kuhn@inrets.fr

Light Rail or Automatic Guided Transit

Francis KUHN

The French National Institute for Transport and Safety Research

INRETS

kuhn@inrets.fr

Summary

1. Light Rail Transit
   1.1 Infrastructures of LRT
   1.2 The choice of type of RoW and investment
   1.3 Operation speed
   1.4 Operating frequency and quality of service
   1.5 Capacity

kuhn@inrets.fr

Summary

2. Automatic Guided Transit
   - 2.1 Infrastructures of AGT
   - 2.2 Site type and investment
   - 2.3 Operation speeds
   - 2.4 Operating headway and service quality
   - 2.5 Capacity

kuhn@inrets.fr

Summary

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

3.1 Investment costs

3.2 Operating costs

4. Technical evolutions of LRT and AGT systems

4.1 Light Rail's evolutions

4.2 Automatic Guided Transit's evolutions

5. Conclusion

kuhn@inrets.fr

1. Light Rail Transit

1. Nowadays, there are 400 LRT and tram (streetcar) networks operating in 50 countries spread across all continents.

2. More than 100 new LRT lines are being planned world-wide.

kuhn@inrets.fr

Tramway moderne de NANTES

INRETS

kuhn@inrets.fr

Le tramway moderne Citadis de Montpellier

kuhn@inrets.fr

Le tramway moderne de Strasbourg

kuhn@inrets.fr

1.1 Infrastructures of Light Rail Transit

Urban transit systems maximise the capacity of the running lanes,

The quality of service and capacity depend on the type and size of vehicle and the degree of segregation in town centres.

If it is necessary to implement big public works we loss some advantages of LRT, from the investment point of view.

kuhn@inrets.fr

1.2 The choice of type of RoW and investment

The choice of a type of site influences the total investment and the offered capacity at peak hours.

Civil engineering costs (per km of double track without rails and energy) according to whether part of the line is on surface, underground or elevated are shown below.

kuhn@inrets.fr

1.2 The choice of type of RoW and investment

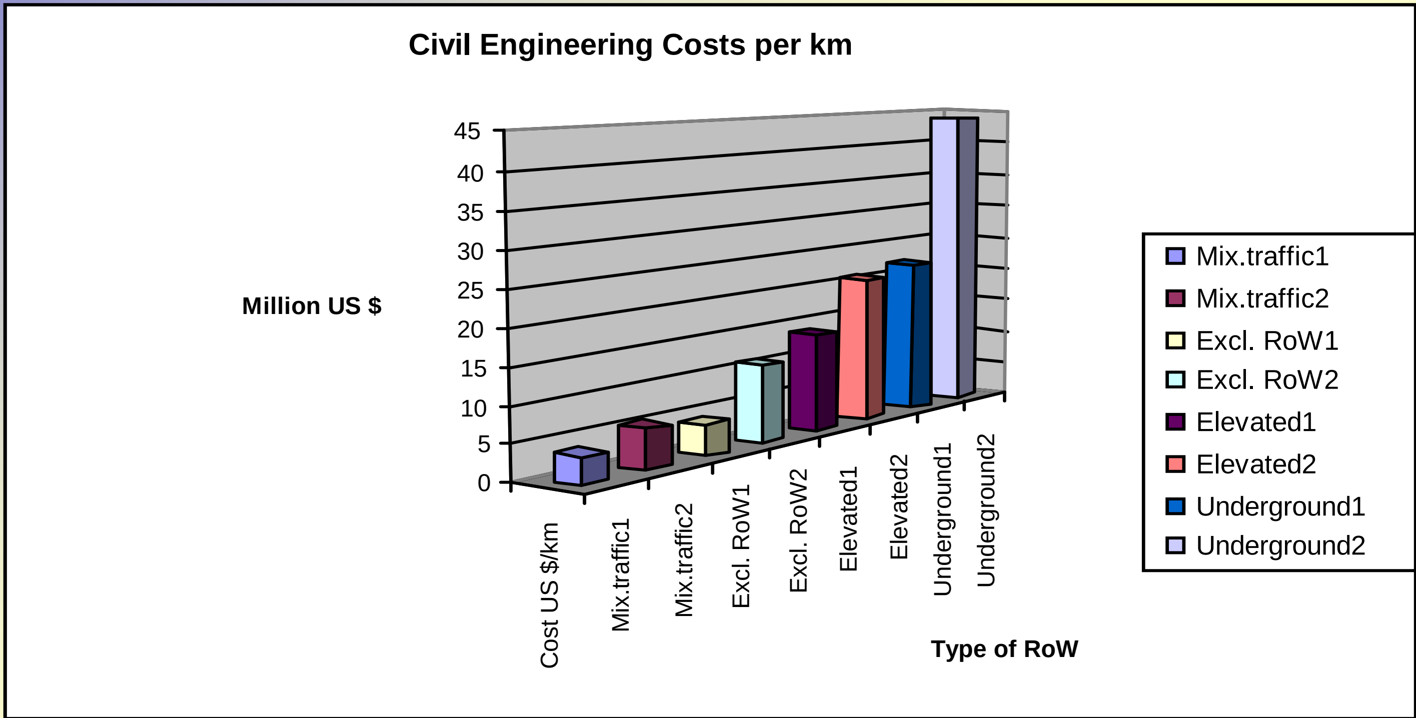


Table 1 Civil engineering costs of LRT
Source : (Kühn, 1997); value 2002 1 US$ = 1 €

INRETS

kuhn@inrets.fr

1.3 Operation speed

The operation speed is generally lower for several reasons :

- traffic conditions,
- the waiting time at the cross-roads,
- the insertion problems,
- the stop time,
- the desired speed reached, in short inter-station links.

