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Cost Reductions for Unmanned Transport Systems

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Abstract

After some considerations on the cost implications of fully automated systems, the paper presents the methods which could lead to a reduction of these costs : development of diagnosis and maintenance aids, flexible modes of operation, alleviation of the constraints relative to track protection in these systems.

Keywords

Urban Transports - Automatic Driving - Platform Doors - Operation - Maintenance - Economics - Flexibility

Introduction

Fully automated urban transportation systems have undergone considerable development since the beginning of the eighties, and the opening of the first lines in Osaka, Kobe and Lille.

At this time there are over forty automatic systems operating throughout the world and half a dozen systems are under construction.

The main reasons for this success are that these systems perform well in terms of availability, safety and quality of service, and that they appear as sufficiently cost-effective to be competitive with more conventional mass transit systems.

However, the cost of full automation is often a subject of discussion for authorities or operators concerned with the implementation of new transit systems in their area of interest.

The discussion may take place in fact at two levels :

- for large cities in which a fully segregated track system is necessary for traffic or environmental reasons, the question is to choose between a conventional manual system or an unmanned one. In that case, cost considerations may intervene, but they are secondary to political or sociological considerations.

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- for smaller cities or less congested areas, where the operation of Light Rail Transit (LRT) systems may be acceptable, the necessity for an unmanned system to drive on a fully-dedicated and well protected infrastructure implies important supplementary costs, and is generally a decisive factor in favor of the LRT solution.

In this paper, we examine successively both of these aspects, and analyze how the economics of unmanned systems may be improved.

Unmanned versus manned-driven systems on fully segregated infrastructure

For such systems, the cost question is of secondary importance ; in fact the extra cost for full automation represents only 3 to 5 % of the total investment cost for a line, and this extra cost can be recovered, during the life of the system, by the savings due to staff reductions. A study (1) made on a Lille-type line shows that, as soon as the frequency on the line is sufficiently high, that is to say for a rolling stock over about 20 trains, the balance between the extra investment costs of the fixed Automatic Train Control (ATC) equipments (which are almost independant of the size of the rolling stock), and the savings due to staff reductions (which are proportional to the number of trains) is positive (Fig. 1).

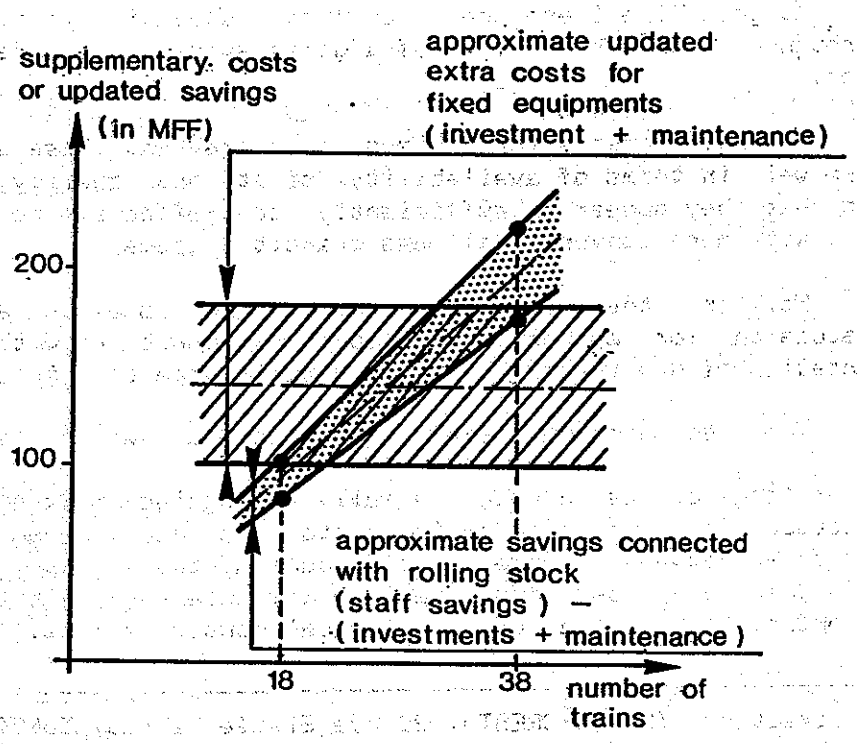

Fig. 1 : Variations of the balance sheet of entirely automatic operation with the size of the train fleet (discounted over 20 years with a discount rate of 5 %)

Moreover, the increase in quality of service and in flexibility of operation afforded by full automation can eventually justify some extra costs.

