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Between bus and light rail, emergence of intermediate urban systems

Abstract :

The concept of intermediate system has to be considered in relation with the search for a good compromise between advantages and inconveniences of bus and subway. A system supplying a quality of service close to the subway' s one, but allowing a spatial cover less costly and a larger flexibility and adaptability of the offer to demand, corresponds to an important market that does not justify a large capacity system such as a subway. The concept of rubber-tyred intermediate guided transit system appeared as an attractive means to combine for the medium importance projects, the qualities of the light rail transit with the economic benefits of the road systems, to achieve in some manner a light rail system at the best cost. The first assessments showed that it is possible to achieve 30% of a standard light rail investment cost adopting such a system. This paper deals with analyzing the buses, trolleybuses and guided vehicles intermediate systems field of application. We describe in a first part, the industrial offer of rubber-tyred systems and streecars and in a second part we analyze the applying domain with benefits recalling the inherent qualities of tyre, and limits of these systems. At the end, we analyze research and development which could lower the cost and we consider the intermediate system capacities : we always keep in mind that transit project costs are in relation to the transit offer.

Key words : bus, trolley bus, rubber-tyred guided systems, streetcar, light rail transit, bimodality, cost reduction, intermediate system capacity, guidance devices.

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Over Head Projector

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Between bus and light rail, Emergence of intermediate urban systems

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Field Code Changed

1. INTRODUCTION

Since the beginning of the seventies, following a long delay, urban public transit began a new development in France, notably owing to a new financing "Versement", an employer's tax[1] that allows investment in particular for dedicated right-of-way public transport systems[2]. As a result several lines went into revenue operation: Lyon, Marseille, Lille, Toulouse and Rennes subway lines and the Nantes, Grenoble, Bobigny–Saint Denis (Paris), Trans Val de Seine (Paris), Strasbourg, Rouen, Montpellier, Orleans and Lyon modern tram lines.

In numerous other cities like Bordeaux, Caen, Clermont Ferrand, Mulhouse, Nice and Valenciennes, the Organising Authorities for urban Public Transport imagined such systems would solve the problems of congestion for a long time in the city centres.

These systems are supplying a good service quality, they are relatively expensive and their productivity is only adapted for areas which are dense enough. Most French large cities are today equipped with one or several Separate Right of Way (RoW)[3] Public Transport lines, but networks must still be completed and urban transport services still need to extend to the medium size cities of 200 000 inhabitants and less or in the periphery of the large cities.

Is it possible for an urban transport system to offer a good compromise between advantages and disadvantages of bus and subway ? The concept of intermediate system formed itself around this question : to conceive a system supplying a quality of service close to a subway, but less costly and

[1] This transportation tax paid by a majority of the employers has been one of the main sources of finance for public transport over the last twenty years.

[2] Dedicated right of way public transport systems or Separate RoW Public Transport System

[3] RoW : Right of Way

with greater flexibility. A system such as this could serve an important market that does not justify a large capacity system such as a subway. (Clement, 1995)

2. THE INTERMEDIATE SUPPLY

First of all, we point out that two main logics of operating urban transport networks coexist in metropolitan areas of sufficient size :

- High passenger volumes : systems like subway and modern tram have an objective to operate transit system in a high capacity corridor ;

- Diffuse passenger volumes : the objective here is to irrigate in a fine way to serve eccentric areas with bus running with ordinary traffic.

Between these two extremes, is there any place for an additional level?

This question leads us to the concept of an intermediate network which would increase the networking of the global network by offering more direct and alternative links to the customers but would lead to an increase of the transfer rate.

The development of new systems which could specifically correspond to the needs of intermediate network has been launched for several reasons :

- Orientations aroused by the State : the National Research and Innovation Program in Public Transport, the help of the Land Transport Directorate in Transport Ministry to the Organising Transport Authorities by subsidies to infrastructures of Separate Public Transport projects including the bus systems, the preconsultation under the aegis of Land Transport Directorate and the Greater Paris Transport Authority of a new small gauge rubber-tyre electric transport system (STEP) on the basis of specifications that recommended a cost of the offered space 40% lower than the Standard French Tramway System vehicle space, and the 1996 air law making compulsory the Urban Mobility Plan for conurbations of 100 000 inhabitants and more.