INRETS

kuhn@inrets.fr

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,
- The random conflicts along the line.
- The signalisation

1.4 Operating frequency and quality of service

- On the surface, the LRT adopts the sight seing driving,
  The lights are influenced or controlled by the trains.

- In the underground section, they use automatic block signals, 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 and a heterogeneity of results in an obligation to foresee regulation devices.

1.4 Operating frequency and quality of service

Operational control systems allow postponement of departures according to the frequency and give the drivers the necessary information to regulate their speed in relation to the scheduled trip times.

Thanks to the separated RoW, the priority at signalised junctions, an adapted signalisation to the type of running site, the LRT offers quality of service with regularity, punctuality, and safety comparable to that of the metro since the investments would be important.

kuhn@inrets.fr

1.5 Capacity

With an interval of 4 minutes, the offer can be between 2600 to 3600 phd (4 or 6 spaces/m^2), multiple units of up to 2 units may be adopted, that brings the capacity to 5200 to 7200 phd.

To obtain more capacity, we must reduce the interval : improve the signalisation, the segregation of the site in relation to the general traffic and increase the number of cars per train.

kuhn@inrets.fr

2. Automatic Guided Transit

These systems are running on segregated RoW, fully automated.

Fully automated driverless operation is the consequence of a research of technical performances : high speeds, reducing intervals, increasing safety,

Most of metros lines around the world are operated automatically at least at peak hours, at those where operation must be the most efficient and where drivers would have to apply more concentration than humanly possible.

kuhn@inrets.fr

VAL 206 à LILLE sur Viaduc

kuhn@inrets.fr

VAL 208 à LILLE

kuhn@inrets.fr

VAL 208 à RENNES

kuhn@inrets.fr

VAL 206 en Station à TOULOUSE : Portes Palières

kuhn@inrets.fr

2. Automatic Guided Transit

The user benefits from the high frequency,

High frequency can also be obtained at off-peak hours by cutting trains between peak and off-peak hours,

High frequency and civil engineering costs of transit systems :

- LRT running with 3 unit trains every 4 minutes offers a capacity of 7800 phd,
- 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.

INRETS

kuhn@inrets.fr

2. Automatic Guided Transit

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, have permitted to define for Lille the small gauge of VAL's system,

kuhn@inrets.fr

2. Automatic Guided Transit

Particular technical solutions were needed :

- 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.

- The necessity to highly develop the means of monitoring and communication.

INRETS

kuhn@inrets.fr

2.1 Infrastructures of Automatic Guided Transit

The AGT systems have to run on segregated RoW.

We understand all the benefits of reduced geometrical size and very short headways,

A comparative analysis showed that civil engineering costs with cut & cover method of VAL 208 are lower by 8 to 17% than these of LRT

For deep tunnelling (TBM) the costs of VAL are lower by 17 to 31% than these of LRT at 7000 to 20000 phd capacities.

