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# RECENT EVOLUTION OF THE CONCEPT OF APM IN FRANCE

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## ABSTRACT

This paper describes three great families of automated people movers : hectometric, urban and suburban systems. Among these the urban systems well represented in France by the VAL are well known, but the developments in the two other families are more recent. The technology of the main components is briefly presented, and we can notice that some technologies are well adapted to one family (for example the propulsion by cable for the hectometric systems), or for an association with another technology (for example the linear motor with another technology (for example the linear motor with the magnetic levitation or with new types of iron wheel sustentation).


## INTRODUCTION

Twenty years ago, automatic people movers were presented as a new solution which could be generalized in many towns in order to solve the great problem of the trips inside urban areas. Several projects were studied in France as well as in other countries in the world. Ten years later, the enthusiasm for this new concept began to decrease because the projects couldn't of course be realized as quick as had been hoped. During this time some attempts were made to improve conventional public transport (metro, tramway, buses), but on the other side great efforts were made to adapt the towns to the circulation of private cars, which didn't suppress at all the traffic jams, which had bad consequences on the quality of life in towns... and which contributes in some cases to make nowdays the implementation of new systems more difficult. Nevertheless a few lines of automatic people movers are now in operation, in construction or in projects, and it is possible to notice some evolutions of the concept as well with regard to the type of application as with regard to the technology chosen for the main components.

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GENERAL SITUATION

Most projects vhich were studied about 15 or 20 years ago grouped the following characteristics :

- vehicles of very small size or cabins

- aerial guideway chosen as a predominant solution for the insertion

- new concepts either for the sustentation (for example air cushion) or for the propulsion (for example linear motor) or for the guiding (for example central guiding) or for the operation mode (for example direct service with off-line stations).

This was the general situation not only in France but in the other countries where automated people movers were developped. But then at the beginning of the eighties only the concept of automatic minimetro could find an application and this concept is on the contrary characterized by the following characteristics :

- vehicles of relative big size, although distinctly smaller than those of a conventional metro

- various types of guideway including underground very often

- the choice of technical components which are as far as possible already tested in existing systems, and of a conventional operation mode : all the vehicles stop at all the stations.

This is in France especially the case for the VAL system. Besides the continuation of the spread of this automatic minimetro we can note nowadays in France :

- The reappearance of systems with small cabins, but only for very specific applications such as the SK hectometric system

- The reappearance of projects where the linear motor represents an innovation for the propulsion, in association whith new solutions for the sustentation

- a new interest for aerial guideway, especially for hectrometric systems and suburban systems but not exclusively.

It appears clear that no automated people mover can be " universal " but different technologies can be used in oder to be as well as possible adapted to the sites of application that we can try to classify in three groups : hectrometric, urban and suburban.

HECTOMETRIC SYSTEMS

The concept of "hectometric system", that we could also call system for short distances or for short to middle distances results from these two ascertainments :

- a need of automated people movers for sites wich are rarely longer than 2 or 3 kms : big "closed complexes (exhibition parks, airports...), connection between lines of public transport or between station and parking, transfer line toward heavy trafficked axes etc...

- the existence of technologies such as mechanical active guideway which are well adapted to this applications but not appropriate to or less efficient for longer lines

Because of the small distances there is no need of high speed (if we except particular cases of single guideway or shuttle where the capacity depends of the speed) but on the contrary the waiting time should be as short as possible. This is the reason why many semi-continuous systems have been invented (among them until now only the SK could find commercial applications). A semi-continuous system consists in small vehicles or cabins which don't stop completely in the stations but advance very slowly, in order to allow an interval as low as possible between the cabins. Of course, the speed in the stations is low enough to permit the embarking and disembarking of passengers without any difficulties.

For the propulsion of hectometric systems, various solutions can be imagined, among which the active guideway which means that the vehicles carry no motors, and that all the power equipment is in the guidway. This equipment consists of linear motors in case of electrical active guidway and of cable, betts, conveyors in case of mechanical active guideway. The active guideway is advantageous for hectometric systems, because there is no need of special equipment for the transmission of information between vehicle and guideway, as the speed is determined directly by the guideway (and information transmission equipment would be relatively more expensive for small systems). Three hectometric systems which have been developped in France utilize the principle of mechanical active guideway, with a propulsion of the vehicles by means of cables. With present-day technologies, the speed of the cable is limited to about 40 km/h, which is usually compatible with the requirement for hectrometric systems, and then for this type of application the cable offers the two following advantages :

- the suppression of adhesion constraint

- the contribution to the collision avoidance, which is more or less important according to the type of system (and we can say here also that electronic devices would be relatively more expansive for small systems).