In fact the decision on the driving mode for mass transit systems appears to be more dependant on political or sociological considerations than on economic ones.

A decrease in the cost of automation may have a positive influence on this kind of decision, and we shall examine the different factors which could contribute in future to reductions in costs.

Alleviation on the cost of Automatic Train Control (ATC) equipments

As it appears on Figure 1, the influence of the price of the fixed ATC equipments is relatively important, and may be a factor for rejecting full automation for lines with low frequencies.

This cost covers essentially some extra Automatic Train Operation (ATO) equipments in interstations and stations, as well as in the terminals and garage zones, some extra Automatic Train Protection (ATP) equipments, and the communication equipment between ground and vehicles, necessitated by the absence of drivers.

Among the main methods which can lead to cost reductions for this equipment, we suggest :

- an increased use of microprocessors, which will allow for a reduction in the number of electronic cards
- the use of the moving block method for Automatic Train Protection. This alleviates the cost of fixed equipment along the tracks, but slightly increases the on-board equipment complexity, and necessarily implies microprocessors in such a safety function. This type of systems is used in Vancouver, Detroit, and will be used in Lyons
- in the longer term, it may be envisaged to suppress totally the communication lines along the tracks, and to substitute to them microwave links which have the property to propagate well in tunnels (2).

It is expected that such methods can lead to reductions on the order of 30 % of the ATC cost.

Development of diagnosis and maintenance aids :

The weight of diagnosis and maintenance costs of the ATC equipment represents annually about 3 to 4 % of the corresponding investment costs and cannot be neglected. Among the developments which may be expected in the future, we can mention the development

of expert systems for the on-line diagnosis of electronic equipment failures. The effect of such a development would be to reduce the direct maintenance costs mentioned above, and to decrease the number of spare trains which are necessary, generally in order of 8 to 10 % of the fleet.

Moreover, thanks to a better treatment of failure situations, the requirements relative to the performances or redundancies of equipments, which are now considered as necessary to cope with these situations, could be alleviated.

Alleviation of platform protections :

In the first unmanned transportation systems, platform doors were generally provided for the protection of users against two main causes of accidents-falling on the track and the dragging away of a passenger by the doors of a vehicle starting from a station.

In some recent systems already opened to the public or under construction, like Vancouver, Miami, Detroit, the Docklands Line or the Lyons D Line, this constraint has been alleviated, and these lines are not equipped with platform doors (Table 1).

Systems with platform doors	Systems without platform doors	
	with falls detection	without falls detection
Kobe Osaka Lille	Vancouver	Miami Detroit Docklands Line

Table 1 : Platform protections in existing urban automatic systems

In some lines, like Vancouver or Lyons, the prevailing rule is that passenger should be ensured a level of safety at least equal to that provided by a driver, which implies an efficient device for detecting falls onto the track along the stations platforms, and a protecting device, such as doors with sensitive edges to prevent the risk of dragging a passenger away.

In the Docklands or the Miami lines, nothing is provided for detecting falls on the track.

The elimination of platform doors leads to savings of about 20 to 30 % of the extra fixed equipments, necessitated by a fully automated system, depending of the stations size.

Flexibility of operation :

One of the main advantages of fully automated systems is their great flexibility of operation :

- flexibility with time :

Unmanned systems can adapt instantaneously to unpredicted variations of the demand, without any constraint due to crew scheduling.

Furthermore, like in many more conventional systems, it is possible to use variable size trains according to the time of day, and this flexibility, which allows savings in energy and maintenance without altering the quality of service, is already used in the Kobe Portliner system.

- Spatial flexibility :

This kind of flexibility, which may lead to far greater savings, is practically not in use now in conventional systems, but could be favoured by the development of full automation which allows a great regularity in the schedules of the trains.

Generally the trains occupancy varies regularly along a line : a typical distribution of occupancy is for instance illustrated on Fig. 2 (extracted from a study on Lille VAL (3)).

