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EFFECTS OF AUTOMATION ON THE IMPROVEMENT OF THE QUALITY OF SERVICE IN URBAN GUIDED TRANSPORTATION SYSTEMS

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Automation has been developing continuously for many years in urban guided transportation systems. If we consider the 220 existing Metro lines mentioned in the UITP World Survey (6), about 80 lines are equipped with automatic driving systems, and almost all the others have received a minimal level of automation consisting in general in a control centre, and either in a cab-signal device, or at last in an automatic stopping device.

Since 1970, out of 50 new lines, 40 are equipped with an automatic driving system, and the advances in this field have led recently to the realization and the operation in some countries of completely unmanned urban transport systems.

The interest of these systems is no more questioned, and is confirmed for instance by decisions recently taken in France, as a result of the fruitful experience acquired on the VAL system, to adopt unmanned automatic operation for the fourth line under construction of Lyons Metro, and for the Toulouse as well as for the Strasbourg or Bordeaux Metros.

Among the main reasons for the interest in automation we can mention :

- first of all, all these systems allow considerable improvements in the quality of service which can be offered to the users ;

- secondly, that this enhanced quality of service does not cost money, the increase in investment cost being counterbalanced by the earnings on operation costs ;

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- at last, that the fears expressed some years ago concerning the acceptability of unmanned operation by the users have been completely cleared.

The present communication will develop these different points of view and will detail successively :

1 - the improvement of the different components of quality of service due to automation, and particularly to unmanned operation :

  . driving safety due to automation train protection,
  . regularity,
  . availability,
  . vehicles frequency and capacity of a line,
  . flexibility of operation and facility of management,
  . capacity.

2 - a comparison of operation costs of automated and non automated urban transports.

  In such comparisons should appear non only the effects of manpower reduction, but also the effects of the energy savings and the maintenance facilities which are permitted by automation.

3 - the experience acquired in the Lille VAL system on the effects of unmanned operation on the users behaviour.

1 - IMPROVEMENT OF THE QUALITY OF SERVICE DUE TO AUTOMATION

As it has just been mentioned, one of the main objectives of the automation of guided transportation systems is the improvement of the quality of service.

In this paragraph, we shall make a survey of the different criteria which can be used to assess these improvements.

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1.1. - Safety

Safety is certainly one of the main preoccupations of transit operators and administrations, and the constraints in this field are very severe.

It is difficult to find detailed statistics on this subject in the literature, taking into account the fact that few completely unmanned systems are in service and that they have not been operated for a long time.

We can however make the following comments.

1.1.1. - Automated systems with drivers

These systems can be ranged into 2 categories :

. systems with a controlled manual driving, giving a protection against the overriding of a red sign or a speed limit,

. systems with automatic driving devices, in which the driver controls only the opening and closing of the doors, and has the possibility to take back manual driving if a failure of the automated devices occurs.

These levels of automation have much contributed in increasing safety, as it is demonstrated in the US Office of Technology Assessment (OTA) Report (1) which mentions for instance the accident statistics of the Chicago Transit System in the period 1965-74 when this system was driven almost completely manually (fig. 1).

TYPE OF ACCIDENT	TOTAL	CONTRIBUTING FACTORS *						
		Car Defect	Track Defect	Weather	Wayside Signals	Cab Signals	Human Error	Vandals
Collision	35	5	0	2	1	1	35	3
Derailment	52	16	4	0	6	0	31	1

* Some accidents had more than one contributing factor

Fig. 1 - Analysis of CTA Accident Record, 1965-74

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These data show clearly that the main causes for collisions or derailments are human errors.

The same report underlines, on the other side, the very low record of collisions or derailments due to automatic driving systems.

1.1.2. - Unmanned systems

The experience accumulated with these systems is limited, but it must be emphasized that, with the exception of a collision registered on Airtrans in 1977, none of these systems has caused any passengers accident due to the automatic driving devices.

This fact is clearly confirmed by the assessments made by UMTA of different American systems (8), (13), and, more recently by the three years of operation of the Lille Metro.

1.2. - Availability

The first experiments with unmanned systems, at the beginning of the years 1970, have raised some doubts concerning the availability of such systems.

For instance, during their first year of operation, the availability of the Morgantown People Mover and of Airtrans did not exceed respectively 56 % and 82,9 %.

However, the operating conditions of both these systems have now considerably improved, as it is illustrated by the graphic fig. 2 relative to Morgantown (9).

The example of VAL, with an average system availability of 0,986 in 1983, 0,994 in 1984 and 0,996 in 1985 shows that now very good availability performances are reached even on the first years of operation of a new system.