kuhn@inrets.fr

2.2 Site type and investment

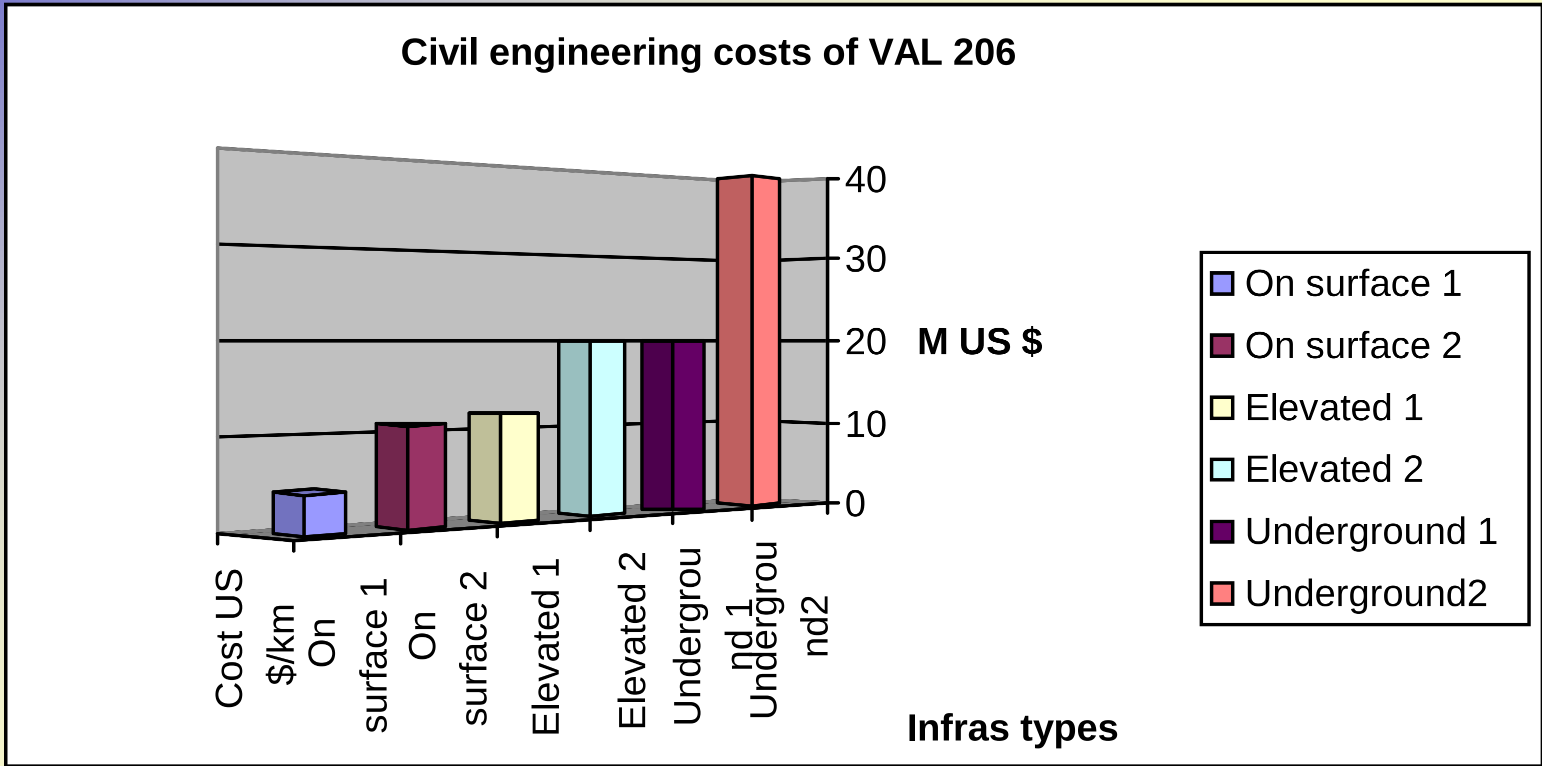


Table 2 Civil engineering costs of VAL 206
Source : (Kühn, 1997); value 2002 1 US$ = 1 €
Nota : These costs do not include the tracks

kuhn@inrets.fr

2.3 Operation speeds

AGT adopts a monitoring speed depending on interstations, and acceleration-deceleration (tyres vehicle) allowed by the motorisation of the vehicles.

Stop times in station are programmed, the dead time is suppressed, the high level commercial speed is optimised and respected.

High speed reduces the necessary number of vehicles to carry the same amount of passengers at peak hour : at 35 km/h 34 vehicules, at 20 km/h 51 vehicles are needed to carry 7000 phd

2.4 Operating headway and service quality

Short headway allows a service quality that cannot be offered by LRT subjected to traffic jams.

The operator adapts better to the users demand, which brings to the transport user another service quality.

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.

kuhn@inrets.fr

2.5 Capacity

With a minimum headway of 60 seconds the supply can be :

- 9600 phd (normal load: 160 spaces)
- 13080 phd (exceptional load : 218 spaces)

and increases with a two-car train until :

- 19200 phd (normal load)
- 26160 phd (exceptional load)