Additional needs include :

- The local collectivity needs as regards systems with investment and operating costs lower than those of the modern tram ;

- The goals of operation flexibility, of better integration in urban environment such as historic centres, of comfort, of accessibility, of environment respect, of adaptation to the diversity of urban shapes. (Poyer *et al*., 1999)

- The demand of todays and future users : the preferential demand concerns frequency improvement, timetable observance, new lines. The users would choose urban transport only if they are practical, fast and reliable because they almost always have the possibility of a modal choice by using their car to make urban trips. They wish to be carried in better conditions than those offered currently on most bus lines.

- The new technologies development : a system approach has prevailed in the research and development of manufacturers for intermediate network new vehicles, integrating the investment, maintenance and operation preoccupations since the beginning of the research process.It should ultimately be possible for the life cycle cost to be announced with the invitation to tenders " system ".

3. THE INTERMEDIATE SYSTEMS FIELD OF APPLICATION

3.1. Bus

The bus remains the most widespread means of urban public transit in the world ; with a flexible implementation, it can adapt itself well to the modifications of demand structures. Its advantage of flexibility, and easy adaptation to streets with mixed traffic can be transformed to an inconvenience if decision-makers do not take necessary measures (separated tracks, traffic light priority, adapted stops) to insure its efficiency. Facing the levels of demand of the third-world cities, the articulated bus and the bi-articulated bus or megabus (under operation in Curitiba and São Paulo) reply to superior needs of capacity. Nevertheless, to reach the Curitiba road transit system capacities, it is necessary to have a specific infrastructure, that is to say a separate right-of-way, and specific arrangments to boarding. (Kühn, 2000)

The rolling stocks of bus type are under study and important developments : they improve low floor realization by means of wheel-motors, propulsion with the gas or the aquazole, motors diesel combustions considering Euro 3 norm adopted for the year 2000 and Euro IV for the year 2005.

3.2. Trolley bus

Till the end of the fifties the trolleybus experienced a particular acceptance worldwide and especially in the Anglo-Saxon countries. It replaced the tramways because the rails did not have to be renewed, because extensions of the routes were possible at much lower costs, and because it drove more rapidly and more quietly, which meant that it was more attractive to the passengers.

As from the middle of the fifties the trend changed. In Germany trolleybuses were operated in about 70 towns and cities, most of them until the late sixties. Today a total of 91 vehicles are operated only in Eberswalde, Esslingen and Solingen. Although the trolleybus has a better accelerating power, has no local exhaust emission and is quieter than a diesel bus, the system was given up in many places without protests worth mentioning.

There are somewhat more than 40,000 trolleybuses in the world today, distributed in 356 cities all over the world. The largest fleets being located in Russia, in Ukraine and in China with respectively 34%, 18%, 12% of the whole of the world fleet. (Rogers, 1997)

The trolleybus survived in five French cities : Lyon, Marseille, Saint Etienne, Limoges, and Grenoble; it has been reintroduced in Nancy in 1982.

Besides the advantages of the corresponding bus, trolleybuses running on electricity benefit from assets peculiar to that mode of traction : absence of pollution, low-noise, comfort, power..

As regards performances, speed and capacity are almost the same as those of the standard and articulated bus. Nevertheless, on a hilly profile and in altitude, the trolleybus gets some superior kinematics performances.

The price for a trolleybus, which is 50 % higher than the price for a standard diesel bus, is explained by the low numbers of trolleybuses in a series. It should, however, also be considered that a trolleybus is usually operated for 15 to 20 years and a diesel bus only for 10 to 14 years.

3.3. The rubber-tyred guided systems

The concept of rubber-tyred guided intermediate urban transport systems covers a large diversity of industrial sectors to very various development levels. These include :

- A bus or trolleybus guidance system

The O-Bahn system developed by Mercedes Benz has been under operation in Essen since 1980, Mannheim and Adelaïde since 1986. The Spurbus system of Daimler-Benz and M.A.N. in Essen, represented at the operation beginning 60 guided buses with lateral mechanical guidance including 18 buses articulated dual-mode which ride on 8,9 km of equipped line. In Adelaïde, 12 km of a line equipped on complete separate right-of-way has been constructed to link the northeast suburb to the city center : the choice took place in favor of the 0-Bahn because of its lower cost compared to the light rail cost and the reduction of the interchange points number for the bus users.