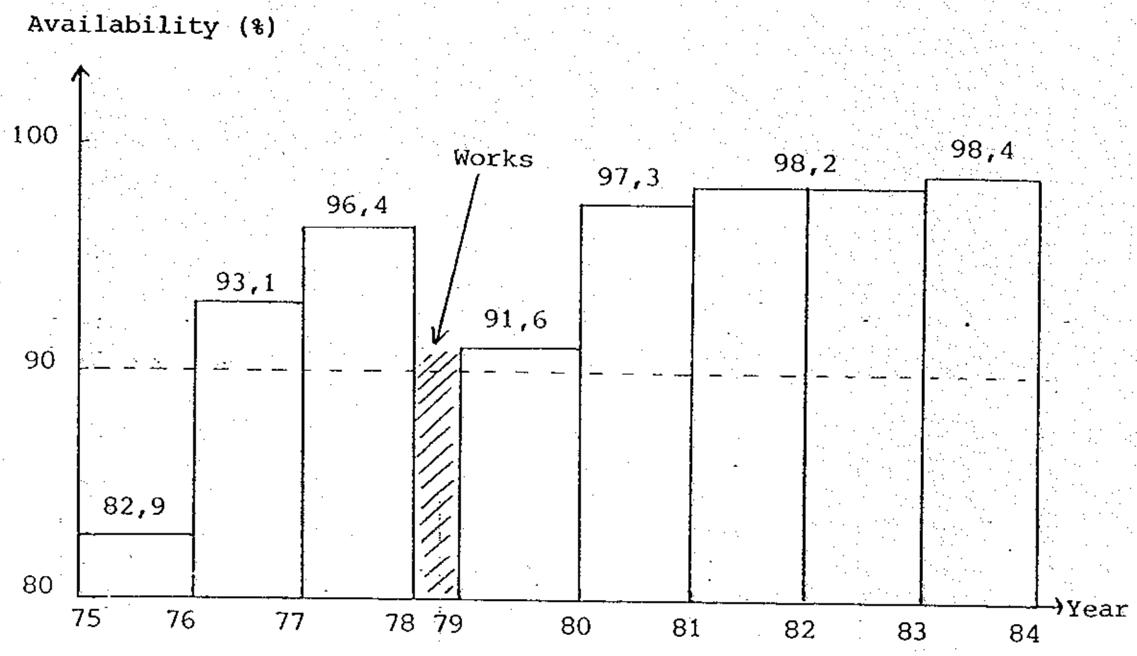

Fig. 2 - Evolution of the availability of Morgantown

1.3. - Regularity and punctuality

Since the occurence of the first systems of automatic driving and of traffic control, it has been recognized that automation could improve the regularity of traffic.

For instance, it is mentioned in (11) that the implementation of an automatic regulation on the Paris Metro has practically reduced to zero the average delay on a line which amounted before to about 15 minutes every day.

The report (1) of the OTA mentions some observations made on the PATCO line at Philadelphia, which show that, compared to the trips made with automatic driving, the trips made with manual driving are in average 20 seconds longer, with a much higher standard deviation.

More recently a study made in 1985 on behalf of the International Metropolitan Railways Committee of UITP (International Union for Public Transports) on data collected among different European networks, shows that a fully-automated line like VAL in Lille presents very good performances of regularity and punctuality compared with those of more conventional lines.