INRETS

kuhn@inrets.fr

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

3.1 LRT Investment costs

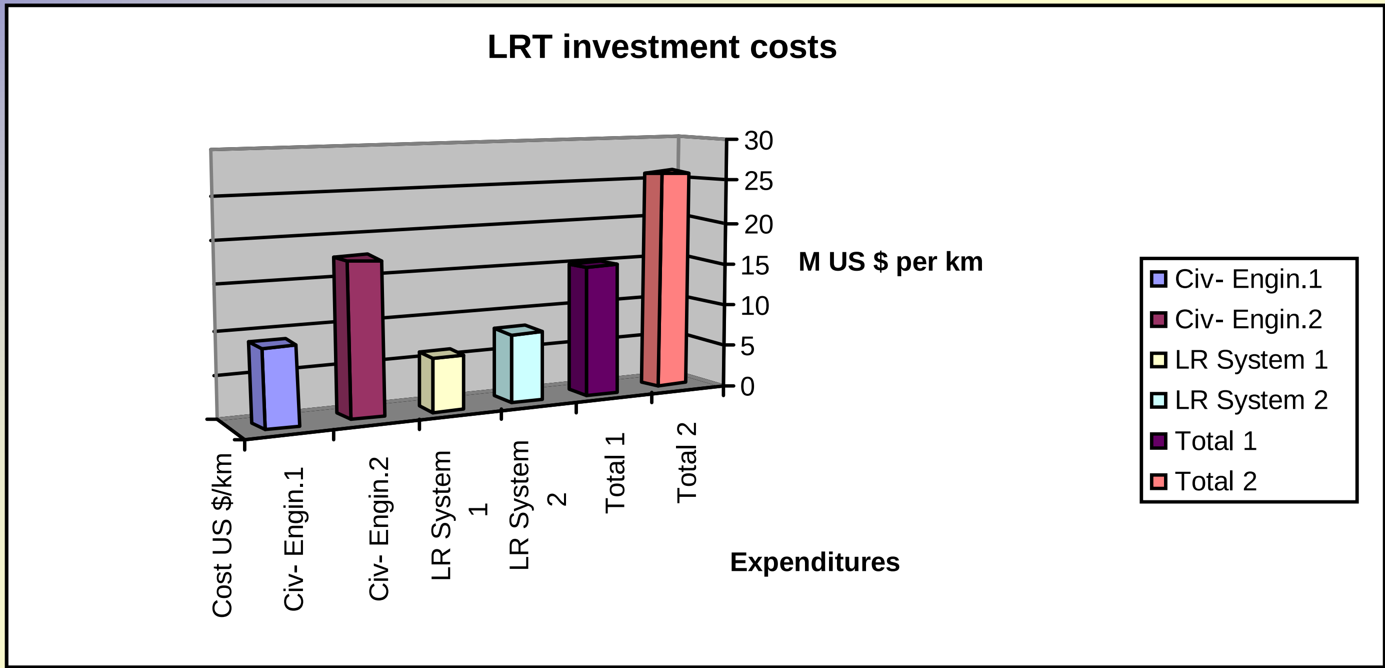


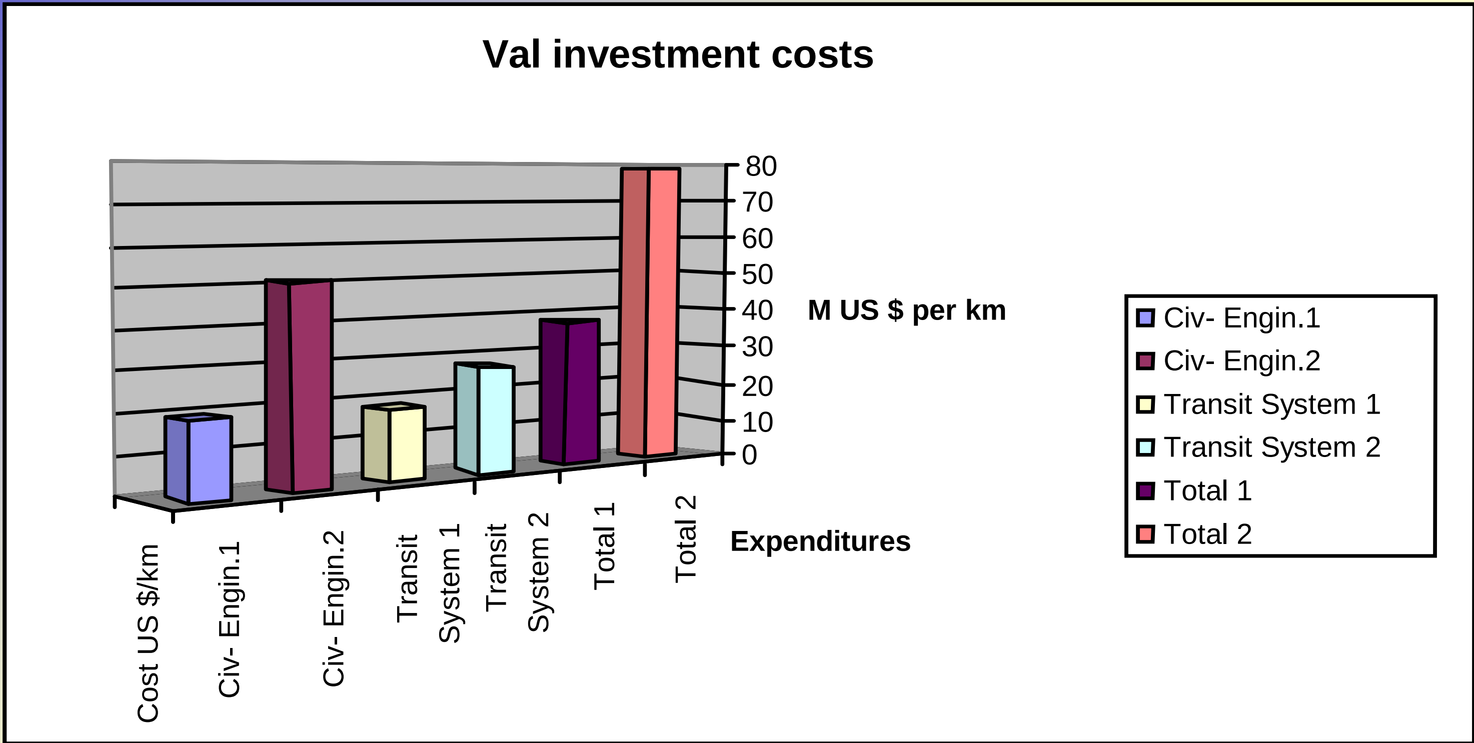
Table 3 LRT investment costs

Source : (Kühn, 1997) & (Bottoms, 2000); value 2002 1 US$ = 1 €

Nota : From 10 recent projects of LRT (111km) under operation in France. Civil engineering costs include workshop, land, design ; LR system costs include tracks, energy, traffic control, operating and control center

kuhn@inrets.fr

3.1 AGT Investment costs



- **Table 4 VAL investment costs**
- Source : (Kühn, 1997); value 2002 1 US$ = 1 €
- Nota : 5 lines under operation totalling 72 km. Transit system costs include rolling stocks and specific eqipment linked to the integral automated system control : tracks, energy, traffic control, operating and control center.
-