Two guided bus systems have been developed in Japan : the Dual Mode Bus System (DMB System) the guidance system of which is similar to that of the Spurbus or O-Bahn system and that concerns rapid services at reduced frequencies and slight capacity, and the Guided Bus System (GB System) that concerns more classical services of improved bus type, the guidance system of which consists in four little wheels by axle. The tracks of these systems are located on viaduct because of a lack of space which leads to relatively high investment costs. A first project of 6,5 km on the Shidami line to the North East of Nagoya is under operation since 1999.

The Trackline of Birmingham : a partially guided bus line (600 meters) along the line 65 was under operation from 1984 to 1987, with “double deckers” laterally guided. The organizing transport authority, West Midlands Passenger Transport Executive (WMPTE) chose a light rail project which stopped this experience in spite of the good results of this operation.

The STREAM system (a dual-mode bus or trolley vehicle developed by Ansaldo) is under experimentation since 1999 in Trieste on a 3,3 km line with a 12 meters long vehicle and a 18 meters long articulated vehicle, in sight of being under operation from 2001. The electric propulsion comes from battery or by collecting power from the track. Collecting current is made by electromagnetic activation of an electric contact line embedded in the roadway and supplying power. Power system consists of an electric contact line embedded in a roadway which has been adapted for urban purposes as the contact line is under voltage only beneath the vehicle. This collecting is adapted to urban insertion. A lateral magnetic guidance system associated with the collecting device has been tested but it is not foreseen for now in Trieste.

The Cegelec-AEG wire guiding system (guide inductive cable) used in the Channel service tunnel and on a test track in Newcastle, was considered for the Millennium shuttle in London.

- About guidance devices for specific vehicles

The Guided Light Transit [4] (Kühn, 1987) or Separated RoW Tramway guided by means of a single central rail has been developed by Bombardier and tested on an experimental site, the Trans-Val-de-Marne, in the southern suburb of Paris, in 1998 ; it has been chosen for the future Separate RoW Public Transport of Caen and for the Nancy dual-mode trolleybus system substitution where the new system will be under operation in September 2001.

From the choice of this system by the City of Caen, the manufacturers Bombardier - ANF and Spie-Énertrans developed the GLT becoming TVR [5] easily accessible with its low floor, dual-mode diesel-electric, which can be either guided with the central rail or autonomous as rubber tyred vehicle. Under every axle there is an arm, on which are fixed two vertical rollers, located before and behind the axle, that follows the rail and drive the wheels by means of rods. The arm can either be brought down or raised by means of an hydraulic jack : to introduce these vertical rollers on the rail, it is necessary to put the vehicle in an introducing zone, that features a V shape switch or dropping place.

This vehicle is monotrace. It is not a super trolleybus since its body, born from the new tram 2000 of Brussels, is a rail rolling stock's one; since it is electrically supplied by a pantograph power collector ; and since it includes three articulated bodies, with a total 24,5 meters length. It can roll to 70 km/h and can climb 13 % maximum gradient, enter in a 12 meters minimum curvature radius while the trams enter in 15 to 20 meters minimum curvature radius according to the track gauge.

The TRANSLOHR system is developed by the Lohr-Industrie manufacturer associated to Fiat-Ferroviara manufacturer. The first prototype circulated on the Trans Val of Marne site, south of Paris, the first quarter 2001.

Lohr-Industrie proposes a rubber - tyred guided trams range. The vehicle is guided by a single centrally embedded rail on a guideway. Every axle is equipped with a guidance device composed of two rollers in V fixed on a swiveling arm. The vehicle is monotrace. The main product is the tram TRANSLOHR STE with permanent guidance, derived from the new small gauge rubber-tyre electric transport system STEP concept. There are three, four and five bodies vehicles[6] ranging in length from 25 metres to 39 metres. Their body gauge is 2,20 meters. These vehicles are easily accessible with a 0,25 meter low floor (above the ride level), always guided vehicles, they have an electric

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[4] Guided Light Transit presented by Brugeoise & Nivelles during the 1985 UITP Conference in Brussels
[5] TVR : Transport sur Voie Réservée, Separated RoW Tramway
[6] Called Translohr STE3, STE4 or STE5

traction, supplied in electric energy by catenary and battery for the circulation in the depot – workshop.

