends corresponding to the data of the whole networks (buses & metro) are lower than fare income/expends ratios of the metros alone.

The « Separated Right of Way Transit » (TCSP[9]) influence » gives a certain productivity of operation and an increasing ridership. Thus, in Nantes the fare income/expends ratio of the Light Rail line in 1987 is of 115% when the ratio of the whole network is 55%. In the same way in Lille, the fare income/expends ratio of the VAL's first line is 111% on 1986 when the whole network ratio is 53%. In 1994, the ratio fare income / expends for VAL alone was 100.5 %, in 2000 this ratio became 135 %.

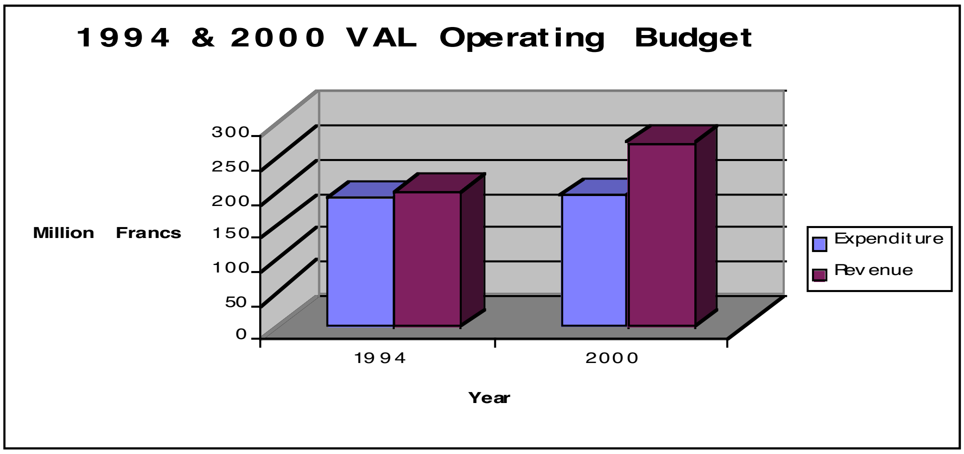
Figure 1 : VAL's network ridership betterave 1984 and 2000



Documentation : (CUDL, 2001)

[9] TCSP : Transport en Commun en Site Propre

Histogram 7 : Profitability of Metro's network



Documentation : (CUDL, 2001)

Summing up, we can say :

- in Lille, the "metro influence" with the opening of 2 lines 25,3 km long stimulates the ridership which was low 51 millions trips with the urban transport perimeter of 1 079493 inhabitants.

The ridership of metro's network which was 21.1 millions in 1984 increased to 29,4 millions in 1988 with the opening of Line 1 bis, increased to 48 millions in 1998 and 55 millions in 1999 with the opening of 16 new stations and 62 millions of passementiers. The whole network (Val + Tramway + Bus) carried in 2000 106.5 millions of passengers.

The ratio trips/capita /year is 97 in 2000 for an average ratio 126.5 in this range of cities of more 300 000 inhabitants.

- in Nantes, the "modern tramway influence" with the opening of 2 lines 26.8 km is less significant, the network's ridership before the opening of light rail line was yet 51 millions trips with a urban transport perimeter of 505281 inhabitants.

The ridership of Tram's network which was 7 millions riders in 1984 increased to 16.6 millions in 1992, to 26 millions in 1993 (21 km) , to 35.8 millions (27 km) in 1998.

This ridership was 83.6 millions trips for the whole network (Bus + Tram) in 1998. The ratio trips/ capita/ year is 167 in 1998 for an average ratio of 135 in this range of cities of more 300 000 inhabitants.

4. Technical evolutions of LRT and AGT systems

4. 1 Light Rail's évolutions

Evolution of the rolling stock

Light Rail Transit vehicles must be attractive, hence modern. The trend of the last years is an increase in transport supply and productivity : vehicles are 20 to 40 m long and 2.20 to 2.65 m wide with possibility of forming unit trains (1line in Guadalajara is designed to operate 5 unit trains 150m long); the unit capacity of these vehicles is between 200 and 300 passengers.

