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THE VAL

LILLE URBAN COMMUNITY METRO'S EXPERIENCE

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Contents

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 (Turin, Lausanne). 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 (Grenoble type) running with 3 unit trains every 4 minutes offers a capacity of 7800 p/h/d, the AGT (VAL type) running with 1 unit train with an interval of 72 seconds offers a 8000 p/h/d[1] 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 means 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 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.

April 1983 : the Lille subway opens for commercial operation. Experimental operation with the public had been going since April 1982. The VAL system, for which the LILLE SUBWAY constitutes the first application, is thus one of the first entirely automatic urban transport systems, that is to say, without any staff being permanently placed on the trains or in the stations.

Background

In 1971, the « Etablissement Public d'Aménagement de Lille – Est » (EPALE) opened a competition for the *in situ* building of a public transit line, using small gauge and entirely automatic rolling stock, to link the New Town of Villeneuve d'Ascq to Lille railway station. The first phase, awarded to MATRA, comprised the construction of two vehicles prototypes and their experimentation on a closed loop test area. At the same time the general program for the Lille

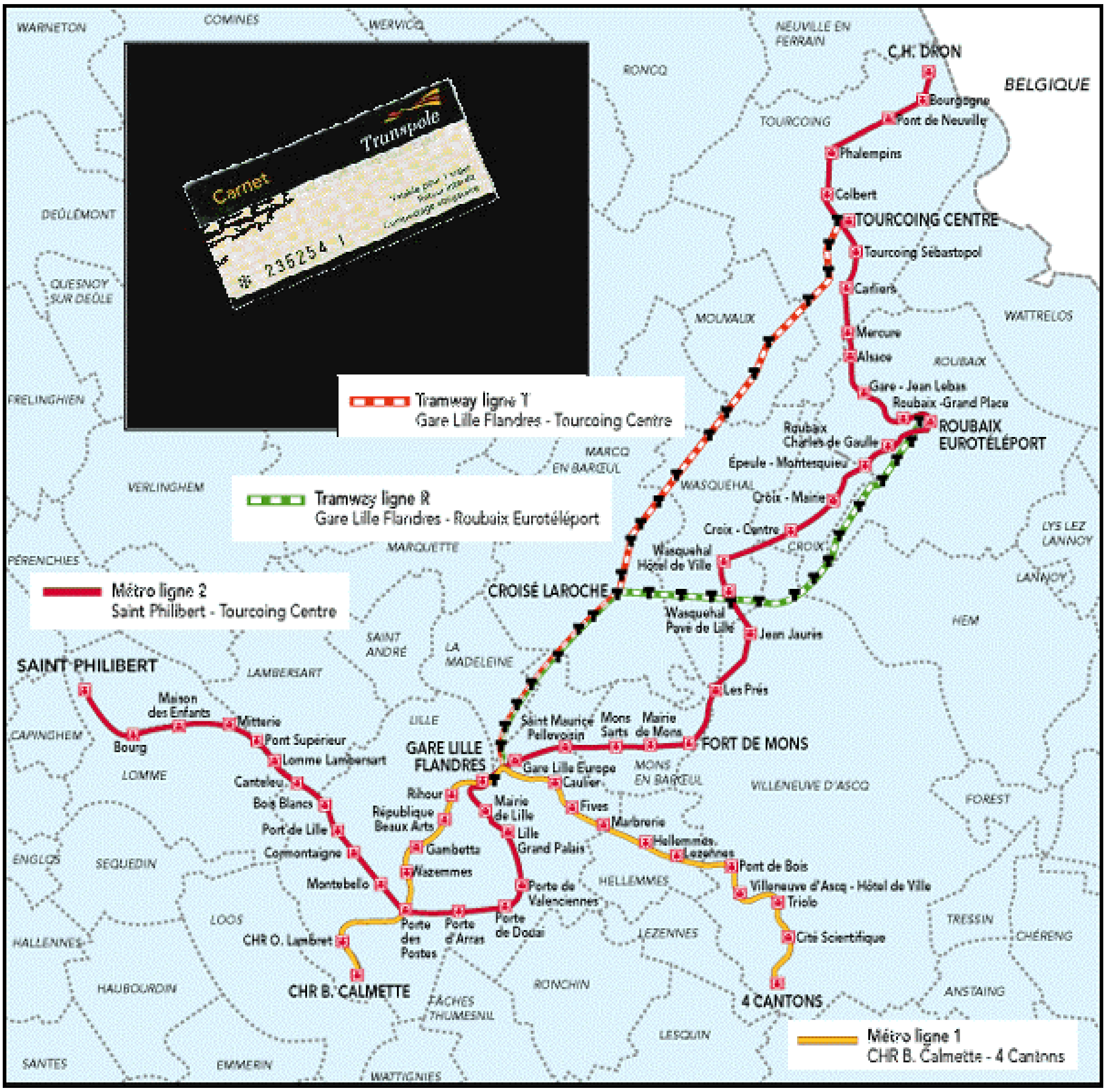
[1] p/h/d : passengers per hour per direction

urban area underground system was defined by the Urban Community (Communauté Urbaine de Lille, CUDL) : a network of four lines built in situ. Consequently, it appeared interesting to study the compatibility of the VAL rolling stock developed at the time with the new program (VAL is the system name and means « Véhicule Automatique Léger », i.e. Light Automated Vehicle »). This study demonstrated that the VAL system was an attractive solution, given a few adjustments. This result was confirmed by SOFRETU, the engineering department of the RATP (Paris Metro Operating Company), who showed that the characteristics of the VAL could provide a saving of 15% on capital investment and 30% on operating costs in relation to conventional, but modern, rolling stock used on the same line[2].

After various adaptation studies of the system, the Ministry of transport and the Urban Community of Lille decided to implement the underground program, first line n°1 – 13 km and 18 stations – on basis of the VAL system. In April 1977, the contract was awarded to MATRA for the system : guideway, mechanical and electrical equipment, rolling stock. SOFRETU[3] was responsible for the infrastructure.

Source : Eudil Lille University
The VAL prototype on the first test track in Villeneuve d'Ascq

[2] A comparison was made with the MP73 metro of Paris
[3] SOFRETU is nowadays called SYSTRA



Source : (CUDL, 2001)

1. The Fundamental Options

1.1. The objectives.

The first objective of the Lille Subway was to offer a high quality service. The main features of the service quality to which the main efforts have been directed are as follows :

- Interval between trains : no longer than 5 minutes during off-peak times and as short as 1 minute during the rush-hours.
- Long operating hours : 20 hours in all from 5 A.M. until 1 A.M.
- Percentage of seating space : 55 % (as opposed to 30 to 40 % observed on modern trains).
- Operating speed : 34 km/h.

The second objective was to reduce the building cost in relation to conventional underground systems by reducing the cost of infrastructure, which must therefore be limited in size and easy to insert into the urban fabric. (Cf. chapter 6)

The third objective was to achieve reduced operating costs while maintaining the high quality of service stated above. The major expense item for the operating budget of a conventional underground system is staff. An attempt had to be made therefore to reduce staff costs.
(Cf. chapter 6)

1.2. The means

In order to reduce the infrastructure costs, it was decided to use compact and light rolling stock. This is reflected in particular by the reduced vehicle width (2.06 m) and height (3.25 m). Furthermore, it was decided to fit the rolling stock with tires for the following reasons :

- Reduction in noise level (especially at the viaducts) and also in the ground vibrations produced by the track.
- High grip factor enabling considerable gradients to be used : it is possible to start up on a gradient of 7 % with an exceptional load, even with one of the motors not working.

The last, and most important, of the fundamental options was integral automation. Thanks to this feature, it was possible to reduce the intervals between trains to those mentioned above (one minute with maximum 30 seconds stopping time at the main station). It would not be possible to achieve these times with manual operation except at the cost of considerably reducing the speed of the trains and probably the level of safety as well. In addition, integral automation allows a considerable reduction in the number of staff required (in a ratio of more than 2 in comparison with a conventional underground system) while maintaining a high frequency level at off-peak times (not more than 5 minutes between trains).

Considerable stress has often been laid on the limits of a policy of dispensing with staff in the field of public transport. In addition to the problems of safety and public order which may be made considerably worse, it is certain that the public needs human presence, not only to inform him but also to give an impression that « things are being taken care of », especially when an incident occurs.

Integral operating automation does not in fact mean dispensing with all staff but rather a different distribution of the staff, employed in a more discerning way. Certainly there is a considerable overall reduction in the total number of staff employed, but a dehumanization of the subway is avoided by the use of a whole series of devices (loud-speakers, alarms, cameras, etc.) and procedures (communications with passengers, surveillance of stations by close-circuit television, use of mobile teams, etc) which provide information and ensure safety. It should be noted that the whole range of technical facilities available enables efficient methods to be provided for security, methods which are not applicable in traditional systems as they are not equipped with these facilities.

Last, but not least, a fact has recently come to light regarding drivers on conventional underground systems. Reduced to a passive role through automatic piloting, the driver experiences a drop in work satisfaction, his job now consisting only of intervening in the event of equipment failure.