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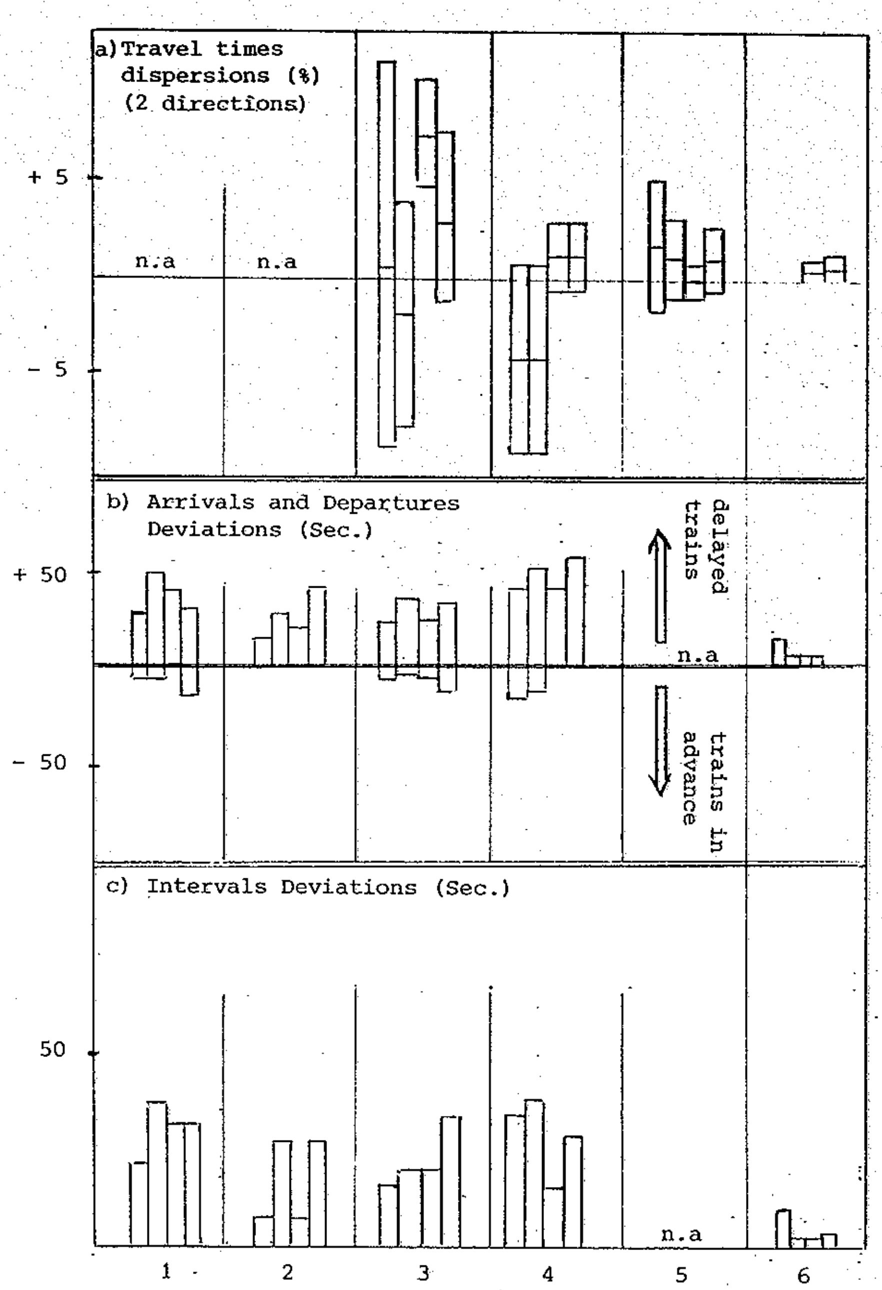

1 - Hamburg (line 1)
2 - München (line Rotkreuzplatz Innsbrücker Ring)
3 - Vienna
   a) lines U1 - U2
   b) c) line U1
4 - Berlin BVG
   a) lines U4 - U9
   c) d) line U9
5 - Paris lines 3-8
6 - Lille VAL

Nota : On graphics b, c, the deviations are measured on both directions, and on both terminals.

Fig. 3 - Regularity and Punctuality criteria (peak-hour morning)

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Some results of this study, selected among the lines with the best performances are illustrated on the graphics fig. 3. These graphics, established with measures made during an average operational day, present :

- the dispersions measured on travel-time between terminals,
- the mean values of the differences between the effective and planned departure times,
- the mean value of the differences between the effective and planned headways.

1.4. - Flexibility of operation

One of the main interests of an automated system for a transportation enterprise is its facility of operation, and of adaptation as well in time as in space of the offer to the demand.

1.4.1. - On-line adaptation

In a metro line, the actual demand often differs from the predictions, due to a variety of causes, like commercial, sportive or social events. In manually-driven systems, due to the rigidity of drivers' rosters, it is very difficult to modify on-line the capacity offered to the users.

In an unmanned system, the offer may be instantaneously adapted to the demand without any difficulty.

We can mention briefly two examples of this flexibility in the operation of VAL in Lille :

. each year, at the beginning of september, during a big commercial festivity in Lille, the VAL is operated 70 hours without interruption, night and day, at a high frequency, from Saturday morning to Monday night.

. at the end of august, the schedule was planned daily for a holiday service with 6 minutes intervals all the day ; on the last Friday and Saturday of the month, the demand grew more than predicted towards the commercial centres, due to the proximity of the school opening day ; the frequency instantaneously was doubled during all the afternoons of both those days.

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1.4.2. - Spatial adaptation

Unmanned driving facilitates a great variety of unconventional modes of operation, for instance :

- single-track operation (fig. 4) :

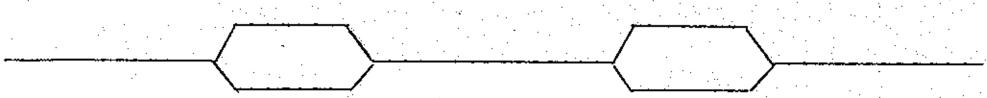

Fig. 4 - Single-track operation

To be efficient, such a mode of operation implies a very good synchronization and a good protection against collisions which can only be provided by automation.