A bimodal version has also been studied : TRANSLOHR SE (the vehicle is able to leave its rail everywhere as to continue in truck driver mode) for the experiment on the Trans Val de Marne site (South of Paris).

The CIVIS system (bimodal vehicle with a disconnectable guidance device) has been developed by the manufacturers Renault Véhicules Industriels[7] and Matra Transport International . It will be under operation on a Clermont Ferrand line in 2001 with a simplified version. The manufacturers propose vehicles of 18 or 19,5 long range, with a 2,60 meters gauge and an electric or diesel electric traction. Vehicles of 12 m or 24,5 meters are theorically possible, but their interest is not so obvious. With an operation autonomy, on rubber-tyred wheels and a first axle steering linked to a video-monitoring system and a road marking recognition system where it is necessary (in station and in a reduced separate right-of-way at high speed), the Civis vehicle is never monotrace. Everywhere, this system can be operated on a busway whithout particular guidance device. At high speed, with restricted gauge road, if the vehicle is guided, the optical guidance should be duplicated by a safety lateral guidance (mechanical kerbs).

Technical conclusions

For these systems we find varied and innovating technical solutions, for the guidance :

- Lateral kerbs and side rollers (O-BAHN)
- An optical guidance (steering linked to a video-monitoring system and a road marking recognition system : CIVIS of Irisbus and Matra Transport International,
- A single centrally embedded rail (of tram type) with disconnectable steering bogies (GLT) or arms supporting tilting rollers in V form (TRANSLOHR),
- An inductive cable guidance system (electronic steering by means of inductive cables embedded in the roadway) (Cegelec-AEG system),
- A magnetic guidance system under design (magnetic steering servitude to an electric cable embedded in the roadway) which has been envisaged for STREAM.

The different vehicles have an ordinary electrical supply and either an internal battery or a thermal generator. Nevertheless we note the constructors' own characteristics :

- The TVR and the TRANSLOHR can both run on a single wire light electric supply of the tramways type as the return current travels via the guiding rail,
- The CIVIS uses electric wheel motor, which means an integral low floor between the wheels,

[7] now IRISBUS

- The STREAM power system consists of an electric contact line embedded in a roadway which has been adapted for urban purposes as voltage is only achieved beneath the vehicle.

3.4. The rail systems

The streetcar

Identified to the urban developments of the end of the industrial revolution era, the tram pursued its development in a sustained manner until beyond World War I before the automotive phenomenon occurs. Riding on a shared right-of-way, it endured traffic obstructions and an investment lack very quickly, it has been replaced progressively by the more flexible bus, except in the Swiss, German cities and the countries of the Eastern Europe, that were more favorable to its resurgence than the other european and north american countries. (Kühn, 1987)

This renewal resulted in a rolling stock integrating the last improvements of the railway technique and the putting in separate right-of-way to change this effective surface transit system.

A research and development program of an intermediate transit system on rail has been undertaken by Alstom in the frame of the National Research and Innovation Program in Public Transport (PREDIT) on the basis of Citadis trams line currently put into operation in Dublin, Montpellier, Orleans, Lyon networks and ordered by Bordeaux, Valenciennes networks, for the future, etc.. The objectives of this program are :

- To reduce one kilometer investment cost of tram project (including infrastructures, energy supply, rolling stock, workshop and engineering) to less than the present figures. Experts judge that the 50 MF or 7 M US$ figure announced were ambitious.

- To reduce in a significant manner the operating cost to 40 % of the Standard French Tramway maintenance cost.

- To enter in the potential intermediate transit market and try to compete with the rubber-tyred systems, this market being those of 100 000 to 300 000 inhabitants cities.

The main stake of the intermediate transit system on rail project is to manage the life cycle cost of the system during its life duration. This project keeps for the rolling stock geometry and the modularity of the Citadis range.