The VAL subway system does not have any drivers. However, it does have a few mobile supervisors (cf. annex) who can intervene very quickly in the event of developing problems. Such a formula should give the tasks of supervision a variety and an interest greater than those currently experienced by underground train drivers, while at the same time being more efficient thanks to the mobility of the supervisors.

2. The Technology

2.1. The rolling stock

2. 1. 1. The VAL 206

The rolling stock is made up of reversible units of two carriages which can only be split up in the workshops and which can be formed in 2-unit trains. The decision to operate this type of unit was made for the purpose of simplification (certain utilities, especially the supply of electricity and compressed air for the ancillaries, are common to the two carriages), and to provide motive power redundancy. Trains may consist of one, two or three units. At Lille initial operation started with one unit although two units are considered in the future. Along the line 1, the stations and their platforms are built for a two-unit trains operation.

Documentation : (CUDL, 2001)

One train on the viaduct of Lille University : see the pedestrian paths along the tracks in case of emergency.

The running and guiding assembly is a swivel axle system and does not therefore have a bogie. The live axle is integral with a roughly rectangular guide frame supporting four guide-wheels, identical to those on the Paris metro, and two switching rollers. The assembly can swivel around its vertical axis. This arrangment, added to the use of a differential gear, allows curves to be negotiated without any drift or slipping, thus giving much purer kinematics than a bogie on a railway track.

Each carriage is fitted with two 120 kW (continuous rating) D.C. series-motors. Each pair of motors is fed with 750 volts D.C. collected by shoes from guide bars. The variable shunt type motors are controlled by an electric chopper which provides for electric braking with recovery by reinjecting current into subway system, the motors then acting as generators. The performance obtained with this type of motive power is 60 km/h and 80 km/h for the nominal and maximum speeds respectively.

With the second order from Urban Community of Lille for the rolling stock of the second line (Line 1 bis), some improvements have taken place.

The main modification affects the control of the traction motors. The current which feeds these motors is adjusted on the new vehicles as well as the previous ones, by an « electronic chopper » which cuts the current at fixed frequency of 300 Hz. By varying the conducting time from 0 to 90 % of the period, the output voltage of the chopper varies accordingly and therefore the propulsion effort produced by the motors. This allows a continuous acceleration without any bump, a precise stop and the braking with the motors working as generators of current feeding back the line with power for supply to running trains.

The chopping of current requires thyristors which are electronic circuit breakers free of any moving part. The thyristors which are used on the previous vehicles require complex auxiliary circuits to switch them from position in (current passes) to off (current cut). These circuits are monitored by protective devices to avoid the breakdowns of the chopper which may allow all the current to pass through and would then damage the equipment. Moreover, because of the large amount of power (300 Amperes under 750 Volts) passing through the thyristors, fans are necessary for their cooling. Since 1988, new thyristors called GTO[4] have been marketed :

- They are easy to switch off with very little waste of energy.

- Therefore, it has been possible to engineer and manufacture a very simple new compact chopper the thyristors of which are cooled by its only contact with the surface on which they are set (this surface is exchanging the calories with the outside air).

- This new chopper allows a saving of power of 10 %. It requires no maintenance as there are no fans to check or filters to clean.

- Besides, in the event of heavy snow falls, the absence of fans and filters is an advantage as there is no possibility of filter obstruction or snow penetration in the equipement. (Ferbeck, 1990)

In the same way, a new converter for feeding the auxiliaries (it tranforms 750 Volts DC in 72 Volts) is based on the same cooling principle, although it uses transistors because of the lesser power.

The other important modification affects the doors of trains as well as the sliding doors in the stations. Their pneumatic jacks were a cause for concern during cold weather. They have been now replaced by electric motors.

[4] GTO : Gate Turn Off

In the event of a failed or disabled vehicle (or a married pair), VAL is the only system which allows its automatic coupling and pushing by the following train. These operations are fully automatic as they are initiate by the control center through a remote automatic sequence. The average time to execute this sequence is five minutes which represents a sizable gain of time when compared to the same being execute by an agent sent at site specially if interstations are long and access difficult.

2. 1. 2. The VAL 206 S

A 206 S single vehicle, which can run on its own and not as a married pair, has been developed.

Because the new electrical equipments are more compact, it has been possible to house under the floor of a single vehicle all the equipments which were distributed under the two bodies of a married pair. In the same way and to make more compacts the equipments, the pneumatic brake has been replaced by an hydraulic brake.

2. 1. 3. The VAL 208

The latest generation of vehicle for the VAL system is the VAL 208. The VAL 208 trains are fully compatible with the trains which are already in service, but they have a completely new design.

Documentation : (CUDL, 2001)

A VAL 208 train on the test track of 4 cantons Workshop in Villeneuve d’Ascq

The principal innovations

Due to the development of innovative technical solutions in the fields of electrical propulsion, braking, guidance and structure of the carriage body, the VAL 208 is lighter, and the reduction in weight, combined with the improved efficiency of its motors, produce energy savings of about 15 %. For the traveller, these new technical solutions also provide more space inside the trains, which have more natural lighting because the window surfaces have been increased by 30 %.

Carriage bodies

The carriage bodies were designed by Roger Talon assisted by Henri Baumgartner. The ends of the chassis are made with moulded parts and wedded aluminium profiles. The body of the train is made of extruded aluminium profiles, bolted together. The windows and external panels in synthetic resin are glued. The main components of the rolling structure are in moulded aluminium, which has contributed a lot to the lightening of the VAL 208.

Insight view of VAL 208

Source : (CUDL, 2001)

The wheel motor

Each carriage is equipped with 4 synchronous wheel motors with permanent magnets, an innovation that was made possible by the production of the first electronic components with sufficient capacity to control high powered motors. Each pair of motors is powered by direct current at 750 Volts, taken from the guide rails.
These motors each develop 65 kW for a weight of only 200 kg, a particularly high power to weight ratio, and they offer a much lower speed of rotation than a DC motor for the same power (2,000 rounds per minute at nominal power).

Source : (CUDL, 2001)

A wheel motor

Braking

Braking is carried out on the VAL 208 to a great extent by the traction system, controlled by Matra transport automatic systems. When braking, electrical energy is recuperated and re-injected into the network, with the motors playing the role of generators. The mechanical braking system, which is hydraulic, takes over from electrical braking under certain conditions : at the end of braking, for emergency braking and for the parking brake (each wheel motor carries a disk on the side opposite the load bearing wheel, an arrangement which was made possible by the low speed of rotation of the wheel motor and the compactness of the hydraulic parts).

Source : (CUDL, 2001)

Track obstacle detector, guide wheels ,brake disc and pad, collecting shoes, wheel motors view

2.2. The permanent way

The track is an essential element of a guided transport system (cf. figure in annex).

Source : (CUDL, 2001)

We see the running tracks, the guide bars fixed with insulating moulded polyester supports spaced at 3.5 meter and the emergency paths along the tracks

Its qualities govern the confort and the performances (mainly because of the adhesion). It must also support power distribution lines and the transmission of all information necessary for the automatic devices, telemonitoring, remote controls and phone communications. Any damage to the guideway is very penalizing for the operations (risk of line shutdown) as it is difficult to make the repairs because this can only be performed during the few hours of traffic interruption.

In addition to these usual requirements, two particular objectives were taken into account when designing the permanent way for the VAL system : simplicity, in order to reduce costs, and a high grip (adhesion) factor enabling 7 % gradients to be negotiated. The permanent way therefore comprises the running-tracks, the guide bars (which are also used to provide the electric current), and the various automatic devices.

Various types of track have been developed by MATRA to accomodate all circumstances : the nature of the running surfaces makes the difference between these various types.

Steel running surfaces

They are essentially made of a special H steel section (with a very large width in regard to its height) which are grooved where necessary because of the poor adhesion which may result from rainfalls. Trial tests have shown that because of these grooves, the stopping distances over humid tracks were in accordance with safety margins ; in such case, it was found that VAL has a better braking behaviour than any other metro, because of its larger wheel base between axles which decreases the load transfer.

The steel running-tracks have been selected for line 1bis and 2 which besides its cleaning, will necessitate no maintenance. This is definitely a major advantage of the pneumatic vehicle which does not wear out the track.

Concrete running surfaces

The running-tracks are made up of two prefabricated reinforced concrete longitudinal beams 5.20 m (17 feet) long, 270 mm (10.6 inches) wide and 120 mm (4.5 inches) thick. The separation for expansion between these longitudinal beams is 5 mm (.20 inch). A special coating is used on elevated structures to provide adequate adhesion in the rain without abrasion to the tires. These longitudinal beams are bolted to the concrete floor and are easy to remove.