- line embranchments (fig. 5) :

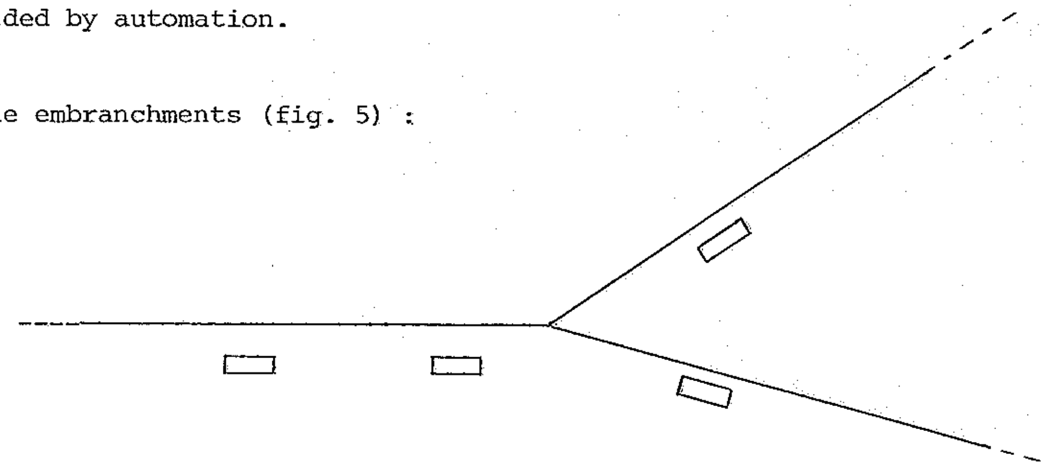

Fig. 5 - Embranchments

When a line presents an embranchment, the intervals on each branch are the double of those on the main line, giving a poor quality of service. Unmanned operation allows the possibility to separate a train in two parts as well as to group again these parts in the station before the embranchment, and to maintain the same frequency over the whole line.

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- variable service according the zones (fig. 6) :

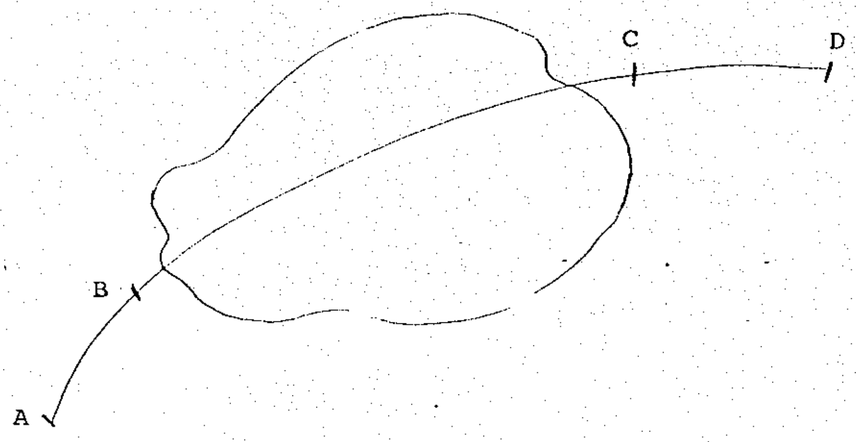

Fig. 6 - Variable service in different zones

In some cities, where the demand is very contrasted in the Centre and in the periphery, a line like the line ABCD (Fig. 6) may be divided into 3 segments, the central segment BC being served by long trains, which are shortened in stations B and C, the segment AB and CD being served only by one or two vehicles. Such a mode of operation leads to energy and maintenance spares for the rollingstock.

1.5. - Facility of management

With the present evolution of society, it appears more and more difficult for operators to find a manpower which accepts the constraints of the operation of a metro network :

- very early or late working hours,
- work during week-ends,
- rigidity of schedule.

A great advantage of full automation is to alleviate the difficulties and make them concern only a minimum staff.

1.6. - Capacity

Automation allows the possibility of maintaining very short intervals between trains, and consequently a maximal capacity for a line, during long periods, which it is difficult, and at least very stressing to realize with drivers.

This is the main reason why the Paris Metro Authority (RATP), like many others in the world, adopted an automatic driving system in the sixties. This is also the reason why the RATP presently is fitting one of its regional lines with automatic driving, with the objective to operate this line with 2 minutes intervals in station, and 1 minute intervals between stations.

Automation is the unique way of realizing, during long periods, and without risks of instability such intervals as those realized on the following unmanned systems :

Airtrans	:	30 seconds
Morgantown	:	15 seconds
VAL (Lille)	:	1 minute

2 - COST-BENEFIT EFFECTIVENESS OF AUTOMATION

If fully-automated systems provide a great improvement of the quality of service, it is interesting to assess the price to pay for that. Unfortunately there exist very few references on this subject, due probably to the difficulty of such an assessment.

A first approach may consist in comparing the cost of different existing systems, at different levels of automation. The results are in general very disappointing, due to the fact that two transportation systems in two different towns are rarely comparable, and they must be interpreted very cautiously.