4. APPLYING DOMAIN : BENEFITS AND LIMITS
4.1. Benefits

The concept of rubber-tyred intermediate guided transit system appeared as an attractive means to combine for the medium importance projects, the qualities of the light rail transit with the economic benefits of the road systems, to achieve in some manner a light rail system at the best cost. The first assessments showed that it is possible to achieve 30% of a standard light rail investment cost adopting such a system.

As for the streetcar, the guidance device of the intermediate guided transit systems on tyres offers several advantages, among which we can note :

- makes easy, to some degree, the manufacturing of larger capacity vehicles than buses,
- encourages the separate right-of-way insertion while reducing the land needs,
- assures an optimal link between platform and vehicle in the stations.

Indeed, the guidance device permits the right-of-way to stay within the limits of the dynamic gauge of the vehicles to which are added a protective air space. It facilitates the insertion of the transit system in the historic city centers, the space spared, compared to that of bus right-of-way, facilitates the improvement of the other uses of the street (parking, sidewalk, bicycle path..) or its embellishment.

The vehicle gauge becomes more and more coercive in the large conurbations, because of the increasing congestion : the guided bus authorizes a reduced right-of-way area to around 15 to 20 % of the necessary bus right-of-way where the buses are operated through a standard traffic considering the dynamic gauge and the necessary protective air space. The choice of a public transit system on Separate RoW considering a surface separated from general traffic right-of-way, the most reduced right-of-way assert itself for a better insertion on the definitive road network (especially if it must go through the centre) and for a reduction of the nuisances of the public works yard (disruptions to residents).

The vehicle guidance allows us to reduce the surface allocated to the system. The guidance also allows a better accessibility while suppressing the gap along the station platforms and a better vehicle stability and a better general comfort for the users.

The railway type guidance device of the intermediate systems (TVR, TRANSLOHR..) allows us to use an electric supply of light rail type and even to constitute large capacity trains (TRANSLOHR STE version).

Under commercial operation two concepts are proposed :

- The use of the guidance device along the total ride. In this case, the intermediate system is under operation like " a light rail transit on tyres ". The scheme of Caen GLT has been designed on this principle but keeping a bimodality for degraded conditions. On the contrary, the Translohr STE did not keep the guidance bimodality that allows to choose larger vehicles length and as a result, allows also a narrower gauge (2,20 meters) to facilitate insertion.

- A mixed ride along a guided separate right-of-way and along a road separate right-of-way, or even along an ordinary road network : the Nancy scheme is designed under this principle. (Debano, 1999)

The guidance in station facilitates an easy and fast transfer between the platform and the vehicle and the quality of the service thanks to a reduced gap between the edge of platform and the floor of the vehicle : the disabled persons with reduced mobility and child stroller access becomes easier.

Quality surface facings can be realized on the tracks like for light rail transit.

The intermediate guided on tyres system track creates a trace in the city that reinforces the legibility of the system and stimulates its use.

The intermediate system uses a non polluting energy, with a high efficiency and a supply device that can become very discreet.

The vehicles are innovating, often personalized and bring silence and comfort of ride, they show a progress in relation to the very ordinary design of buses.

The rubber-tyre guided intermediate systems benefit from inherent qualities of the tyre notably the adhesion that gives them, e.g. the performances superior to iron in emergency braking and to climb elevated slopes .

We recall the inherent qualities of the tyre below :

- Absence of vibrations : on the subways and the trams arranged tracks, the tyre, thanks to its structure and absorption capacities, transmits few vibrations to the environment, contrary to the steel wheel.

- Adhesion : thanks to an elevated adhesion coefficient tyres permit going over elevated slopes (until 13%, the limitation is due to standing passengers comfort) whereas steel wheels vehicles cannot ride on gradient slopes superior to 7 % without motorization of all the axles. The adhesion of the tyre reinforces the users and pedestrians safety, as reducing the emergency braking distances what allows to operate very short intervals vehicles if necessary

- Comfort of the user, respect of the environment : on straight line and, more again, in curve, the tyre proves to be less noisy than steel wheel. This advantage increases with the vehicle and track oldness, notably in curve where the strident grating of steel wheels on the rails becomes unpleasant for both passengers and residents.