INRETS

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

3.1 Investment costs

The LR lines are designed to supply of around 2500 phd with one-car train, the commercial speed is around 18-20 km/h

The VAL's lines are designed to supply 9600 phd with one unit train, the commercial speed is around 32-34 km/h

Definitively, these above costs show that on average :

- the equipement linked to the integral automated system control and the rolling stock of an AGT has a cost equal to double up to triple of the LRT system & cars,

- the civil engineering of Val's sytem has a cost equal to double up to triple of the LRT civil engineering

kuhn@inrets.fr

3.2 Operating costs

The operation VAL's costs:

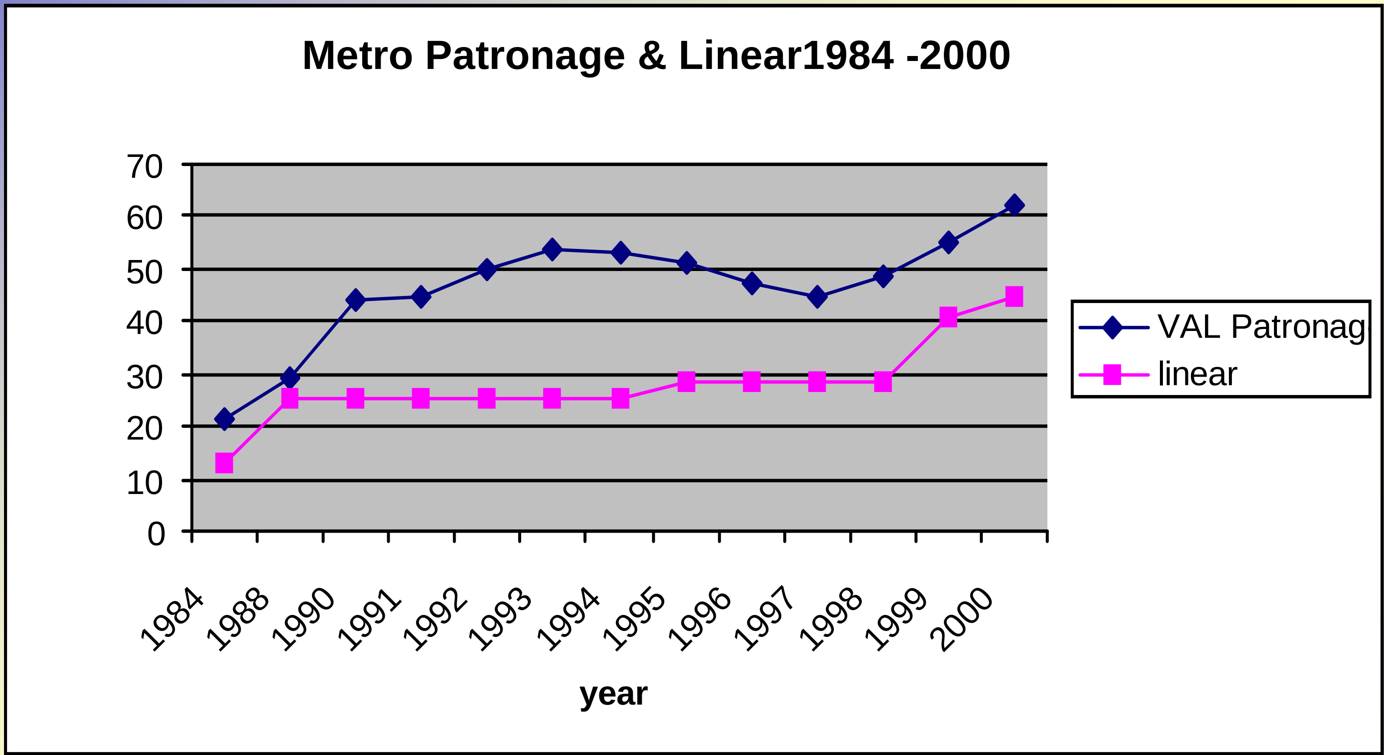
- for 1986 : first line 13.3 km with 38 one-unit trains,
- for 1988 61 trains,
- for 1990 : 2 lines 25.3 km with 83 trains,
- for 1995 : 2 lines 28.6 km with 83 trains,
- for 2000 : 2 lines of 45 km with 143 trains.