Lateral guidance is provided by two steel H profiles which are fixed in place with insulating moulded polyester supports spaced at 3.5 meter (11.5 feet) intervals on straight sections and 3.0 meters (9.8 feet) on curves. Electrical insulating supports are necessary because the lateral guidance beams provide simultaneously provide propulsion power. One of these bars acts as the positive rail and the other acts as the negative rail. The lateral guidance wheels run on the side of this H section 200 mm (7.9 inches) above the running surface.
The climate of the Lille area has necessitated the provision of heating for the running-tracks and guide-bars in the above ground sections to maintain good adhesion and current pick-up in the event of icy or frosty weather.

The automatic equipment mainly comprises a « carpet » (flat duct) 170 mm (6.69 inches) wide containing the various power lines (cf.figure in annex).

The permanent way thus constructed is hardly any more complicated than a conventional railway track with a third rail. As regards track switching devices, it is even simpler. Yet switching has always been a tricky problem for subway trains using tires. For the Lille subway, a simple, quick and reliable switching device was required. Each axle has therefore been fitted with two metal rollers located in the axis of the vehicle. When they come over the points, these rollers engage in a groove formed by two rails and fitted with a point which sends the train in the desired direction. The smallness of the point, both in length and especially in width (50 mm or 1.96 inches)) allows switching operations to be done quickly (3 secs.) and reliably. The switching device which has been designed is therefore even simpler than the conventional systems as it only has one point instead of two.

2.3. Automatic devices

A certain number of requirements had to be taken into account when defining what automatic devices were needed :

- The interval between trains should be brought down to less than a minute with 30 seconds maximum stopping time at stations.
- The precision with which the trains stop at stations must be greater than 30 cm. The platforms are in fact fitted with landing doors opposite which the train must stop.
- The absence of staff on board the trains necessitates a high level of reliability and safety.

Source : (CUDL, 2001)

The platform facades or platform doors « an impassable glass barrier »
The precision of train stops in a VAL station with the landing doors

Command and control system

The VAL command and control system is designated to operate fully automatically. It is fundamentally a fixed block system. The command and control system consist of the hardware and software necessary to provide the following functions :

- Automatic Train Protection (ATP)
- Automatic Train Operation (ATO)
- Automatic Train Supervision (ATS)
- Manual back-up Mode Operations.

ATP functions perform all sections necessary to provide safe operations regardless of malfunctions.

ATO functions perform all non-safety-related automatic vehicle operations.

ATS functions provide a capability to change modes of operations.

Manual back-up mode operations are used in the event of a malfunction that cannot be safely resumed in an automaticc mode.

The ATP, ATO, and ATS functions are performed by control system equipment distributed at three locations : the Control Center, the wayside, and on board the vehicle. A block diagram of the control system equipment is given in figure 5 of annex. The command and control equipment is as follows :

- Control Center equipment consists of control display panels, computers, and data communications equipment.

- Wayside control equipment consists of wayside control and communications units (WCU), dwell operation control unit (DOCU), data transmission units (DTU), transmission lines, ultrasonic detectors (UD) and visual signals. This equipment is located both in the station and along the guideway.

- On-board train control equipment includes : the safety and control equipment, including redundant ATP and ATO electronics and power supplies ; uplink receivers to receive unit speed commands, remote commands, and voice communication via the guideway transmission line ; two redundant downlink transmitters for passenger unit presence detection signals ; a downlink transmitter for ATS and one transmitter for voice communications ; two redundant tachometers per car generating a voltage proportional to speed ; and two redundant phonic wheels producting pulses for each 3.81 mm (0.15 inch) advancement of the vehicle.

- Circulation of units in the yard is entirely automatic, or remotely controlled from the control center, except into the workshop. Storage of the units is managed by the Control Center computer as part of the ATO of the line.

2. 3. 1. Train position detection

The track is divided into blocks grouped together into autonomous sections corresponding generally to one or two interstations. The presence of trains in the blocks is controlled for safety purposes by a ground based logic system, located in the technical quarters of the stations. This logic system makes allowance for the direction in which the trains are travelling as they enter and leave each block.

The principle of train detection is shown in figure 2 of annex. It uses :

- Negative detection of any train at the limits of zones corresponding to each wayside equipment, using the occultation of an ultrasonic or infra-red beam modulated at 34 kHz,

- Trains emission of carriers inbto the transmission line,

- Tracking of trains using a vital logic. This logic is fully failsafe and detects any failure in the transmission system. This characteristic is used for the emergency evacuation function. In case of emergency, passengers may pull an emergency handle that breaks the power supply of on-board antennas. This situation is detected by wayside equipment that releases the emergency braking of all trains on the section and opens traction power breakers in the power substations. (Lardennois, 1994)

2. 3. 2. Vehicle speed control

Control is carried out by a system of two twin wire crossed transmission lines situated in the carpet. The first twin wire transmission line is fitted with cross points whose distance apart determines the normal operation program. The second line, which is of the same type, determines the disturbed operation program, with a halt at the end of the block. If there is an incident, for example the abnormal occupation of the following block, the system stops the train from reading the normal operation program and forces it to read the disturbed operation program, which results in the train coming to a halt at the end of the block. (CUDL, 1999)

2. 3. 3. Traffic control

The operating program for a given day is fed into the Control and Command Post (CCP), computer in the form of a timetable giving the terminus departure times. In addition, in the storage of the computer are the nominal operating programs for the various interstations in addition to the stopping times at stations.
On the basis of this data the CCP can transmit to each station the theoretical arrival time of the next train. The station equipment determines whether the train is early or late in relation to this theoritecal timetable and intervenes as follows to remedy any discrepancies :

- Variation of stopping time at the station,

- Speed instruction given to the train (+/- 20 km/h depending on whether the train is late or early),

- Finally, if the time difference is too great, the CCP alters the timetable in all the stations so as to maintain the scheduled train frequency.

Telemonitoring : the operating and control center

The CCP makes available to the operating staff a set of facilities designed to regulate train movements under the best conditions. During normal operation, the CCP staff does not intervene in the running of the system. Their role is essentially one of monitoring operations, except in the case of starting and stopping services and adapting train frequency to meet demands.

In the event of a problem arising, the CCP staff will have to intervene actively. To this end, they have available to them a great amount of information and remote control facilities enabling them, for instance, to initiate the switching over to redundant equipment or to take over control from certain automatic devices. It is from the CCP, which has more than 40,000 remote measurements and remote commands, that the commands are issued for the introduction and withdrawal of metro trains to and from the lines, from the garages where they are parked and in accordance with well defined protocols.

Once the train is on the line, it is taken in charge by the automatic pilot of the system, by means of the detection and command equipment situated on the line, in the stations and on board. However, the CCP can intervene remotely at any time on all the trains and equipment.
Information for passengers and the control of their behaviour are provided by interphone and closed-circuit television networks. These links enable the passengers to get in touch with the CCP.

Source : CUDL, 2001)

Inside the CCP

Installed at Gare Lille Flandres, the Control Center sees, hears and observes everything. At the heart of the setup, there is the Optical track Diagram (TCO), a vast led diagram which provides a very detailed display of the track routes and indicates the position of all the trains. Video monitors show pictures of what is going on on the platforms : so, the operators can constantly check the operating programs pre-established for each day. At any time, the operators can contact the intervention teams and ask them to go to a given point in the network.

On VAL, a passenger never feels alone ; all the trains are equipped with easily accessible intercoms. This means that, at any time the passengers can contact an operator at the CCP. This also works in the other way, since if there is an incident, the intercom comes on automatically. The CCP can then listen to what is going on in the vehicle. (Duquenne, 2001)

3. Safety and Availability

As regards safety, integral automation does not pose any new problem. In fact, on a great number of subway networks and railways, were most safety functions are performed automatically either in whole or in part, the operating conditions are such that any failure of the automatic devices endangering safety would rarely give the driver any chance of avoiding the accident. In fact, the only new safety functions on the Lille subway relate to :

- The movement of the trains along the platform when leaving a station which is traditionally controlled by the guard. The adopted solution, viz. the closing off of the platform edges with doors, is in fact an extension of the use of the well-known arrangment used on lifts ;

- The cutting off of the traction current in the event of the emergency evacuation of trains in between stations. This has led us to provide the possibility of switching the current off from inside the train and to make this feature available to passengers. The device is located above each of the doors and brings all the trains in the section to a standstill and unlocks the door.

As regards the automatic safety devices in particular, we have rigorously implemented the criteria of intrinsic (or positive) safety as applied to railways. When considering the types of component failures in electronic circuits, we assumed the most pessimistic situations.

If the problems of safety are not new in nature, integral automation poses special difficulties. This led us on the one hand to carry out a very extensive study of the reliability of each piece of equipment, and on the other hand, to provide for the taking of certain measures to limit the duration of any problems :

- Redundancy provided for virtually all the equipment required for train movement ; The switching over from one piece of equipment to the other is done by remote control from the OCC ;
- In the rare case where switching over to a redundant piece of equipement is either impossible or of no use, it is possible to push a train using the train behind, the operation being entire remote controlled and not requiring any on-the-spot intervention staff ;
- As a last resort, simplified manual control devices enable control to be regained of the vehicles from the stations (operation of landing doors and starting order) and terminuses (control of routes and points).