The use of choppers with traction motors allows a progressive traction control offering rolling comfort and a better use of adherence as well as consumption savings during starting and at reduced speeds.

Asynchronous motors fed by inverters appear progressively, offering a reduction of the expenses for maintenance of the motor, a reduction of weight and volume of the motor, an increasing of maximum rotation speed and a reduction of equipment.

Acceleration performances are required for increasing the commercial speeds, so we assist to an increasing propulsion power : nowadays the power-to-weight ratio is between 12 and 14 kw/ton.

The tendency of many networks in Europe is to adopt a low floor for their new rolling stock. These networks adopt vehicles with low floors in order to facilitate their access especially by handicapped persons, in order to improve exchange times at stations and facilitate the insertion of platforms into urban space. Many networks adopt low-floor LRVs which can be classified in three types:

- the intermediate Low-Floor unit added to existing rolling stock, approximately 200 of this design are in use in Amsterdam, Wurzburg,Darmstadt, Freiburg, Basel and Nantes networks,
- the partial Low-Floor between traction bogies, more than 1000 LRVs of this design are in use in Grenoble, Paris, Rouen, St Etienne, Sheffield, etc. networks,
- the 100 percent Low-Floor design, no steps inside, which is under operation in the Bremen, Frankfurt, Strasbourg, Bruxelles, Bonn, Köln, Munich, Zwickau, Braunschweig, Vienna networks. In all, more than 1000 all-low-floor vehicles have been delivered or ordered.

Operating methods and traffic control

Numerous networks have introduced aids to the operation of the tramway lines. These aids can be classified into three categories :

- block system of the track by means of track loops and spacing signalling on the line sections with exclusive right of way, especially in tunnels;
- priority at junctions with traffic lights.
- systems of supervision and areawide traffic control : setting up of a LRV fleet management and Automatic Vehicle Location (AVL) system.

The potential of Light Rail Transit

A study made among 10 networks around the world, by TRL and INRETS (Gardner, 1994), on the theme of the performance and potential of LRT in developing cities shows that the observed maximum peak hourly flows were found in three networks with a high percentage of separated right of way in Tunis (9330 phd), Alexandria (El Ramel 13414 phd) and Manila (a 100% segregated right of way, on viaduct : 19000 phd in 1994 and 28000 phd in 2001), the other 7 networks have an average flow of 4500 phd at peak hours. So it is full segregation, an advanced signalling system providing theoritical minimum headways of 85 secs. in Manila, 105 secs. in Mexico (line A), 150 secs. in Guadalajara, and a number of vehicle well adapted that can supply a high capacity .

4.2 Automatic Guided Transit's évolutions

The first lines under construction and operation of the VAL system (Lille 2 lines, Toulouse 2 lines, Orly one line, Rennes : 1 line) are characterised by the following features :

- safety electronic equipments based on a "fail-safe" technology,
- fixed-block automatic protection system,
- platform protection by platform doors.

There has been however some evolution on the different points in the family of mass transit systems, which will be briefly reviewed hereunder.

Use of microprocessors for safety functions

The Paris Metro Authority, RATP, decided to develop a new control system, called Sacem, for its regional network, the RER, in order to enhance the capacity of the lines ; this new system required the extinction of the wayside signals, and the use of a cab-signal involving safe track-vehicles transmissions and a safe computation of the stopping distances on board the trains. For the safety functions, RATP has promoted the development of an architecture based on a single microprocessor protected by data coding, called "vital coded monoprocessor".

This new architecture is now a standard for safety realisations in mass transit systems in France (David Y., 1991), and has been already used on Paris Rer line A, on Laon Poma, and on Lyons' Maggaly system, line 14 METEOR of Paris network, as well as on the Chicago Airport's VAL line and line 8 (Urban metro) and line A (LRT) of Mexico network.

Development of a moving block (ATP) system

Lyons' Authorities decided to adopt a moving block Automatic Train Protection (ATP) for the 4th line of their metro network in order to obtain a better flexibility of operation.

Platform doors

Since the opening of the first Val line in Lille in 1983, the use of platform doors is considered in France as the most efficient way for preventing accidents. There are used on the network of Toulouse, Orly, Rennes, and on the Météor line. In Lyon, the Authority and the metro operator chose a conventional method based on a double barrier of infrared beams, regularly spaced with 15 cm intervals, layed down above the tracks.