The operation LRT's costs :

- for 1987 : first line 10.6 km with 20 trains,
- for 1990 : line 12.6 km with 28 trains,
- for 1995 : 2 lines 27 km with 46 trains,
- for 1998 : 2 lines 27 km with 46 trains

kuhn@inrets.fr

.2 Operating costs



INRETS

kuhn@inrets.fr

3.2 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
Operating costs in MF **In US $**	65 MF **9.4 M $**	73 MF **12.2 $**	115 MF **21.1M $**	155 MF **29.2 M$**	
P.P.K. cost **In Francs** **In US Cents**	0.101 F **1.4 Cts**	0.107F **1.79 Cts**	0.091F **1.67 Cts**	0.111 F **2 Cts**	0.098 F **1.4 Cts**
Trip cost **In Francs** **In US Cents**	2.40 F **34.7 Cts**	2.51 F **42.2 Cts**	2.61 F **48 Cts**	3.04 F **57 Cts**	3,22 F **46 Cts**

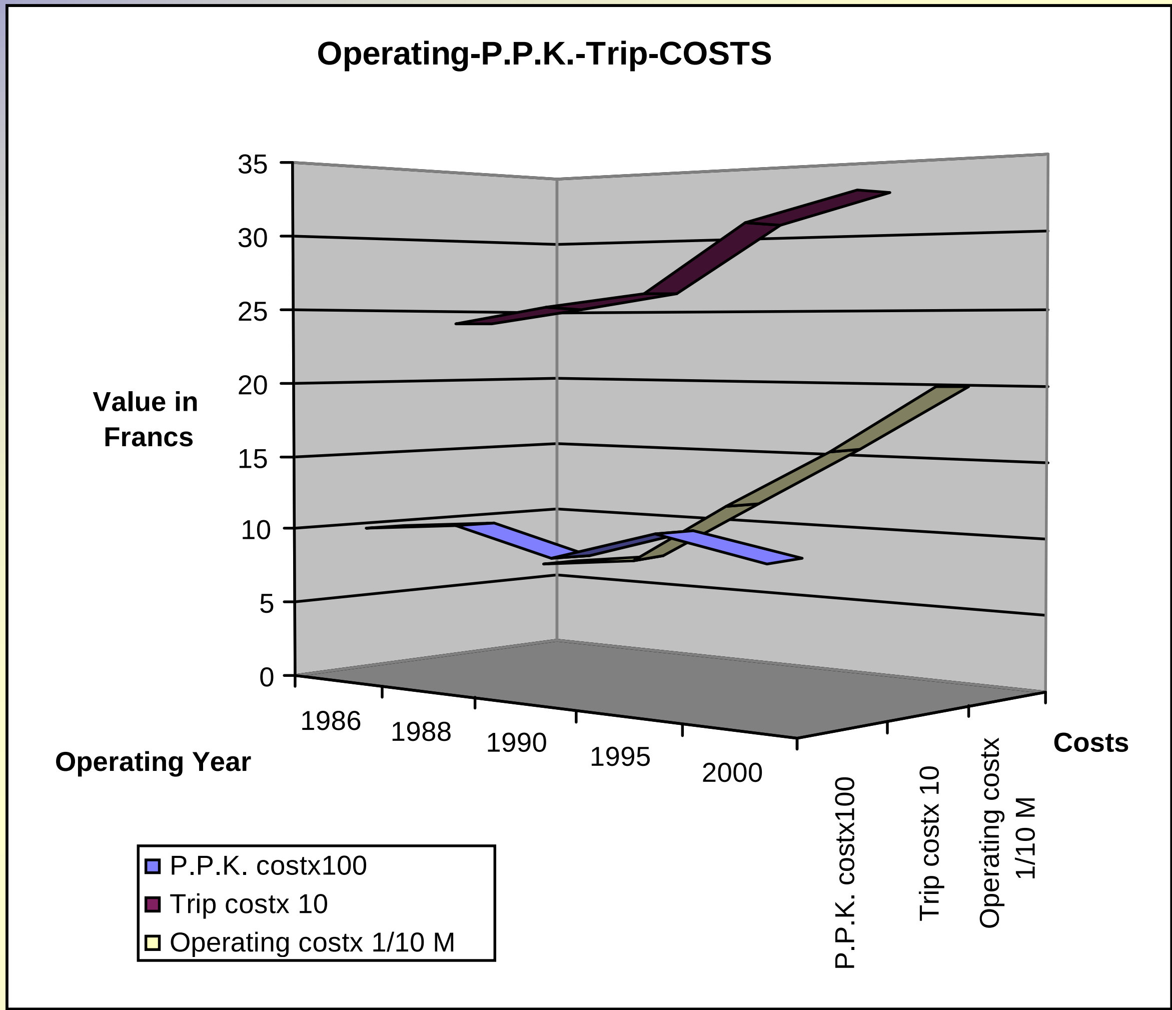
Source : (Kühn, 2001)