It is thus possible to achieve an availability comparable with that of a subway with a driver or guard on board. (Tremong, 1985)

Source : (CUDL, 2001)

Landing doors in a station on viaduct


Source : (CUDL, 2001)

Landing doors and comfort accessibility

In order to increase passengers safety, and improve protection against vandalism, there are several improvements of VAL system, the most significant against vandalism is the evolution of emergency evacuation function.

The International Public Transit Union (UITP) gives recommendation for processing emergency evacuation in metro tunnels. The basis of these recommendations is, that in case of fire with production of smoke, the worst place for leaving passengers is the tunnel. Indeed, there are life hazards due to suffocation, while the visibility is very low.

UITP recommends, in case of an emergency stop handle is pulled by a passenger, to try to continue the trip until the next station. Three restrictive conditions have been defined in Lille application case :

- The train speed has to be maintained over 1m/s
- The maximum delay is 3 minutes
- The availability of car's intercoms

If these three conditions are satisfied, the emergency handle action is differed and can be rearmed at distance by the CCP ;

This improvement called « UITP emergency against vandalism » has decreased the delays. In 1997, without this evolution, the delays due to emergency handle action were 500 minutes. In 1999, with this improvement the delays were 200 minutes. (Duquenne, 2001)

4. Operation and Maintenance

As state above, during normal trouble-free steady operation, the system works without any intervention from the staff. The transition stages (placing train in the depot and taking them out, shunting) or remotely controlled from the CCP, train operation being completely automated even in the terminuses and depot. At the CCP, operation is normally ensured by a person in charge of the CCP and one to five controllers for Line 1 (variable, depending on the amount of traffic).

The distribution of these controllers along line 1 is based on the following five posts :

- Three line and station management posts ;
- The control desk for the management of the terminuses and the depot ;
- The control desk for power distribution and management of track ancillaries.

The line staff is distributed as follows :

- Depending on the time of day, one to three trouble-shooting teams of two technicians based in the principal stations ;
- Two to four itinerant inspectors ;

- Two inspectors permanently stationed in the terminuses.

Given the long operating hours (20 hours per day), the total number of operating staff will be around eighty. In addition to this staff, a brigade of the urban police force is assigned to special subway duty.

In order to improve the safety, rapidity and ease of work, the workshops have not been fitted with pits but with sets of synchronized cylinder lifts enabling a complete unit to be lifted up without uncoupling. The workshops also include several automatic test rigs for electronic equipment.

A test track (700 m of double track) is provided to complete testing if necessary.

Source : (CUDL, 2001)

Quatre Cantons Line 1 workshop.

5. Development of the VAL network

On 3rd february 1984, the Lille Urban Community Council adopted the path for the first part of line 2 (then called line 1bis), connecting Lille to the Western part of the area, across 12 km and 18 stations. On 3rd April 1989, the line was put into commercial service between the « Saint Philibert » station in Lomme and the « Gare de Lille Flandres » station in the centre of Lille.

Following discussion on 10th July 1989, 17th November 1989 and 21st December 1990, the Lille Urban Community decided to continue development of metro line 2 towards the North of the urban area, between Lille, Roubaix and Tourcoing (20 km and 25 stations). On 5th May 1994, a section of the line was opened between stations « Gare Lille Flandres » and « Gare Lille Europe ».

Line 2 will be progressively put into full service, to be completed by the year 2000 ; finally, the whole of line number 2, between « St Philibert » in Lomme and « C.H. Dron » in Tourcoing, will cover 32 km and 43 stations.

This line is made up of :

- The « St Philibert » - « gare Lille-Flandres » section (12 km, 18 stations). It was opened to the public in april 1989. This first part of line 2 links the SNCF train station Lille Flandres to the Lambersart and Lomme communes, to the West of the city area, passing through the South of Lille, along the boulevards on the ring road. It crosses the first line at two stations : « Gare Lille – Flandres and « Porte des Postes ».
- The « Gare Lille Flandres » - « C.H. Dron » section (20 km, 25 stations). This line is being developed towards the Nrth of the city area to link Lille to the communes of Roubaix and Tourcoing. This operation consists of 4 stages, to be broken up as follows :

    - The « Gare Lille – Flandres » - « gare Lille-Europe » section. About 500 meters long, it serves the TGV train station, the Euralille International Business Center and the fringes of the St Maurice quarter. This section was put into service on 5th may 1994.
    - The « Gare Lille Europe » - « Fort de Mons » section. This section, 3 km long, follows the axis of the rue du Faubourg de Roubaix in Lille and serves the Mons-en-Baroeul city : it was under operation in february 1995 ;
    - The « Fort de Mons » - « Tourcoing centre ». over about 13 km, this section serves, successiveley, the cities of Villeneuve d'Ascq, Wasquehal, Croix, Roubaix and stopped temporarily in the centre of Tourcoing. It was under operation in March 1999.
    - The « Tourcoing Centre » - « C.H.Dron » section. Over 3 km long, the line crosses the North of Tourcoing as far as the Dron Hospital. It was into service on November 2000.

In this way, the public transport development plan, defined in 1974, has progressively become a reality.

The first version of the VAL, Villeneuve d'Ascq to Lille, has been replaced by the metropolitan VAL which from now one appears to be the backbone for public transport in the area.

5.1. Description

The VAL system in service in Lille, France came about originally from the planning of a new town, four miles from Lille, called Villeneuve d'Ascq. During planning of the new town, it was decided that rapid transit service was needed between Villeneuve d'Ascq and Lille. High frequency but inexpensive service was considered fundamental to the system's success.

Date	STEP
1972	MATRA VAL system is selected : a one mile test tract is built to qualify the system
1977	Turnkey contract for line 1 : 13 km (8 miles), 18 stations
1980	Qualification of the VAL system by UMTA[5] after 15 days of continuous operation on the test track
1982	Revenue service on the first section : 4 km (2.5 miles), 4 stations
1983 May	Revenue service on the second section : 9.6 km (6 miles), 13 stations.
1983 Dec.	Revenue service on the entire line : 13 km (8 miles), 18 stations
1984 Feb.	The CUDL adopted the path for the first part of line 2 (called line 1 bis)
1989 April	The line 1 bis was put into service from station « St Philibert » in Lomme to station « Gares de Lille » in Lille
1989 July	The CUDL decided to continue the development of metro line 2 to the north of the conurbation, between Lille, Roubaix, and Tourcoing (20 km and 25 stations).
1994 May	Opening of a 500 meters section of line 2 between « Gares de Lille » station et « Lille Europe » station.
1995 Mar.	Openeing of the Lille Europe – Fort de Mons section of VAL line 2 (3 km, 4 stations, subway depot for 22 trains).
1999 Aug.	Opening of the « Fort de Mons – Tourcoing centre » line 2 section of 13 km.
2000 Nov.	Opening of the « Tourcoing Centre – C.H. Dron » line 2 section of 3 km.

[5] UMTA : Urban Mass Transportation Administration

5.2. The network : key figures

A diversified network that has several modes of transport

The TRAIN

8 railway lines in a star shape around Lille Flandres station

120 km of railways

32 communes served

41 stations

The VAL

2 lines

45 km served and 62 stations in 2000

143 trains in service in 2000

35 stations with connections to one or more bus or tram routes

The TRAM

1 line in the form of a Y

19 km served and 36 stops

24 tram vehicles

14 stops with connections to one or more bus routes

BUSES

36 urban bus routes and 42 suburban coach routes,

including 8 cross frontier routes with Belgium

311 urban buses and 100 coaches

800 km of routes

more than 1500 bus stops

TAXIS on REQUEST

29 taxis terminals

linking 26 suburban communes to the metro

Source : (CUDL, 2001)

The urban community of Lille has 1,100,000 inhabitants, who live in 87 communes in an area of a little more than 600 square km. The conurbation has many centres, and includes 4 important focal points – Lille, Roubaix, Tourcoing and Villeneuve d'Ascq – and continues beyond the Belgian frontier, where almost 500,000 people live. Such a large urban structure involves a great deal of movement, and called for a modern, diversified network of public transport which encourages interchangeability to simplify the movements of its inhabitants.

5.3. The organisation of the modes of transport

The public transport network is organised around the heavy network which is well developed in the territory of the Urban Community, with the TER (Regional Express Train), metro and tram :

- The TER allows acces to the metropolis and handles medium and long distance journeys ;
- The metro and the tram offer frequent and rapid service to the most highly populated urban areas ;
- The buses handle local service for urban areas and connection to main lines ;
- The coaches, which also handle connections to main lines, provide suburban and inter-city connections ;
- The taxi terminals provide an additional service to peripheral areas ;
- The specialised services for handicapped people provide a service on request in the conurbation.