A second approach may consist in assessing, on a well-defined line, the cost differences between two different modes of operation. This method is certainly more reliable, but needs also some precautions, because, as it has been shown before, the interest of automation being to allow a better quality of service, it is rarely realistic to suppose that man-driven system might be operated with exactly the same performances as an unmanned one. On the other hand it is difficult to assess the patronage increase that an improvement in quality of service may produce.

We will briefly try both these approaches.

2.1. - Global comparison of the staff productivity in different metropolitan networks

Already in 1976, in the report (1) of OTA an analysis of the ratios operation cost/vehicles x miles and staff/vehicles for different American networks with different levels of automation had shown that a certain amount of automation lead to a significant, although limited, reduction of the staff.

We have made a similar exercise with the 1983 world statistics of UITP (6) with which we have compared the 1985 data of VAL (which opened in mid-1983 only).

The results are illustrated in fig. 7 where we have represented for different one-line networks, and for three networks in capital cities, the ratios :

. staff/million vehicle x km
. staff/million transported passengers.

When looking at these graphics, it appears :

- first of all that these ratios present a great dispersion due to the reason already mentioned ;

- secondly that the manpower productivity is much greater on an unmanned line like VAL than on more conventional lines or networks.

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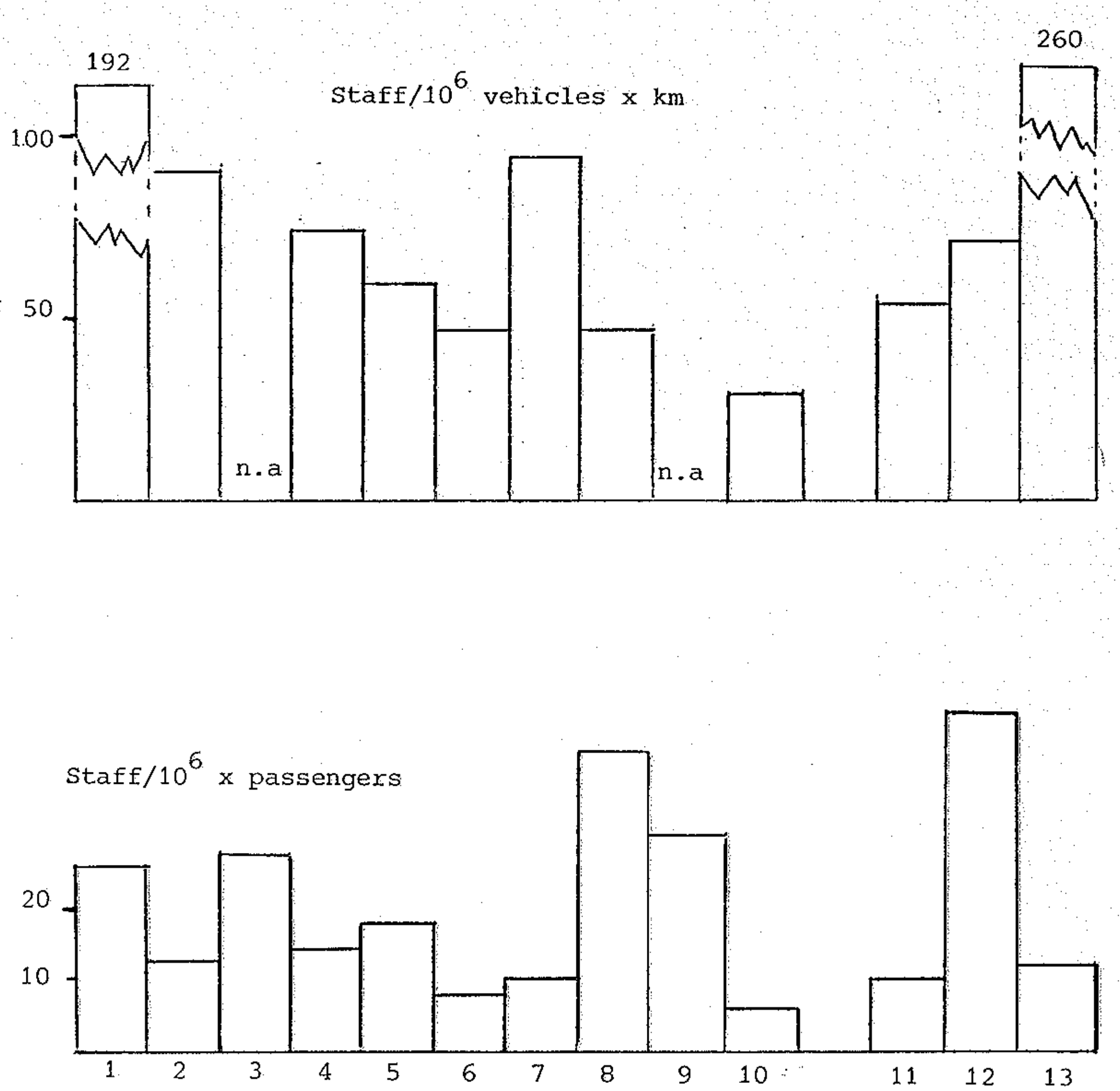