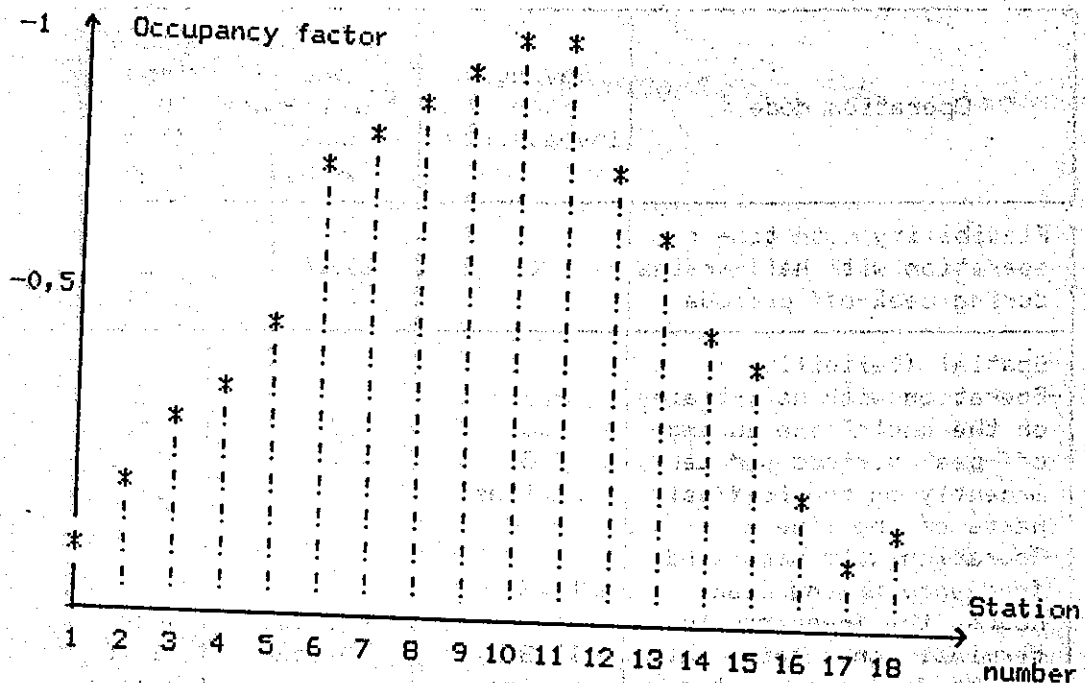

Fig. 2 : Typical occupancy factor = $\frac{\text{passenger number}}{\text{train capacity}}$ in VAL (Lille line 1)

A possible mode of operation may consist in modulating the transport capacity along the line.

Two possibilities may be envisaged :

- without altering the frequency at the extremities of the line, by cutting the trains in two parts in stations A and B, and serving the outer portions of the line by reduced size trains -which is hardly possible with unmanned trains- but which implies an extra ATO and ATP equipment on board each train (Fig. 3).

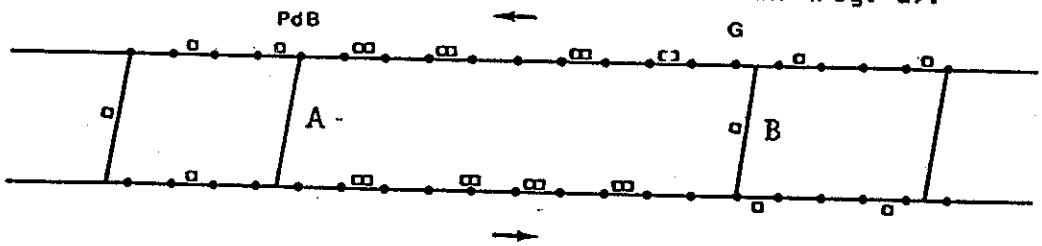

Fig. 3 : Line operation with variable size trains according to the zone

- with a lower frequency at the extremities of the line, by sending only one train over two (or more) towards the outer stations, the other trains turning back at stations A and B.

A theoretical study undertaken on Lille Line 1 has led to the following results concerning the savings which could be provided by such a mode of operation (Table 2).