Source : (CUDL, 2001)

Lille Europe High Speed Train Station

Source : (CUDL, 2001)

A Tram line Terminal

Source : (CUDL, 2001)

An articulated bus PR 180 of bus network

6. The economics of VAL

6.1. Labor productivity

As developed for VAL, automation not only means driverless operation and high frequency at low labor operation costs, but also a fully developed ATS[6] with fully monitored systems resulting in considerable savings in maintenance costs. By combining driverless train operation with state of the art maintenance facilities, the VAL system achieves a quantum leap in labor productivity. This high labor productivity is illustrated in the fact that wages and salaries account for 43 %[7] of total operating expenses. This proportion compares with 65 to 75 % for most transportation systems in operation today.

Total 1988 staff for Lille line n° 1 (13 km and 18 stations) was 183 agents (cf details in annex)

A good measure of overall productivity is the ratio between total staff and number transported by year.

The VAL of Lille with a staff of 183 in 1988 and ridership of 29,4 million has reached a ratio of 160,600 passengers per employee per year, a productivity nearly twice as high as the best manually operated systems worldwide.

With the opening of Lille's second line, total length has doubled, as well as the number of stations and the fleet represented 83 VAL 206 train sets. In other words the system size has doubled, yet total staff was only 285.

The figure below shows the VAL system compared to some of the best rail systems. In 1990, a total staff of 266 produced 44.2 million passenger trips, i.e., a productivity of 170,000 trips per employee per year.

With the same number of agents the number of trips increased until 48 million trips in 1998, i.e. a productivity of 180,000 trips per employee per year. If the Lille system were manually operated, multiple shift operation would require a minimum staff of 3 operators per train set. The net savings of VAL over a driver operated system was in the order of 250 staff in 1990 and 429[8] in 2001.

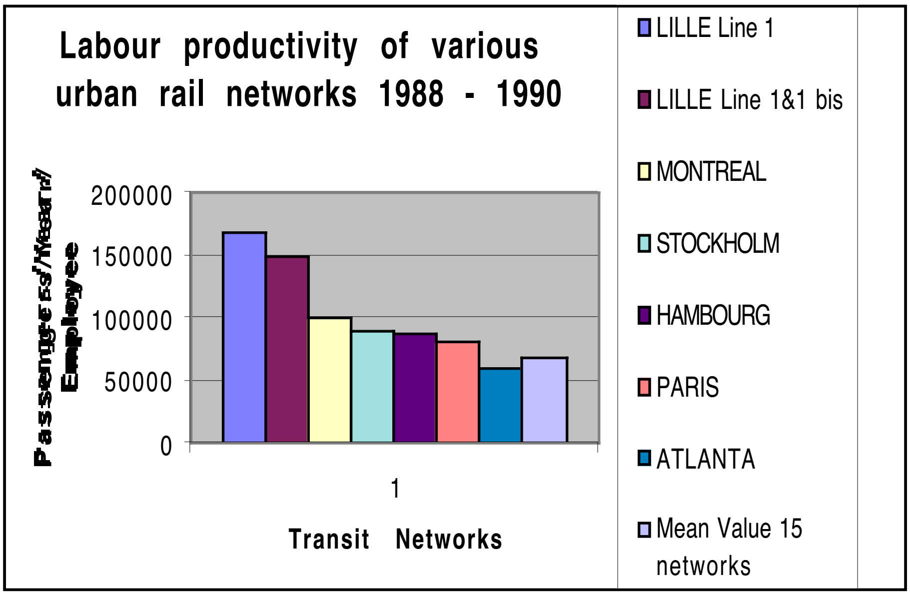
Thanks to extensive telemetry, immediate knowledge of the status of all sub-assemblies, rolling stock as well as wayside equipment, is available. This results in substantial cost savings and explains the fleet's availability.

In Lille, maintenance staff required was 9,5 per million car-kilometers in 1990 ; the US average for metro rail system is 26, in the case of the Lille light rail this ratio was 27 staff per million car-kilometers.

[6] ATS : Automatic Train Supervision

[7] % of wages and salaries for the first line in 1985

[8] 143 train sets with 3 operators each



Source : (Lardennois, 1993)

6. 2. Operating results

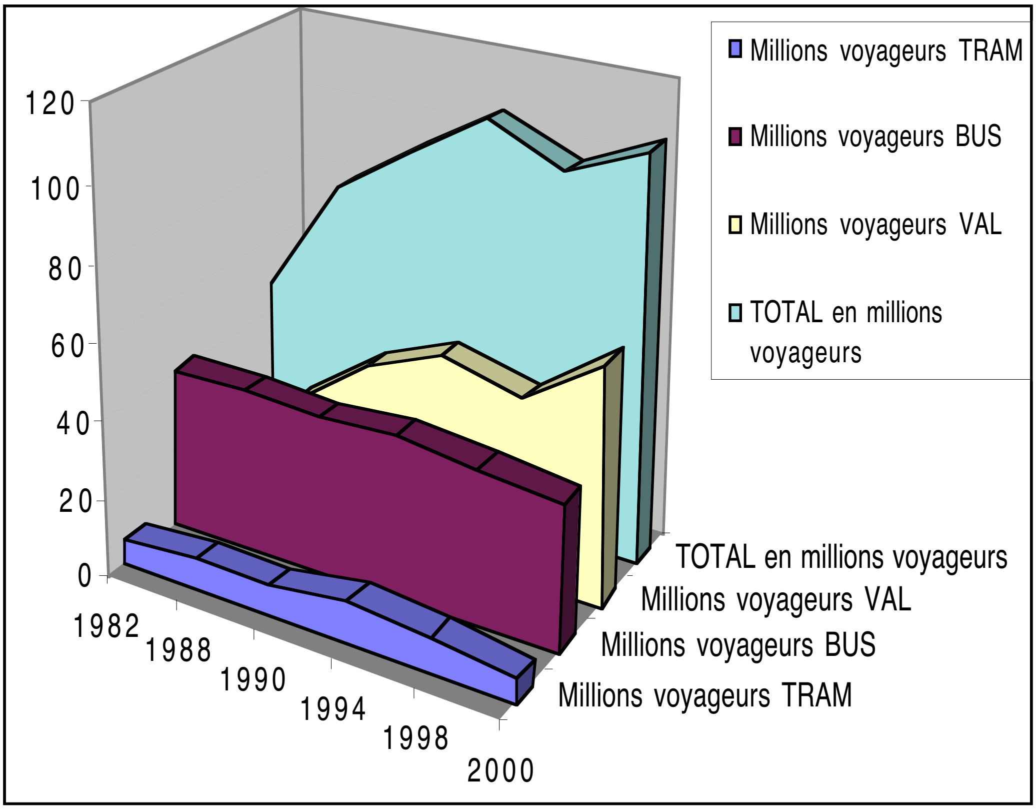
Patronage of Lille's automated line n°1 has grown at a remarkable rate : 21.1 million in 1984 to 29.4 million in 1988. After the second line came into service in 1989, the patronage reached 48 million by 1992 and continued to grow. Some problems of frequentation[9] and fraud occured between 1995 and 1998[10] : the patronage lowered in 1997 to 45 million trips but soon increased to 48 million in 1998, 55 million trips in 1999 with the opening of 16 stations on august 1999 and 62 million trips in 2000. In the same time the linear which was of 13 km and 18 stations on 1984 increased to 45 km and 62 stations, the rolling stocks increased from 38 trains in 1984 to 143 trains in year 2000.

The global patronage of Lille transit network (Tram + Bus + Val) increased between 1982 to 2000 from 48 million trips to 106.5 million trips thanks to frequentation of VAL which increased from 0 to 62 million trips : the buses carry around 40 million passengers a year, tram around 9 million passengers a year.

[9] a problem of bomb in Paris RER occured in 1995 and a certain psychosis appeared in urban transport

[10] In december 1998 a Local Contract for Safety was signed between Lille Urban Community and the State to increase the human presence in public transport systems : 350 Safety operatives were recruited to ensure a peaceful atmosphere, to resolve potential conflicts by mediation and to discourage fraud.