1 - Bruwelles
2 - Marseilles
3 - Glasgow
4 - Newcastle
5 - Oslo
6 - Rotterdam
7 - Amsterdam
8 - San Francisco
9 - Philadelphia PATCO
10 - Lille VAL
11 - Paris
12 - London
13 - West Berlin

Fig. 7 - Staff productivity criteria

2.2. - Detailed analysis of the cost-benefit effectiveness of unmanned driving

Among the few studies made on this subject, we can mention :

2.2.1. - A study on VAL line in Lille

A study was made in 1975 in Lille comparing the cost-effectiveness of two different possibilities for the line n° 1 :

- the use of the conventional pneumatic rolling-stock MP 73 of Paris Metro,
- the VAL system.

This study which showed that the choice of VAL could lead to annual savings of about 30 % of the total operation cost was a key factor in the decisions process concerning the Lille Metro.

2.2.2. - A study on Kobe KNT Line (3)

The authors have tried to assess the effects on the financial balance of the line of the suppression of the drivers, and of the station staff permitted by the presence of platform doors, these effects being partially compensated by the necessity to provide more intervention patrols.

It results from this study that the benefit of automation amounts to 4,65 billions yens (30 M$) over a 17 years period.

2.2.3. - BMFT study (17)

The German Research Ministry (Bundes Ministerium für Forschung und Technologie) has financed recently an assessment of the cost-benefit effectiveness to different level of automation on the line 2 of Hamburg Metro.

The calcultations show that, compared to a conventional system, over a period of 20 years, an unmanned system generates a benefit of 440 000 DM (220 000 $) a year including 15 % spares on energy.

The other levels of automation do not generate any benefit.

2.2.4. - French study on the Lyons Metro

In France, a study has been made last year to assess the benefit of operating the Lyons line n° 4 completely unmanned. It results from this study that for an additional investment cost of 180 MF (27,6 M$), unmanned driving could save 9,6 MF (1,47 M$) a year.

This assessment is less positive than those we mention before, because the Lyons Metro decided to automate its line 4 a long time after it ordered the rolling-stock and the civil works on the assumption of a manned system.

Consequently the savings in rolling-stock and civil works could not match in this case the additional cost of automation.

Despite this handicap, the Lyons Metro decided to automate the line n°4.

2.2.5. - Evolution of the cost-benefit balance with the size of the fleet

It is interesting to note that, if we consider a system with a certain fleet of trains, if we increase or decrease moderately this fleet, only certain factors are changing in the investment and operation costs which are sensitive to automation :

- the investment costs of the on-board automatic driving systems,
- the salaries of the drivers for manually driven-systems,
- the control and intervention personnel,
- the maintenance costs.

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It can be ascertained that, due to the weight of the drivers salaries, the variation rate of these factors with the number N of vehicles in the case of an unmanned system is about half the corresponding rate for a manually driven system.

The graphic fig. 6 illustrates this and shows that the cost-benefit effectiveness of unmanned operation grows with the size of the fleet, that is to say with the trains frequency on the line.