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

kuhn@inrets.fr

3.2 Operating costs in LILLE



INRETS

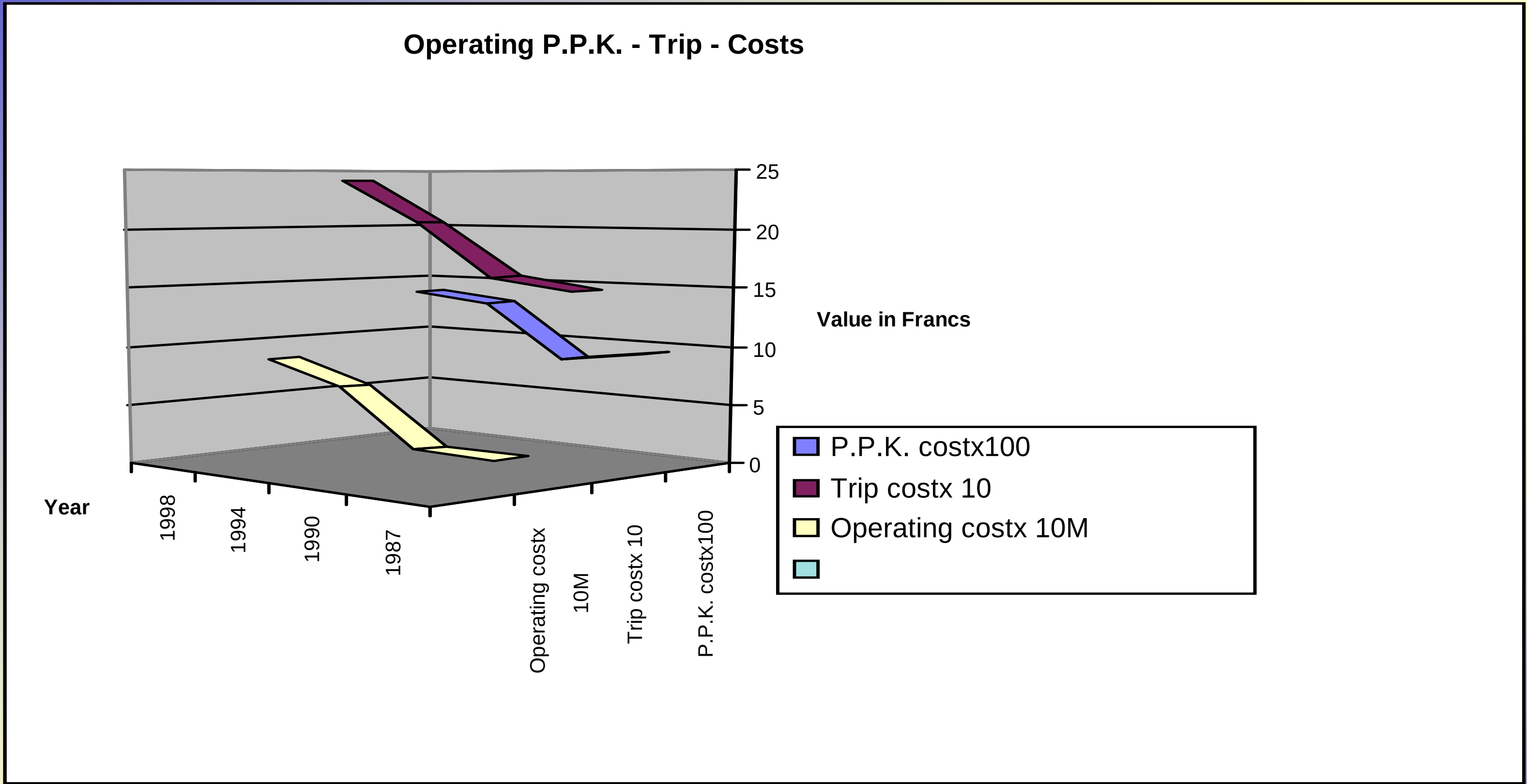
kuhn@inrets.fr

NAN TES	1987	1990	1994	1998
P.P.K. $x10^6$	207	250	511	620
Trips x 10^6	13.07	13,26	32,9	35,8
Operating Costs	19.79MF 3.29M$	21,2MF 3,88 M$	67,2MF 12,21M$	86,1 MF 14,66M$
P.P.K. Cost	0.0956F 1.59Cents	0.0848F 1.55Cents	0,131F 2,3 Cents	0,139 F 2,36Cents
Trip cost	1.51F 24.8Cents	1,59F 29,3 Cents	2,04 F 37,1Cents	2,40 F 40,9Cents

INRETS

kuhn@inrets.fr

3.2 Operating costs in NANTES



kuhn@inrets.fr

3.2 Operating costs

The VAL PPK costs are around 13 to 68 % less than the PPK LRT costs.

The VAL trip costs are between 64 to 12 % higher than LRT trip costs.

The productivity per employee was :

- for VAL : 15542 train.km in 1986, increased to 25306 train.km in 1995, an increase of 63 %.
- For LRT : 10417 train.km in 1987, increased to 11149 km.train in 1994, an increase of 7 %.

kuhn@inrets.fr

3.2 Operating costs

The ratios (depreciation excluded) fare income/expends of LRT in 1987 is of 115 % against 55 % for the (bus+tram) network.

For VAL network, the ratio is 111 % in 1986 and 53 % for the (bus+tram+Val) network.

In 1994 the ratio is 100,5 % and increases to 135 % in 2000.

INRETS

 kuhn@inrets.fr

3.2 Operating costs

- in Lille, the "metro influence" with the opening of 2 lines 28.6 km long stimulates the ridership which was low 51 millions trips with the urban transport perimeter of 1 079493 inhabitants
- the metro's ridership was 21 M in 1984 , 48 M in 1992, 62 M in 2000.
- the ratio trips/capita is 97 in 2000 for an average ratio 135 in this range of cities.