- Maneuverability : with a superior handle capacity compared to the steel wheels vehicle's one, a vehicle on tyre can change direction more easily. The use of tyre for tram rolling stocks allows to reduce from 18 to 12 meters curvature radius. It permits a better insertion in often crowded city center. The terminals can be achieved in loops because of the small necessary area due to the small curvature . The loop terminal allows us to reduce the number of doors to only one facade of vehicles and only one cabin. Also, if they are bimodal, the vehicles on tyre can evolve outside of the tracks and can reach the garages and workshops without particular infrastructures.

The tyre allows to achieve infrastructure savings. (cf. chap.5.3. following).

4.2. Limits

Operating in small density areas, vehicles invesment cost of which is equivalent to that of several standard buses cost, with a small rate occupancy, with a diesel motor conceived for exceptional use, on an urban roads whose surface presents numerous imperfections, could give prohibitive operating cost for carried passengers.

When a transit network defines the operating constraints of its future intermediate network, it should try to avoid a too large number of functionalities dragging too complex systems with radically new technical choices. On the same idea manufacturers should not forget to keep in mind the attractive cost objective for the whole system life cycle cost during all its life duration.

5. THE SEARCH FOR COST SAVINGS

5.1. The modularity

A real revolution appeared in the vehicle design : standard modules available "on the shelf" are gathered according to the customer's desire, that is to say an organising authority confronted to particular physical, technical and economic constraints. The use of components and facilities standards minimizes the costs and reduced the delivery times, without restricting the choice of it.

We can mention for the modular trams Bombardier's City Runner, the Siemens Combino, the Alstom Citadis and the AD Tranz Variotram. The manufacturer Lohr-Industrie proposes a small gauge tram on rubber-tyres in several versions. Bombardier proposes the Guided Light Transit GLT becoming the TVR choosen by the cities of Caen and Nancy, of modular construction, whose structure is born of the Brussels tram 2000. Some elements, as the technical modules, will be common to the other vehicles developed by Bombardier, specially the new Brussels and Köln trams.

The Alstom Citadis range is of a modular design, it declines itself in several widths and lengths. By assembling the basis elements (carrying, motor or suspended) the Citadis range can evolve from a version 202 (22 meters long) to a 602 version (60 meters long).

The Civis, intermediate transit system, uses the guided articulated and electric road vehicle of Matra and Irisbus, born of the bus of the future, (diesel-electric, or modern full low-floor trolleybus). This vehicle uses electric wheel motors supplied by collected electric energy or by an internal combustion motor and a generator. Many components are used on the three types of bus, specially the wheel motors, which is favorable to the large-scale effect and therefore to the cost decrease.

One manufacturers objective is the specific energy consumption reduction (by unit of weight). Among several possibilities of savings, one can mention the use of components[8] that makes the use of electric supply more efficient.

[8] E. g, IGBT : Insulated Gate Bipolar Transistor

5.2. The components born of the road vehicles

Several bus manufacturers move toward the diesel-electric bus, equipped with a generator transversely located at the rear of the vehicle and with electric motorization of the wheels. Tomorrow's trolleybus will be a full low floor. Its purchase cost today, two times higher than the standard bus cost, could be close to the future bus cost, if we exclude the specific facilities (trolley poles, auxiliaries, switches, etc.) that represent 20% of the global cost. Thanks to the subsets use, the TVR will also benefit, of the technological evolution consecutive to the bus diesel-electric manufacture. The ratio between the trolleybus offered space cost and the GLT offered space cost is in an order of 1 to 2, whereas it should decrease.

5.3. The infrastructures

A large part of savings announced by the arrival of the new intermediate systems on the market depends on the infrastructures. Three types of direct cost reduction can be obtained in the case of the tram on rubber-tyres :

- First, the most favourable design of structures as regards fatigue, that takes into account the lightness of the axle load and the number of axles passage during the tracks utilization ;

- Then, considering the light pavement thickness necessary in front of the calculated traffic, the possibility to keep transverse supply networks under the tracks, but also longitudinal networks if one protects them against leakage currents ;

- Finally, in some cases, the use of bimodal vehicle allows to go to the garage-workshop, located far enough from the line terminus, along the existing road network, and to use a bus extended depot without putting switches on the tracks and supply catenaries, the vehicles being able to circulate with batteries or a thermal motor foreseen in the bimodal vehicle.