Evolution in Traffic VAL + TRAM + BUS
from 1982 to 2000



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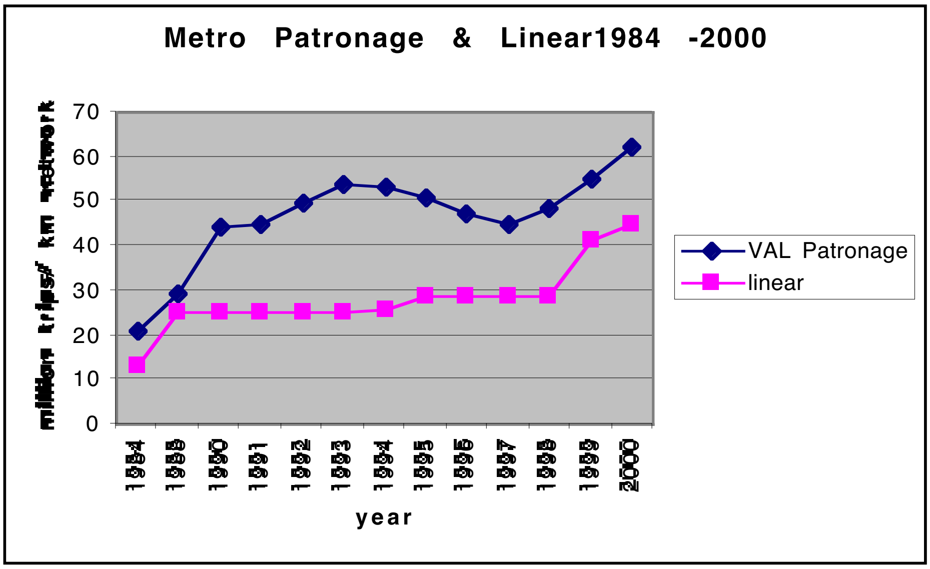
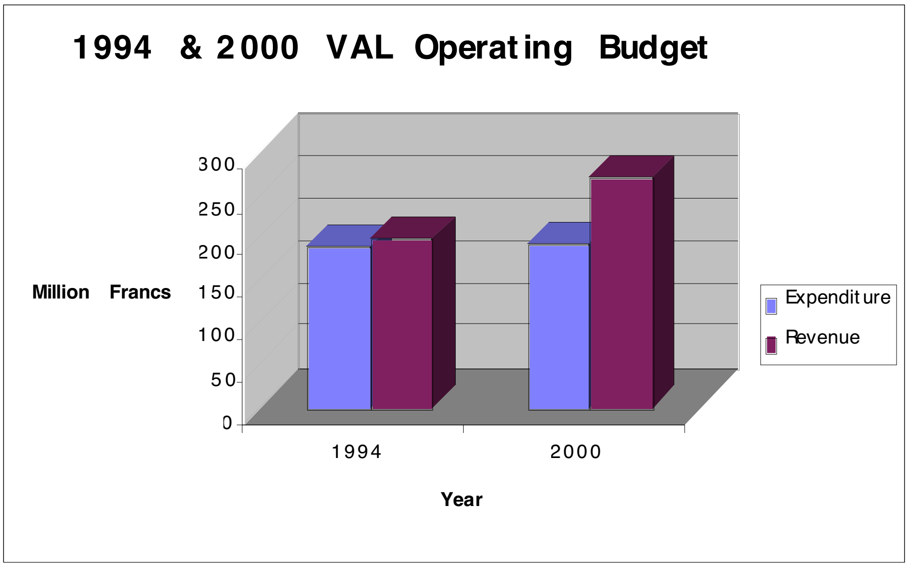


Documentation : (CUDL, 2001)

Network profitability



Documentation : (CUDL, 2001)

In 1994, the expenditures to operate (12 million vehicle-km) the Val were of an amount of 190 Million Francs with a revenue of 191 Million Francs. The ratio cost / revenue was equal to 1,005 .

In 2000, the expenditures (18,54 million vehicle-km) were of an amount of 199,6 MF, the revenue increased to 269,6 MF. The ratio cost / revenue was equal to 1,350.

6. 3. Investment costs

The Automated Guided Transit system 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 done by Inrets (Kühn F., 1992) allowed us to verify that the construction costs are linked to the vehicle 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 8.4% to 16.9% than these of Light Rail for 7000 to 20000 p/h/d 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 17.3 to 31.4% less for the VAL 206 at 7000 to 20000 p/h/d capacities.

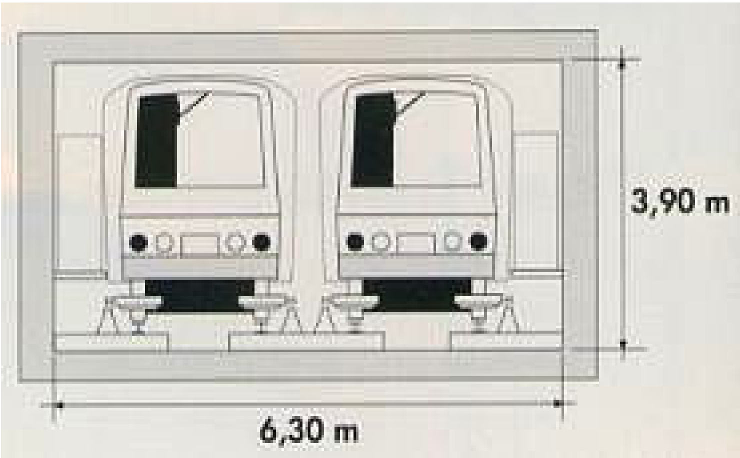
6. 3. 1. Site type and investment

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 Table below :

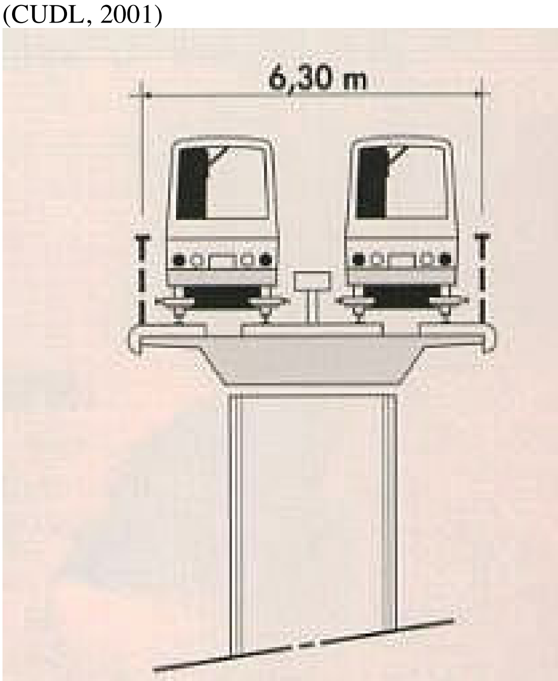
Civil engineering costs of VAL 206

VAL Infrastructure	on Surface	Elevated	Underground
Costs in MF	29 to 72	78 to 130	130 to 260
Costs in M $ U.S.	3.7 to 9.2	10 to 13.8	16.7 to 33.3

Source : (Lesne J., 1992) . Value 2001; 1 US $July 2001 = 7.80 Francs .



Source : (CUDL, 2001)



Source : (CUDL, 2001)

Tunnel boring machine for the second line

Source : (Eudil, 2001)

Toulouse's VAL on a viaduct

Source : (CUDL, 2001)

Val 208 in a deep underground

Source : (CUDL, 2001)
Cut and cuver civil engineering underground

6. 3. 2. 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 p/h/d on a 10 km line; with a 20 km/h commercial speed we must use a fleet of 51 Light Rail rolling stocks (Grenoble type) that is to say 50% more.

6. 3. 3. Operating headway and service quality

The adopted headways on Lille's first line at the peak hour are between 60 and 100, 120 and 130 seconds 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).

6. 3. 4. Capacity

At the peak hour, with a minimum headway of 60 seconds the supply[11] can be of 9600 p/h/d[12]., and increases until 19200 p/h/d with a two-car train at a normal load and 26160 p/h/d. (excep.load).

As for VAL system, 4 lines under operation totalling 42.3 km in 1997 allows us to give the cost of civil engineering and the cost of the specific equipment linked to the integral automated

[11] 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

[12] p/h/d : passengers per hour per direction

system control and the rolling stock. These costs are in a range of prices such as shown in the Table below:

VAL investment costs

Expenditures	Cost in MF, M. US $ per km	Average in MF, M US.$ per km	Percentage of total cost
Civil Engineering	128 to 334 MF **16.4 to 42.8 M$**	231 MF **29.6 M$**	61%
Transit System	120 to 180 MF **15.4 to 23 M$**	150 MF **19.2 M$**	39%
Total	248 to 514 MF **31.2 to 66 M$**	381 MF **49 M$**	

Source : (Lesne J., 1992). Value jan. 2001;
U.S.$ July 2001 = 7.80 Francs

We found that the mean cost per km for 42.3 km under operation before 1997 is 49 M US $ (value 2001). The last information given by CUDL was for the construction of the last 16.5 km the cost was 5587 MF(716 M US $) i.e. 338 MF/km (43.3 M US $).

They bought 60 trains for 1085 MF (139 M US $) to operate the 19 km added since 1994 that is to say 57 MF per km operated (7.3 M US $). If we add the 2 figures we found 395 MF (50.6 M US$) per km : this mean cost is similar to the result of the table above.

The cost range of "Civil Engineering" comes from the percentage of underground works : thus, 2 lines with 75% 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 3.26 trains/km, 1 line with 2.98 trains/km, at last 1 line with 1.11 train/km.

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

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

6. 3. 5. 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 the year 2000 (2 lines of 45 km in operation with 143 trains) the amount of supplied passenger places-km, of annual trips with the corresponding costs are represented in the table below in Francs & Dollars (without general and structural expenses, and taxes).