INRETS

3.2 Operating costs

- in Nantes, the "metro 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 and it increases to 84 M in 1994 and 1998 with a urban transport perimeter of 505 281 inhabs.

- The LRT ridership was 7 M in 1984, 26 M in 1993, 36 M in 1998,

- The ratio trips/capita is 167 in 1998 for an average ratio 135 in this range of cities.

4.Technical evolutions of LRT & AGT systems
4.1 Light Rail's evolutions

Evolution of the rolling stock

LRV must be attractive, hence modern

The use of choppers with traction motors,

Asynchronous motors fed by inverters offer a reduction of maintenance expenses

Acceleration performances : the power-to-weight ratio is between 12 and 14 kW/ton

New rolling stocks adopt low floor: the intermediate LF, the partial LF, the 100 % LF

kuhn@inrets.fr

4.1 Light Rail's evolutions

Operating methods and traffic control

Aids to the operation of the tramway:
- block system of the track ,
- priority at junctions with traffic lights,
- systems of supervision & areawide traffic control

The potential of LRT

Tunis 9300 phd, Alexandria 13400 phd, Manila 19000 to 28000 phd, Guadalaraja 14000 to 25000 phd

kuhn@inrets.fr

4.2 Automatic Guided transit's evolutions

VAL system is characterised by:

- safety electronic equipement based on a « fail safe technology »
- fixed-block automatic protection system,
- Platform protection by platform doors

Use of microprocessors for safety functions

Development of a moving block (ATP) system

Platform doors or a double barrier of infrared beams

New Val vehicle 208 with « wheel-motors »

kuhn@inrets.fr

5. Conclusion

After the decline in the fifties, LRT recovered dynamism:

- creation of new networks,
- improvement of existing networks,
- extra low-floor LRV
- these systems can be operated at grade on surface and developed in stages

LRT is well adapted to a range of cities between 200 000 to 700 000 inhabs.where underground is hardly imaginable.

5. Conclusion

AGT systems have a service quality, a flexibility, a regularity of metronome, a safety, owing to a fully automated driverless operation requiring exclusive RoW

Investment costs

Val system & Rolling stocks have a cost equal to 2 up to 3 that of the equipment linked to LRT system for a supply of 9600 phd vs 2500 phd

Val civil engineering & added expenditures have a cost equal to 2 up to 3 that of the LRT civil engineering.

kuhn@inrets.fr

5. Conclusion

Operating costs

In Lille the « metro influence » stimulated ridership and increasing the number of rolling stocks from 38 (1984) to 143(1999) the P.P.K. decreased from 1,79 Cents (1988) to 1,40 Cents (2000) Productivity/empl.increased from 15542 to 25306 km x trains between 1986 and 1995.

In Nantes the « tram influence » stimulated ridership and increasing the number of rolling stocks from 20 (1984) to 46(1995) the P.P.K. increased from 1,59 Cents (1987) to 2,36 Cents (1998) Productivity/empl.increased from 10417 to 11149 km x trains between 1987 and 1994.

kuhn@inrets.fr

5. Conclusion

Val system needs to operate in high density area not necessarely large cities : with important vehicle fleets the operating costs will decrease.

If the future transit system needs to be up-graded, the construction cost of the system increases: then there is a choice to do between an LRT or an AGT system because the exclusive RoW is naturally necessary : an AGT could be implemented with an acceptable overcost decreasing when the needed capacity grows.

5. Conclusion

There is a need of the 2 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 choosing to prohibit some roads to the private cars, get separated RoW for an LRT, street operation with predomently reserved running is both feasible and actually contributes to the humanising of the city

INRETS

kuhn@inrets.fr

Linéaire cumulé de Tramway moderne en France

City	1995	2001	2004	2007+
Bordeaux			21.3	42
Grenoble	14.7	20	34.5	34.5
Ile-de-France(Paris)	9	20.3	23.3	86
Le Mans				13.5
Lille	21.4	21.4	21.4	21.4
Lyon		18.7	25	37
Marseille	3.1	3.1	5	9
Montpellier		15.2	15.2	38.2
Mulhouse			19	19
Nantes	26.2	33.3	39	42.1
Nice			10	10
Orleans		18	18	33
Rouen	11.4	15.6	15.6	15.6
Saint-Etienne	9.3	9.3	17.8	17.8
Strasbourg	12.2	24.4	33.4	41
Toulon			17.3	30.3
Valenciennes			9.4	20.6
Total	107.3	199.3	297.2	511

kuhn@inrets.fr

Le Métro Léger de Manille

INRETS

kuhn@inrets.fr

Le Métro Léger de Tunis

kuhn@inrets.fr

Le métro léger de Tuen Mun


Watt I-80
SacJobs.com

kuhn@inrets.fr

VAL 206 à TOULOUSE

kuhn@inrets.fr

VAL d'accès à l'Aéroport d'ORLY

kuhn@inrets.fr

Métro Automatique de l'Agglomération de LYON : MAGGALY

kuhn@inrets.fr

Ligne METEOR : Portes palières

Rame de METEOR : Ligne 14 du Métro de PARIS