In the case of the light rail transit, the first two factors of cost reduction are possible. The third type is only partially feasible, if it is necessary to construct a railroad track until the garage that could be an extended bus depot in which there are no catenaries. The light tram can be equipped of an autonomy consisting in embarked batteries or other devices, that it will use otherwise if there is a current breakdown ; the electric supply design will be able to be calculated thus with this constraint, without redundant electric substations, with an objective of cost savings. (Soulas, 2000 a)

Thanks to vibration lack, it is possible to suppress or to reduce the different elastic levels necessary to absorb noise and vibration in the case of a railroad track passing close to dwellings, hospitals, offices, etc. Otherwise, the reduction of the pavement thickness structure permits us to maintain some supply networks under the track, the cover on these pipes or cables being sufficient during the earthworks and therefore when the Separate RoW Public Transport system is under operation. The absence of vibrations reduces the track maintenance expenses and decreases the mechanical solicitations and the vehicle mechanical ageing.

The road technique used for the Separate RoW Public Transport System pavements realization allows us to get some competitive realization costs while opening the calls of offer to the numerous specialized road construction enterprises.

It is possible to adopt a more hilly profile and therefore more inclined slopes and shorter curvature radius which encourages the insertion of the separate right-of-way in urbanized areas and reduces the earthworks volumes and pavement construction.

The light rail transit investment cost (100 to 150 MF/km or 13,5 to 20 ,3 MUS $/km) can appear excessive in the case of projects intended to serve limited passenger volumes (1000 to 2000 p/p/h/d, what is frequently the case of medium size french conurbations projects. In spite of its saving benefit (30 to 40 MF / km or 4,0 to 5,4 MUS $ / km), the busway appears rarely like an alternative.

The buses always endure a real image deficit and the realization of the busways is not considered as a tool permitting to sufficiently improve the urban site quality. The urban insertion quality and the care brought to the intermediate system realization are not extra investments because they contribute to give to this system an excellent image encouraging its use.

6. THE OPERATION

The bimodality

a) About guidance

The intermediate system flexibility could allow a reduction of passengers transfer number : the guided mode being applied in central area on separate right-of-way, in the less dense peripheral areas the vehicle would not be guided and would ride in mixed traffic on the ordinary roads. This use flexibility of the vehicle allows us to have simplified infrastructures in the workshop without railways, switches and catenary energy supply. But we should not lose sight of the system limits (cf. §4.2.) and guidance bimodality inconveniences.(GART, 1996)

b) About energy supply

The vehicles have an electric supply of trolleybus or tram type and a second autonomous propulsion with performances which are reduced or not compared to those of the nominal electric propulsion.

7. THE INTERMEDIATE SYSTEM CAPACITY

We sum up below in the tables 1 and 2, the theoretical capacities that the operated systems with articulated bus, bi-articulated bus, the CIVIS, the TVR (GLT), the TRANSLOHR, the CITADIS range and the Standard French Tramway can supply. The surface transit systems operators generally adopt in France intervals of about 3 or 5 minutes, the theoretical supply has been calculated according to these two intervals. The unit capacity of every vehicle is displayed according to the norm of comfort of 4 p/m2. We only keep the large capacity vehicles ; nevertheless, capacity characteristics of the articulated bus and the french standard tram under operation in Grenoble, Bobigny, Rouen and Nantes appear in the tables 1 and 2.

The CIVIS system is initially proposed in a 18 meters version long ; we must assimilate its capacity to the articulate bus' one, when it will be proposed in version biarticulated of 25 meters long, its capacity will be able to be assimilated currently to the Mégabus' one under operation e.g. in Bordeaux, Curitiba, or São Paulo.

The tables 1 and 2 present the unit capacity of every vehicle provided by the manufacturers at the rate of 4 standing passengers per square meter (4p/m^2) . The number of seated spaces is located between 30 and 40% of the total capacity.