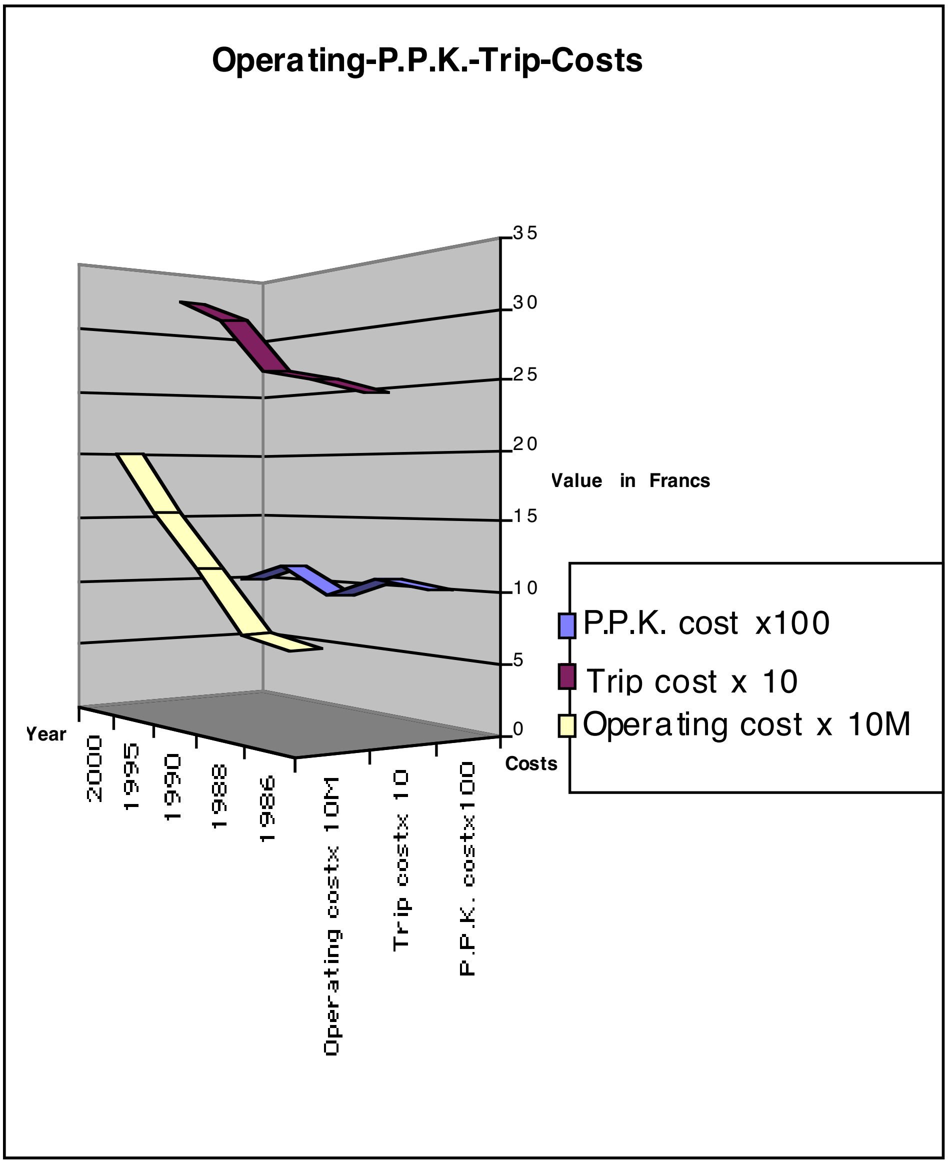
VAL Operating Costs

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
Operating costs in MF **In US $**	65 MF **9.4 M $**	73 MF **12.2 $**	115 MF **21.1M $**	155 MF **29.2 M$**	200 MF **28.7 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 : (Dtt, 1995), (Dtt, 1990). (Kühn, 1997) & (CUDL, 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



7. Automatic Guided Transit's evolutions

The first lines under construction and operation of the VAL system (Lille 2 lines, Toulouse 2 lines, Orly one 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, 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

Lyon's 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 : a study conducted in Lyon in 1987 had shown that the possibility of operating variable size trains according to the time of the day, and to automatically achieve train separation in the train storage facility could lead to significant savings, in order of 4 MF/year, in electric energy and in maintenance.

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. 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.

8. Manless systems in Urban Transit Applications

Automated trains have inherent advantages over their conventional or attended counterparts.

Over the past two decades, several manless systems were designed and put into operation, offering a high quality of service, attracting more riders and generating increased revenues. Unlike conventional or driverless (i.e. manned but not driven) metro systems, a manless solution consists of fully automated trains, without any driver or attendant on board the vehicles. The flexibility of operation of these systems leads to a well-quantifiable economic benefit. This is due not only to their minimising overall life cycle costs, but especially because manless systems provide very high flexibility to adapt in real time to traffic demand, including prompt reaction to sudden increase in capacity demand and to unforeseen events without any constraint to any system operating staff.

The analysis of existing fully proven manless technology in operation in the cities of Paris, Lille, Toulouse, Lyon, Chicago O'hare and Taipei has demonstrated outstanding records in terms of safety and availability. Moreover, by offering more interesting jobs, manless rail transit systems achieve higher employee and passenger satisfaction.

The results speak for themselves. Since the start up of the VAL in Lille in 1983, more than one billion passengers have been transported by these manless systems delivered by MTI, without outstanding records in term of safety and availability. (Jarsaillon, 1999)

With the advanced automatic train control system of line 14 (METEOR) of the Paris Metro, the brain of which engineered and developed the possibility of converting existing traditional subway lines into manless operation can now be easily performed. With the METEOR automatic train control allowing simultaneous manual and manless train operation, traditional metros can be gradually upgraded into manless systems without system shutdown. Without any doubt, this METEOR achievement is landmark for the future.

8. 1. The evolution of automation in mass transit system

Most of the Mass Transit Systems, currently in operation around the world are equipped with more or less advanced Automatic Train Control (ATC) equipment for enforcing safety and performances.

Basically the ATC functions are performed by one or a combination of the following subsystems :

- Automatic Train Protection (ATP) (avoiding train collision)
- Automatic Train Operation (ATO) (providing regular service and optimising traffic regulation)
- Automatic Train Supervision (ATS) (equipment and traffic data management)

Following the evolution of the technology and the requirements of transit authorities to meet the ever demanding expectations of passengers and their employees, three basic concepts for the automation of Mass Transit System were implemented during the past decades. They can be classified as :

First generation :

Conventional trains with drivers were initially equipped only with simple, basic equipment, the function of which being to stop the train in case of non respect of the traffic signals by the drivers. Further developments of ATP functions led to improve performances on lines equipped with conventional signaling based on track circuits, by visual display in the drivers cab of some operating and maintenance data. The London and Paris metro systems are examples of this category.

Second generation A :

Trains were then equipped with ATP and ATO subsystems, relieving the drivers from some of their functions. In normal operation, the driver tasks are limited to control of the proper berthing at stations, the opening / closing of the doors in stations as well as the train departure from the stations. The driver is also responsible for the train operation in case of ATP / ATO failure. Such systems have been in operation for several decades in major cities all around the world. The metros of Atlanta, Washington, and Singapore are such examples.

Second generation B :

This category is usually referred to as « driverless » because the trains are not equipped with conventional driver cabs. However, the proper operation of the trains still relies on attendants on board the trains, whose function is not only in some cases to acknowledge a safe departure of the train after door closings in station, but primarely to restore, as quickly as possible, the normal operation of the trains on the line in case of failures or abnormal conditions. A typical example is the London Docklands network and the new Ankara metro.

Third generation :

« Manless » systems are those for which any normal or degraded modes of operation are either system built in features or directly managed from an operation control center and thus they do not require any driver or attendant on board the vehicles. The systems in Lille, Toulouse and the new METEOR line are examples of this category.

These manless systems were initially developed for small airport applications, often referred to as automated people movers. However, development of the manless technology is becoming increasingly accepted by transit authorities for urban applications, achieving very high flexibility in operation for the satisfaction of the passengers.

8. 2. The unique advantages of manless operation

There are several advantages of this third-generation system that are unique to this technology. These include :

- A better quality of service by shorter but more frequent trains : very short headway can be achieved since no driving or supervisory actions are required from on board personnel and turnbacks at the end of the line are performed quickly and automatically without the need for drivers or attendants to move from one end of the train to the other. As an example, the VAL system in Lille has one minute headways during peak hours, and down to six minutes during off peak hours.

- The consequences are great : today, manless systems reach the same capacity as other systems but with shorter train lengths. This helps to reduce the cost of the infrastructure ; i.e. the length and the design of the stations, the size of the tunnels and the guideways, contributing also to the reduction of time and nuisance during construction. In addition, because waiting time in the station is vastly reduced, the attractiveness of a manless system for the public translates into additional revenues for the operators.