Operation Mode	Savings on Investments	Operation and Maintenance Annual Savings	Updated Savings over 20 years (discount rate +5%)
Flexibility with time : operation with half-trains during peak-off periods	0	200 000 $/year	2,8 millions $
Spatial flexibility : -Operation with half-trains on the whole line during off-peak periods and permanently on the terminal parts of the line	6,3 to 7,8 millions $	500 000 $/year	12,7 to 14,2 millions $
-Operation with modulated frequency during peak hours, the frequency in terminal zones being half of the frequency of the central zone	10,8 to 12,3 millions $	400 000 $/year	16,3 to 17,8 millions $

Table 2 : Savings associated with different flexible modes of operation on a line

The savings (energy + maintenance) generated by the operation of half-size trains during the off-peak periods are very low and hardly justify the increased complexity of the line operation. By contrast, the operation of a line with trains whose size varies according to the served zone allows an important reduction on the rolling-stock and generates very significant savings.

Another evaluation of this kind of operation has been undertaken on Toulouse Line A (Fig. 4) on behalf of the Toulouse authorities.

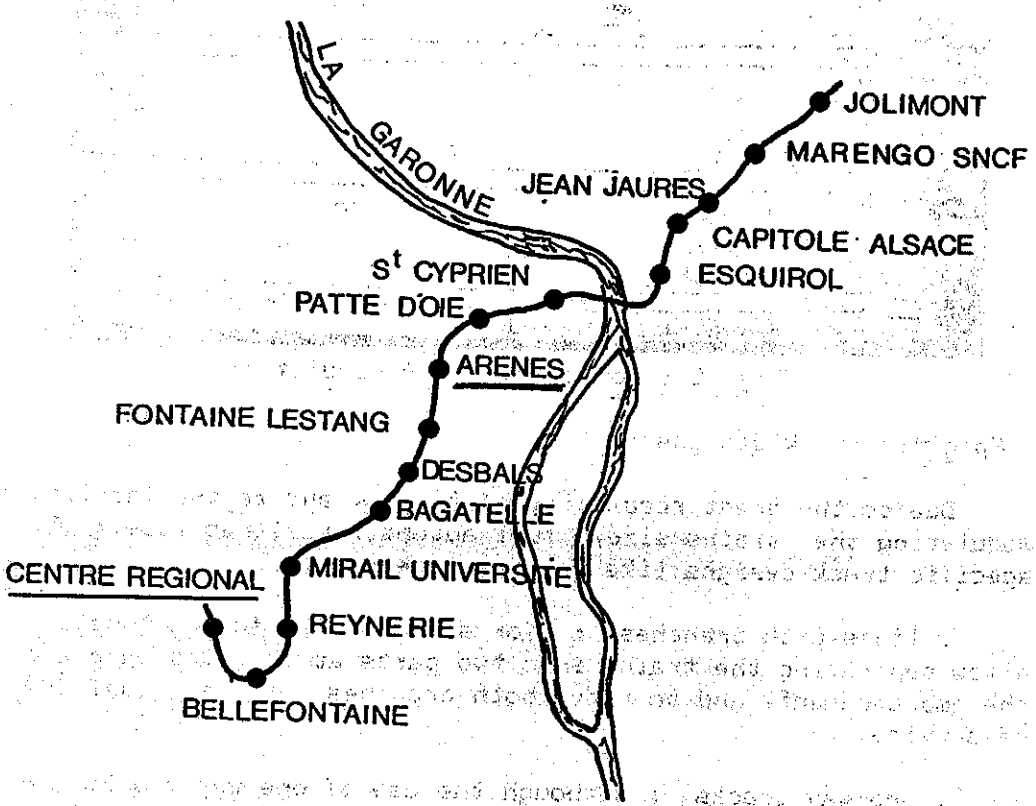

Fig. 4 : Toulouse Line A

This line is such that it could be operated with a reduced frequency on one half of its length, from ARENES to MIRAIL CENTRE REGIONAL.

A simulation model (6) has been developed on a digital computer (Macintosh II), which displays the line configuration and the progression of the trains (Fig. 5). The first results obtained with this simulation have shown that such a mode of operation (full frequency on one part of the line, half frequency on the other one) would be possible even with current traffic perturbations ; the savings generated would be on the order of 8 trains, that is to say an investment of 12.3 millions $.