Other technical evolutions

In complement to these three main innovations concerning the "system" aspect of the lines under consideration, a number of other technical evolutions in the design of the vehicles or of the ground equipments have been introduced, for instance, on VAL line 2 of Lille network, the use of :

- electric vehicle doors instead of the pneumatic ones,
- GTO thyristors in the power control equipment,

- optic fiber in ground transmissions,
- a new VAL vehicle called VAL 208 with the"wheel-motors", it means one motor of synchronous type for each wheel of the vehicle instead of 2 DC motors in each vehicle, with a traction chopper for each of them.

5. Conclusion

After an important decline in the fifties, LRT systems have recovered a certain dynamism taking expression :

- in the creation of new networks ;
- in the improvement of existing networks ;
- in the improvement of rolling stock with extra low-floor light rail vehicles ;

The main reason of this dynamism is that these systems can be operated at grade on surface, they can be developed in stages. LRT is particularly well adapted to a range of cities and conurbations with populations between 200,000 and 700,000 inhabitants, in which the construction of underground networks is hardly imaginable because of the necessary investments.

AGT systems have a service quality, a flexibility, a regularity of metronome, a safety that the LRT can reach in the same way with difficulty ; the main reason is because AGT uses a fully automated driverless operation but it requires fully exclusive right of way and stations, and with higher car and system costs, total AGT construction cost is invariably higher than LRT construction cost. We saw in the chapter 3 above "Comparison of 2 systems" that :

- From the investment point of view on average, the equipment linked to the integral automated system control and the rolling stock of VAL has a cost equal to double up to triple that of the equipment linked to LRT system and its rolling stock cost, for the first system the supply is 9600 phd. and for the second the supply is around 2500 phd. As for the civil engineering and the added expenditures, they have a cost for the VAL's system equal on average to the double up to triple that of LRT civil engineering cost, the exclusive right of way generally obtained by a 80 to 90% tunnelling construction of a line, the LRT is satisfied with a separated right of way on the surface with only 10% tunnelling construction of their line.

- From the operating cost point of view

. in Lille, the "metro influence" with the opening of 2 lines 28.6 km long stimulated the ridership, the passenger place-km cost which was 1.79 cents at the opening of the second line decreased to 1.67 cents after two years of the 2 lines operating in 1990 then 10 years after with 45 km of lines the P.P.K. cost decrescendo to 1.4 cents. The productivity per employee was 15542 km.trains in 1986, it became 25306 km.trains in 1995.

. in Nantes, the "modern tramway influence" is less significant, with the opening of 2 lines 22.8 km long stimulated the ridership which was 51 millions for a served area of 464 857 inhabitants.The passenger place-km cost which was 1.59 cents in 1987, increased to 2.3 cents in 1994 and increased to 2.36 cents in 1998.

The productivity per employee was 10417 trains.km in 1987, it became 11149 trains.km in 1994.

We think that to increase the productivity of investment costs, the VAL system needs to operate in a high density area, not necessarily large city, and with important vehicle fleets the operating costs will decrease, the productivity per employee going on increasing with the opening of new lines of the network. With a large number of cars to operate the AGT operating costs decrease in relation with the LRT operating costs for a same supplied capacity.

When a city has a lack of land, generally in the centre, the future transit system needs to be up-graded (in underground or on viaduct), the construction cost of the system increases ; then there is a choice to do between an LRT or an AGT system because the exclusive right of way is naturally necessary. An automatic guided transit with its flexibility, service quality, safety could be implemented with an acceptable overcost decreasing when the needed capacity grows.

At last, we think there is a need of the two systems for the cities, large or not :

- a high density city without land to give to surface public transport could choose an AGT if the ridership to carry is sufficient, the service quality is then high and the "image of metro" attracts the users of private cars,

- a middle size city which makes the choice to prohibit some roads to the private cars, could then get separated right of way for a Light Rail and decides to implement it : Light Rail schemes of the 1980s have shown that street operation with predomently reserved running is both feasible and actually contributes to the humanising of the city.

6. References

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