- Maximising the benefits of a multimodal integrated network : on segregated right of way, manless systems provide high attractive commercial speed (nearly twice as much as LRT's) and punctuality, thus offering short travel time and high traffic volume. Easy connection with other modes of transport is provided by the high frequency of trains thereby avoiding dissuasive waiting times, at transfer stations, even during off peak hours. As an example, in Toulouse, after only two years of VAL operation : 50 % of VAL ridership consists of mixed trips (VAL + bus, VAL + private cars, VAL + railway). Moreover, with the VAL implementation, the traffic of the overall Public Transportation Network has increased by around 40 %, with the following breakdown : 110 % on the VAL corridor itself ; 30 % on the bus network itself, when it is interconnected with the VAL line, and 1 % on the bus lines which are not connected with the VAL.

- A highly flexible operation, adapted in real time to the demand, increases transportation efficiency : manless systems translate into unprecedented flexibility for metro operation, since no constraints arise due to the unavailability of drivers or attendant personnel. At any time, trains can be automatically inserted or removed into/from revenue service by simple, remote commands from central control operators, adjusting the fleet to the demand for normal traffic as well as exceptional or unforeseen events. Compared to other solutions, where the dependence on on-board personnel leads to inflexibility in terms of shifts, and trade union work rules, manless systems can offer an optimised transportation capacity. As an example, on the Paris metro network, in December 1998, traffic was suddenly interrupted simultaneously on both RER (regional express) line A and metro Line 1, and thousands of passengers rerouted towards Line 14, the new Meteor line. Thanks to Meteor's manless operation, the authority could very quickly, without any constraints, increase the traffic capacity of line 14 by shortening train headway from four minutes down to two minutes.

- Human resources are shifted to passenger care instead of routine driving : in order to increase quality of service, metro systems need to deploy more passenger care (to help families, the elderly, handicapped persons, and tourists) by providing better information, security in the trains and in the stations, particularly during off peak hours, and increasing cleanliness of the trains and the stations. In addition, passengers expect more frequent trains during off peak hours, in conventional systems this could only be achieved by largely increasing the operating staff for systems. Such solutions would lead either to increasing deficits of the operating companies or to higher prices, the operators being trapped in a non-optimised system ; manless metros resolve easily this dilemna by reassigning on board personnel to roving services without additional expenses.

9. Conclusion

The completion of the metro system and the openeing of the first section to the public in may 1983 marked a turning point in the development of Lille and its surroundings. The putting into service of an automatically operated metro with no driver on board was a world first.

This is the Lille Subway System – certainly the most modern of subways, but perhaps the most traditional of new systems : no linear motors, magnetic supports, etc. This results from a deliberate desire to call upon, as far as possible, tried and tested equipment similar to that used on existing subways. This approach enables a high quality of service to be provided, capable of giving public transport a new image, while at the same time avoiding the serious difficulties encountered by a certain number of avant-garde systems.

A very wide range of collective means of transport serve the Lille community territory : trains, the VAL, the tramway with its integral low floor, the bus and taxis upon request. The complementary nature of the means of transport provided to travellers aims to make intermodality part of their everyday lives.

In 2000, over 106 million people used the multimodal network. There will be 200 million, in the horizon 2010 – 2015, if the objective defined in the development and Urban Planning Guidelines, set down to promote a synergy between the different means of transport in the metropolitan territory, is reached.

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ANNEX

VAL SYSTEM CHARACTERISTICS

Characteristics obtained with VAL 206[13] vehicle

System Performance

Max. theoretical one-way capacity[14]	12,480 pas/h
Max. practical one-way capacity[15]	9,400 pas/h
Normal one-way design capacity	7,500 pas/h
Practical headway with on-line stations	60 seconds
Service availability	Schedule : 20 h/day
Type of service	Line-haul ; on-line stations
Type of network	Line-haul
Traveling unit	Married pair
Interior noise	75 db A
Exterior noise[16]	72 db A

Unit Performance

Max.speed	80 km/h (50 mph)

[13] According to MTI standards, the number following VAL is the width in centimeters of the train unit.
[14] with 6 pas/m^2 and jump seats up
[15] with 4 pas/m^2 and jump seats up

[16] At 60 km/h and at 7.5 m distance from track

Commercial speed	34 km/h (21.75 mph)
Speed manual mode	18 km/h (workshop) 3 km/h (accosting speed)
Max.grade on line with full performance[17]	7 %
Average acceleration / deceleration	1.3 m/sec^2 (0,132 g)
Max.jerk	0,65 m/sec^3 (0,66 g/sec)
Min.emergency deceleration	1.8 m/sec^2 (0.183 g)
Max.emergency deceleration	2.4 m/sec^2 (0.244 g)
Stopping precision in station	0.3 m
Degredation if guideway is wet	None
Degredation for ice & snow	None – electrically heated
Unit design capacity	68 seated and 56 standing viz. 124 spaces
Unit crush capacity	44 seated and 164 standing viz. 208 spaces.
Energy consumption of two car unit	6 kWh/mile

Stations

Type	On-line, 1-berth
Type boarding	Level
Tickets & fare collection	Automatic fare collection with honor system
Security	Closed circuit TV ; Police
Max. wait time (off-peak)	5 minutes
Vehicle in-station dwell time	10 – 30 sec.
Station spacing (average)	0.85 km (.52 mile)

Reliability & safety

Fail-safe features	Components individually fail-safe
Strategy for passenger evacuation	Walkways

[17] Using two motors of four

Strategy for removal of failed vehicle	Automatic push capability ; manual backup ; & small recover diesel vehicles
System life	Design goal 30 years
Unit life	Design goal 30 years
System mean time between failure (MTBF)	52 hours (est.)
System mean time to restore (MTTR)	0.3 hours
System availability	Design 99 % ; Operational 99.4 %
Vehicle MTBF	624 hours
Guideway MTBF	926 hours
Control Center and communication MTBF	2880 hours
Fixed ATC equipement MTBF	303 hours.

Personnel Requirements Line 1 (13 km) in 1988		Total Staff
Units & stations Unmanned		
1. Central control		28
2. Maintenance		
Rolling stock	31	
Fixed sytem equipement	18	
Track and building	24	
Fare collection system	3	
Management	9	
		85
3. Roving teams		10
4. Ticket control, passenger information and fare collection operation and passenger information		34
5. Administrative & management		26
TOTAL Staff 1988		183

VAL Vehicle Characteristics

Dimensions

Unit length, overall	25,840 mm (84.8 feet)
Width, outside	2,060 mm (6.8 feet)
Height, clear inside	2,045 mm (6.7 feet)
Width, clear inside	2,010 mm (6.6 feet)
Height, overall	3,250 mm (10.7 feet)
Floor height	950 mm
Weight, empty	29,600 kg (65,120 pounds)
Weight,gross	208 passagers = 14,560 kg 44,160kg (97,152 pounds)

Suspension

Supported, vertical	Air cushion (4 per vehicle) elastomeric series suspension with 4 pneumatic tires per vehicles mounted on 2 axles
Axle	Steerable
Lateral guidance	8 pneumatic horizontally mounted rubber tires per vehicle
In switching area	4 vertically mounted steel wheels
Roll	4 hydraulic shock absorbers

Propulsion & braking

Type & n° of motors

VAL 206 :	2 DC rotary 380 V motors in series Motor rating : 120 kW x 2

Type drive	Mechanical coupling through a differential
Type power	750 V DC
Power collection	Sliding contact shoes on steel power rails ; 5 shoes per car (+, - , & ground)
Auxiliaries	72 V DC stepped down from 750 V DC
Battery	72 V with battery charger.
Type motor controller	Chopper
Type service brakes	Conjugated regenerative braking and pneumatic friction disks
Type emergency brakes	Pneumatic friction disks

Body

Type frame	one-piece integrated body and frame made of aluminum
Body end material	Reinforced fiberglass
Doors	VAL 206 : 6 bi-parting, externally hung, pneumatically powered per side

VAL 208

Characteristics

Carriage weight :	28,000 kg (61,600 pounds)
Usable internal space :	46 m^2
Power supply :	750 V (D.C.)
Unit Power :	520 kW
1 motor per wheel	(8 per unit)

Options

Air conditioning

Onboard video surveillance

Dynamic route map display

Modulated organisation of internal space

Onboard maintenance service system

Dimensions of VAL 208

Width, outside	2,080 mm instead of 2,060 mm
Weight, empty	28,000 kg
Weight, normal	156 passengers = 10,920 kg
	38,920 kg (85,624 kg)
Weight,gross	245 passengers = 17,150 kg
	45,150 kg (99,330 pounds)

The other dimensions are similar to VAL 206's dimensions

Capacity

Unit design capacity 4 pas/m^2	46 seated and 110 standing viz. 156 spaces
Unit crush capacity 6 pas/m^2	40 seated and 170 standing Viz. 210 spaces
Energy consumption of two car unit	6 kWh/mile

Propulsion & braking

Type & number of motors

VAL 208 :	4 wheel – motors synchronous type with permanent magnet in each unit

	Motor rating : 65 kW x 8 = 520 kW

Body

Type frame	one-piece integrated body and frame made of aluminum
Body end material	Reinforced fiberglass
Doors	6 bi-parting , externally hung, electically powered per side