Among the two cable systems based on the semi-continuous principle, the SK has been the more successful one because a few applications have been either achieved or foreseen. This is the first example of hectometrie system that seems well adapted to the market with regard to the technical and economic characteristics. We will not go further into this theme SK because another paper is presented on this subject.

The other system called DELTA V has been successfuly tested on a prototype loop but has not yet found a commercial application. The variation of distance between vehicles occurs by the winding and the uncoiling of cable pieces on drums supported by small moving trucks. The cabins are smaller than those of the SK (about four persons), and the intervals are also smaller (about 6 seconds). This system would be well adapted to sites requiring either a very high climbing capability (even more than 70 % is possible), or a very small curve radius or a very small width (the width of the cabin is not more than 1 meter).

The third cable system, now also generally classified among hectomectric systems, although it was originally conceived for more ambitious applications, is the POMA 2000. The first application takes places in the town of Laon, in a specific urban area, but on a length of 1,5 km which justifies the hectometric denomination. A special version of the POMA 2000 has been studied for this site, which is described in another paper. Disregarding the technology, an interesting aspect of this realization is the type of insertion into the town : the guideway is most of the time elevated or at grade.

Very simple cable systems, for example a simplified version of POMA 2000 can be used to realize shuttle on short lines, also in case of high traffic. Such a project had been foreseen between Gare du Nord and Gare de l'Est in Paris. It was called NAHSAT (Navette Hectometrique Sans Attente) because the length of the train of vehicles allowed to make the waiting time lower than the time necessary to walk along the quay. The project has been postponed because of difficulties to find the financing of the tunnel, but it showed the adaptation of this type of system to this kind of application.

URBAN SYSTEMS

Specific urban systems adated to many kilometer long lines, with interstations usually shorter than 1 km and maximal speed that rarely exceeds 80 km/h, represent the most important application case for APM, but we will not expatiate too much on this subject which is already approached in other papers. In Lille two lines of VAL are already constructed and in operation, a third line in project. VAL has also been chosen in France by Toulouse and Strasbourg, and studies are now carried out for other towns. VAL has been chosen for two sites in the United States and projects are envisaged for other countries.

Among the technical characteristics, we can note the electrical rotative DC motor. Although this motor is conventional in itself, innnovation is possible with regard to the control equipment, and for the second line in Lille the vehicles are equipped with improved choppers using GTO thyristors. For all the present projects the propulsion by electrical rotative motors is associated with a sustentation by means of pneumatic tyres, for reasons of noise reduction and adhesion.

For the future the urban APM systems will be either derivated from the VAL or new systems, in both cases possible technological evolutions are :

- new command and control systems for high performance APM. Some solutions are described in another paper presentesd by INRETS - CRESTA

- innovation in the field of propulsion and sustentation, as they are described in the next paragraph "suburban systems", because the first application has been envisaged for this field.

In the next few years there will be examples of conventional metros becoming completely automated, such as line D of the Lyon Metro, with technologies similar to those which could be applied to the systems that we are now calling APM. But the specificity of the APM will remain the smaller size of the vehicles, which allows a high quality of service, especially in terms of waiting time, even for traffics which are distinctly lower than those of a conventional metro. This trend will be even more important in the future : after the equipment of the big urban metropoles, there will remain, at least in France, lines with lower traffics volumes. This is the reason why researches have to be carried out in order to make future APM competitive for smaller towns, eventually with the use of aerial guideway.

As APM systems in France are usually not foreseen as DPM, urban systems can serve stations in suburbs at the ends of the lines, but as the main objective is to go though the center of the town they are not called suburban systems

## SUBURBAN SYSTEMS

For specific applications such as pole-to-pole connections, links between city and airport, fast ringways... where the lines are not necessarily much longer than those of specific urban applications but where the interstations are a few kilometers long, there is a need for systems with the following characteristics :

- a relatively high speed, about 150 km/h, sometimes more

- small curve radius to facilitate insertion into urban areas at the end of the line

- a good acceleration and deceleration capability

- a design well adapted to aerial guideway, of course without excluding an insertion at grade or underground, this last solution has to be avoided as far as possible, but can be sometimes necessary on limited sections, for example for the end of a line in a dense urban area.

The feasibility study of a suburban system called STARLIM ( Système de Transport Automatique Rapide with Linear Induction Motor) has been carried out in the context of a French-German co-operation grouping a few organisations, including INRETS, and a few manufacturers among which MATRA-TRANSPORT is the main contractor on the French part and THYSSEN-HENSCHEL the main contractor on the German part.

The propulsion is based on the U shaped asynchronous linear motor (CELDUC motor) which has been developed in France, and which had already been successfuly tested on the big wheel in Grenoble, and had proved :

- its better electrical characteristics compared to those of the asynchronous flat linear motor (with regard to the product efficiency x power factor).