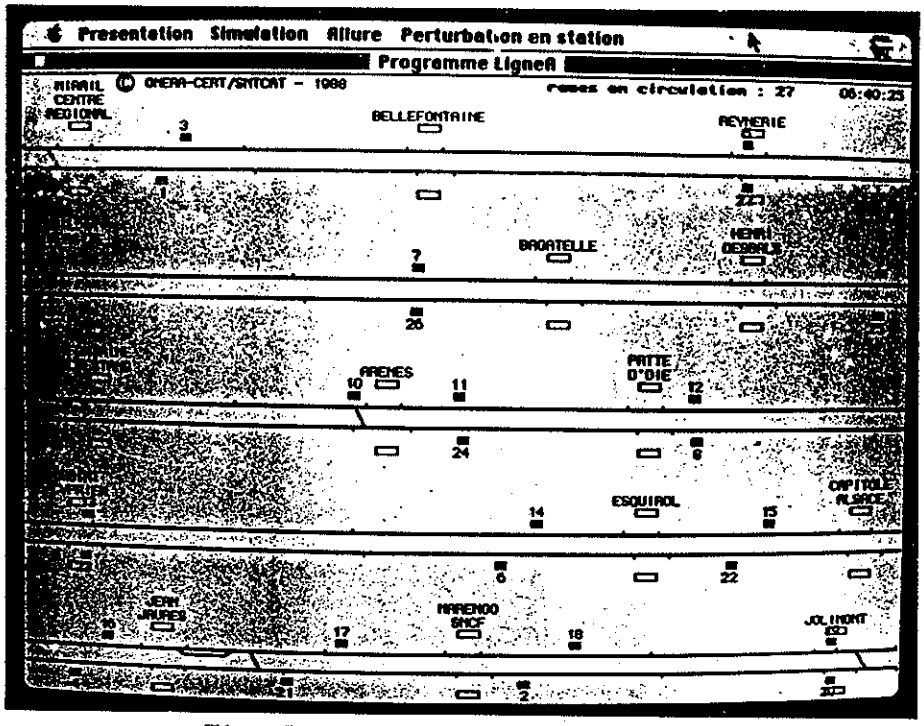

Fig. 5 : Toulouse Line A simulation

- Specific track designs :

Due to the great regularity of trains, and to the facility for modulating the trains size, full automation lends itself well to specific track designs like for instance :

. lines with branches : for such lines, full automation may allow separating the trains into two parts at the station preceding the embranchment, and to serve both branches with an equal quality of service.

. one-way tracks : although the use of one-way tracks penalises the frequency of a line, it may generate important savings on public works, and is already of relatively current practice, at least on LRT lines. It may be of a great interest in association with spatial flexibility schemes mentioned above, and full automation may contribute to optimise the intervals between trains.

Unmanned systems versus LRT systems

Obviously when considering investment costs, LRT systems with partially or totally at-grade tracks are more attractive, especially for medium size cities in which the demand is relatively low, than systems with fully separated and protected tracks, the cost per km ratio between these two types of systems being currently on the order of 2 to 3.

However many of new LRT lines, as well as renovated lines in older networks, have now, for environmental or traffic reasons, a great portion of their length on separated tracks.

Starting from these considerations, and from the premise that unmanned systems are already allowed to land and start in non protected stations, we wonder if it would not be possible to extend unmanned driving to such LRT systems. The main conditions for such an evolution should certainly be, at least on the beginning :

- that the major part of the line be on separated and well protected tracks. Interfaces with users or other traffic should be allowed only in some limited zones, like stations and at-grade street crossings.

- that these zones be equipped with efficient automatic monitoring devices for the detection of risks of intrusions on the tracks, completed by a visual survey from a control center through closed circuit television cameras.

One of the main interests of such a mode of operation would be to allow peripheral zones in a city to be served at relatively low cost by fully automated systems built in the central zone on well separated and protected tracks.

Researches are underway in France (4) on the possibilities of using automatic TV image processing for the monitoring of intersection which could be crossed at-grade by automated LRT systems.

Conclusion

We have tried to show that there is potential for extending the use of fully automated systems. It appears that this mode of operation is already quite cost effective, and that it should be taken seriously in consideration for each new mass transit projects in a city.

The most promising aspects of full automation could derive from the following ideas :

- to take benefit of its flexibility to adopt new operation modes allowing an optimal adaptation of the offer to the demand,
- to extend the use of full automation to LRT systems on not totally segregated tracks.

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