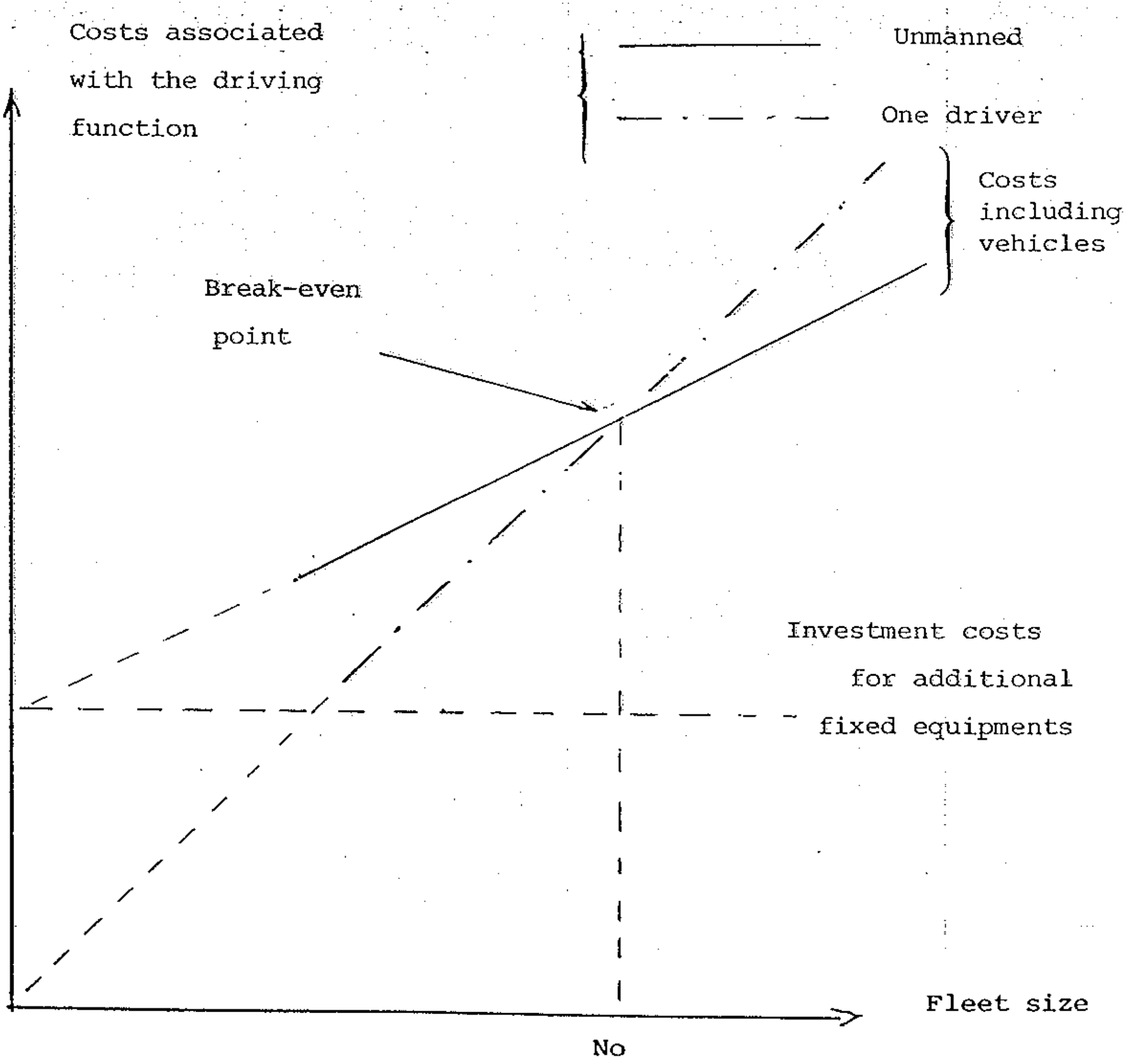

Fig. 8 - Effect of the fleet size on the cost-benefit effectiveness of automation

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2.2.6. - Energy and maintenance savings associated with automated driving

One of the main interests of unmanned driven systems, which has been clearly demonstrated for instance in Lille, is to allow at a moderate cost the operation of the trains with a good frequency even at off-peak hours.

However, in order to alleviate this cost, and obtain some energy and maintenance savings, it may be interesting to modulate the length of the trains according to the traffic.

Supplementary investments		
- Rolling stocks	:	21 MF
- Fixed equipments	:	2 MF
- Studies, engineering	:	7 MF
TOTAL	:	30 MF
Savings on operation costs		
- Energy savings (30 %, or 7.10^6 kWh)	=	2,036 MF
- Maintenance	=	1,260 MF
- Supplementary manpower (for manoeuvers)	=	- 0,3 MF
TOTAL SAVINGS/YEAR	=	2,996 MF

Fig. 11 - Lyons Metro - Savings due to operation with variable length trains

For instance a study on the line 4 of Lyons Metro has shown that the possibility of operating the line with 4 vehicles-trains at peak hours, and 2 vehicles-trains at off-peak hours could lead to energy and maintenance savings of about 2 MF (300 000 $) a year (fig. 11).

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3 - ACCEPTANCE OF UNMANNED-DRIVING BY THE USERS

At the beginning of the seventies, some fears were expressed concerning the effect of unmanned driving on the users behaviour.

These fears appeared very exaggerated when the first automated systems appeared in the American airports and exhibition parks.

They have been completely cleared these last years after the opening of the first fully-automated mass transit systems in Lille, Kobe and Osaka.

Firstly it appears clearly that the number of vandalism acts or of agressions is not higher than in the manually-driven systems due to the effectiveness of the CCTV surveillance network in the stations, and of the good phone communications between the PCC, the cars and the stations.

Secondly, the users have a good appreciation of this mode of operation : this is confirmed by the fact that more than 350 million of passengers have been carried up to now on unmanned systems. This is confirmed also by some studies made on this subject :

3.1. - In Lille, an enquiry has been made in 1984 among 1500 VAL users, in order to assess the effect of the various technological innovations of this system on the public.

People were asked to range these innovations according their importance.