- The absence of parasitic attraction forces between inductor and armature

For the sustentation, various solutions could be envisaged, the magnetic levitation has been chosen for the following reasons :

- The components (magnets and control equipment) have already been developed for the TRANSRAPID system which has bean tested for a few years on a prototype loop in Germany

- the reduction of noise is an important crtiterion for urban penetrations

- magnetic levitation is well adapted to aerial guideway.

The magnetic levitation is of the EMS "Electromagnetic Sustentation" type, that means that the sustentation force is created by electromagnets reacting on the lower face of the sustentation rail placed on the guideway. The current in the electromagnet is regulated so that the air gap remains as near as possible to the value 8 mm.

The guiding is also magnetic and utilizes the same principle, the reaction surfaces are the two flanks of the U-shaped reaction rail of the linear motor. The tests carried out a few years ago on the big wheel of Grenoble (beforce the launching of the STARLIM feasibility study) concerned both the U-shaped linear motor and the magnetic guiding on the two external faces of the reaction rail. This program was called U-LIM-AS, it is the reason why the STARLIM projeet is sometimes called U-LIM-AS.

It is important to note the good adaptation of the linear motor, especially of the U-shaped linear motor to the magnetic levitation.

Contrary to other projects, for STARLIM the realization mode of the linear motor is the "short stator", that means that the vehicle carries the inductor of the motor, and guideway is more simple because there is only a reaction rail instead of a three-phase winding. A captation of energy is then necessary, it occurs on the same rails as the sustentation rails.

<u>General characteristics</u>

| | |
|---|---|
| Maximum speed : | 150 km/h ( 200 km/h ) |
| Mechanical power : | 700 kw ( 1050 kw) |
| Acceleration : | 1,3 m/s2 up to 10 m/s ( 15 m/s) |
| Maximum gradient : | 10 % |
| Minimum curve radius : | 30 m |
| Minimum profile radius : | 500 m |
| Minimum headway : | 90 s |

| | | |
|---|---|---|
| <u>Vehicle :</u> | length : | 30 m |
| | height : | 2,90 m |
| | width : | 2,60 m |
| | capacity (4 p/m2) : | 164 passengers / vehicle |
| | seated : | 68 |
| | *standing* (4 p/m2) : | 96 |

A comparative economic study made on a theoretical line showed that STARLIM is competitive with conventional systems, at least for the type of application that we consider. This result could be obtained although the vehicles (with high technology ) are relatively more expensive because :

- the infrastructure costs represent the most important part of the project, and when aerial guideway is necessary (at least on some sections) the lightness of STARLIM and its guideway is a great advantage compared to conventional rail systems

- the high speed is also an economic advantage compared to systems conceived for urban applications, because the number of vehicle can be reduced.

We can now point out some characteristics inherent to the propulsion by linear motor, independantly of the STARLIM project. As the cable for hectrometric systems, the linear motor supresses the adhesion constraints. This is a great advantage for APM, which must guarantee the required level of acceleration and deceleration in any weather conditions. The linear motor allows the realization of electrtical braking : by utilization of the inverter for normal braking and by injection of DC current from on-board batteries into the windings of the linear motor for emergency braking. Other advantages of the propulsion by linear motor are the reduction of noise and wear, and the realization of a lower vehicle.

Besides the association linear motor / magnetic levitation there is another favourable association : linear motor/ sustentation by iron wheels for the following reasons :

- this allows a reduced air gap, which is favourable for the performances of the linear motor

- the adhesion value is possibly smaller with iron wheels than with tyres, but there is no need of adhesion with the linear motor.

But conventional bogies are inapropriate for such applications because they cannot offer both a high speed and an adaptation to curves with small curve radis. This is the reason why INRETS-LTN has invented a new solution called ERIOM (Essieu à Roues Indépendantes à Orientation Magnétique) which is particularly well adapted to the U-shaped linear motor but could also find other applications. The principle consists in a magnetically steerable axle with independant wheels. The iron wheels are cylindrical and without flanges. Two sets of two electromagnets integrated in a control loop are mounted at each end of a beam perpendicular to the axle. The U-shaped armature rail of the linear motor is used as a reaction surface for the electromagnets and a reference for the air gap measurement by means of sensors.

The tests have been carried out at a reduced scale (1/4) on the big wheel of Grenoble.

## CONCLUSION

The problem of transportation inside urban areas can only be solved by the implementation of performant public transport. There are many cases where an APM can be the best solution but it is important to choose the more appropriate technology for hectometric, urban or suburban systems. In the future we can imagine an optimum combination of these transport means : for some specific needs suburban and hectometric systems could realize a complement of an urban network.

KEYWORDS

Urban

Hectometric

Suburban

Propulsion by cable

Linear motor

Magnetic levitation

Active guideway

Semi-continuous

Small cabins

Aerial guideway