At the third line "theoretical supply ", we find the offer in passengers per hour per direction p/h/d of a line; this supply corresponds to an unit capacity of 4p/m^2.

Table1: Unit capacities of the intermediate transit vehicles and correspondent supply in p/h/d with a 3 and 5 minutes interval.

Urban Transit Systems	Interval	Articulated Bus L=17,7m	Biarticulated Bus L=24,40m	Civis L=18m	TVR L=24,50 m	Translohr STE4 L=32 m	Translohr STE5 L=39 m
Unit Capacity		97	140	120	143	156	196
Theoritical Supply	5' 3'	1200 1900	1700 2800	1400 2400	1700 2900	1900 3100	2350 3900

Source : (Kühn, 1998)

Table 2 : Unit capacities of the intermediate transit vehicles and correspondent supply in p/h/d with a 3 and 5 minutes interval.

Urban Transit Systems	Interval	Citadis TGA-202 L=22m*	Citadis TGA-301 L=29m	Citadis TGA-302 L=31,3 m	Citadis TGA-402 L=42m	TFS Grenoble L=29,4 m
Unit Capacity		142	190	204	279	174
Theoritical Supply	5' 3'	1700 2800	2300 3800	2450 4100	3350 5600	2100 3500

• These vehicles are 2,4 meters wide save the TGA 302 l = 2,65 m wide and TFS l = 2,35 m wide.

Source : (Kühn, 1998)

Rolling stocks characteristics presented above are given by the manufacturers : Irisbus for the articulated bus and the biarticulated bus or mégabus; Irisbus-MTI for the CIVIS system; Alstom for the Standard French Tramway System TFS and the CITADIS range ; Bombardier-ANF for the TVR ; Lohr-Industrie for the TRANSLOHR range.

The theoretical supplies are located in a fork whose high limit can be reached unusually at the superpeak hour with one interval of 3 minutes and therefore in overload. Some emergent country networks adopt shorter intervals, nearly one minute, on separate right-of-way to carry a maximum passengers on important corridors.

Thus, in Curitiba, the 12,4 km long exclusive busway of Boqueiro is operated with 55 biarticulated buses (Volvo do Brasil) of an unit capacity of 270 spaces ($8p/m^2$) with an interval of 70 to 90 seconds at the peak hour : the capacity offer is located between 10 800 to 13 900 passengers per hour and per direction.

As regards the capacity, with a 3 minutes interval, the articulated bus can carry 1 900 to 3 500 passengers per hour depending on whether one adopts the transit norm of comfort of the 4 standing passengers per square meter ($4p/m^2$) or the overload configuration of 8 standing passengers per square meter ($8p/m^2$) and 25 % of seated spaces. These capacities can be increased while operating buses on busways and while using stations whose platform level and vehicle floor level are identical and while using all doors for passengers alighting and boarding.

The TVR can transport 2900 passengers per hour per direction pphd, the Translohr STE4 can transport 3100 pphd, the Citadis TGA 302 can transport 4100 pphd, always with a 3 minutes interval. These supplies are sufficient for the european medium city networks aimed.

Only following systems are now under operation : the articulated bus, the biarticulated bus and the french standard tramway TFS, the CITADIS, as well as the TVR next September 2001 in Nancy. The other systems of intermediate rubber-tyred guided transport encompassing a wide range of industrial technologies, each at varying stages of development, are under prototype design but are proposed currently in the calls for tenders.

6. CONCLUSION

Through this communication we try to show the possibilities of the vehicles capable to constitute an intermediate transit system. We explained the reasons why in France a large variety of new systems is now under development.

The research finds that costs will decrease as a result of modular construction, the use of standard elements and components from mass-produced road vehicles. Other savings will come from applying highway construction technique to reduce infrastructure costs. The improved performances offered by rolling on rubber tyres are an incentive for transit authorities to invite tenders based on performances before selecting a specific transit system.

One should keep in mind that the implementation of a new system alone is not sufficient to improve drastically public transport networks. Other decisions are also necessary such as space reservation, parking management, etc…,. These are indispensable to reach the carrying capacity levels quoted above and to get the priority of the urban transit vehicles vis-à-vis the private car : only a collective awareness will allow us to facilitate these realizations.

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