The results show that the users ranked very highly the following innovations :

- the high speed of vehicles,
- the platform doors.

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Then at third and fourth rank :

- the accessibility of the vehicles with their floor at the level of the platforms,
- the possibility of communicating with the PC.

Curiously, the absence of driver was ranged in the last rank by 63,5 % of the sample.

This enquiry showed also that 94,6 % of the users have a good safety feeling in the VAL.

3.2. - A similar enquiry has been made in Kobe (3)

In this city, unmanned driving was adopted on the KNT after two phases during which a man was present in the vehicles.

Three successive enquiries were made during these three phases. They have shown that the appreciation of the system by the users is rather independent of the mode of operation.

4 - CONCLUSION

This paper shows that unmanned operation of urban public transport systems presents a lot of positive aspects which can be of value for industrial countries as well as for developing countries.

For developing countries, which are characterized by very large cities with a great demand for public transports, we can underline, among these positive aspects, the following ones :

- the facility of adaptation of a line to different configurations in economic conditions with a sizable improvement in the quality of service,

- the cost-benefit ratio which is obtained and which is maximal for lines with a great demand and a great frequency,

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- the excellent safety level of automated system, which cannot be obtained by manual driving.

Moreover it is worth noting the reasons why cities like Toulouse, Strasbourg and Bordeaux have preferred the VAL system to the heavy metro :

- better availability, flexibility and safety during peak and off-peak hours,

- lower investment and quickest construction and commissioning because of lighter infrastructure,

- assurance of breaking even between the revenues and the operation and maintenance of the VAL system, saving therefore the annual subsidies which they would allow for a heavy metro.

The same reasons will be even more decisive for the developing countries when they select their transport system.

Consequently, whether in industrial or developing countries, the unmanned systems will become more and more the transport mode of the future.

BIBLIOGRAPHY

(1) Automatic Train Control in Rapid Transit.
Rapport OTA - United States Congress - May 1976

(2) Assessment of Six Domestic Automated Guideway Transit Systems.
W. SIDDIGEE and H.D. EVOY
AGT Conference - Cambridge (MA) - 1978

(3) Kobe New Transit System "Portliner" - Experience of Unmanned Operation.
T. OKADA
ASCE Conference on "Automated People Movers" - Miami - Mars 1985

(4) Downtown People Mover - Operating and Maintenance Personnel Requirements.
D.J. OCHSNER and H.L. MOORE
ASCE Conference on "Automated People Movers" - Miami - Mars 1985

(5) La qualité du transport urbain.
P. ESSIG
Revue Générale des Chemins de Fer - Avril 1984

(6) Les métros dans le monde.
UITP - 1983

(7) The Possibility of People Mover Cost Reduction in Japan.
Y. TSUKIO
ASCE Conference on "Automated People Movers" - Miami - Mars 1985

(8) Assessment of the Phase I Morgantown People Mover System.
Report n° UMTA-IT 06-0157-79-01 - December 1979

(9) Toward User-Oriented Failure Management Strategies for the Morgantown People Mover.
E.S. NEUMANN and Al
ASCE Conference on "Automated People Movers" - Miami - Mars 1985

.../...

(10) Airtrans System Maintenance.
P.A. SLOBODA
ASCE Conference on "Automated People Movers" - Miami - Mars 1985

(11) L'expérience de la RATP en matière de commande automatique du mouvement des trains.
J. MAJOR et Al
Symposium IFAC/IFIP/IFORS Control in Transportation Systems - Versailles - 1971

(12) Evaluation de l'automatisation intégrale de la ligne D.
Rapport SEMALY - Mai 1985 (non publié)

(13) Assessment of Operational Automated Guideway Systems - Airtrans Phase II.
Report UMTA-IT 06-0157-79-06 - January 1980

(14) Lille DPM System and VAL Family.
S. MIMOUN
ASCE Conference on "Automated People Movers" - Miami - Mars 1985

(15) VAL Automated Guideway Transit : Three Years of Revenue Operation.
B. LE COUR GRANDMAISON
UTA 81th Annual Meeting - Vancouver - June 1986

(16) Effets sur la clientèle d'un changement de l'offre dans le domaine du transport collectif urabin de voyageurs - Le cas du VAL de Lille.
Thèse USTL - O. HEDDEBAUT-GABILLARD - Septembre 1985

(17) Nutzen- Kosten Untersuchung zum Prozeszrechner gesteuerten U-Bahn Automatisierungssystem Hamburg (PUSH)
D. WIRSCHING and Al
Nahverkehrsforschung 85

(18) Les systèmes nouveaux de transport au Japon. Rapport de mission.
P. PREVOT - Rapport INRETS-CRESTA - Janvier 1985

.../...

(19) Bilan global technico-économique des rames scindables.
Note interne SEMALY - Février 1985 (non publiée)